SUBCOURSE TR0670

EDITION 8

RAILWAY TRACK MAINTENANCE I

THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

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REFERENCE TEXT 670

RAILWAY TRACK MAINTENANCE I

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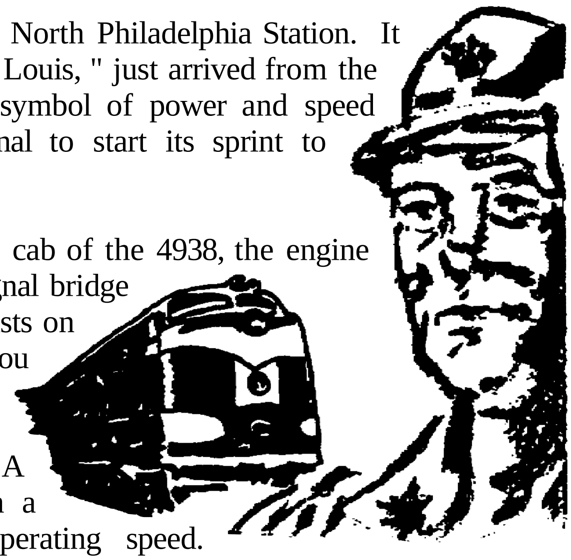


Sixteen passenger cars stand behind a locomotive at North Philadelphia Station. It is 7:29 a.m. and this is No. 4, the streamlined "Spirit of St. Louis, " just arrived from the West. Standing poised and quiet for the moment, this symbol of power and speed seems as alert as an excited racehorse awaiting the signal to start its sprint to Manhattan Island.

Imagine yourself sitting in the engineer's seat in the cab of the 4938, the engine ready to pull No. 4. Three vertical amber lights on the signal bridge ahead show that the track is clear. Presently, two short blasts on the signal tell you that the conductor is ready to roll. You move the controller back a notch or two. Relays pop behind you and ammeters reflect the current surging from the locomotive's transformers to the traction motors. A mighty 8,000 horsepower is ready to go to work. With a throbbing hum, you glide forward, accelerating to operating speed. Industries, suburbs, and farmlands spring into view and are quickly left behind. The speedometer needle stays at a steady 80 miles per hour.

Ahead your attention is taken by the two shiny rails guiding you to your destination with so little effort on your part. Track is often considered a supporting role in the cast of the, railroad show–top billing goes to trains like the "Spirit of St. Louis. " But this show has no one star, and most assuredly, track is not a subordinate. Track and roadbed are the foundation on which railway operations take place. They are all-important to the business of railroading; they demand and deserve much attention.

Now let the regular engineer take over the 4938, and turn your thoughts to the track for awhile. On another track a westbound tonnage freight is crossing from one track to another so that a Pittsburgh-bound train may pass it without either train stopping.

That's a simple maneuver that's so often taken for granted but one that depends on switches for its execution. Above the clanking of steel tires against the frog points, you hear the flanges squeal as the heavy freight cars swing over the switch points. After the speeding freight has passed, a blast of compressed air slams the heavy switch points back against the stock rails so that the faster Pittsburgh-bound train can continue down the track and pass the freight.

Looking forward again from the 4938, you see the track curving up ahead. The speedometer still reads 80. Number 4 sweeps around the curve and continues on is way without reducing speed. Passengers probably are not aware that their train has rounded a curve. Engineering skill, built into the track with slide rules, calculations, and transits, enables the train to take the curve at top speed and ride as though racing down straight track.

Soon farmlands change to suburbs and the suburbs become industrial areas. This is metropolitan New York, 90 miles northeast of Philadelphia. Number 4 dives into the eastbound tube of the North River tunnels. Gently the airbrakes slow the "Spirit of St. Louis," and steel rails guide it alongside the station platform in central Manhattan.

What makes easy-riding track, and what is done to poor track to improve it? What is the secret of modern curved track? How are switches built and how do they operate? Who maintains track and how is the work done? Perhaps these are a few of the many questions you are now asking. The answers to these questions and many more will be found in this text and its sequel, Railway Track Maintenance II.

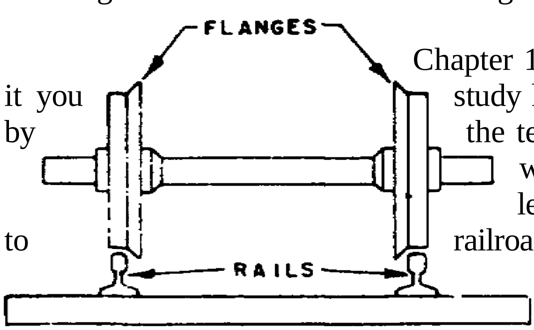
Railway Track Maintenance I is divided into three chapters; the first gives the fundamentals of railway engineering, and the second and third explain the roadbed, ballast, drainage of the track, and the track itself.

Chapter 1

FUNDAMENTALS OF RAILWAY ENGINEERING

1.1. GENERAL

Through gravity, friction, and inertia, our physical environment imposes certain limitations on movement. To effect movement, these forces must be overcome by the expenditure of energy. The various modes of transport have been developed to overcome these restrictions in different ways. Each mode has its individual characteristics. Those of railroads enable them to move large numbers of persons and great quantities of freight between any two points on the rail line with comparative ease and high speed. Railroads are able to do this because they employ cars rolling on flanged wheels over steel rails. These two elements, flanged wheels and steel rails, as shown in the sketch, are the essential elements of rail transportation. A student of any phase of railroading must thoroughly understand the characteristics of railways resulting from the use of rails and flanged wheels.



Chapter 1 discusses the fundamentals of railroad engineering. In it you study how the railroads meet operational difficulties presented by the terrain over which they travel. And you become familiar with such terms as grade, alinement, profile, gage, cross level, surface, and track clearance; and their relationship to railroad engineering and to the job of the track supervisor.

1.2. MEETING OPERATIONAL PROBLEMS

A set of flanged wheels rolling on two steel rails is guided along the path of those rails and does not have to be steered. A number of cars supported by these wheels can, therefore, be grouped to form a train and be operated as a unit by one crew. Not only does such an operation reduce labor requirements but also enables railroads to use large, efficient prime movers–locomotives–to move the groups of cars rather than less efficient individual power units applied to each car.

The direction-determining characteristic of rails also works as a severe limitation in railroad operations. Several trains operating on the same track must proceed in the same direction and at the same speed to avoid collisions. The turnout was developed to alleviate this inflexibility. Systems of turnouts make passing possible and provide a means for trains to leave one track and proceed to diverse destinations over other paths. Yards, interlockings, passing sidings, crossovers, and elaborate signaling mechanisms depend upon or are associated closely with these turnouts. Such installations have been made at great expense to achieve a flexibility in traffic handling that is, nevertheless, inferior to that of many other modes. Here is a fundamental characteristic of railroads that appears over and over again: railroads depend upon expensive fixed installations to exploit their basic advantage–moving large numbers of persons and great quantities of freight easily and speedily. Railroads must handle a large volume of traffic to justify the expense.

Physical analysis shows that the coefficient of friction between rails and smooth wheels is low. Hence, less energy is expended in moving any particular load by rail. Lower energy expenditures result in lower fuel costs. However, the friction between rail and wheel is the means of transmitting traction or braking forces. Since this friction is small, the tractive effort that may be applied is low. Trains are, therefore, limited to light grades even though rail lines must cross uneven or mountainous terrain. The difficulty is solved by judicious use of cuts, fills, loops, switchbacks, tunnels, and bridges. Again, railroads depend on expensive stationary construction to operate.

One of the principal problems railroads must solve is that of determining how far to go in reducing operating difficulties and expense by increasing the elaborateness of the physical plant. Obviously, a point is reached beyond which the expense of improving the stationary plant cannot be justified from the standpoint of ease of operations. Ordinarily, heavy traffic lines not only justify but demand refinement of fixed facilities. But a low traffic level may not support a rail line, or, at best, it may justify only a simple, unrefined plant.

You should now understand one of the foremost principles of railroading in general and of maintenance of way in particular. It is this: any problem of railway maintenance or construction must be solved in relation to the density and type of traffic that the rail line carries or is expected to carry. This principle underlies all discussion in this text. To make it clearer, here are two examples.

Should you visit Frenchtown, New Jersey, you would see the line of the old Belvidere and Delaware, now part of the vast Penn Central Railroad, and affectionately referred to as the Bel Del. This railroad wanders up the New Jersey side of the Delaware River from Trenton to Phillipsburg and on to Manunka Chunk. Even to the uninitiated eye, it presents a picture of a dying enterprise. The sight of small rusty rails and tall grass among weathered ties encourages a feeling of compassion. But such a feeling is uncalled for. Although no signs are evident of exacting maintenance on the Bel Del, its absence indicates sound management because of the little traffic on the line. Only folly could induce the railroad's officials to expend a great deal of effort and cash on maintenance not warranted by traffic density.

Look at another single-track line: the Denver and Rio Grande Western (D&RGW) trackage leading westward out of Denver. You don't need years of maintenance-of-way experience to see that, although the line is single track, considerable effort has been directed at putting and keeping it in excellent physical condition. It makes the Bel Del back in the Delaware Valley seem old-fashioned: that picturesque trackage inspires thoughts of times past and yet is a part of a modern, sensible operation. But here on the D&RGW, no such inconsistency is apparent. The fine roadbed complements the 6,000-horsepower diesel-electrics roaring up the eastward slope of the Rockies to Moffat Tunnel with their ladings of coastbound freight. The importance and volume of the traffic would make stingy maintenance effort economic suicide for the railroad.

To find an example that violates the principle of track maintenance in proportion to traffic is difficult. This fact is evidence that railroads don't ignore so sound a principle. Today's division engineers and track supervisors know how to keep their railroad safe and economically geared to the existing or anticipated level of traffic. They have knowledge, a proper appreciation for track, and an understanding of what a rail can and cannot do. Using the words of a dean of railway engineers: "They know how to do well with one dollar what any bungler can accomplish, after a fashion, with two." It is the work of these division engineers and track supervisors with which you are to become familiar.

1.3. EFFECT OF GRADE ON RAILROAD LOCATION

The bulk of railroad locating has been done. In some cases, the location was wisely chosen; in others, the choice was poorly made. The locating engineers had to solve numerous economic and technical problems. However you may look at it, good or bad, the railroads have been built, and aside from extensions and relocations, this kind of work is no longer a major concern. Your endeavors, then, should be directed not toward learning how to locate a railroad but rather toward an understanding of construction elements and why railroads were built as they were. Only then will you have a proper appreciation of a sound program of maintenance.

a. Path of the railroad. Plane geometry teaches that a straight line is the shortest distance between two points. For the distances traversed by railroads from one city or station to another, the surface of the earth can be satisfactorily simulated by a plane. Obviously, then, the most desirable path for a railroad is a straight line. However, the limitations mentioned earlier, arising from smooth rails and wheels, coupled with the irregularities of the earth's surface, generally prohibit such a route. If a railroad line were laid straight from one city to another, such a line would usually involve grades of such steepness that trains, as we know them, could not pass over it.

Once it was believed that smooth-wheeled trains operating on smooth tracks could climb only the lightest grades. This erroneous opinion resulted in the use of rack railways and inclined planes.

(1) Rack railways. To eliminate the slippage of a locomotive's driving wheels on steep grades, a rack (rack rail) was placed between the rails. This rack in turn meshed with a gear wheel or pinion of the locomotive. A locomotive so equipped was also referred to as a cogwheel locomotive.

(2) Inclined planes. To overcome steep slopes, engineers built inclined planes requiring stationary engines at the top of each grade. Trains traveled over level tracks as far as possible and were then pulled up extremely steep grades by cables attached to the stationary engines. Afterward the trains proceeded to the next incline where they were either let down or pulled up the succeeding hill. This operation may be compared to that of a canal and locks, the planes corresponding roughly to the locks.

In a few places, inclined planes are in use today. Notable are the triple Ashley planes of the Jersey Central at Wilkes-Barre, Pennsylvania. But for the most part, they have long been gone from the railroad scene.

b. The “George Washington.” In 1836, one of the important events in railroad history took place. The locomotive "George Washington' climbed the Belmont plane at Philadelphia hauling a

16-ton train without the aid of a stationary steam engine. It became apparent that the cumbersome inclined planes that slowed traffic were not necessary and that the theory of railway location needed revision. As a result, a series of longer, more gradual ups and downs, known as developments, replaced the short steep cog grades or inclined planes. Although routes were longer, as illustrated in figure 1.1, time and money were saved.

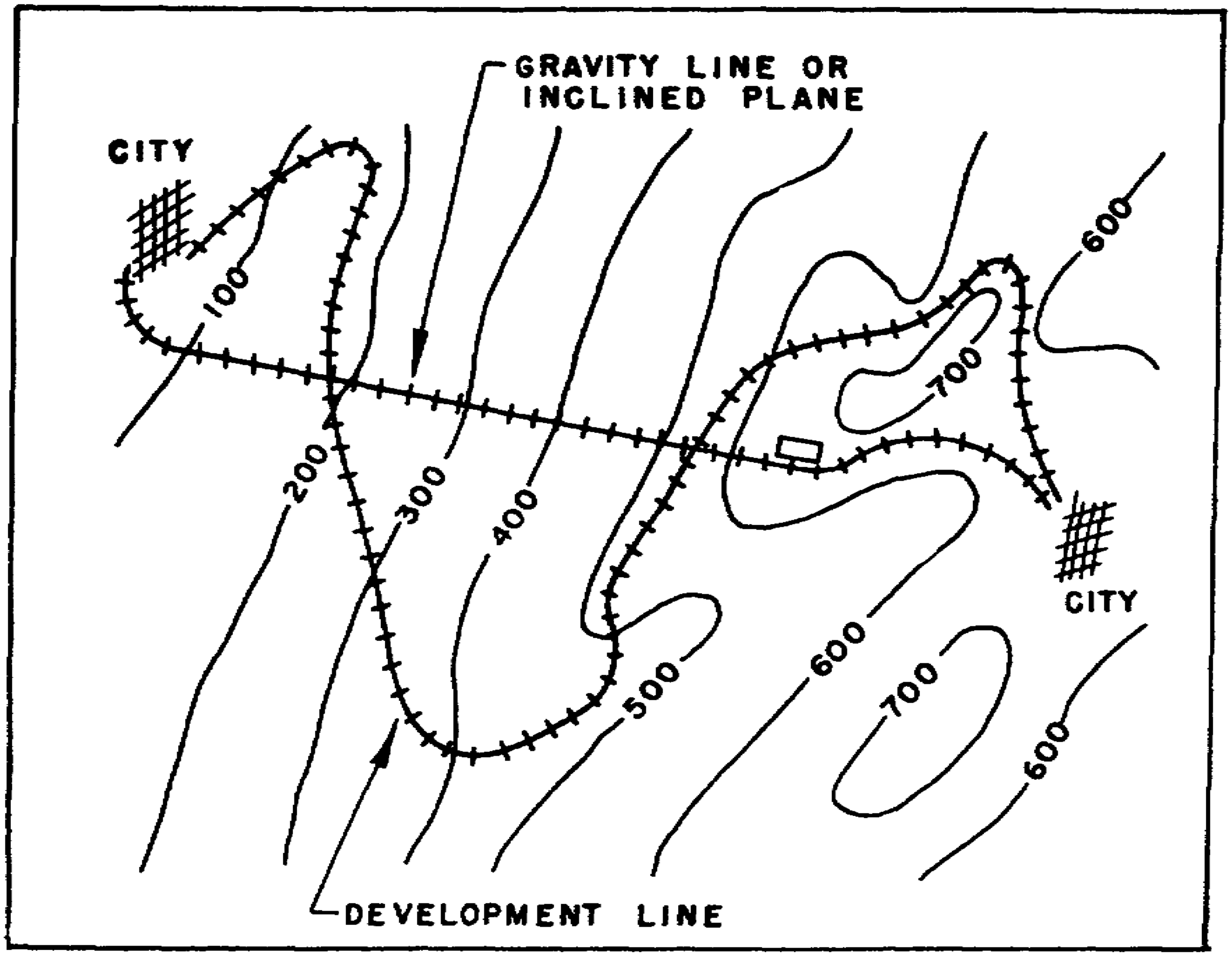


Figure 1.1. Gravity and Development Lines.

The successful experiment of the "George Washington" made a permanent change in the theory of railway location. It was a turning point in railway progress.

1.4. ALINEMENT

The path a railroad follows is known as its horizontal alinement or simply alinement. It may be defined as the ground plan of the railroad as distinguished from its profile. In a profile, you see the ups and downs of the railroad's path. But on the ground plan you see stretches of straight track, connected by arcs or curves. The straight stretches are referred to as tangents; the arcs, as curves. By definition, a tangent is a straight line that touches the circumference of a circle at only point, the point of tangency. A radius of the circle drawn to that point of tangency is perpendicular to the tangent. The radius and the tangent form a right, or 90-degree, angle. An arc is any part of the circumference of a circle and is formed by drawing a nontangent line other than the diameter through two points on the circumference. Tangent and nontangent lines and an arc are shown in figure 1.2; tangents and curves, in figure 1.3. Curvature, easement, and right of way are three terms with which you should be familiar in studying alinement.

a. Curvature. The measure or amount of curving is known as curvature. It tells you whether or not a curve is sharp. The sharpness of a curve depends upon the length of the radius of the circle of which it is an arc. If the radius is long, the curve has a light curvature–it is not sharp. Conversely, if the radius is short, the curve is sharp. In some countries, the sharpness of curves is measured in terms of the radius. In the United States, curvature is measured in degrees. The geometry of this measurement is discussed in Railway Track Maintenance II. It is sufficient for now that you know that the larger the number of degrees of curvature, the

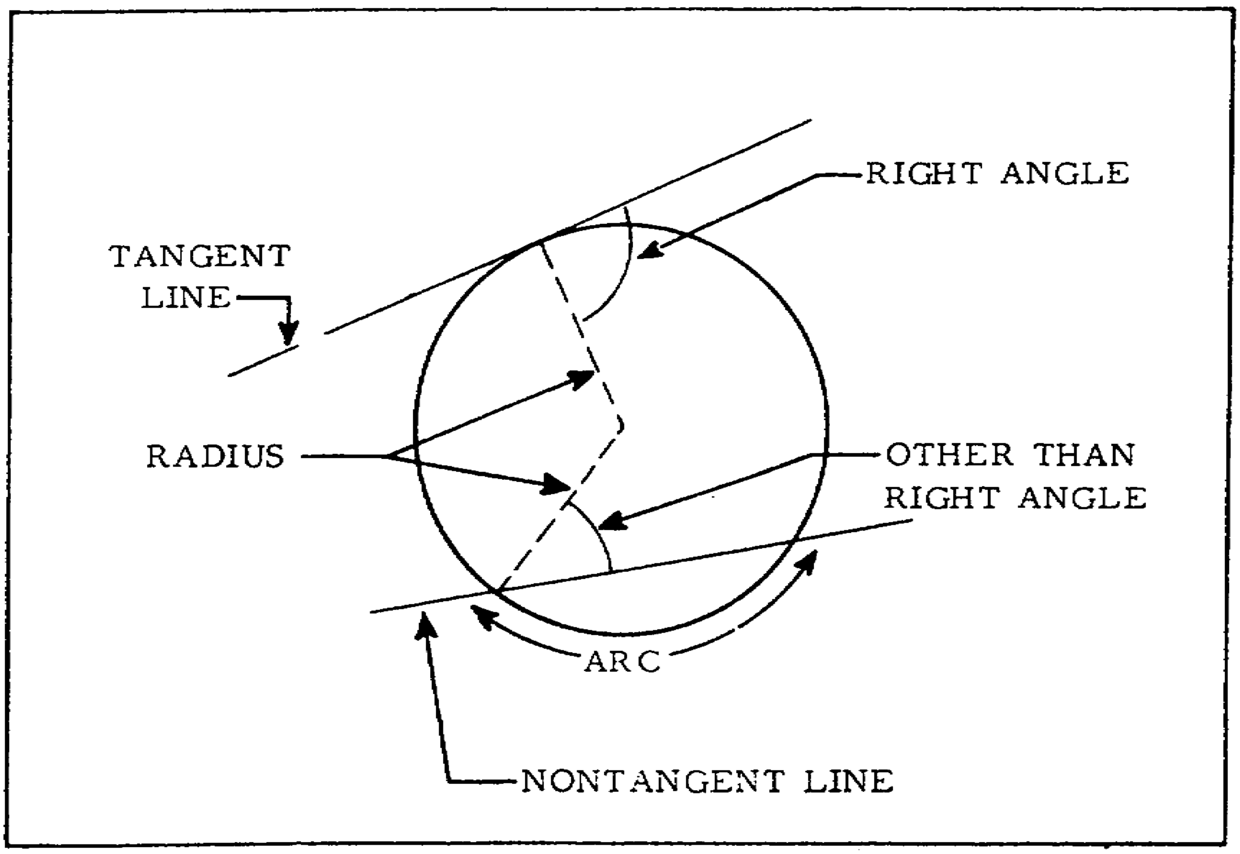


Figure 1.2. Tangent and Nontangent Lines.

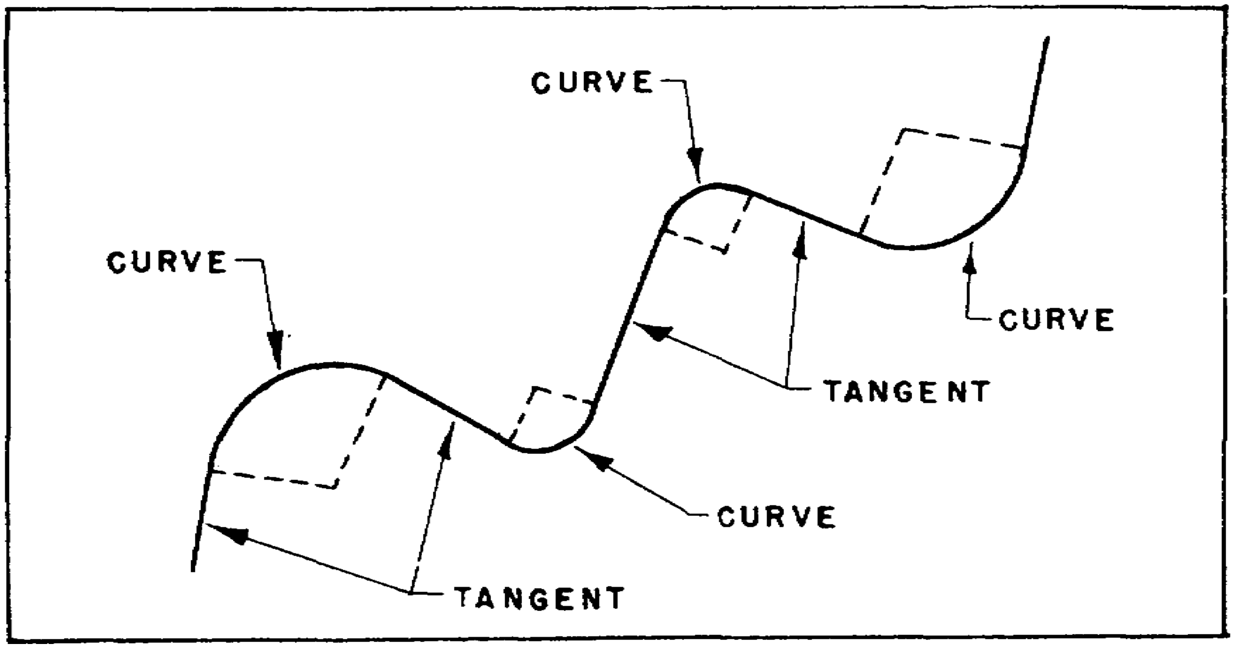


Figure 1.3. Tangents and Curves.

sharper the curve; for example, a 10-degree curve is sharper than a 3-degree curve.

b. Easement. In actual practice, the ends of the curves are flattened out to provide a smoother ride for trains. The flattened out portions are called easements or transition curves. Geometrically they are segments of spirals. However, they are not discussed here but in Railway Track Maintenance II where they are treated in some detail.

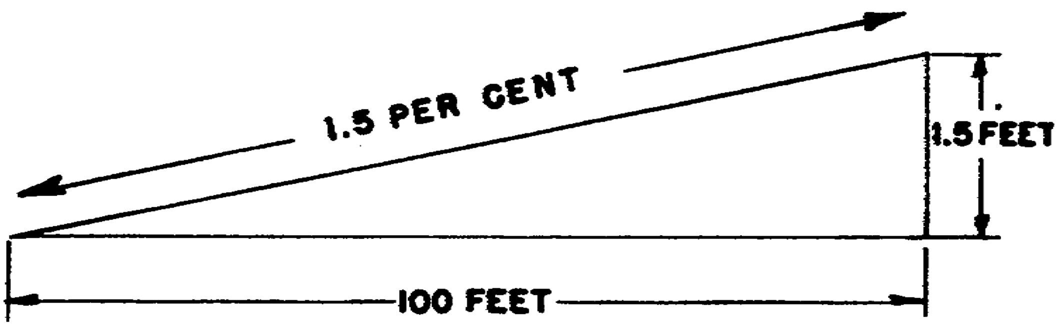
c. Right of way. As we mention earlier, the path a railroad follows, known as its alinement, is made up of curves and tangents. Along the line are many and various structures and facilities: towers, stations, fences, bridges, tunnels, etc. The strip of land occupied by the tracks and other structures is called the right of way. The legal definition of right of way is "the authority by which the railroad holds the land over which it travels." But we are interested in the meaning first referred to, the strip of land. Unless otherwise indicated, the term right of way as used in track maintenance means the property itself rather than the right by which the property is held.

A railroad's right of way is shown on a right-of-way map. On it, the right of way is shown by property lines and the track is represented by a centerline, an imaginary line which runs halfway between the two rails of a track. It is on this line that all construction or maintenance clearance measurements are based. The symbol used to show a centerline is ℄ . A typical example of its use on a railroad diagram is seen in figure 1.6.

1.5. PROFILE

When looking at the surface of the rail from the side (a vertical projection), the ups and downs are visible but the horizontal curves are not. A picture of a railroad from the side is known as a profile; the ups and downs are referred to as grades. In this country, the steepness of a grade is given in percent, arrived at by dividing the vertical rise by the horizontal length of the grade and multiplying the result by 100.

A simple way to determine percent grade is to find the rise in feet over a horizontal distance of 100 feet. This gives you the percent grade. For instance, if a railroad rises 1.5 feet in a horizontal distance of 100 feet, as shown in figure 1.4, the grade is 1.5 percent.



$$\text{PER CENT GRADE} = \frac{1.5}{100} \times 100$$

$$= 1.5$$

Figure 1.4. Determining Percent Grade.

a. Irregularities in the terrain make changes in the rate of grade on a rail line necessary. However, abrupt changes are not permissible. You can readily imagine the result if a speeding train came down a 2 percent grade and suddenly hit level tracks. The impact of the front wheels hitting the level tracks would damage both the locomotive and the tracks. Furthermore, if the change were great enough, the center section of the locomotive would be lifted off the track and be derailed.

b. Using a vertical curve wherever different gradients meet solves the problem. The angle formed where the grades meet must be eliminated, and they must be connected by a curve. The length of the curve depends upon the size of the angle and the length of trains traveling over the line. Figure 1.5 illustrates why long trains and sharp angles require long vertical curves.

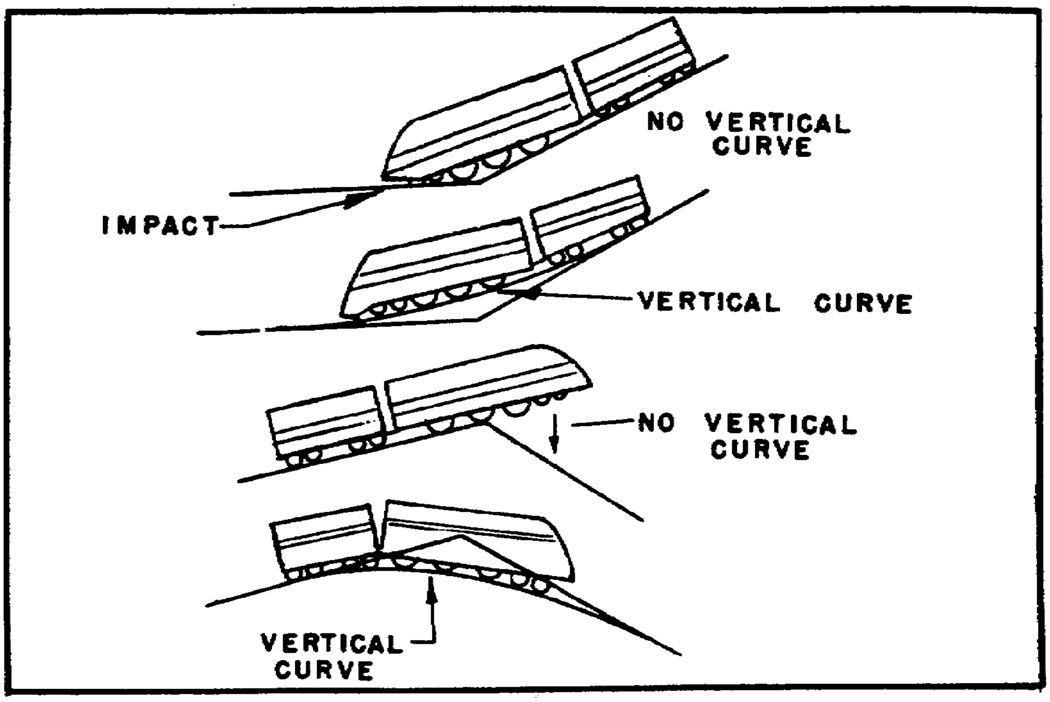


Figure 1.5. Need for Vertical Curves.

1.6. GAGE

The gage of a railroad, as figure 1.6 shows, is the distance between the rails. It is measured at the gage line, that is, between points five-eighths of an inch from the top inside of the rails and at right angles to them. Cars and locomotives can move over tracks only if their gages match. In the United States, standard gage is 56 1/2 inches.

The following subparagraphs discuss the terms applied to the sides of a rail, the development

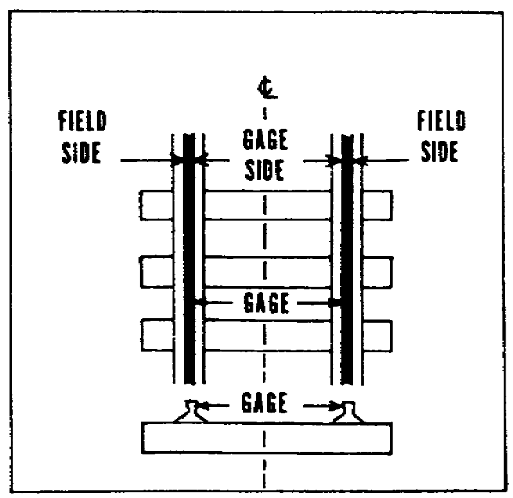


Figure 1.6. Rail Gage.

of standard gage, the gages used in various parts of the world, and the necessity for varying the standard gage.

a. "Sides" of a rail. Gage is measured from the "gage side" of a rail. The opposite side is called the "field side." Before a rail is placed in track, it has no gage or field side. Once it is laid, the side facing the centerline of the track becomes the gage side; the side facing away from the centerline becomes the field side, as illustrated in figure 1.6.

b. Development of standard gage. Some rail lines within our borders have a different gage; for instance, the 36-inch gage Rlio Grande Line in the Rocky Mountains. Such lines are rare now, but at the end of the nineteenth century they were common. Until 1886, the railroads in the South were predominantly 60 inches in gage, but such important lines as the Erie and the Missouri Pacific were originally laid with gages of 72 and 66 inches, respectively.

The preciseness of 56 1/2 inches implies that there is a technical justification. In studying railroading, you find cases where odd dimensions have such a justification. But so far no one has been able to provide a reason for the modern standard gage. We know that the 56 1/2-inch gage was used in England before most U. S. railroads were built, and that the Baltimore and Ohio and many railroads in Pennsylvania adopted it at the outset, apparently following the British tradition. The question is, Where did the British get the 56 1/2-inch gage? One plausible answer is that it corresponded to the ruts the Roman chariots cut in their roads. But probably we should say that the 56 1/2-inch gage just happened and that in the United States it was the one to survive the adoption of a common gage.

c. Other gages. Elsewhere in the world, other gages have survived. In Russia, the 60-inch gage is standard. In Ireland, trains run over 63-inch gage tracks, and in Spain and Portugal, a 66-inch gage is in use. The rest of Europe generally use the 56 1/2-inch gage. In some countries, the gage has not been standardized: India and South American countries have considerable mileage with various gages.

d. Necessary gage variations. You know that standard gage in the United States and certain other countries is 56 1/2 inches. Now you are going to learn that this gage doesn't always measure 56 1/2 inches between rails. To prevent binding, it has been found necessary to broaden the gage around sharp curves, as shown in figure 1.7. In some cases, the gage becomes 57 inches or greater. Of course, odd gages–those other than 56 1/2 inches–also increase on sharp curves for the same reason. The gage is always widened on the inside, or low, rail.

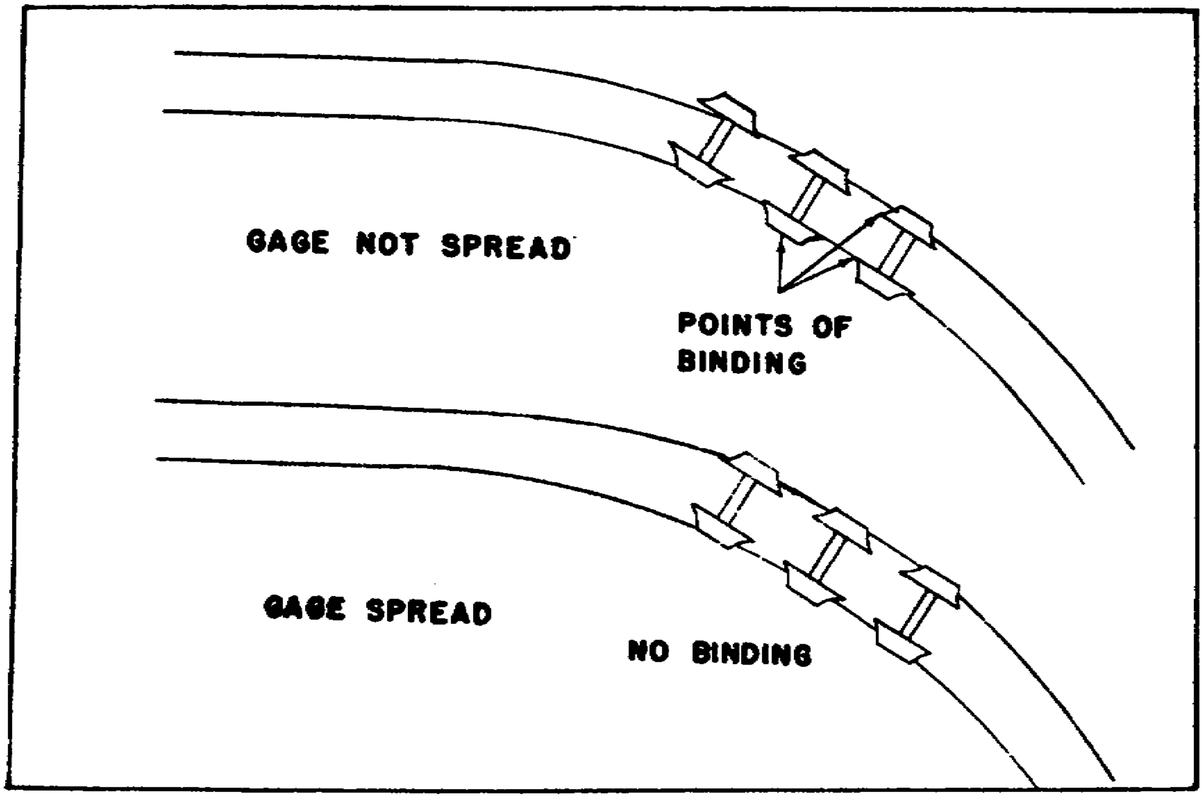


Figure 1.7. Gage on Sharp Curves.

You read earlier that the gage of locomotives and rolling stock must match the gage of the track over which it is going to run. However, this is not literally true. The gage of rail equipment is invariably slightly less than that of the track. The difference is maintained to insure a tolerance in case the track gage should accidentally be slightly narrow and to further reduce the effect of binding on curves.

On high-speed lines, some railroads have specified a slightly narrower gage. For example, on one major commercial railroad specifications for standard track require a gage of 56 3/8 inches on all tangents where trains are expected to operate at speeds in excess of 50 mph. In high-speed operation, the freedom of rail equipment to move a small lateral distance between the rails results in a rough, uncomfortable ride for passengers and is destructive to track and equipment.

1.7. CROSS LEVEL AND SURFACE

The cross level is the height or elevation of the two rails, making up the track, in relation to each other. The cross level of a track, among other things, affects the way a train moves over the rails. Good maintenance requires proper cross level, as illustrated in figure 1.8. On tangent track, both rails must have the same elevation. In other words, an imaginary line at right angles to the two rails connecting their tops must be level. Curved track, however, is banked; the outside rail is raised. The condition of cross level where one rail is purposely raised is known as superelevation and is discussed fully in Railway Track Maintenance II.

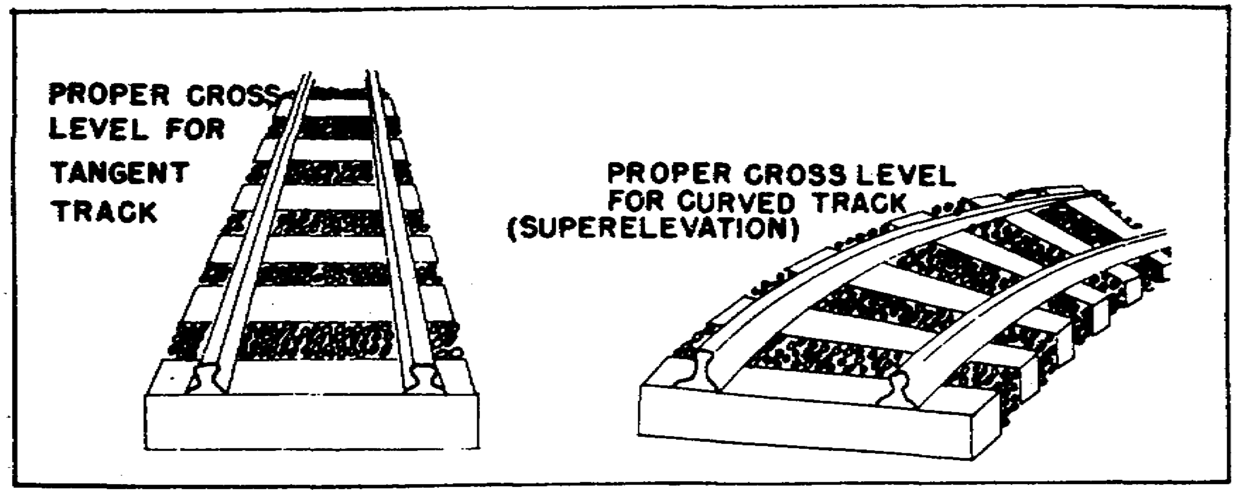


Figure 1.8. Proper Cross Level of Track.

The concept of surface is difficult to differentiate from grade and cross level. As commonly used, surface describes the smoothness of track. Technically, it is the height relation of successive points along one rail of a track. Proper track surface is attained when the rail is at the same height throughout its length or when its elevation changes evenly. Proper and poor surfaces are compared in figure 1.9. Although grade is also a height relation of successive points along track, this term should be used in referring to large changes occurring over long distances. The term grade should be reserved for changes of elevation purposely made when the line was constructed. Surface, on the other hand, refers to irregularities of elevation occurring because of faulty maintenance.

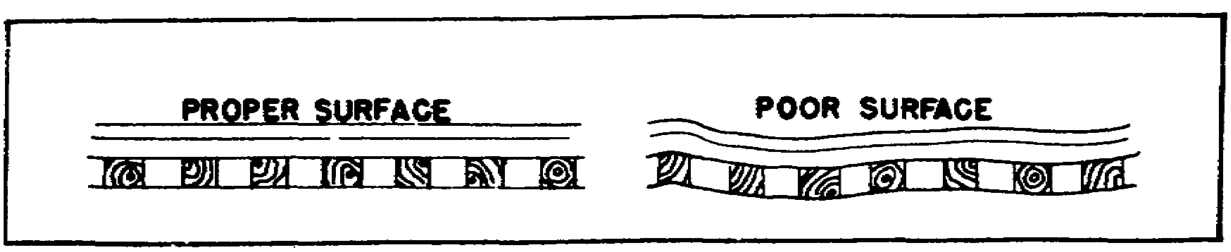


Figure 1.9. Proper and Poor Surface Compared.

1.8. CLEARANCE

The similarity between the gage of British and American railroads made possible the race between the Baltimore and Ohio's "Royal Blue" and the London, Midland and Scottish's "Coronation Scot, " between Washington and Jersey City in the late 1930's. Had you been present anywhere along the line, you would have seen a surprising difference in the size of the two trains. The "Coronation Scot" was lower and narrower than the "Royal Blue. " The difference would have been apparent between any British train and one from the United States. The "Coronation Scot" had to be smaller than the "Royal Blue" to pass through tunnels, between station platforms, under bridges, and between structures along an English line. Rail equipment must be made to conform to these clearance limitations.

A track-clearance chart or diagram is prepared for each section of a railroad, showing the maximum dimensions of rail equipment and load that can pass over the line. The clearance chart is of primary importance to those in the transportation department who must route odd-sized shipments. It is also important to the maintenance official since he must be careful not to restrict existing clearances in his maintenance work. For example, he cannot raise track in tunnels or under bridges without authority from higher headquarters. Nor may he change alinement if such restricting elements as structures or walls are nearby.

Illustrated in graphic form in figure 1.10 are some of the more common clearances that are typical of those involved. The sketch is not drawn to scale nor are the dimensions necessarily those of any specific track-clearance diagram. They are shown with an outline of a car on the tracks to emphasize the importance of proper understanding of clearance limitations. Two track-clearance diagrams, one for bridges and one for a single-track tunnel, designed by the American Railway Engineering Association (AREA), are shown in figure 1.11.

1.9. SUMMARY

An important principle of railroading and of maintenance of way is that any railway maintenance or construction problem must be solved in relation to the density and type of traffic the line carries or expects to carry. The path the rail line follows is called its alinement, or ground plan--stretches of straight (tangent) track connected by arcs or curves. When looking at the side of the rail, you see its profile, that is, its ups and downs. Steepness of grade in the United States is expressed in percent. Standard gage in this country is

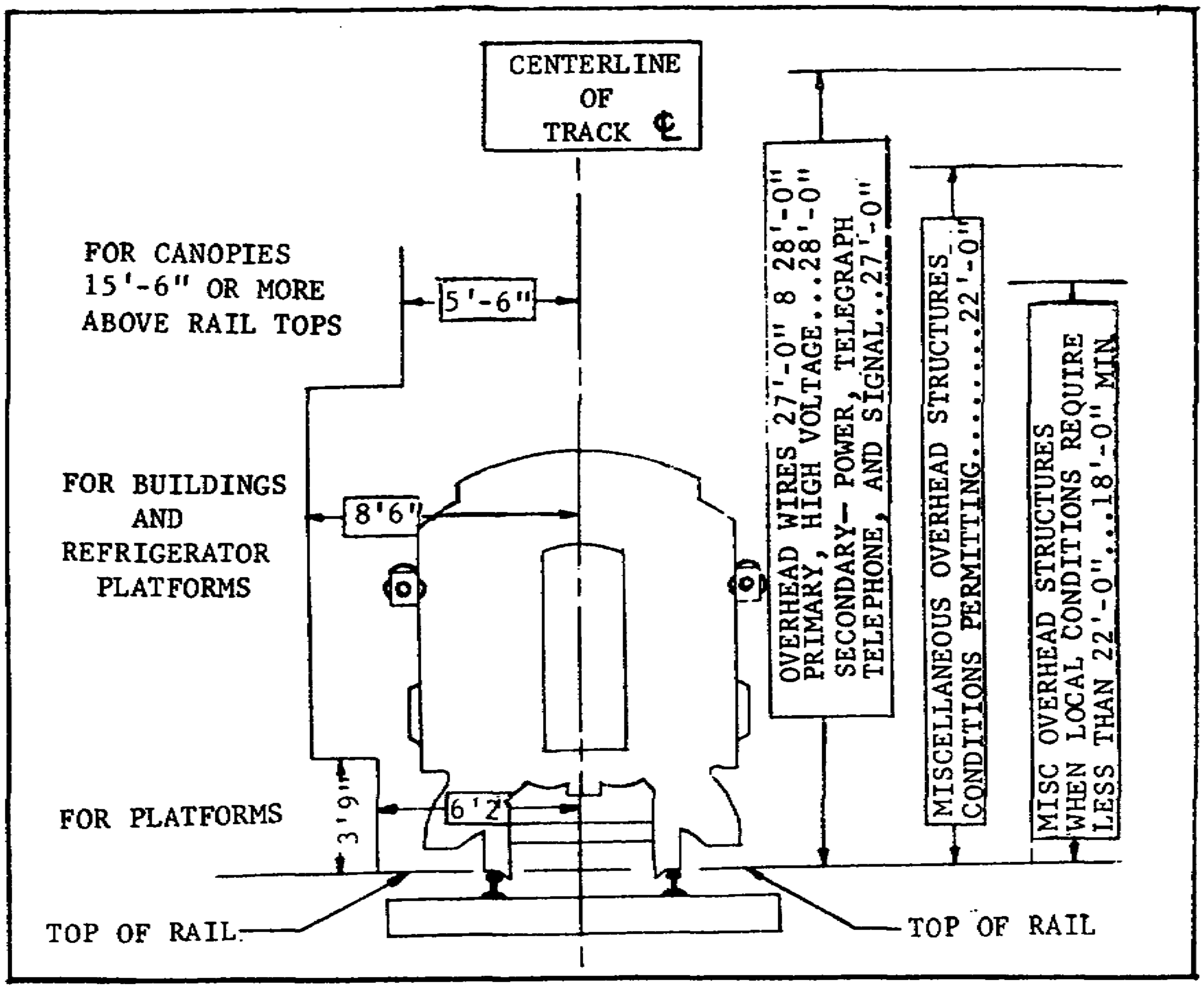


Figure 1.10. Typical Clearances.

56 1/2 inches, but it is widened on sharp curves and sometimes made narrower on high-speed lines. Cross level refers to the relative height of the two rails; surface refers to their smoothness.

Rail equipment must conform to certain clearance limitations. Each section of a railroad has its track-clearance chart or diagram, showing the maximum dimensions of rail equipment and load that can pass over the line. Maintenance personnel must observe the clearance limitations also, especially when raising track level in tunnels or if changing alinement when structures or walls are nearby.

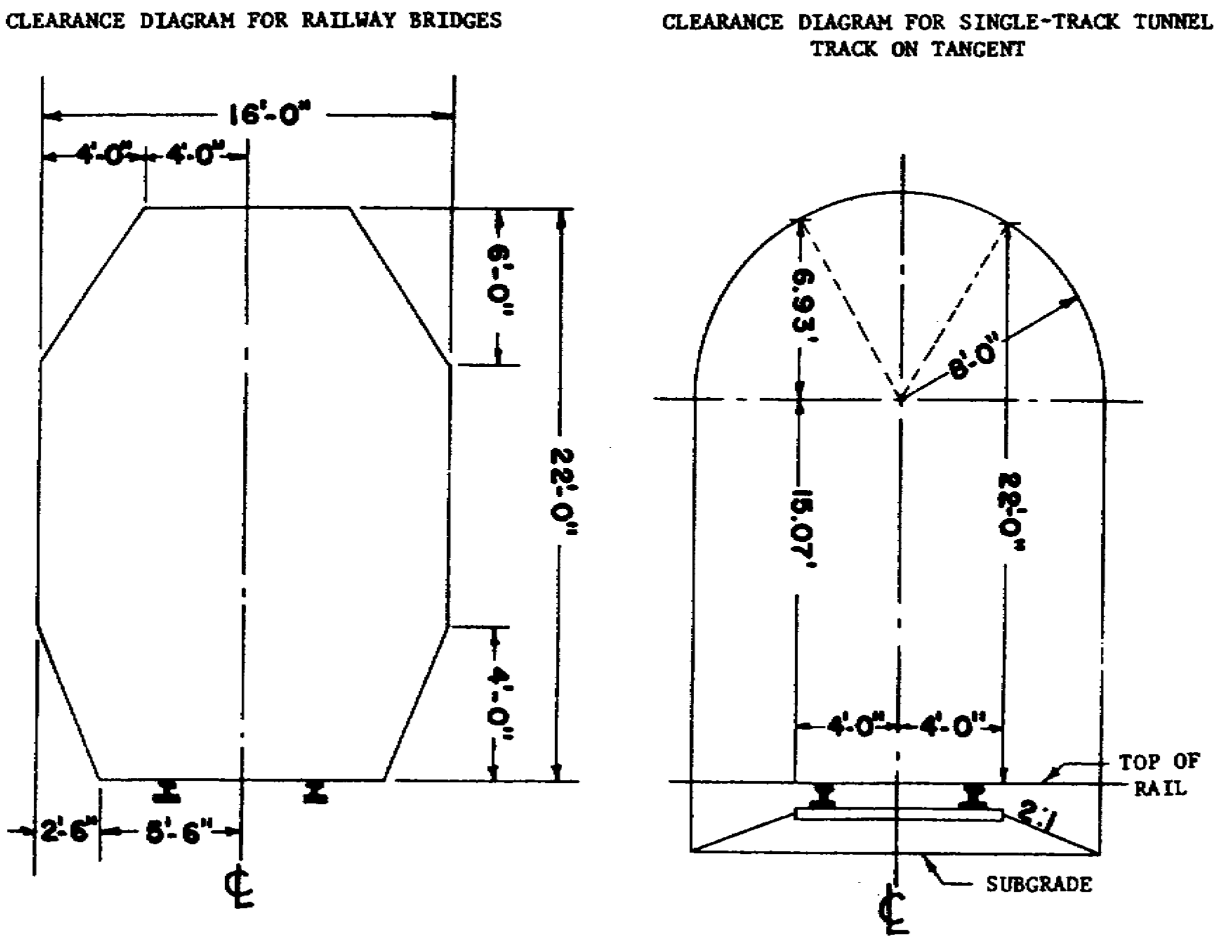
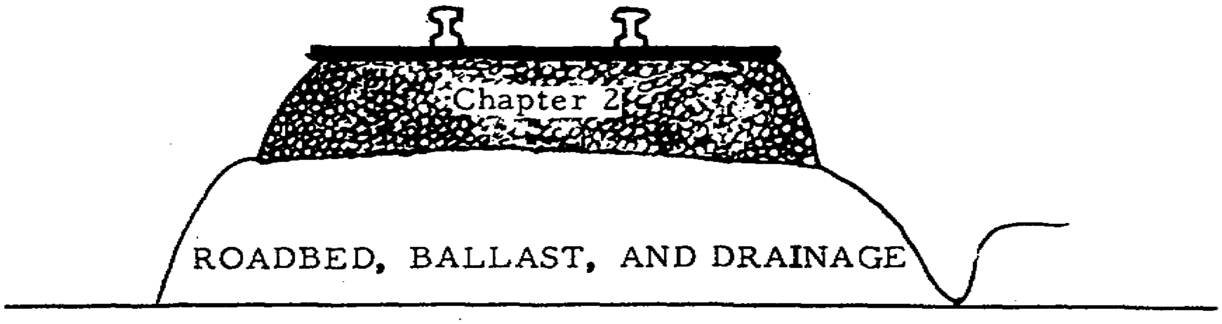


Figure 1.11. AREA Clearance Diagrams.



2.1. INTRODUCTION

One spring day in 1953, the "Colonial Express," arriving at Washington, D.C., after an overnight run from Boston, suffered an airbrake failure and crashed through the bumping block at the end of Union Station's track No. 16. The locomotive and first car arrived on the concrete floor instead of alongside the platform. The concrete floor promptly collapsed, dropping the equipment into the mailroom below. Yes, modern rail equipment is heavy.

Because the locomotive weighed 130 tons, it is not surprising the concrete floor gave way. This incident illustrates the impact the forces involved in operating locomotives and trains can have. If the track between Boston and Washington had been laid directly on the surface of the ground instead of on an adequate roadbed, the 130-ton locomotive of the "Colonial Express" would have caused the ground to give way in many places just as it did the concrete floor. The rails of such track would bend or break in many places, speed would necessarily be cut, and derailment would occur often.

To add to these problems, rain would frequently cause the tracks to be covered with water, and the resulting mud would offer no resistance to the weight of trains. Furthermore, the ground surface is irregular. Track laid directly on such an irregular surface would result in an extremely rough ride as well as damage to rolling stock, freight, and rails. Operation over such track would be a nuisance and an economic failure.

An adequate roadbed is essential to a stable track, because it must provide the proper foundation for the trains rolling over the track. The ballast used on it must be of the correct composition and depth, and the roadbed must be well drained. Chapter 2 contains two sections. The first discusses the roadbed and ballast; the second, roadbed drainage.

Section I. Roadbed and Ballast

2.2. GENERAL

Rail equipment is directly supported by the rails of the track, and each rail is supported at intervals along its length by crossties. The rail, therefore, acts as a girder between ties. The ties support the rails and in turn are supported by ballast laid on the subgrade.

A roadbed is a strip of terrain that varies in width from 18 feet for a single track on tangent to 33 feet for a double track on a curve. The roadbed follows the line of the railroad. It provides a means of holding the tracks above the surrounding land so that water cannot remain on them. Ballast laid upon the subgrade distributes the weight of a train over a wide area so that the ground can support it, as figure 2.1 shows.

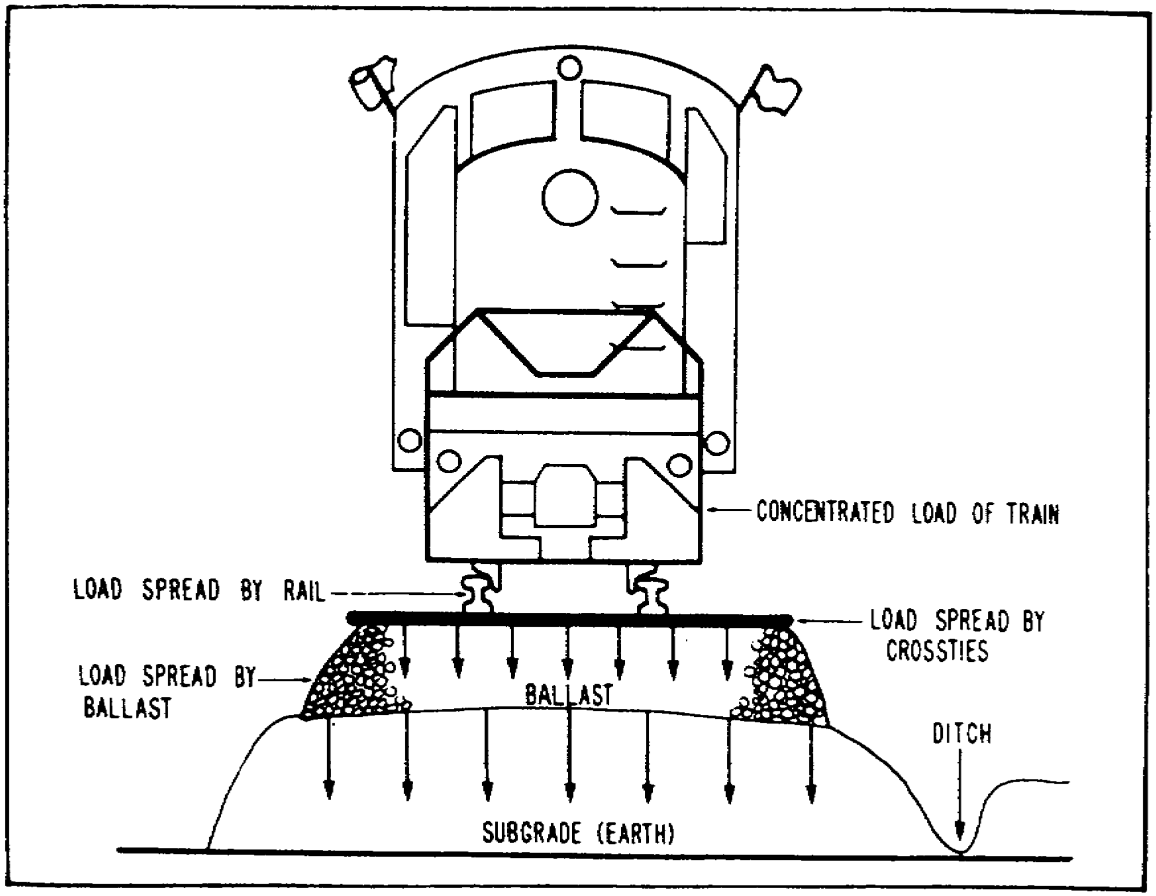


Figure 2.1. Spreading Train Weight to Roadbed.

Section I discusses terrain irregularities and how they are compensated for, and ballast–its composition, selection, and section.

2.3. TERRAIN IRREGULARITIES

The roadbed compensates for minor terrain irregularities by filling in low spots, or fills, and cutting through high spots, or cuts. The two types of cuts, sidehill and through, are diagramed in figure 2.2. But where there are fills and cuts, there are slopes; and where there are slopes, there are problems of erosion and stability. In the following subparagraphs, sidehill and through cuts, fills, and slopes are discussed.

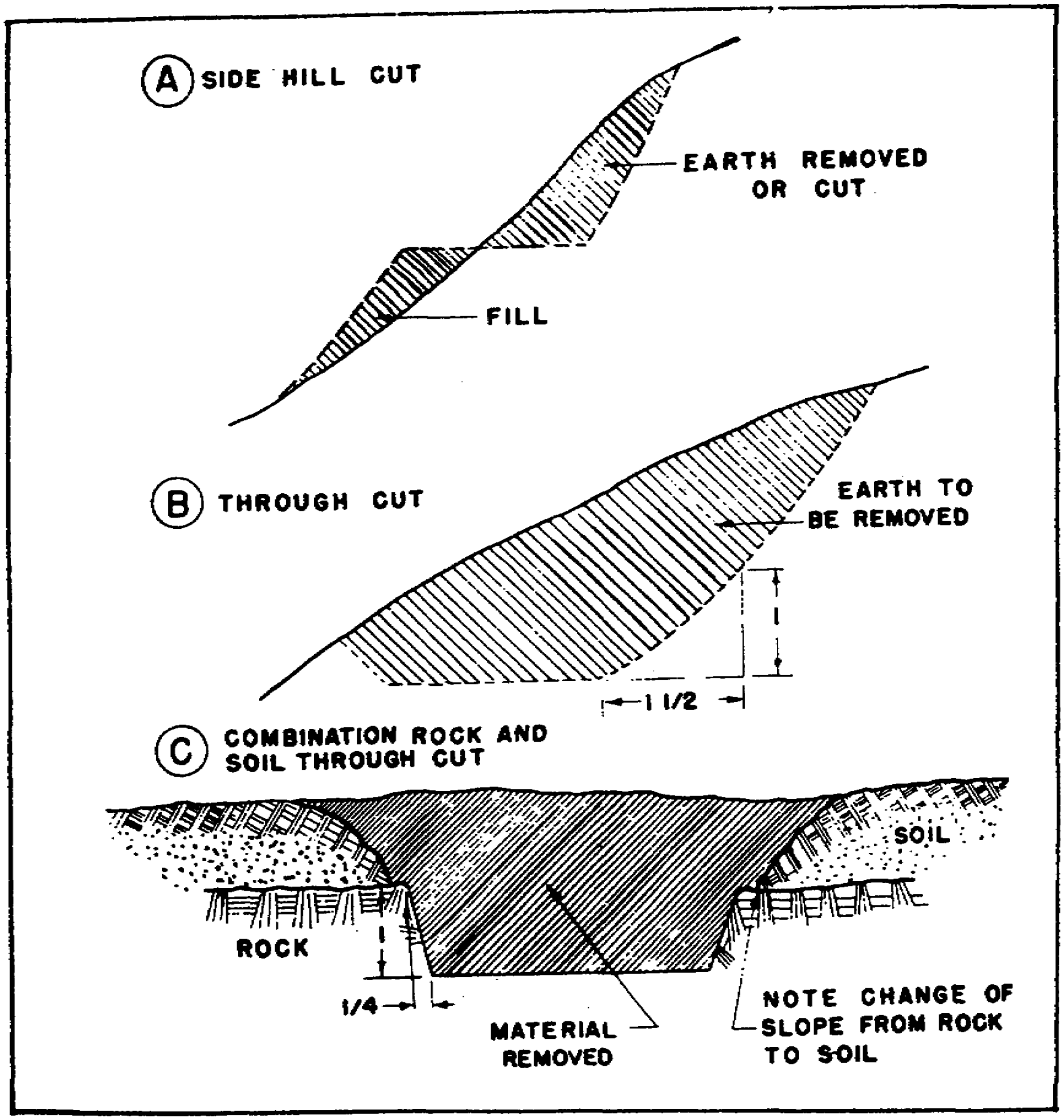


Figure 2.2. Kinds of Cuts.

a. In a sidehill cut, the roadbed surface lies partly below and partly above the normal level of the ground. The earth which must be removed in making this cut may generally be dropped over the other side of the proposed track line to provide fill material.

b. In a through cut, the entire roadbed lies beneath the normal surface of the ground.

c. In a fill, the entire roadbed lies above the normal surface of the ground. Fills are used to avoid building bridges over ravines and other low areas.

d. Slopes are inevitable wherever there are cuts and fills. And wherever there are slopes, you can expect to have erosion and stability problems. Although the design of cuts, fills, and slopes is a construction problem that does not come within the scope of this text, the track supervisor who is well informed on design can prevent the necessity of major repair work and can make minor repairs that poor design creates. Design of slopes as used in cuts and fills depends upon a knowledge of soil stability and rock formation. A few simple rules to guide the track supervisor are given below.

(1) Ordinary stable soil may be sloped at a ratio of 1 1/2 horizontal to 1 vertical (1 1/2:1) without danger of sliding. Rock may be sloped at a ratio of from 1/8 to 1/2 horizontal to 1 vertical, depending on the formation and composition of the rock.

(2) Cuts are sometimes made through combinations of rock and soil. When this occurs, the slope changes at the point where rock changes to soil in the cut, as shown in part C of figure 2.2. The rock is at the lower section of the cut.

e. Erosion is one of the things that the track supervisor must constantly guard against. Unprotected slopes in a cut may wash away in heavy rainfall and cover the track with dirt. Operations must be halted until it is removed. On a fill, a washout may leave the track unsupported, again bringing operations to a standstill until repairs are made. Commercial rail lines rely to dependability for business, and military lines, being main supply routes, must be kept open. Therefore, such occurrences as washouts must be avoided.

Three ways of preventing erosion of slope walls are intercepting ditches and dikes, inducing plant growth on the slopes, and building retaining walls.

(1) Intercepting ditches and dikes are discussed in section II where track drainage is discussed in detail.

(2) Plant roots hold the soil together, giving it additional stability. For civilian railroads, introducing plant growth serves the further purpose of beautifying the right of way, a consideration often underrated in importance in a competitive transportation market. A wide variety of vegetation can be used: honeysuckle, shrubs, vines, roses, and various pasture sods. Experience shows that vegetation on slopes pays for itself many times over by eliminating other costly maintenance.

(3) Where space does not permit proper sloping or where slopes persist in sliding, the usual remedy is to construct a retaining wall at the foot of the slope. The wall may be of concrete, stone, timbers, or discarded crossties.

2.4. BALLAST

Ballast is laid upon the subgrade, the prepared dirt surface of the roadbed. A good ballast material should be workable, durable and strong enough to resist crushing, and angular in shape to resist movement and to permit drainage when compacted. Ballast supports the crossties resting upon it, holding them firmly in place. It thereby maintains alinement, provides uniform support for the track, and, if properly structured, distributes traffic weight evenly on the roadbed. Ballast provides a flexible base so that ties can be moved to adjust rails to proper alinement and surface. It reduces dust and deters the growth of vegetation along the tracks. The following three paragraphs discuss ballast materials, their selection, and the ballast section.

2.5. BALLAST MATERIALS

Materials used for ballast and their application vary greatly. The right ballast material to choose depends on the location and on the kind of traffic expected. High-speed, large-volume, or heavy-tonnage traffic all justify an expensive ballast. The type of roadbed also influences ballasting. A high fill of easily drained, stable soil does not require as much ballast as a cut where satisfactory drainage is hard to get. The materials used for ballast depend upon their availability and cost. Brief discussions of the properties of the more common ballast materials follow.

a. Broken or crushed stone, usually some form of lime-stone, ranges in size from 3/4 to 2 1/2 inches. This material is sometimes considered difficult to handle and is always expensive. But it provides excellent drainage, tends to hold the tracks firmly in place, resists being crushed into dust, and is easily cleaned. It is probably the most desirable ballast for trackage for heavy-tonnage, high-speed service. Traprock, one of several forms of fine-grained, igneous stone, is often used as ballast.

b. Gravel in adequate quantities is usually available to most railroads from local gravel pits. Such gravel is known as pit-run or unprocessed. It may sometimes be used for ballast as it comes from the pit but is usually screened or screened and washed before use. Good gravel ballast contains only small quantities of dust and sand. For tracks used only for light service, such as branch lines and passing and yard tracks, it is unnecessary to wash or screen the gravel. However, if heavy service is expected and pit-run gravel is to be used, it should contain no more than 2 percent dust or more than 40 percent sand. The percentage is determined by weight.

c. Slag is the waste product from furnaces for the reduction of ore. For railroads running through or near locations where large quantities of iron or other metals are processed, slag is abundant and cheap. However, it should be used with caution because its quality varies widely. Good slag ballast is free from dust and has excellent drainage qualities. The better slag ballast compares favorably with crushed stone.

d. Cinders are the residue from coal used in furnaces. The advantages of cinders as ballast lie in their fine drainage properties and ease of handling. Although cinder ballast is quickly reduced to objectionable dust under traffic, it may be used in yards if cinders are easily obtainable and economical.

e. Sand, where plentiful, is sometimes used for ballast. It has the advantage of excellent drainage and economy; however, it does not make a good ballast for several reasons. It is easily washed or blown away, creates a considerable dust problem in dry areas, and makes track resurfacing difficult. Sand should be used for ballast only as an expedient or on light-traffic roads.

f. Other materials sometimes used as ballast include shells; small pieces of an ore-stone mixture called chats; and an impure, dull-colored, flintlike quartz called cherts. However, they seldom excel the quality of cinders or gravel. The selection of such materials must be made on the same basis as other more orthodox ballast materials: they must be free from dust, must be able to withstand the movement of trains without being crushed, and must hold the track in proper line and surface.

2.6. SELECTING BALLAST

Civilian railroads are interested in overall economy in selecting ballast, not only in the purchase price but also in the cost of maintenance once the ballast is in place. For this reason, selecting proper ballast is a problem that must be solved for each individual case. Crushed rock, although far superior to cinders, would never be used on lightly traveled lines because the saving in maintenance could never offset the original high price, unless rock were extremely plentiful and cheap in the area. Similarly, cinders, although far cheaper than crushed rock, would not be used as ballast on a heavily traveled main line because the cost of continually putting the track back in proper condition would more than eliminate the initial saving. However, good slag might be cheap enough to justify its use even on the heaviest traveled lines in steel-production areas, since its quality compares favorably with crushed stone. Slag would certainly be used on branch lines.

For military lines, ballast selection should be made on a basis similar to that governing a commercial railroad. Of first importance is its availability. Military track officials may and usually must use whatever material they find at hand for ballast. Nevertheless, the selection should be made carefully. A main-line railroad in a theater of operations is a vital supply route; the condition of its ballast is important. Although cost is not a primary worry, it should be considered in selecting ballast. Anything that affects cost for civilian railroads affects the capability of military track officials to successfully carry out their military mission. For exam-ple, a heavily traveled main line in the United States would probably be ballasted with crushed stone, because it is more economical in the long run. Fewer men and machines are needed to keep the track in repair economically. It is also good practice for the military to use high-quality ballast on an important rail artery, because neither men nor machines are ordinarily on hand to maintain poorly ballasted track in a theater of operations.

Using the right ballast in the right place helps a civilian railroad save money. The same method helps the military to maintain trackage in a satisfactory condition despite shortages of men and tools. However, the military track official's job is more difficult than that of his civilian counterpart. Accomplishing it successfully depends largely upon the ability to make proper compromises and expedients.

2.7. BALLAST SECTION

The ballast section is the cross section of a track between and above the toes (the lowest points) of the ballast slopes; it may or may not include the subballast. Deciding on the amount, depth, and disposition of ballast in a ballast section is no less a problem than that of picking the right material. Again, traffic and terrain govern the decision. In general, heavier, faster trains require a deeper ballast section than do others. Remember that ballast provides drainage, holds track in line and surface as permanently as possible, distributes train weight over the roadbed, reduces dust and weed growth, and provides a means for returning track to line and surface after passing trains move it. If these purposes are kept in mind, the specifications given below for depth and the position of ballast will seem reasonable.

To insure that ballast will hold track in place, the crossties are submerged in it until only the top 2 inches are exposed, as shown in figure 2.3. This anchors the tie in place almost permanently. Since the track must be adequately drained, the ballast must be deep enough to drain off all the water falling on or running over the track. Military specifications require a minimum depth of 4 inches under the tie bottom, but 8 to 10 inches are preferable. In subparagraphs a and b, details are given on the ballast sections for military main lines and other less heavily traveled ones.

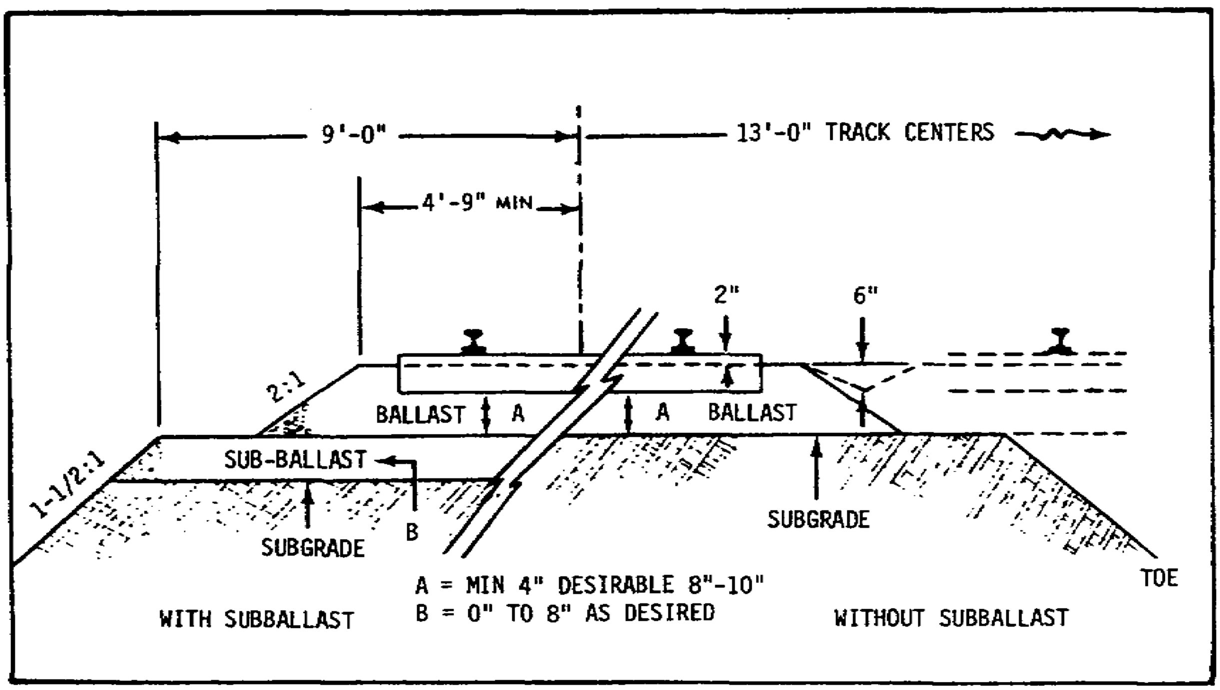


Figure 2.3. Typical Main-Line Ballast Section

a. For a military main line, a depth of 12 inches of top-quality ballast is usually maintained. Let us assume that the military standard 6-inch deep ties are being used. They are set in the top 4 inches of the ballast; the remaining 8 inches extend from the bottom of the tie to the top of the subballast, if it is used. Subballast, a low-quality ballast, usually consists of a layer of cinders spread before the top ballast is put down. Using subballast reduces the unit pressure on the roadbed where a normal ballast section would settle or crush the roadbed. Subballast helps to keep the track dry; it carries off the water draining down through the ballast and helps to prevent the mud beneath from working up into and contaminating the ballast itself. Subballast is not used on old lines because continually adding new ballast through the years provides a deep enough section of top ballast.

b. On less heavily traveled main lines, subballast is not used and as little as 6 inches of ballast may support the ties. But a good quality ballast is still desirable. Gravel and slag are often used on this type of trackage, and even cinders may be good enough. Minor branch lines are often ballasted with as little as 4 inches of cinders or gravel.

2.8. SUMMARY

The roadbed provides a means of holding the track above the surrounding land to prevent water from standing on the tracks. Minor terrain irregularities on the right of way are compensated for by filling in low spots and cutting through high spots. Slopes on the roadbed must be protected from erosion by ditches and dikes. A material such as crushed rock, cinders, slag, gravel, or sand is used as ballast to stabilize ties, distribute the weight of the train to the roadbed, and aid in track drainage. The amount, depth, and disposition of ballast in the ballast section are governed by the traffic and the terrain.

Section II. Drainage

2.9. GENERAL

Adequate, well-maintained track is essential in operating any railroad. Water and the damage it causes constantly threaten the track, because practically all major track damage can be attributed directly or indirectly to water. The time and effort spent on achieving and maintaining adequate drainage are never wasted. However, ideal roadbed drainage is difficult to achieve because few track locations drain perfectly. You seldom find ideal drainage on either military or commercial lines.

The importance attached to achieving good drainage is pointed out in the rules of two large commercial lines:

> Cold is damaging only by reason of the water which it freezes; therefore, the first and most important provision for good track is drainage.

> Drainage is of the first importance in track maintenance.

The remaining paragraphs of the section discuss why drainage is needed, how to obtain it, how water pockets are corrected, why and how ballast is cleaned, and how side ditches and other drains are constructed.

2.10. NEED FOR DRAINAGE

Everyone becoming acquainted with track maintenance soon becomes aware that water is track's greatest enemy. They learn that water splits rocks when it freezes, washes away roadbed material when ice and snow melt, rusts track joints, rots ties, and sometimes in a spring freshet washes away the entire track. They learn that adequate track drainage is of primary importance in keeping a train operating. Pumping ties and water pockets result when track drainage is adequate.

a. Pumping ties. As heavily loaded trains pass over an inadequately drained track, they force the ties down into the ballast, pushing the ballast into the subsoil of the roadbed. After each train passes, the resiliency of the steel rails lifts the ties up, leaving a hole under each tie. After numerous trains have passed, this movement of the ties "pumps" water into the already formed holes, and the water rots the ties.

If a section of track has several pumping ties, the track becomes spongy, uneven, and unstable. The immediate remedy is to pack new ballast under the tie or ties. Although this apparently clears up the trouble at first, it only adds to the difficulty in the long run. As the ballast under each tie goes deeper, the subsoil is forced up between the ties, as figure 2.4 shows. Not only is instability created but even the little drainage previously possible is prevented. Furthermore, the holes are soon re-formed, and water pockets result.

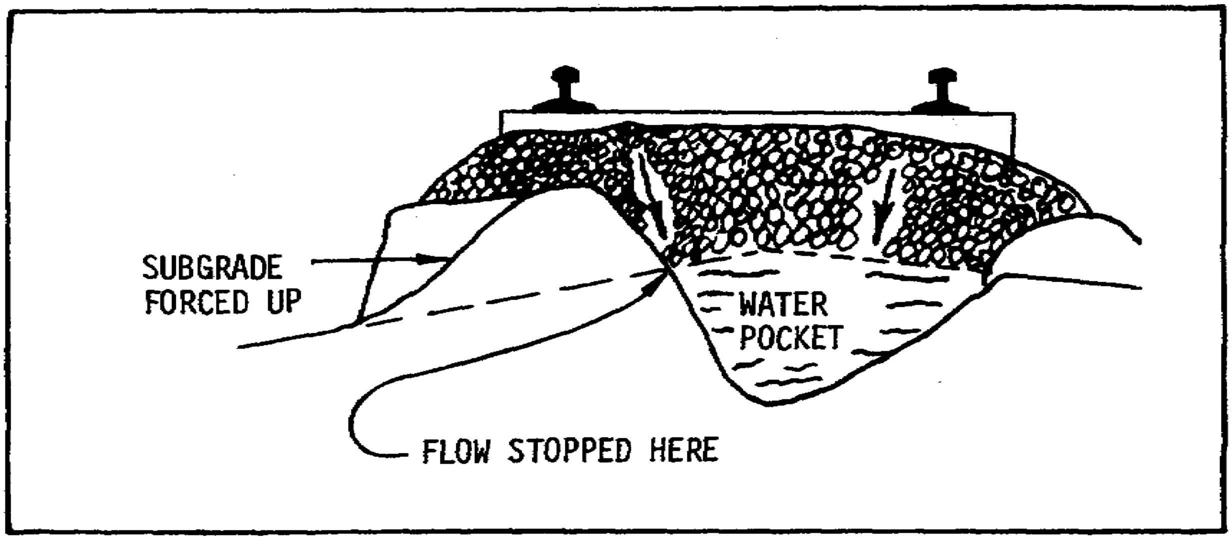


Figure 2.4. Drainage Obstructed When Subsoil Forced Up

b. Water pockets. Continually adding ballast under pumping ties eventually results in large accumulations of porous ballast deep in the roadbed, sometimes to a depth of several feet, surrounded by subsoil that is impenetrable to water. As water collects in the porous material and cannot drain out, a water pocket forms. Obviously, a water pocket does not offer the same resistance to train loads as solid roadbed. Such variable support results in uneven track and spongy roadbed. Adding ballast, a penetrable material, to the soft spots in an attempt to achieve uniform support only increases the size of the water pockets and forces the subsoil up into the ballast section, cutting off any possible drainage from the ballast. Water pockets can present problems in deep cuts, in fills, under heavy traffic, and in freezing weather.

(1) In deep cuts. Water pockets commonly occur in deep cuts where adequate drainage is extremely difficult to establish. Such cuts are known as wet cuts. Water pockets in a cut result in reduced train speeds and extensive track maintenance.

(2) In fills. Water pockets can form in fills in spite of the ease of drainage normally expected to prevent the pockets. In fills or embankments, water pockets are dangerous and are economic liabilities. In an embankment, water pockets may cause the fill to fail just as a train passes over the track. Here they could be caused by using a small amount of porous material in proportion to a large mount of impenetrable soil in the original construction of the embankment.

(3) Under heavy traffic. Operating numerous heavily loaded trains over a line with poor ballast is often the reason for

water pockets forming: the ballast is soon compressed under the ties. And when a rail line is either new or recently repaired, water pockets soon form for the same reason, particularly if traffic over the line is heavy.

(4, In freezing weather. If water pockets are allowed to remain until winter, freezing temperatures cause ice to form in the pockets. As the ice expands, a heaving roadbed soon appears. The uneven track can be leveled only by adding shims, bearing pieces used to raise rails, at the low spots. Shims are placed either between the tie and the tie plate or between the tie and the rail. Draining the water pockets has to wait until the spring thaw. The amount of labor and material needed at this stage is much greater than that required earlier to prevent or eliminate the water pockets.

2.11. CORRECTING WATER POCKETS

Water pockets are simply another drainage problem. And they can be a continual aggravation where the subsoil's stability or the track's location makes drainage a serious problem. For example, a wet cut is typical of such locations.

The classic solution to the water-pocket problem is to construct a cross drain from the location of the pocket to a side ditch that carries the water away from the roadbed. Now that the water has a way out, the problem is solved. Cross drains are discussed in paragraph 2.15 and shown in figures 2.8 and 2.9. Side ditches are discussed in paragraph 2.14 and an example of one is shown in figure 2.5. Grouting, another method used to correct a water pocket, is discussed in paragraph 2.15d and illustrated in figure 2.10.

2.12. OBTAINING DRAINAGE

Now that you know the great necessity for drainage, how do you go about obtaining it? There are but two requirements for achieving good drainage: a force to move the water and a path for it to follow. Gravity provides a universal force to satisfy the first need; it is only necessary to provide the path required, and gravity will move the water through it.

You read earlier that the roadbed supports the track above the level of surrounding ground. If nothing on the roadbed obstructs the flow of water, it runs off the tracks and roadbed to the ground. However, if water is allowed to remain on the ground close to the roadbed, the stability of the surrounding soil is endangered.

One function of ballast is to provide drainage. Good ballast is porous, and rain or water from other sources falling on the track passes through it easily, finding its way to the impenetrable sub-grade. The water then passes through the subballast over the sub-grade and into a drainage ditch or drain, as figure 2.5 shows. As you read earlier and see in figure 2.4, water pockets may result in forcing the subsoil up into the ballast and thereby hamper drainage. Then, too, ballast ground into dust or fine dirt and cinders blown onto the track may obstruct drainage. Severely contaminated ballast must be cleaned or replaced.

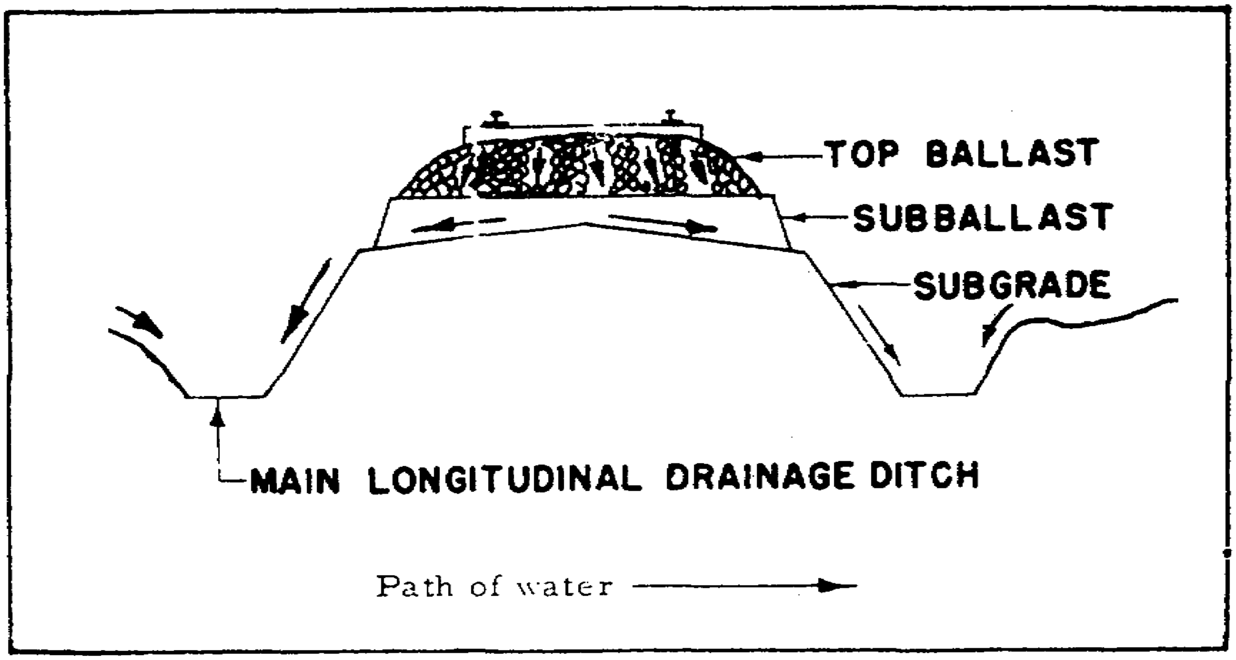


Figure 2.5. Ballast As Drainage Medium.

2.13. CORRECTING CONTAMINATED BALLAST

Whenever ballast becomes so contaminated that drainage is seriously impaired, it must be cleaned or, if cleaning is impossible, replaced. Usually, the first sign is a poor track surface, one that refuses to remain corrected for any length of time. Investigating such spots generally reveals poor drainage and pumping ties.

Not all types of ballast can be cleaned. Pit-run gravel or cinders are usually replaced when they become too dirty to serve as satisfactory ballast. However, crushed stone or traprock is easily cleaned; slag or screened-gravel ballast can also be satisfactorily cleaned. To clean ballast, it is dug away from the ties and screened or forked. The following methods are used:

a. Stone, slag, or screened-gravel ballast. To clean stone, slag, or screened-gravel ballast, follow the steps given here.

(1) Remove shoulder ballast (the ballast from the ends of ties outward from track) down to subgrade.

(2) Remove ballast from cribs (the space between ties) down to bottom of ties.

(3) Remove ballast from the space between tracks down to 6 inches below bottom of ties or down to subgrade if the ballast below the ties is less than 6 inches deep.

(4) Clean all ballast removed, using ballast forks or screens.

(5) Replace the cleaned ballast and add any new ballast needed to achieve the required ballast section.

b. Pit-run gravel or cinder ballast. In cleaning pit-run gravel or cinder ballast, follow these steps.

(1) Remove all ballast except that directly under ties.

(2) Dress the subgrade.

(3) Add new ballast and raise track as required. (Railway Track Maintenance II explains the procedure in more detail.)

c. Mechanical cleaning. In recent years, many civilian railroads have found the cost of cleaning long stretches of ballast by the manual methods given in subparagraphs a and b to be prohibitive because of the tremendous labor requirements. The civilian lines have resorted to mechanized methods for cleaning ballast. One type of machine they use moves along the track digging up shoulder or between-track ballast, screening it, and replacing it. However, the ballast cleaner does not remove or screen the crib ballast. One widely held theory that the crib ballast is eventually replaced by the shoulder or between-track ballast in tamping seems supported by the success of mechanized ballast cleaners. The initial cost of the machines is high, and they must be kept in constant use to justify the investment.

d. Frequency of cleaning. Actually inspecting how badly the ballast is contaminated is the only way to determine the frequency of cleaning. However, experience shows that tracks in terminals usually require that ballast be cleaned every 1 to 3 years, heavy-traffic roads every to 3 to 5 years, and light-traffic lines every 5 to 8 years.

2.14. LONGITUDINAL OR SIDE DITCH

The effectiveness of the supplementary drains discussed in paragraph 2.15 depends upon a side or longitudinal drain large enough to carry off all the water collected by the supplementary ones. The usual practice is to provide a large ditch running parallel to the tracks, leading the water to a natural stream at its intersection with the right of way, as figure 2.6 shows. Sometimes a pipe is substituted for the ditch. The size of the side ditch depends on the needs of the trackage to be drained. To have sufficient capacity, the ditch should never be less than 1 foot deep or less than 1 foot wide at the bottom, as shown in figure 2.7. Its sides should be made on a slope of no more than 1 unit high to 1 1/2 units across; for example, if the height is 2 feet, then the horizontal dimension of the side should not be less than 3 feet. The grade of the main ditch should be at least 0.3 percent. Where water movement is so rapid that scouring (erosion) occurs, the ditch should be paved.

In a wet cut, two serious difficulties pertaining to the main longitudinal drains arise. First, the original cost of railroad construction prohibits sufficient width for an ordinary side ditch. Second, the usual profile of a wet cut is nearly level, making it difficult to obtain a satisfactory grade for the side ditch. The solution lies in using large pipe drains instead of ditches. Subparagraph a describes the pipes used in longitudinal ditches; Subparagraph b, the procedures for cleaning the pipes.

a. Pipe drains. Because pipes offer lower resistance to the flow of-water than do ditches and because of their greater capacity for their size, they are ideal for use in a nearly level wet cut. The installation of this type of side drain is shown in figure 2.9. The main pipe must be at least 10 inches in diameter, and it may be either corrugated steel or vitrified sewer pipe. The grade may be as little as 0.25 percent. To insure that water can get into the drain all along its length, corrugated steel pipe must be perforated. For the same reason, the joints of vitrified sewer pipe are opened about one-half inch. The pipes must be covered with gravel, cinders, stone, or straw so that dirt cannot get in and clog the pipe.

b. Methods of cleaning longitudinal drains. Once a satisfactory longitudinal drain has been installed, the track supervisor has to direct his attention to keeping it clean. Pipe drains do not offer a serious problem, since storm water washes them clean. However,

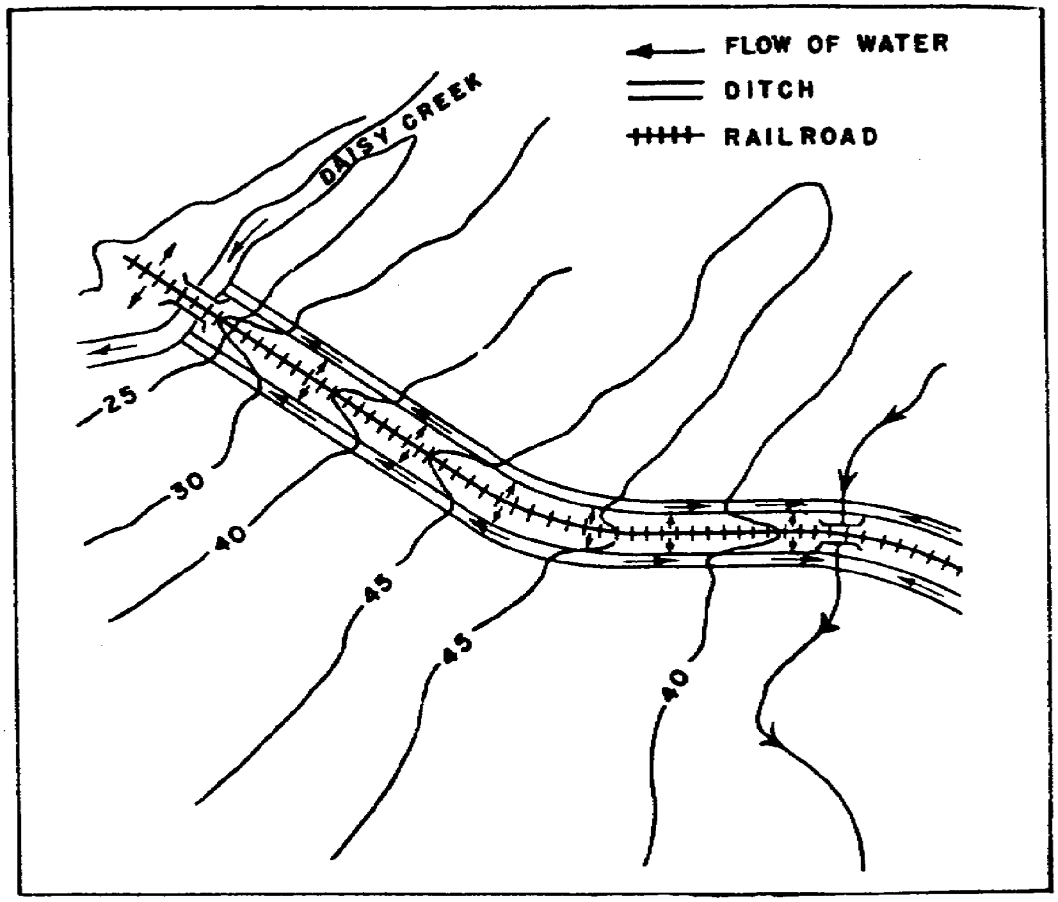


Figure 2.6. Principles of Longitudinal Drainage.

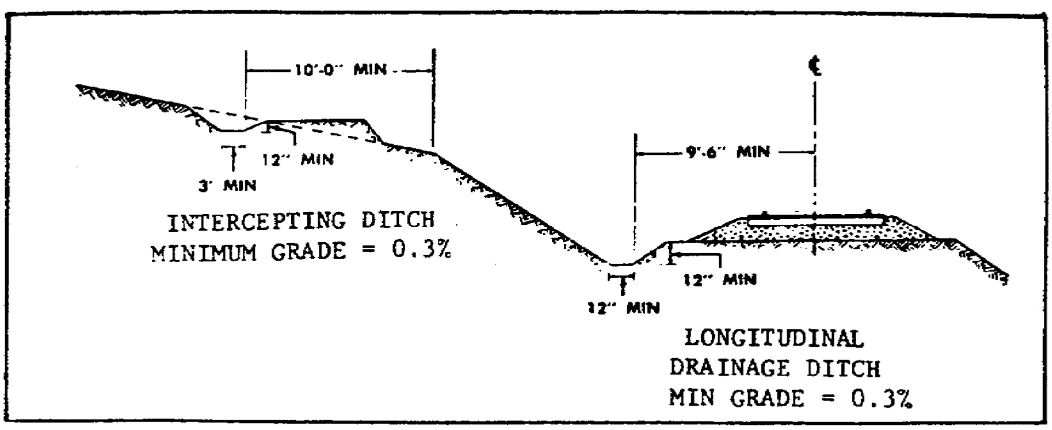


Figure 2.7. Minimum Dimensions and Grades of Intercepting and Longitudinal Ditches.

the side ditch requires a good deal of attention. Several approved procedures may be followed for cleaning side ditches. The one to be used, of course, depends on the labor and equipment available; the choice is affected to some extent by the density of traffic moving over the rail line. Cleaning methods can be broken down into two groups: on-track and off-track procedures.

(1) On-track procedures involve a work train moving along the tracks at a slow rate of speed, the cleaning being done at the rate of the train's movement. This work obviously blocks the track for other train movements. It can be used only on multiple-track lines where the other track or tracks are capable of handling the regular traffic, or on single-track lines where traffic density is so low that the work-train operation does not seriously interfere with regular traffic or vice versa. The chief advantage in on-track cleaning is its economy when large quantities of refuse must be hauled a great distance. Where this is not necessary, it is usually more practical to use an off-track procedure.

The most common method of cleaning ditches with a work train is simply to employ a force of men with handtools to clean the ditch and deposit the refuse in cars of the work train. It usually requires a force of 18 to 20 men working by hand to justify the use of a work train.

On-track ditch maintenance may involve using a mechanical ditcher or spreader that uses a steel blade to clean or enlarge the side ditch. Since the ditcher blocks adjoining tracks on multiple-track lines, it can be used only when the track is going to be empty.

(2) Off-track procedures must be used when traffic requirements prohibit using a work train. The number of off-track methods available to the track supervisor depends largely on his ingenuity; terrain, drainage, and available resources govern the method chosen. Only a few of the methods are mentioned here.

Bulldozers, dragline excavators, crawler cranes, and wheelbarrows, if available, are a few of the implements that may be used to advantage. The contour of the land adjacent to the ditches is always the determining influence in choosing the proper method. High embankments or fills with narrow shoulders and narrow cuts obviously exclude the use of large equipment. Wheelbarrows are often the only implements that can be used in such locations. To speed cleaning with wheelbarrows, wooden runways are often used.

2.15. SUPPLEMENTARY DRAINAGE

A cross drain is mentioned in the discussion of the classic solution to the water-pocket problem in paragraph 2.12. Actually, a cross, or lateral, drain is only one type of supplementary drainage, that is, the drainage needed to dry up water pockets and to divert water before it reaches and endangers the track. Other remedies used to solve the drainage problem are intercepting ditches, cinder trenches, grouting, and French drains.

a. Cross or lateral drain. The simplest form of cross drain is the removal of ballast from several cribs, that is, from the spaces between several ties. Sometimes pipes are driven at a slant into the roadbed from the side, as shown in figure 2.8. Cross drains tap any water tending to form water pockets and lead it to the main side ditch or to a pipe drain. Lateral pipe drains should be about 4 inches in diameter. If the drainage problem is severe, it may be necessary to locate cross drains every one-half rail length, that is, at about 20-foot intervals.

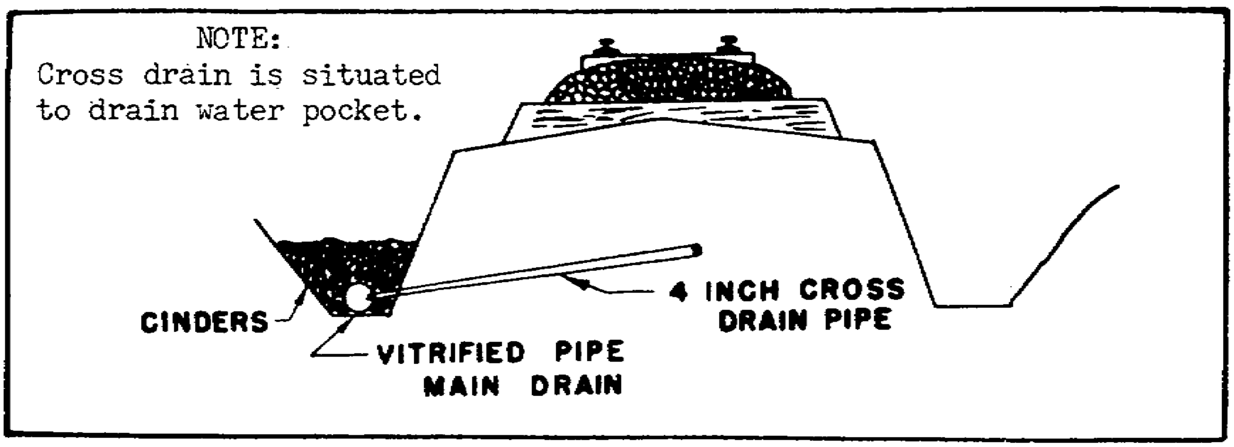


Figure 2.8. Cross Drain Installation With Pipe Drain in Subgrade.

A procedure often used with pipe drains is to have them run on top of the subgrade directly below the ballast and drain into the side ditch, as shown in figure 2.9. This arrangement aids the flow of water across the subgrade, preventing it from seeping into the subsoil, if the soil is spongy and soft rather than solid and impenetrable. In addition, these drains lead off spring water if springs occur in the roadbed, as they frequently do in wet cuts. Perforated pipes 2 to 3 inches in diameter are used. Although vitrified pipe is specified for drainage, corrugated metal pipe is frequently used, especially for short-term military use. It should be perforated to allow water to seep through, and galvanized or asphalt-coated to

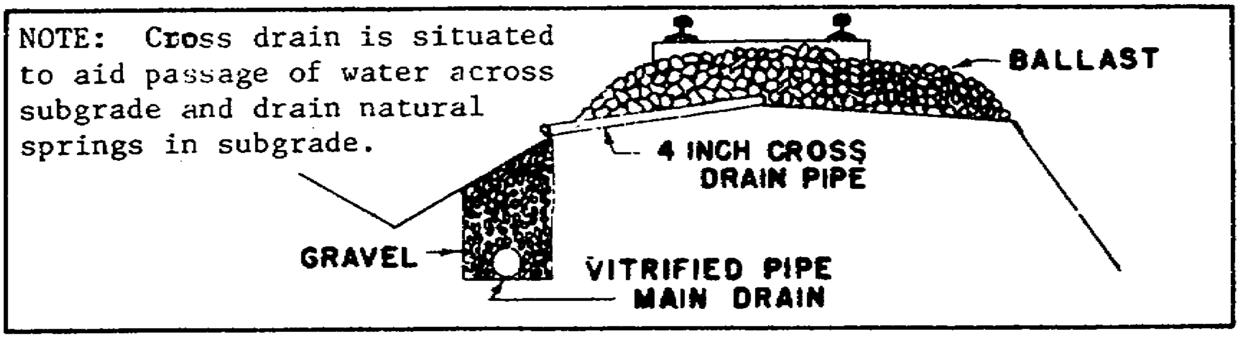


Figure 2.9. Cross Drain Installation With Pipe Drain on Top of Subgrade.

prolong life. The intervals at which pipe cross drains are installed depend on the severity of the problem.

b. Intercepting ditches. Installed in the walls of a wet cut (fig. 2.7), intercepting ditches divert water before it reaches the track and has a chance to do any damage. Furthermore, they prevent water from running down the face of the cut and causing erosion. The minimum dimensions for an intercepting ditch are 3 feet wide at the bottom and 1 foot deep. If experience shows that these dimensions are not sufficiently large, they must be increased. These ditches must have a minimum grade of 0.3 percent to move the water away. If the soil is not firm, water movement in the ditch causes scouring. Should this happen, the ditch must be paved with asphalt, concrete, stone, or bricks. In place of the intercepting ditch, a dike is some-times constructed at the top of the cut.

c. Cinder trenches. A system of trenches filled with cinders may be used as cross drains if the location does not require pipe laterals but does need some supplementary drainage. These drains or those formed by merely removing ballast from a crib should, in no case, be located directly under a rail joint (ch. 3, sec. IV).

d. Grouting. One inexpensive remedy for water pockets is grouting. Grout is a fluid mixture of cement and water or of cement, sand, and water. The mixture is injected under pressure into the void of the water pocket to force out the water and seal off the pocket, as illustrated in figure 2.10. Commercial grouting equipment is available.

e. French drains. Where water pockets are chronic and are located higher than the drainage ditch, as in fills, the use of French, or rock, drains is often justified. Such a drain is constructed by removing the fill materials from the affected area and

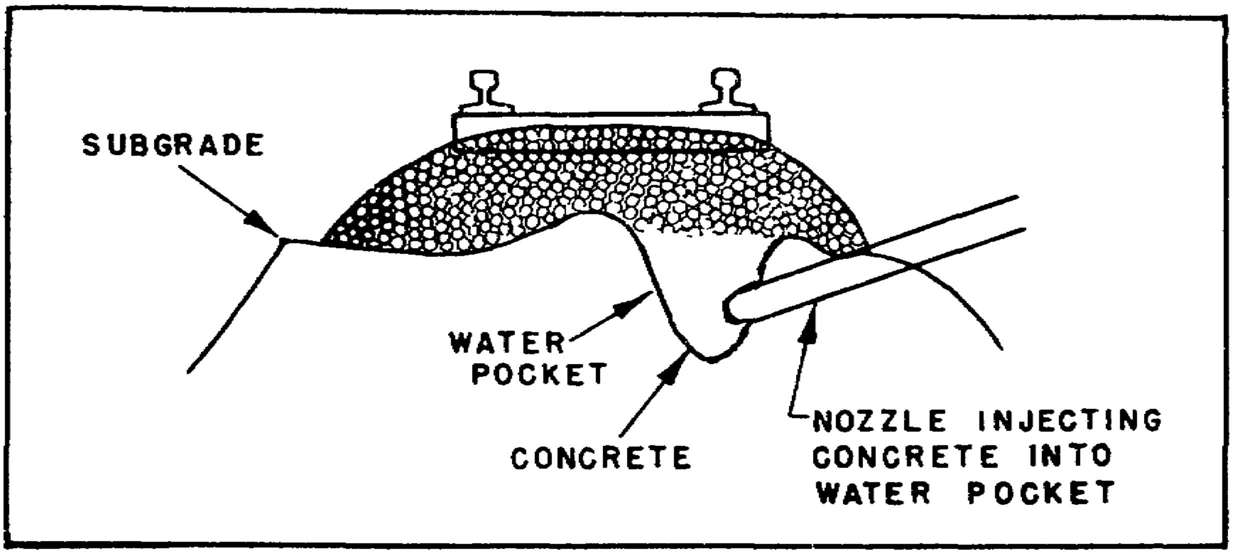
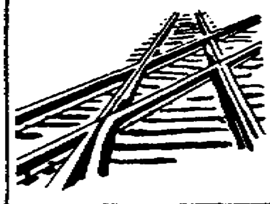


Figure 2.10. Grouting Corrects Water Pocket.

replacing it with stones or rocks. Water cannot be trapped in the rocks because of the many passages between them; this action cures the water pocket. If trains are operated over the railroad while the French drain is being constructed, some form of temporary support is needed to hold up the tracks with the fill material removed. This support may be timber shoring, heavy wooden beams, and columns that serve as a bridge. These members are removed when the stone is in place.

2.16. SUMMARY

Drainage is important in track maintenance. Poor drainage can cause pumping ties and water pockets that, when ice forms, lead to a heaving roadbed. Water pockets can be drained with a pipe and drainage ditch or by filling them in with stones or grout. Areas surrounding the roadbed must be drained by ditches, pipes, or rock drains; and the ballast and ditches must be cleaned so that water cannot be blocked.



Chapter 3

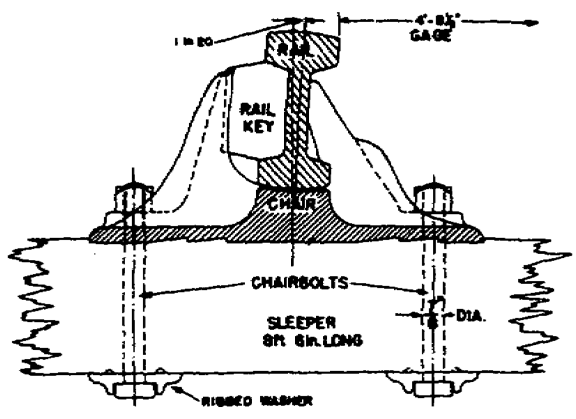
TRACK ELEMENTS

3.1. INTRODUCTION

Railroad track has two primary functions: to transmit train weight to the roadbed, and to guide the wheels of trains in the desired direction. To carry out these purposes, various forms of track have been and are being used; however, the use of two rails in basic. The differences in track construction involve variations in the form or shape of the rails and in the means of holding the rails in place.

In the United States, the earlier forms of track consisted of two timbers running longitudinally with the right of way. Fastened to the upper surface of each timber was an iron strip on which the car wheels rolled. These timbers were known as stringers and rested on granite blocks, but the blocks proved unsatisfactory because they cracked in freezing weather and moved in mud, disturbing proper gage. Wooden stringers also failed the test of long-time usage. The iron strips wore badly and often became unfastened, especially at the ends. The curled-up, unfastened iron strips, commonly referred to as "snake heads," fouled operations by delaying or severely damaging trains.

Prime effort then was directed toward finding a more satisfactory rail. British practice, on which most early American procedures were based, involves a solid, peculiarly shaped iron rail which necessitates cast-iron chairs or pedestals for support, as shown in the inserted sketch. This complicated system of rail support was far too costly for use in the United States where exceedingly long distances had yet to be spanned by rail lines.



Nevertheless, Robert L. Stevens, an early American railway engineer, was impressed with the idea of solid iron rails. He introduced a change of paramount importance to the United States by importing flat-based, solid iron rails rolled in England. These rails were used in the building of the Camden and Amboy Railroad. The flat base eliminated the need for the iron chairs, as the rails could be easily fastened to wooden pedestals by hookhead spikes that Stevens designed. The "T-rail" as it was called and the spike Stevens designed have changed a great deal, but the fundamental ideas remain the same.

The wooden pedestals to which Stevens fastened his rail were plugs set in blocks of stone. Had Stevens been farsighted enough to see the advantages of using crossties for support instead of pedestals, he would be known as the father of modern track instead of as the inventor of the T-rail.

In time, the pedestal method of support proved too costly, and what was thought to be a futile attempt to substitute wooden crossties for the pedestals proved highly successful. The wooden crossties provided such excellent support that gage and surface were more easily maintained than before. With these developments, the essentials of track, as we know it today, were established.

Modern main-line track construction bears only a slight resemblance to the first successful endeavors to use the T-rails supported by wooden crossties. Yet, significantly, improvements in modern track reflect no fundamental change in theory but rather modifications in design and addition of new features that enable the basic elements to perform their original functions more effectively.

Chapter 3 is divided into four sections: rail, crossties, track fastenings, and rail joints.

Section I. Rail

3.2. GENERAL

The trackwalker is the first line of defense against track failure. As he walks along an assigned section of track, he looks closely at the structure of steel and wood that must provide a safe path for trains. He critically examines rails and their joints, and he keeps a sharp eye for loose spikes, detective ties or tie plates, and displaced rail anchors. Each of these items has a definite purpose, and anything which would interfere with proper operation must be corrected by the trackwalker or reported if he cannot do it alone.

So that you will have a deeper insight into the mechanics of track, the elements making up track are discussed in detail in the paragraphs following. To have more than the trackwalker's appreciation for defective track, a person must understand the capabilities and design of the track components.

3.3. RAILS OF STEEL

The greatest difference between Stevens' and today's rails is not immediately noticeable because the difference is in their composition. Stevens' rail was rolled iron while modern rail is made of steel. Stevens knew that steel possessed qualities that made it superior to iron for rails, but the method of its manufacture at that time made its cost prohibitive for any uses but those requiring only small quantities. His selection of rolled iron for rails was appropriate and justified. Later, when the Bessemer process for making steel was developed, steel rails became practical. The greater resistance of steel to impact, its higher ultimate strength, and its greater resistance to wear were exploited when steel could be made in large quantities at a reasonable price.

The Pennsylvania Railroad, now the Penn Central, was the first company to use steel rail in the United States. This rail, like the first iron T-rail, was imported from England in 1863. The first American steel rail was produced in 1865.

3.4. METHOD OF MANUFACTURE

The Bessemer process for making steel was used for many years. Today the open-hearth process is much more common. In this process, pig iron and scrap steel are melted in a furnace. Air is blown across the molten metal combining with and removing carbon, a lower content of which being the major difference between iron and steel. The carbon content is brought below the desired level; then the metal is recarbonized to the exact requirement. Other alloying elements, such as manganese, are added. The furnace or hearth is then tapped and the molten steel poured into a ladle. Each batch so prepared is known as a heat of steel and is given a heat number.

The molten steel is poured into molds and cooled. When the steel has solidified, the mold is removed, leaving an ingot. The ingots receive heat treatment and then are rolled into blooms about 8 inches square. The bloom is an intermediate stage in form between ingot and rail. At the rolling mills, the bloom becomes a rail. All this rolling from ingot to rail is done with the steel at high temperature. As the hot rail reaches the final rolling stages and before it cools, it is automatically stamped and branded with important information. One roll has lettering cut into the face, and, as it is pressed against the hot web, results in raised lettering. Another wheellike roll, having raised letters that may be readily changed, is pressed against the other side of the web. This information gives the date, place, and type of manufacture as well as the shape and weight of the rail. Paragraph 3.8 tells you how to read the "biography" of a rail from this information.

3.5. FORM

When designing a rail, the section must be determined, that is, the actual measurement, to a thirty-second of an inch, of each surface of the section--cross section--of the rail. Note in figure 3.1 the labels applied to the various surfaces of a section. Note that the topmost part on which the wheels roll is known as the head (HD) or ball. The bottom of the section that rests on the crosstie or on the tie plate is called the base (B) or flange. Between the base and the head is the web (W).

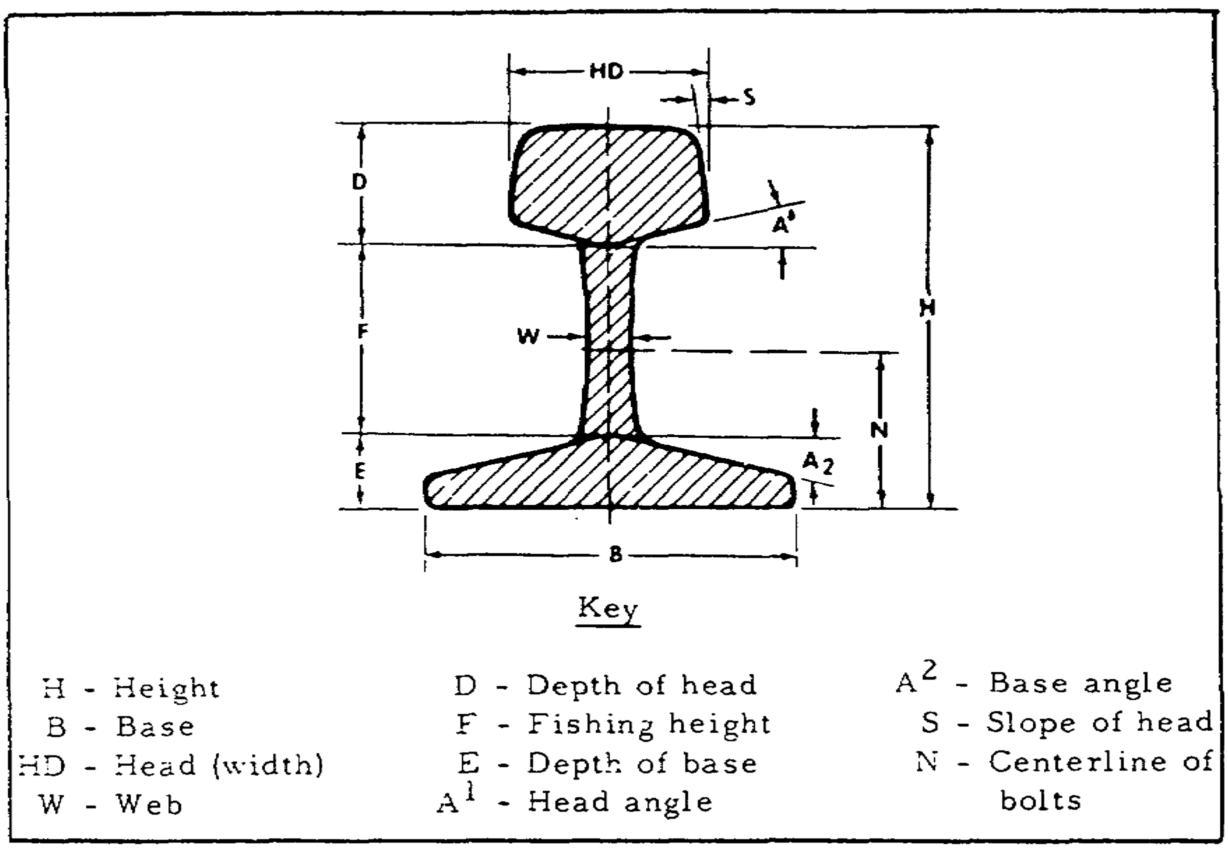


Figure 3.1. Rail Section.

The design of a rail depends upon the weight and speed of trains it is to support, their frequency, and certain influences resulting from the manufacturing process. Data on the various standard T-rail sections are given in table I. Note that the letters at the top of the eleven columns to the right on the table correspond to those on the rail section shown in figure 3.1. The branding symbols given stand for the following rail systems: R.A.-A and R.A.-B, American Railway Association and American Railway Engineering Association; R.E., American Railway Engineering Association; and A.S.C.E., American Society of Civil Engineers.

The most generally used designation of rail is its weight, specified in pounds per yard. Rail which weighs 100 pounds per yard is called 100-pound rail, the "per yard" being understood. Similarly, rail referred to as 75-pound rail weighs 75 pounds for every yard of length. The military standard for theater issue is 85-pound rail in 39-foot lengths; 100-and 115-pound rail may be found on stateside installations.

The weight designation of rail is informative but not completely descriptive. Two rails of the same weight may vary in section: one may be shorter and have a thicker web or its head may be narrower and deeper than the other. Their design is influenced by the manufacturing process.

So that rail may be rolled from blooms with satisfactory temperature control, it is necessary that the amount of metal in the head and flange (base) be approximately equal. The head must contain enough metal so that the rail can withstand a great deal of wear before it must be replaced. Modern practice shows that a deep, narrow head is subject to greater end wear. The base should be wide so that the load is spread over the tie and the rail has a satisfactory resistance to overturning.

3.6. STIFFNESS

The resistance of a rail to being bent is known as its stiffness. Stiffer rail bends less and therefore offers less resistance to train movement and reduces maintenance requirements. A more flexible rail bends more severely under traffic, disturbing ties and ballast.

The stiffness of any beam, whether it is a roof beam or a rail, depends upon its shape and size. The actual theory of the determination of stiffness is based on calculus, the study of which is far beyond the scope of this text. Engineers have shown, however, that stiffness is related to area and height or depth. Since rails are

Table I. Standard T-Rail Sections

[Dimensions in inches]

Branding symbol	Weight per yard	U. S. Steel Corp.	Beth. Steel Co.	Colo. F. & I. Co.	Inland Steel Co.	H Height	B Base	HD Head Width	W Web	D Depth of head	F Fishing height	E Depth of base	A^1 Head angle	A^2 Base angle	S Slope of head	N Centerline of bolts
R. A.-A---	100	10020	100-RA	*1001	110020	6	5 1/2	2 3/4	9/16	1 9/16	3 3/8	1 1/16	1 to 4	1 to 4	1/16 to 1	2 15/16
Do-------	90	9020	90-RA	702	9020	5 5/8	5 1/8	2 9/16	9/16	1 15/32	3 5/32	1	1 to 4	1 to 4	1/16 to 1	2 29/32
Do-------	80	8020	80-RA	....	....	5 1/8	4 5/8	2 1/2	33/64	1 7/16	2 23/32	31/32	1 to 4	1 to 4	1/16 to 1	2 9/16
R. A.-B---	100	10030	100-RB	1002	10030	5 41/64	5 9/64	2 21/32	9/16	1 45/64	2 55/64	1 5/64	13°	13°	3°	2 65/128
Do-------	90	9030	90-RB	* 905	....	5 17/64	4 49/64	2 9/16	9/16	1 39/64	2 5/8	1 1/32	13°	13°	3°	2 11/32
Do-------	80	*8030	*80-RB	....	....	4 15/16	4 7/16	2 7/16	35/64	1 15/32	2 15/32	1	13°	13°	3°	2 15/64
R. E.------	133	13331	133-RE	1330	13331	7 1/16	6	3	11/16	1 15/16	3 15/16	1 3/16	1 to 3	1 to 4.011	4°	3 3/4
Do-------	132	13225	132-RE	1321	13225	7 1/8	6	3	21/32	1 3/4	4 3/16	1 3/16	1 to 4	1 to 4	1 to 40	3 7/8
Do-------	131	13128	131-RE	1311	*13128	7 1/8	6	3	21/32	1 3/4	4 3/16	1 3/16	1 to 4	1 to 4	1 to 40	4 1/4
Do-------	130	*13025	130-RE	*1300	*13025	6 3/4	6	2 15/16	21/32	1 27/32	3 11/16	1 7/32	1 to 4	1 to 4	1/16 to 1	3 3/8
Do-------	115	11525	115-RE	1150	11525	6 5/8	5 1/2	2 23/32	5/8	1 11/16	3 13/16	1 1/8	1 to 4	1 to 4	1 to 40	3 1/4
Do-------	112	11228	112-RE	1121	*11228	6 5/8	5 1/2	2 23/32	19/32	1 11/16	3 13/16	1 1/8	1 to 4	1 to 4	1 to 40	3 3/4
Do-------	110	11025	110-RE	1100	11025	6 1/4	5 1/2	2 25/32	19/32	1 23/32	3 13/32	1 1/8	1 to 4	1 to 4	1/16 to 1	3 1/8
Do-------	100	10025	100-RE	10025	10025	6	5 3/8	2 11/16	9/16	1 21/32	3 9/32	1 1/16	1 to 4	1 to 4	1/16 to 1	2 31/32
A.S.C.E.---	100	10040	100-AS	....	....	5 3/4	5 3/4	2 3/4	9/16	1 45/64	3 5/64	31/32	13°	13°	STR.	2 65/128
Do-------	90	9040	90-AS	....	9040	5 3/8	5 3/8	2 5/8	9/16	1 19/32	2 55/64	59/64	13°	13°	STR.	2 45/128
Do-------	85	8540	85-AS	851	8540	5 3/16	5 3/16	2 9/16	9/16	1 35/64	2 3/4	57/64	13°	13°	STR.	2 17/64
Do-------	80	8040	80-AS	800	8040	5	5	2 1/2	35/64	1 1/2	2 5/8	7/8	13°	13°	STR.	2 3/16
Do-------	75	7540	75-AS	755	....	4 13/16	4 13/16	2 15/32	17/32	1 27/64	2 35/64	27/32	13°	13°	STR.	2 15/128
Do-------	70	7040	70-AS	* 701	....	4 5/8	4 5/8	2 7/16	33/64	1 11/32	2 15/32	13/16	13°	13°	STR.	2 3/64
Do-------	65	6540	65-AS	651	....	4 7/16	4 7/16	2 13/32	1/2	1 9/32	2 3/8	25/32	13°	13°	STR.	1 31/32
Do-------	60	6040	*60-AS	603	....	4 1/4	4 1/4	2 3/8	31/64	1 7/32	2 17/64	49/64	13°	13°	STR.	1 115/128
Do-------	40	4040	40-AS	....	....	3 1/2	3 1/2	1 7/8	25/64	1 1/64	1 55/64	5/8	13°	13°	STR.	1 71/128
Do-------	30	3040	30-AS	....	....	3 1/8	3 1/8	1 11/16	21/64	7/8	1 22/32	17/32	13°	13°	STR.	1 25/64

*Not in current production.

similar in shape, we are able to draw several conclusions concerning their stiffness without going into the true theory of the concept. The first conclusion is that for rails of similar shape, the one with the greater height is stiffer. Secondly, since they are made of similar material, their weight is proportional to their cross-sectional area. It is roughly true that rails vary in stiffness in direct proportion to the square of their weight. Suppose you are comparing 100-and 80-pound rails. Your equation would be–

$$\frac{100^2}{80^2} = \frac{10,000}{6,400} = 1.56 \text{ or } 1.6$$

Therefore, the 100-pound rail is 1.6 times stiffer than the 80-pound.

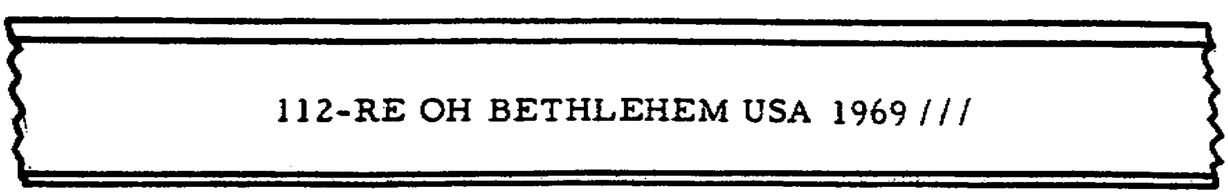
3.7. SECTIONS

The several different types of rail sections in use vary in their capabilities and characteristics. The subparagraphs following describe several types of rail sections; additional data on them are given in table I.

The first standard rail sections were developed by the American Society of Civil Engineers and are known as ASCE sections. Later the American Railway Association (ARA) and the American Railway Engineering Association, jointly, improved on the designs with two series of sections, RA-A and RA-B. The A series was meant for use in high-speed territory; notice its height and thin head. The B series was designed for use in heavy curvature, grade, and tonnage districts; notice its narrow, deep head for long rail life. Still later the American Railway Engineering Association alone assumed the task of determining proper rail sections. The heavy rails they developed became known as RE sections.

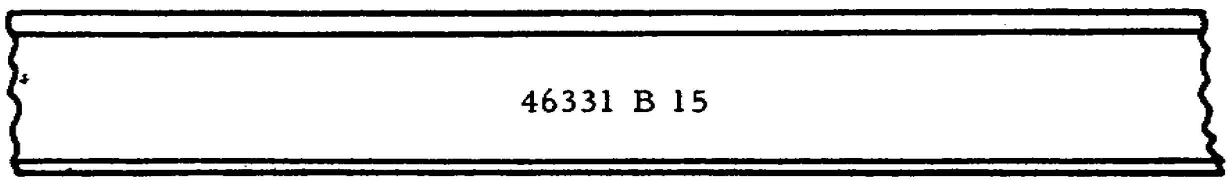
3.8. MARKINGS

The story of a rail's manufacture is branded and stamped on its web. For instance, you might find the following marking branded on a rail:



This rail is a 112-pound RE section, made of open-hearth steel at the Bethlehem Steel Company's Bethlehem Mill, in March 1969. The month is indicated by slash marks (/). This example has three for March, the third month in the year. One additional slash mark is added for each month, starting with one mark for January, two for February, and so on up to twelve marks for December.

On the opposite side of the web, additional information is stamped. An example might be as follows:



This means that the rail came from heat No. 46331 and was the second rail rolled from the 15th ingot poured. If CC appeared here, it would indicate that the controlled cooling process was used. Similarly, CH stands for controlled cooling and end hardened. End hardening is a special process that reduces the effect of excess wear at the joints (par. 3.29).

3.9. LENGTH

The length of T-rail sections has increased continually since this type of rail was introduced. For many years, the 33-foot section was standard. Now the 39-foot length, the military standard, is most generally used in the United States. A section of 39-foot rail fits easily into the standard 40-foot gondola for ease of transport. Longer rails require fewer track joints per mile, and, since joints are a source of continual trouble and expense in track maintenance, any means of reducing this nuisance is welcomed. European railroads have used rail sections as long as 60 feet for many years in an effort to reduce joint maintenance problems. American lines are developing continuous welded rail for the same reason. Its advantages in economy will become obvious as you study the section covering joints. However, it does not seem probable that military railroads will adopt this innovation in the near future, if at all.

The disadvantages of continuous welding are twofold. First, there is the problem of a satisfactory means of welding short rail sections together to make a continuous rail. Second is the problem of expansion and contraction because of temperature changes, the solution to which lies in restricting rail movement by securely fastening the rails to ties embedded in ballast. This action sets up an internal stress in the rail, but this stress for ordinary temperature changes is considerably below the ultimate stress which rail steel can withstand.

3.10. FAILURES

Aside from being a nuisance and an economic liability, broken rails are often the cause of disastrous derailments and wrecks. The immediate cause of a broken rail is usually an impact load beyond the strength of the rail. The ultimate source of the failure, however, can usually be traced to an imperfection in the molecular structure of the steel. This type of imperfection is particularly dangerous in that it is often inside the rail and therefore invisible. Obviously, some steps must be taken to prevent such imperfections from leading to rail failure. Many of the changes in rail form were adopted in an effort to reduce the occurrence of structural imperfections or flaws.

Rail failures include transverse and compound fissures, split and crushed heads, split webs, and broken bases. These and other failures, described in the subparagraphs following, are shown in figure 3.2.

a. Transverse fissure. The most frequent and aggravating of all the flaws is the transverse fissure, caused by hydrogen remaining in the rail after its manufacture. The fissure–crack–is a crosswise break, starting from a nucleus inside the head of the rail and spreading outward. The failure can be recognized by either a bright or dark, round or oval smooth area around the nucleus. An example is shown in figure 3.2A. Until the rail actually fails, it appears sound from the outside.

It is common practice to record the heat numbers of all rails put in service. Whenever a rail fails because of transverse fissure, the heat number is taken and kept on file. After a number of rails from the same heat have failed, poor steel is suspected. Often, all rails having that heat number are removed from service.

Electronic detecting devices are used to spot transverse fissures in rails before they fail. When found, such rails are immediately removed from service. It is unlikely that such devices would be found in a theater of operations. In those localities, the trackage should be inspected closely to detect the more advanced cases of fissured rail visible to the naked eye.

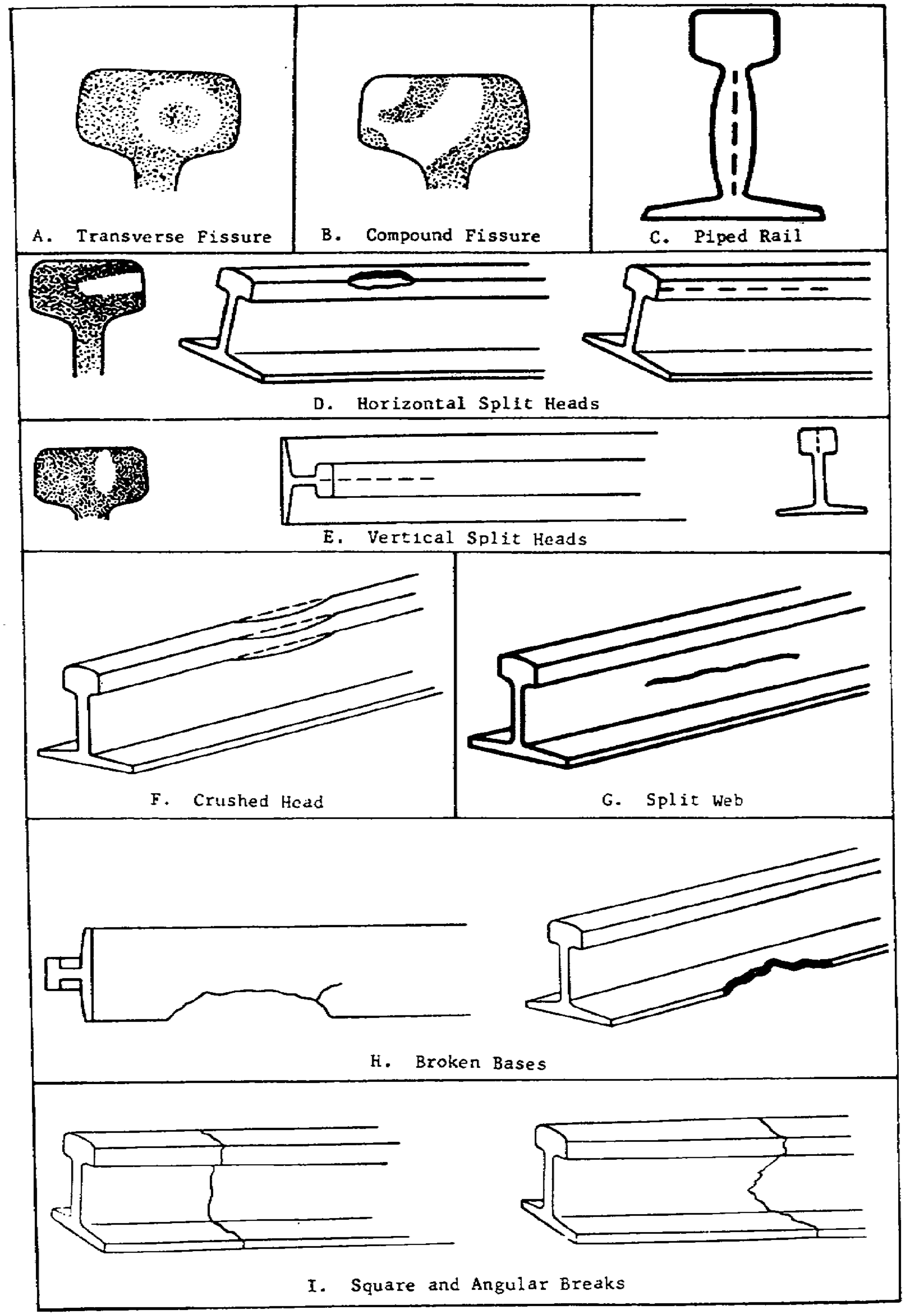


Figure 3.2. Rail Defects.

b. Horizontal split head. Horizontal breaks beginning inside the head of the rail and spreading outward are called horizontal split heads. They are illustrated in figure 3.2D. They are usually indicated on the side of the head either by a longitudinal seam or crack or by the flow of metal.

c. Compound fissure. A horizontal split head which, in spreading, turns up or down in the head of the rail is called a compound fissure. An example is shown in figure 3.2B.

d. Vertical split head. Splits may run vertically through or near the middle of the head and extend into or through it, as shown in figure 3.2E. Such splits are called vertical split heads. 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.

e. Crushed head. A flattening or crushing of the head, as shown in figure 3.2F, is called a crushed head.

f. Split web. Cracks may run lengthwise along the side of the web and frequently extend into or through the web. Such cracks result in what are called split webs. Figure 3.2G shows an example.

g. Broken base. Any rail base with a crack or break in it can be said to have a broken base. Note in the two views shown in figure 3.2H that pieces of the bases are missing.

h. Square and angular breaks. Any partial or complete break in which there is no sign of a fissure or any of the other defects discussed, is known as a square or angular break, depending on its shape. Examples are shown in figure 3.2I.

i. Piped rail. A vertical split, usually in the web, occurring because of the failure of the shrinkage cavity in the ingot to unite, is called a piped rail. See the example shown in figure 3.2C.

j. Other failures. Fractures of the web at bolthole locations are dangerous and arc discussed in more detail in section IV which treats joints and joint maintenance. Rail-end batter is also discussed in that section as well as other failures and specific remedies.

3.11. SUMMARY

The modern T-rail is made of steel, usually refined by the open-hearth process, and marked with its weight, section, manufacturer, and the month and year of manufacture. Additional markings make it possible to tell from which heat and even from which ingot the rail came. This information is valuable because such rail failures as breaks and cracks can usually be traced to an imperfection in the molecular structure of the steel. If rails from a particular heat continually fail, all from that heat are removed.

A rail section in the United States is generally 39 feet long. Longer sections are advisable because they make fewer joints, and faulty joints cause most of the work in track maintenance.

Section I. Crossties

3.12. GENERAL

Rails must be adequately braced and supported and be subject to a minimum of lateral, or transverse, stress. The support supplied must be neither rigid nor too yielding: uniform elasticity throughout is preferred. The railroads rely on crossties to provide the needed bracing and support, reduce lateral stress, and provide the elasticity of support desired.

Wood is used for ties more often than any other material, although steel and concrete have been used to a limited extent, mostly in Europe where timber is scarce and expensive. Wood is preferred because it has a tremendous resistance to impact loads, is usually easy to obtain especially in the United States, and provides a base into which inexpensive hook head (cut) spikes can be driven. The disadvantages in using wood lie in its low resistance to abrasive and cutting wear, susceptibility to rot from moisture, and cost in areas where it is scarce.

An essential part of the track structure, the crosstie has several important functions. With the aid of fasteners, it provides a means for holding the rail in proper gage and line; it transmits train weight from rails to ballast; and it can be moved by adjusting ballast distribution around it, providing a means of obtaining proper track surface and alinement.

The life of ties in service depends on the kind of material, amount and character of traffic, climatic conditions, method of preservative treatment used, and amount of tie-protecting devices (tie armor) used in constructing the track. The remaining paragraphs of the section discuss wooden and other kinds of ties, tie size and spacing, and wooden tie preservation.

3.13. WOODEN TIES

Many varieties of wood are used for ties. Gone are the days when most railways obtained the wood for their ties from the forests beside their rights of way. Now, with few lines able to do this, a wide variety of woods are use, from ash to black walnut among the hardwoods, from cedar to spruce among the softwoods. The four varieties most commonly used in the United States are Douglas fir, red oak, white oak, and longleaf pine. Besides the kind of timber used, ties are further designated by the part of the tree from which they are make: heartwood from the center of the tree and sapwood from near the bark. In the box are listed the varieties of wood used, grouped according to hardwoods and softwood.

Hardwoods

Ash	Gum	Oak
Beech	Hickory	chestnut
Birch	Locust	red
Catalpa	black	white
Cherry	honey	Poplar
Chestnut	Maple	Sycamore
Elm		Walnut, black

Softwoods

Cedar	Hemlock	Pine
Cottonwood	Larch or	longleaf
Cypress	Tamarack	western
Fir, Douglas		Redwood
		Spruce

Regardless of the wood used, a tie should be free from large splits, numerous knots, and obvious rot and decay. Its grain should be reasonably straight and true. A tie should be straight but can be curved if a straight line across the top surface, joining the centers of the two ends, does not leave the tie, as shown by the dotted lines in figure 3.3A. A tie is unsatisfactory if a straight line across the side surfaces, joining the centers of the two ends, falls in an area less-than 2 inches from the-top or bottom of the tie, as shown by the dotted lines in figure 3.3B.

3.14. OTHER KINDS OF TIES

In some places, crossties made of materials other than wood are used. However, it is generally accepted that wood, because of its more desirable qualities, is the best crosstie material. Its disadvantages; primarily economic, in some world areas have necessitated substitution of other tie materials. Such substitution is common in sections of Europe. The usual substitute materials are steel, concrete, and reinforced concrete.

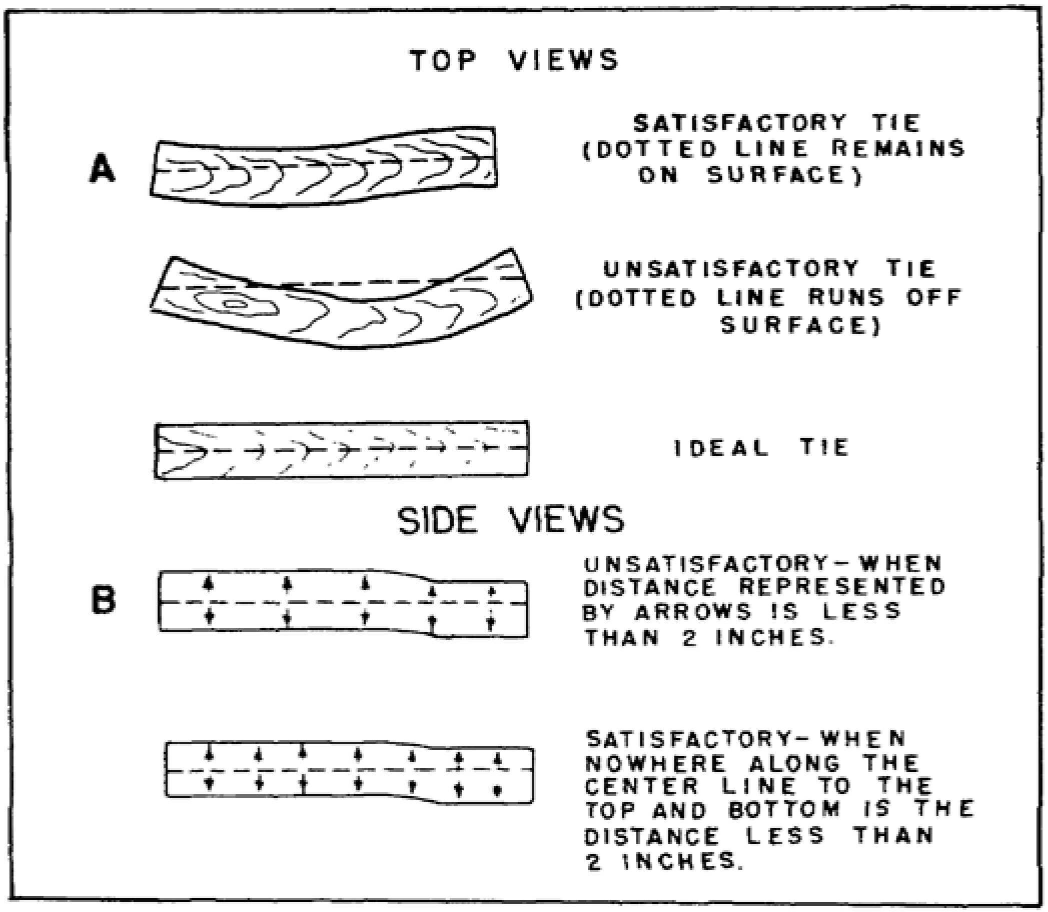


Figure 3.3. Curvature of Crossties.

a. Steel ties have the advantage of long life and reduced labor and maintenance. The most serious drawback to their use is that they become twisted in wrecks or track destruction, causing removal difficulties. Breakage and rust necessitate many renewals. Steel ties cause excessive insulation problems on lines depending on track circuits for signaling, and they are noisy and expensive.

b. Concrete and reinforced concrete ties have the same general advantages as steel ties. However, they are far too heavy for ease in handling, lack the resiliency needed to withstand the shocks of rail traffic, are easily crushed in derailments, and cause short-circuit problems in track-circuit territory.

3.15. SIZE

Recent trends in track construction have been toward larger and higher quality ties, not only for more effectiveness in service but for economic reasons as well. For the rails to have satisfactory support, a tie should approach 9 inches in width. Standard tie length in the United States varies from 8 to 9 feet; tie thickness, from 6 to 7 inches. Given in table II are typical tie sizes with recommended uses for each.

Table II. Typical Tie Sizes

Length	Width	Thickness	Use
9 ft	9 in.	8 in.	High-speed main line
8 ft 6 in.	8 in.	6 in.	Acceptable for high-speed service; military standard
8 ft	7 in.	6 in.	Permissible but not desirable for main line; may be used in sidings and yards.

Bridge ties are sized and spaced to conform with the design of the particular bridge. Ties placed under switches are longer than standard ones. Switch tie size is discussed further in Railway Track Maintenance II.

3.16. SPACING

The number of ties per length of track depends on the volume, weight, and speed of the traffic and on rail weight. The decision as to the number of ties per rail length depends upon the space to be left between them, the length of unsupported rail. Experience shows that this space should not exceed 18 inches. For case in manual tamping, the space should not be less than 10 inches; for machine tamping, 8 inches is sufficient. On tangents, military engineers prescribe spacing ties at 24-inch intervals, measured from the center of one tie to the center of the next one; on curves and through tunnels, at 22-inch intervals.

One large commercial railroad specifies the spacing for ties given in table II.

Table III. Tie Spacing on One Commercial Railroad

Service	No. of ties per 33-ft rail	No. of ties per 39-ft rail
Main-line track with over 100-pound rail, speeds over 50 mph, and 15 million gross tons per mile per year	20	24
Main-line track with over 100-pound rail, moderate speeds, and from 7 to 15 million gross tons per mile per year	18	20
Sidings and heavily traveled industrial track	16	18
Storage track	14	16

Military railroads constructed by the Corps of Engineers have tie spacing as shown in table IV. Note that the last 60 feet of any spur takes fewer ties per rail. When transportation personnel are required to operate previously existing railroads in a theater of operations, such high standards of construction may not be found.

Table IV. Tie Spacing Specified by Corps of Engineers

Service	No. of ties per 26-ft rail	No. of ties per 30-ft rail	No. of ties per 33-ft rail	No. of ties per 39-ft rail
Main-line running track	14	16	18	21
Storage track	12	14	16	18
Last 60 feet of spur track	10	12	13	16

3.17. PRESERVATION

According to one estimate, tie renewals cost two to three times as much as rail replacements. To reduce this expense, several practices are followed to extend the life of the ties, to pre-vent their decay, and to deter their cracking and splitting. Probably the most important of these is the widespread use of ties that have been treated with a chemical preservative. Other practices include using antisplitting irons, stacking ties in certain ways, and placing the heartwood side of ties on the ballast.

a. Chemical treatment. Have you ever wondered why wooden ties are so black? The answer is simply that these ties were creosoted before being put into service, to prolong their life and to prevent decay. One commercial railroad reports that creosoting extends tie life 10 to 30 years. Care must be taken in handling the creosoted ties; creosote can burn bare skin and cause a rash similar to poison ivy. When handling them, gloves must be worn, and the outside of the gloves must not be allowed to touch anyone's skin.

Creosoting is the most extensively used process for preserving ties; zinc chloride is used in another. But whichever process is used, adequate distribution of the preservative and thorough penetration of the wood are essential.

Although military railroads at stateside installations use treated ties for their economic advantage, military railroad operations in a theater would probably not extend over a period long enough to warrant preservative treatment of new ties. The military track supervisor in a theater should inspect a rail line early in its operation and, if it is laid with untreated ties, he must anticipate the need for frequent replacements.

Before ties are placed in service, they must be adzed and any needed spike holes bored. Adzing consists of planing away only enough wood to provide a smooth, satisfactory seat for the rail or tie plate. See figure 3.4. All adzing and boring must be done before the tie is treated with a chemical preservative. Cutting or boring after treatment might result in exposing untreated

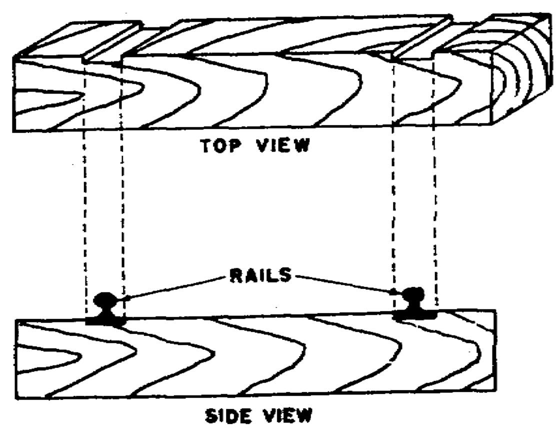


Figure 3.4. Adzed Crosstie.

wood whereby those areas would be vulnerable to rot and decay. However, for military use and especially for emergency or temporary tracks, adzing and boring beforehand may be dispensed with.

b. Antisplitting irons. As ties season, the moisture in the wood near the surfaces tends to dry more rapidly than moisture close to the center. As a result, internal stress builds up and causes a checking or splitting of the ties. This is especially true of hardwoods. Checking is undersirable since the cracks tend to hold water and fungi which produce rot. To reduce tie failure because of checking, antisplitting irons are made in a number of shapes, some of which are shown in Figure 3.5. The irons are bands of steel with sharpened edges that are driven into the ends of ties. They should be so placed as to cross at right angles the greatest possible number of radial lines of the wood. Do not use antisplitting irons while ties are still green or unseasoned, or checking may begin. However, use irons early enough to prevent any checking that may start in the normal seasoning process. Usually, irons are applied before or when ties are delivered to the storage yard and stacked for seasoning.

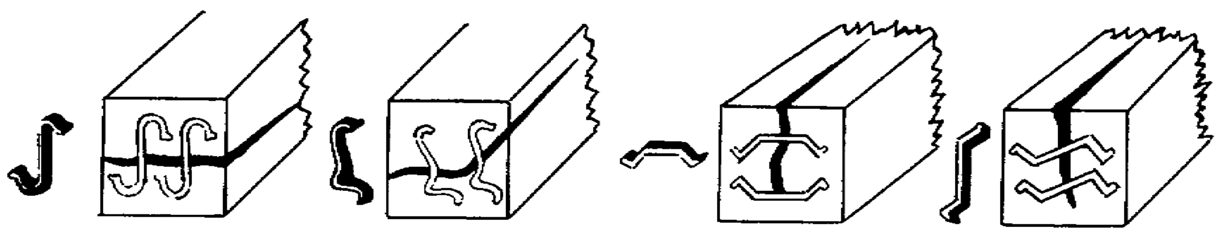


Figure 3.5. Antisplitting Irons.

Crossties may be made of concrete or steel but are usually made of wood, or cheap resilient material and one that allows the use of driven spikes to hold the rails. Both hardwoods and softwoods are used. Ideal ties are straight but may be curved slightly as long as a straight line drawn from one end to the other does not leave the edge of the tie. In the United States, standard ties are 8' to 9' long and are placed 10 to 18 inches apart. For commercial use, wooden ties are preserved by creosote or zinc chloride. Ties used in a theater of operations are not permanent enough to warrant such treatment. Adzing and boring are done before the chemical is applied. Drive antisplitting irons into the ends of ties to prevent checking. Always place the heartwood side of the tree on the ballast. Stacking ties properly help prevent rotting and oil evaporation.

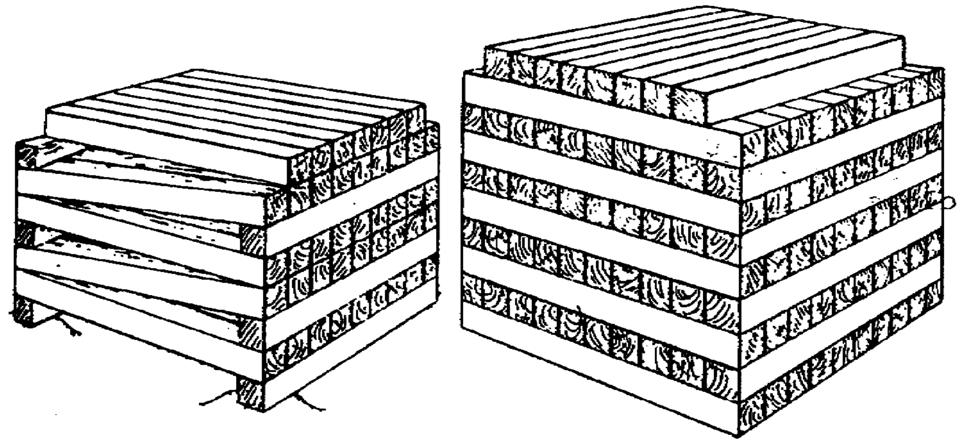


Figure 3.6. Methods of Stacking Ties.

Decay is deterred by placing the heart face down. As the tie weathers, the heart face shrinks and become concave. Checks tend to hold moisture, the cause of most decay, and more moisture would be held by the checks if the concave surface was on top.

3.18. SUMMARY

Crossties may be made of concrete or steel but are usually made of wood, or cheap resilient material and one that allows the use of driven spikes to hold the rails. Both hardwoods and softwoods are used. Ideal ties are straight but may be curved slightly as long as a straight line drawn from one end to the other does not leave the edge of the tie. In the United States, standard ties are 8' to 9' long and are placed 10 to 18 inches apart. For commercial use, wooden ties are preserved by creosote or zinc chloride. Ties used in a theater of operations are not permanent enough to warrant such treatment. Adzing and boring are done before the chemical is applied. Drive antisplitting irons into the ends of ties to prevent checking. Always place the heartwood side of the tree on the ballast. Stacking ties properly help prevent rotting and oil evaporation.

Section III. Track Fastenings

3.19. GENERAL

One writer on rail subjects speaks of "the tie that binds." But something must bind that crosstie to the rail. Several fixtures called track fastenings unite rail and tie.

When treated ties are used, wood decay is practically non-existent and therefore is seldom the reason for tie renewal. More often, mechanical wear is the cause, that brought on by rails, spikes, and ballast under the impact of a moving train. Tie-protecting devices (tie armor) have been developed to minimize tie damage. These devices are usually referred to as tie plates. Other track fastenings–spikes, rail anchors, braces, and gage rods--make their contribution to efficient track.

3.20. TIE PLATES

Tie plates serve as seats under the rail, between the rail and crossties. The plate spreads train weight over a wider area of the tie than does the base of the rail and reduces tie wear resulting from abrasion or crushing of the tie by the rail. Figure 3.7 shows the effects of wear on a tie not protected by a tie plate.

Tie plates are made of steel. They have square holes punched in them to receive spikes and have an indented, flat surface on the upper side to fit the base of the type of rail for which they are designed to be used. Figure 3.8 shows the details of a typical tie plate. Tie plates are seldom used on tangent track in a theater of operations. Two per tie should be used if they are available. They are used on temporary construction for turnouts,

Figure 3.7. Rail-Cut Tie.

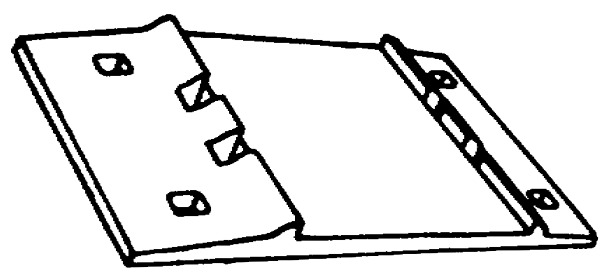


Figure 3.8. Typical Tie Plate.

crossovers, bridges, tunnels, main-line curves, and other curves exceeding 3 degrees.

3.21. SPIKES AND TIE PLUGS

Track spikes fasten T-rails to ties, hold track in gage and line, prevent rail from overturning, and hold tie plates in place. The ordinary spike used in the United States has a square shank and a hook head. It is used to fasten rail either directly to the tie or to the tie with an intervening tie plate. Figure 3.9 shows the details of a cut, or hook head, track spike. The spike is driven with the chisel point parallel to the direction of the track and with the head overlapping the rail flange. On tangent track, one spike on each side of each rail on each tie is sufficient (fig. 3.10). On curved track, additional spikes are required. Figure 3.11 shows you how a driven spike appears when a tie plate is in place.

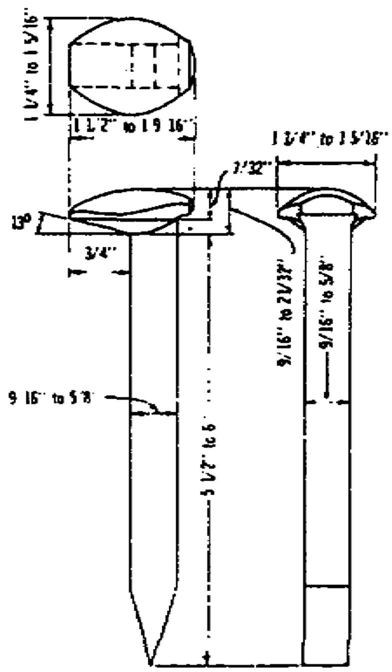


Figure 3.9. Details of Cut Spike.

Spikes may be driven by hand, by using a spike maul, or with an automatic spiking machine. When manually driven, care should be taken that the rail base is not struck accidentally. Such a blow may eventually cause rail failure.

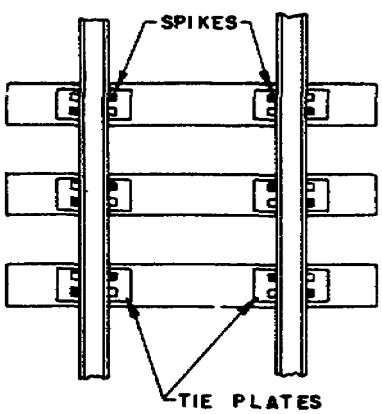


Figure 3.10. Correct Method of Setting Spikes.

Some railways in Europe and elsewhere use screw spikes more extensively than hook head spikes. One is shown in figure 3.12. The holding power of a screw spike is nearly three times that of a cut or hook head spike. On the other hand, they are driven much more slowly, even with

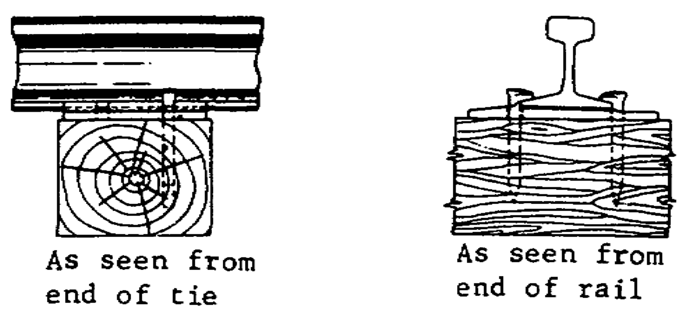


Figure 3.11. Using Spikes With Tie Plates.

power wrenches, but their fine holding power is easily lost under weather and service.

When spikes are pulled, the holes left in the ties are filled with tie plugs to protect the tie from decay and to give good holding power to new spikes. Tie plugs made of a softwood are preferred to those of hardwood. They fill the hole better and absorb moisture, swell, and split less easily than hardwood ones. As shown in figure 3.13, the plugs have square heads and rectangular shanks. They are designed to be driven into the tie to completely fill the top of the spike hole which is usually enlarged from both the thrust of the rail against the spike and the pulling of the spike.

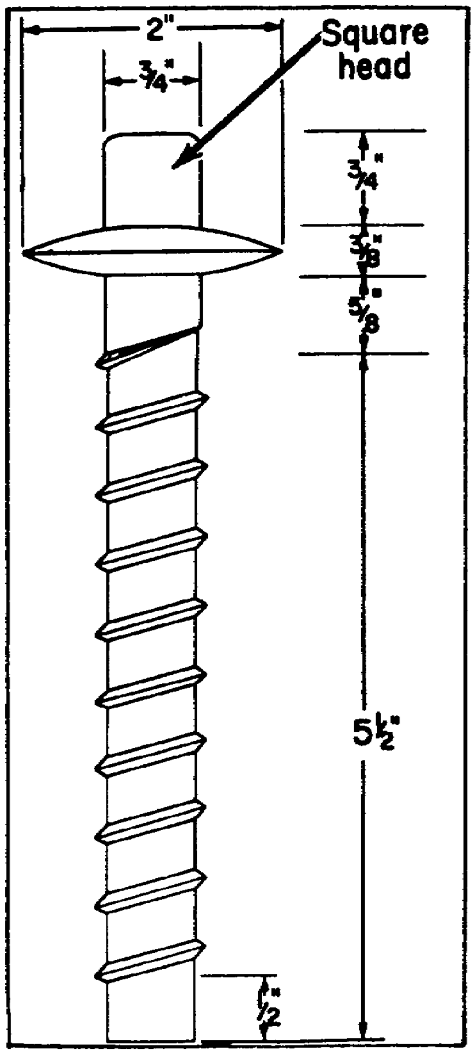


Figure <u>3.12</u>. <u>Screw Spike</u>.

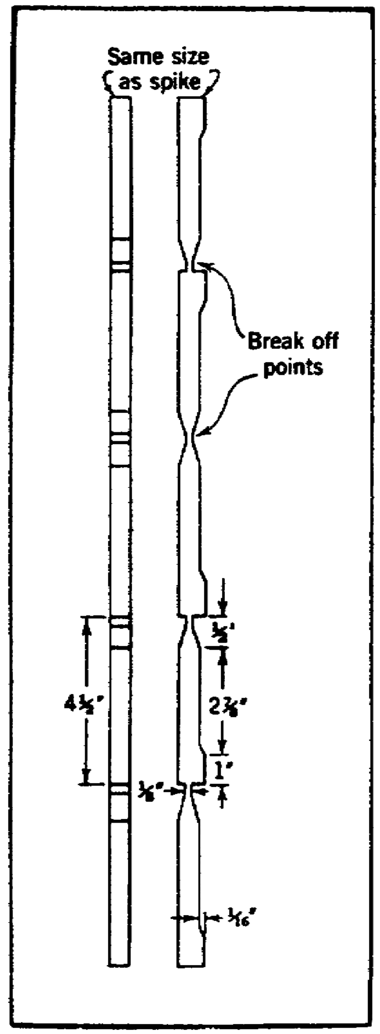


Figure <u>3.13</u>. <u>Tie Plugs</u>.

3.22. RAIL ANCHORS, BRACES, AND GAGE RODS

Where there is a tendency for rail to move longitudinally in track under one-way traffic or on heavy grades, rail anchors are used to restrain the movement. The anchor is firmly attached to the base of the rail and bears against the side of the tie facing oncoming traffic. Anchors are always put on both rails of the track and are located opposite each other to prevent uneven movement of ties. Figure 3.14 illustrates a rail anchor, and figure 3.15 shows the proper installation locations. Anchors must bear directly on ties at all times for effectiveness. If the anchor loses contact for any reason, it must be removed and reset.

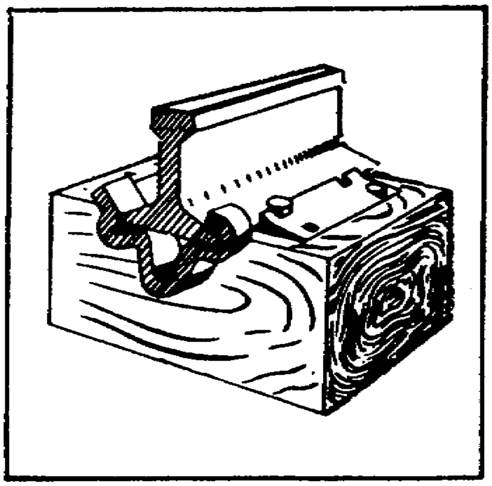


Figure 3.14. Typical Rail Anchor.

A rail brace, like the one in figure 3.16, is used on curves and switches to resist excessive lateral thrust on the rail. Placed outside the rail, the brace is spiked to the tie and bears against the rail web and head. Military standards require four braces on each length of rail on 3- to 6-degree curves, six on each length of rail on 6- to 10-degree curves, and a brace on alternate ties for curves sharper than 10 degrees.

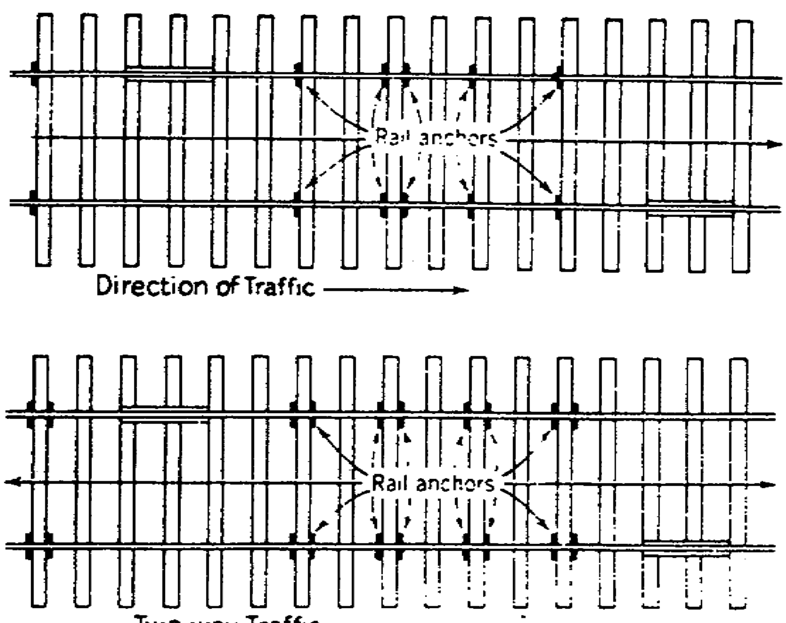


Figure 3.15. Rail Anchors Correctly Located.

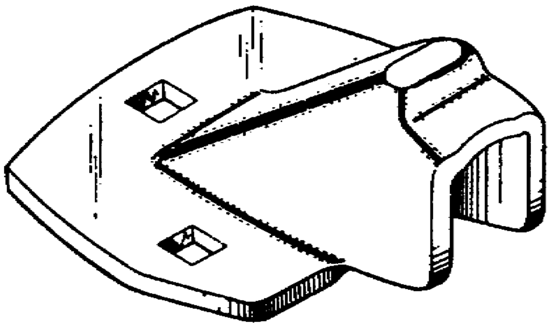


Figure 3.16. Typical Rail Brace.

Gage rods are used to hold track to proper gage. They are generally used on curves. One is shown in figure 3.17. The only guide to location and extent of use is experience. If track on a particular curve is continually spreading, then gage rods are justified. In track-circuit territory, they must be insulated.

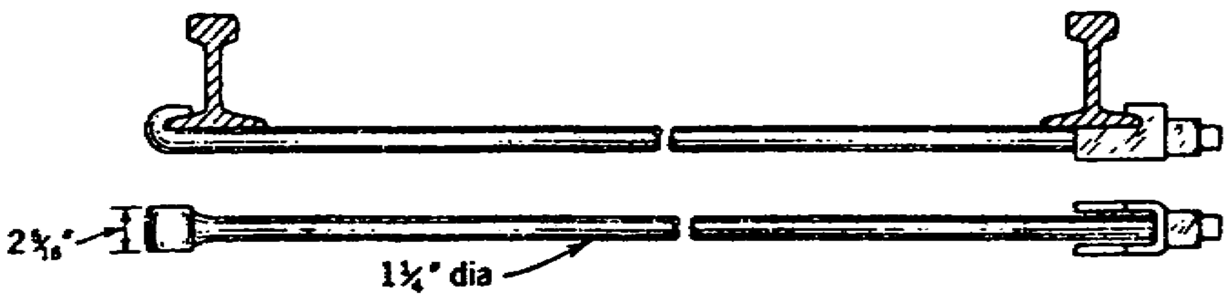


Figure 3.17. Typical Gage Rod.

3.23. SUMMARY

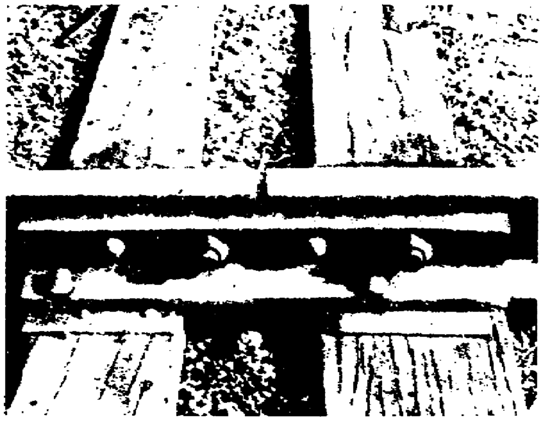
Several fixtures are used to fasten parts of the track together. Steel tie plates spread the train weight over a wider area than does the rail base and keep the rails from cutting into the tie. The rails are held on the ties by hook head spikes, and the holes left by pulling the spikes are filled with softwood plugs. Screw spikes are used in some European and other countries. Thrust of the rail is resisted by rail anchors, braces, and gage rods.

Section IV. Rail Joints

3.24. GENERAL

Perhaps the most characteristic sound associated with railroads is the continuous "clickity clack" heard when a train is moving over track. To the casual passenger, it is a friendly sound but to a track maintenance man, it is a reminder of the rail joints that demand constant attention. A typical rail joint is pictured on the next page.

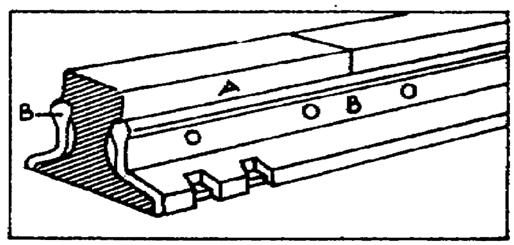
Theoretically, a perfect rail joint would have the same strength and characteristics as the rail itself so that together they would behave like one continuous length of rail. But joints are invariably weaker than the rest of the rail. When good track surface is lost, it is usually at the joints.



All problems of track maintenance are accentuated at the joints. When a train wheel passes over a joint, a severe blow is delivered to the end of the succeeding rail length, causing battered rail ends--one of the more serious forms of wear to which rails are subjected. Battered rail left in main tracks causes rough riding, damage to equipment and lading, and, eventually, pumping ties at joint locations. This section explains the design, classification, installation, and maintenance of rail joints, and the need for compromise, insulated, and bonded joints.

3.25. DESCRIPTION

Where two lengths of rail meet, they must be spliced. The splice is made with a rail joint consisting of a pair of bars bolted one on each side of the two rails to be joined, as the sketch shows. In the sketch, A indicates the rail; B the bars. Each bar extends across the space between the rails. The bars are variously called joint, splice, or angle bars. In this text, they are referred to as angle bars (par. 3.26<u>a</u>).



The subparagraphs following describe the bars and the bolts used to join them to the rail, the method of joining the bars to the rail, and the methods of joint support.

<u>a</u>. <u>The bars</u>. Either four-or six-bolt bars are used; the length of the bar determines the number. Four-bolt bars are generally 18 to 24 inches long; six-bolt ones, 36 to 40 inches. The six-bolt bars are more advantageous economically than the four-bolt ones. They provide longer bar and rail life and preserve track surface at the joint. The four-bolt bars are simpler to install, less expensive in cost, and lighter, and require fewer bolts. For these reasons, they are more often used on military railroads.

b. The bolts. The strength and tightness of the bolts securing the bars to the rail contribute greatly to the efficiency of the rail joint. The bolts used to splice light rail are either 7/8 or 1 inch in diameter; those for heavy rail, 1 1/4 inches. Typical bolts, shown in figure 3.18A and 3.18B, have either hexagonal or square nuts, and the boltheads are either hexagonal or square. Figure 3.18C shows one type of spring lock washer that is placed between the nut and the bar, to prevent the nut from working loose. The section of the bolt directly under the head is oval. Alternate holes in the bar are also oval while the remainder are round. When the oval section of the bolt is fitted into the oval bolthole, the bolt is prevented from turning because of jarring or vibration.

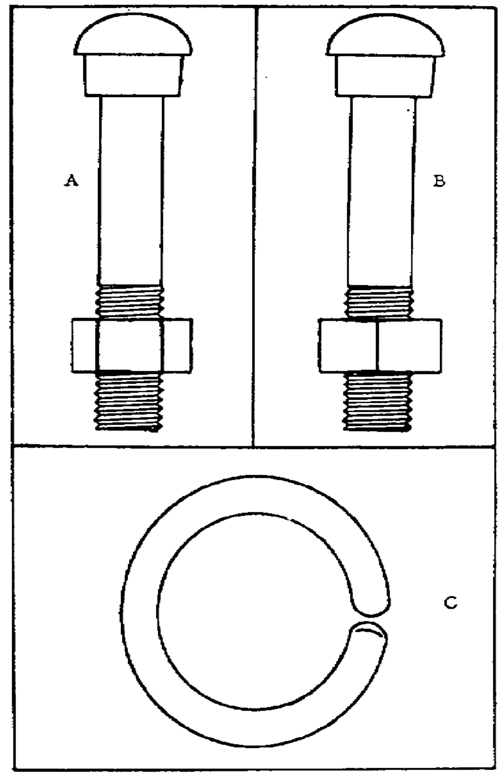
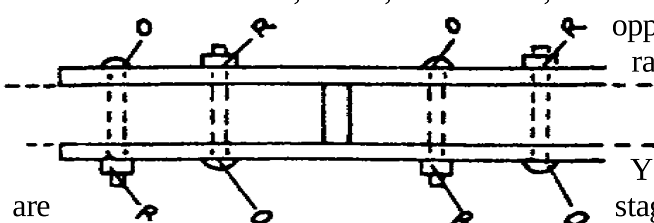


Figure 3.18. Typical Rail Joint Bolts, Nuts, and Spring Lock Washer.

The oval holes also serve another purpose. Rails, 75 pounds and up, are bolted so that the nuts alternate between the inside and outside of the rail. Looking at the outside of the rail, for example, you would see a bolthead, a nut, a bolthead, and a nut; looking at the inside, you would see the opposite sequence. The sketch given here views a rail joint from above; R indicates round hole; O, oval.



You may ask, Why are the bolts staggered? They are staggered for a good reason: the wheel rim of a derailed car could shear off all the nuts if they were all installed on one side. To insure, then, that the bolts will be staggered when installed, the bars are manufactured with the alternate round and oval holes and the bolts are made with the oval neck section. For low rail and that lighter than 75 pounds, the bolts are applied with all the nuts to the outside of the track. To do so prevents the nuts from being stuck, especially on worn rails, by the flanges of worn wheels.

3.26. CLASSIFICATION

A joint bar, when classified according to its cross section, falls into one of three classifications: angle, head-free, or head-contact. The last two, so-called symmetrical bars, are generally used on heavy rail, which, having greater height than lightweight rail, has more space between its head and base. Unlike the angle bar, the symmetrical bars have no flanges; they are large enough to provide sufficient stiffness without them. The more uniform shape of the symmetrical bars offers greater resistance to stress. Details on the three types are given in the subparagraphs following shown in figure 3.19.

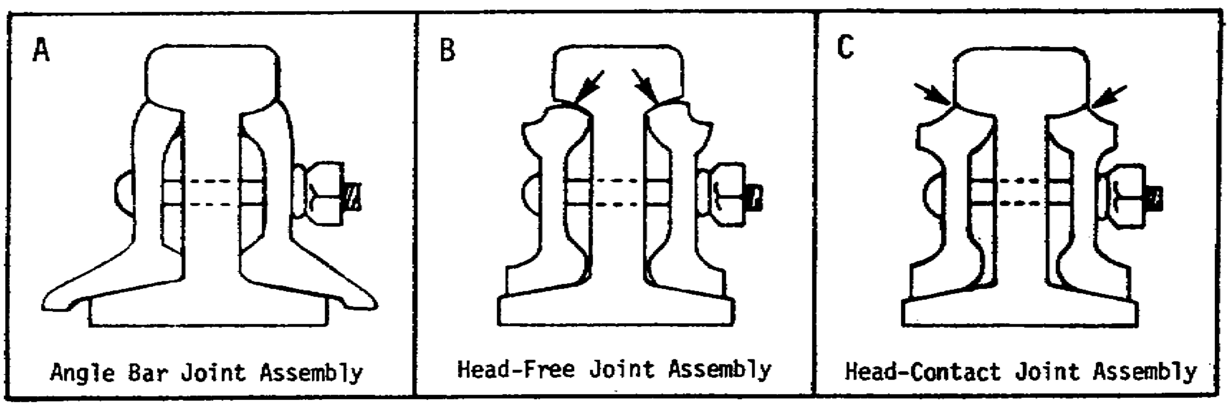


Figure <u>3.19</u>. <u>Types of Rail Joint Assemblies</u>.

<u>a</u>. <u>A typical angle bar</u> is easily identified by the large flange, or toe, at the bottom which hides the rail base. An angle bar is the most desirable form of joint bar for use with small rail having a limited distance between the head and flange (the fishing space); the extra metal in the flange increases the bar's stiffness. Figure 3.19A pictures an angle bar joint assembly.

<u>b</u>. <u>A head-free joint bar</u> contacts the rail at the fillet curve between the head and web. The arrows in figure 3.19B denote the points of contact in a typical assembly. This bar has a greater area of contact with the rail than the head-contact type, discussed next, and thereby permits heavier loads. Also, the head-free bar adjusts its fit with the rail more easily and with less loss of bolt tension.

c. A head-contact joint bar bears against the underside of the rail head. The arrows in figure 3.19C indicate the points of contact in a typical assembly.

3.27. SUPPORT AND LOCATION

How a rail joint is supported and located relative to its opposite number on the other rail vary among roads. A rail joint may be supported by one tie, suspended between two ties, or supported by three ties. On some lines, a rail joint is placed opposite one on the other rail or opposite the center of the other rail. These varying practices are examined in the subparagraphs following.

a. Support. Any one of three methods of supporting a rail joint may be used. A joint may be supported by one tie, suspended between two ties, or supported by three ties.

(1) One tie. Having the ends of the two rails to be spliced on one tie is called a supported joint. This form of joint is particularly suitable for lightweight rails. See figure 3.20A.

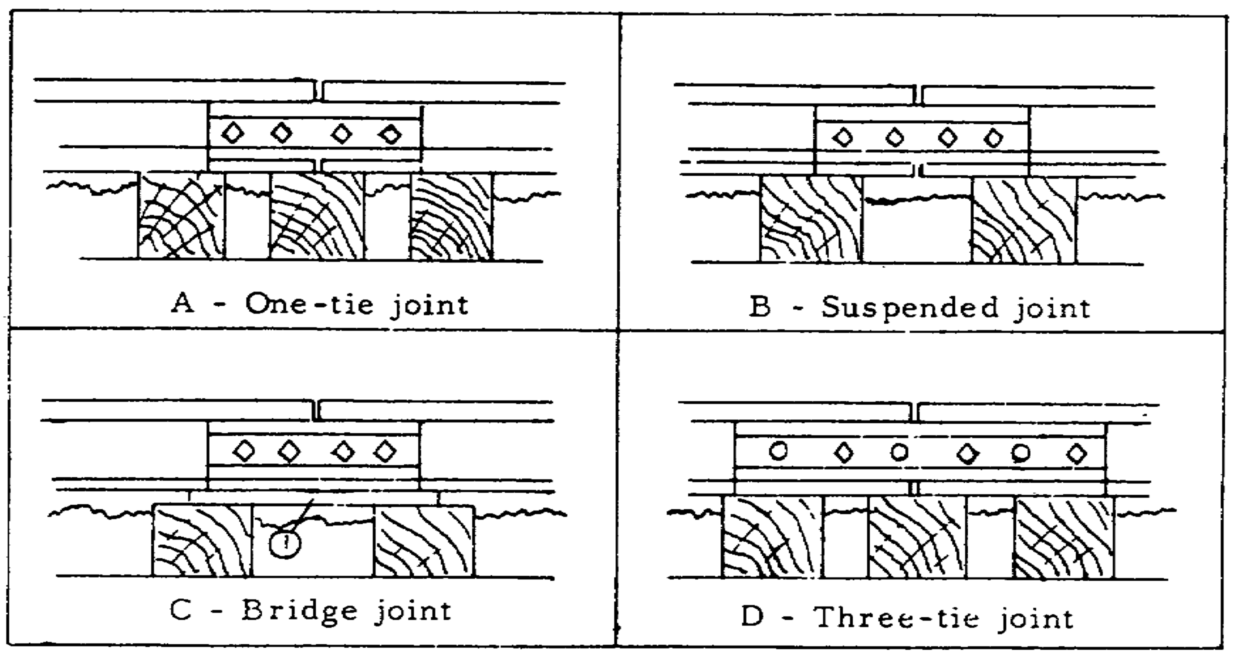


Figure 3.20. Methods of Joint Support.

(2) Two ties. In a suspended joint, the rail ends meet between a pair of ties, as figure 3.20B shows. The two ties in question are laid closer together than usual. Often a base or bridge plate extending from one tie to the other carries the rail ends. When

a plate is added to suspended joint, this type of joint is referred to as a bridge joint, as shown in figure 3.20C, in which the plate is labeled (1) .

(3) Three ties. A joint that extends across three ties is used a great deal in main-line tracks. The ties are laid close together--6 to 8 inches, and the rail ends rest on the middle tie. An example is seen in figure 3.20D.

b. Location. The terms broken joint and square joint describe the location of a joint in a rail. A broken joint is one which appears across from the center of the opposite rail. An allowance of from 12 to 24 inches from the center is made on most roads. A square joint refers to one that is directly across from another in the opposite rail.

On North American lines, the broken joint is found more often than the square one. It has never been determined that one provides a safer track than the other; however, alternate (broken) joints seem to be the more desirable especially for track carrying heavy traffic.

Standard military practice is to use the broken joint. Its location should not exceed 30 inches from the center of the opposite rail, preferably not more than 18.

3.28. INSTALLATION

You have the parts of the joint assembly–the two bars and the four or six bolts, nuts, and washers--ready to install. All parts have been well lubricated; even slight rust on the threads may prevent the correct tension from being reached in tightening the bolts or may cause the threads to be stripped. What procedure do you follow in installing the assembly? The subparagraphs following take you through the steps.

a. Allowing space for expansion. The rail ends are in place on or between the ties as standard practice for your road dictates. But how far apart must the ends be? When joint bars are applied, rail expansion and contraction caused by temperature changes must be provided for. Rails laid in hot weather are placed close together so that when they contract in cold weather the space (rail gap) will not be too large. Similarly, rails laid in cold weather have a space between length ends so that there is room to expand. Joint bars and bolts are made so as to allow the rail to move a small amount within the joint. The space provided depends on the prevailing temperature as well as upon the length of rail used, as table V shows.

Table V. Rail Gap

Temperature, °F	Gap between 33-foot rails, in.	Gap between 39-foot rails, in.
-20 to 0	5/16	3/8
0 to 25	3/16	1/4
26 to 50	1/8	3/16
51 to 75	1/8	1/8
76 to 100	1/16	1/16
Over 100	None	None

The space is usually established by placing a wooden shim of the correct dimension between the rail ends. The shim may be left in place as it is soon crushed when the rails expand. If a metal shim is used, it must be removed after the rails are fastened because it will interfere with expansion.

b. Applying the bars. Paragraph 3.25b, which describes track bolts, states that on heavy rail the boltheads alternate from outside to inside of the rail and that on light rail they do not. As you direct your crew in applying the joint bars, check to make sure that the standard practice in locating the boltheads for your road is being followed for the weight of rail you are laying.

The bars are in place and the crew has run the bolts through the holes and put on the washers and the nuts. Now comes the crucial tightening of the bolts, either with power or hand wrenches. In the insert, track bolts are being tightened with a hand wrench. Providing tension in track bolts draws the bars into place when they are first applied and holds the bars in place so that the two working together resist bending. This initial tightening should provide enough re-serve so that retightening will not be

necessary before the next routine maintenance period. How tight the bolts are to be drawn initially should be within the range set--in excess of 10, 000 pounds per bolt is specified on some roads.

c. Spiking. The next step is to spike the joint. Look again at the sketch of the angle bar near the beginning of paragraph 3.25 and note the slots in the flange. Hook head spikes driven through these slots fasten the rail joint to the ties. Sometimes the spikes are driven against the bar ends. Spiking joints prevents the rail from creeping as trains pass along the rails. In those places where ties are laid directly on stringers, such as on bridges or trestles with open floors, the joints are not spiked. The rails must be left free to move on the ties.

3.29. MAINTENANCE

For a moment, let's pretend we're watching a slow-motion film in which the camera is focused on a single wheel as it rolls along a rail. As the wheel passes over the next rail joint, watch its action. Does it jump or change direction? Is there a noticeable bump or jar as it hits the end of the next rail? Watch, too, for wear at the joints. Is that rail end badly worn? Are the joint bars themselves badly worn? Now, turn off the projector and think about your observations. As your thoughts jell, you begin to see the need for excellent rail-joint maintenance. In the next few subparagraphs are discussed the overall need for maintaining rail joints in tiptop condition, the defects that create the need for maintenance, and the methods used in maintaining rail joints.

a. Overall need. The joints are the weakest spots in the track; they demand the constant attention of the rail maintenance crew; loose, low joints create a bumpy ride as well as noise; joints require much expensive work to hold track surface. Some of these thoughts are brought out in earlier paragraphs; others are mentioned here for the first time. But all of them point out the overall need to keep rail joints up to par. Well-maintained track requires well-maintained joints.

b. Defects. What can go wrong with a rail joint? Wear, cracks and breaks, and loose track bolts are some of the things that can happen.

(1) Wear. When a train wheel passes over a joint, a severe blow is delivered to the end of the next rail, causing the end to be battered--one of the more serious forms of wear to which rails are subjected. Sections on which the ends have been hardened are

widely used and have decreased the amount of wear. The ends of 6-hole joint bars are also subject to a great deal of end wear. Badly battered rail causes rough riding, damage to equipment and lading, and, eventually, pumping ties below joints.

The abrasive action of the wheels grinding on the top of joint bars can result in wear. On some bars, the abrasion has been found to be as much as 1/16 of an inch deep and to extend 8 inches on either side of the bar's center. Most of the wear on 4-hole bars occurs in the center.

(2) Cracks and fractures. A break in a joint bar may start at the top and continue downward, often into a bolthole. Most cracks, however, start either from the spike slot or from the flange angle and, as often as not, work their way to boltholes. Cracks become breaks if the cracked bar is not replaced.

(3) Loose bolts. Both a rail and a rail joint tend to yield, and rightly so, under a load. But when a poorly supported rail joint gives under a load, a lateral thrust that comes from under the head tends to move the bar away from the rail. The impact of the thrust falls upon the boltheads and the nuts and loosens them; loss of support results.

c. Methods. Rail-joint maintenance is a continual process. One authority advises that main-line rail joints be inspected daily and repaired promptly. With about 270 rail joints per mile of track, maintenance of them is also an expensive process.

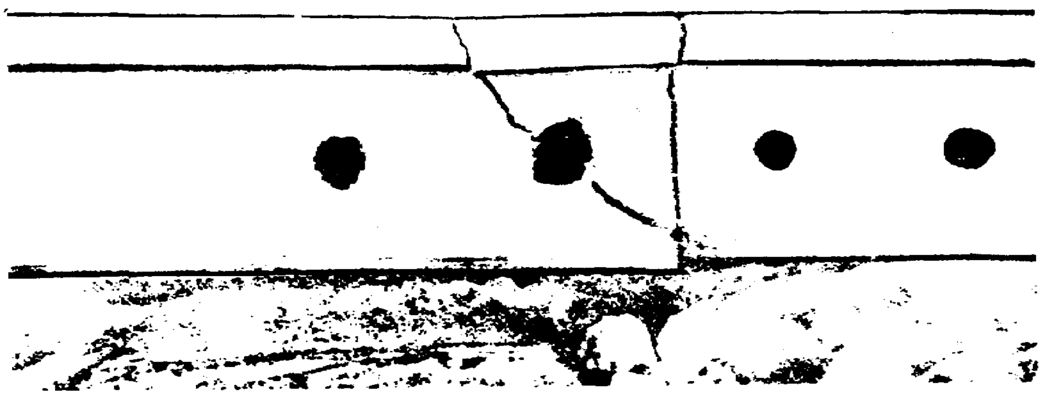
On one inspection, you find a number of rails with battered ends, severe wear on the top of several bars, a crack in one bar running from the spike slot to a bolthole, and several loose bolts in some newly applied bars. What procedures do you follow to correct these and other faults?

(1) Batter and wear. Badly battered rail and badly worn joint bars should be replaced. However, you have the alternative of building up the low spots by welding and then grinding the weld to the proper contour. But welding and grinding are time-consuming processes.

(2) Cracks and breaks. Replace any badly cracked or broken joint bars at once. Figure 3.21 shows two examples of broken joint bars, both of which had had boltholes made by cutting

with an acetylene torch instead of by drilling. When replacing joint bars, follow the steps for the installation given in paragraph 3.28.

Broken Web and Base



Broken Web and Head

Figure 3.21. Broken Joint Bars.

Renewing joint bars is one of the more dangerous on-track maintenance jobs. Assign at least two men to do the work when one bar is to be renewed; provide flag protection for them when both bars of a joint are to be renewed.

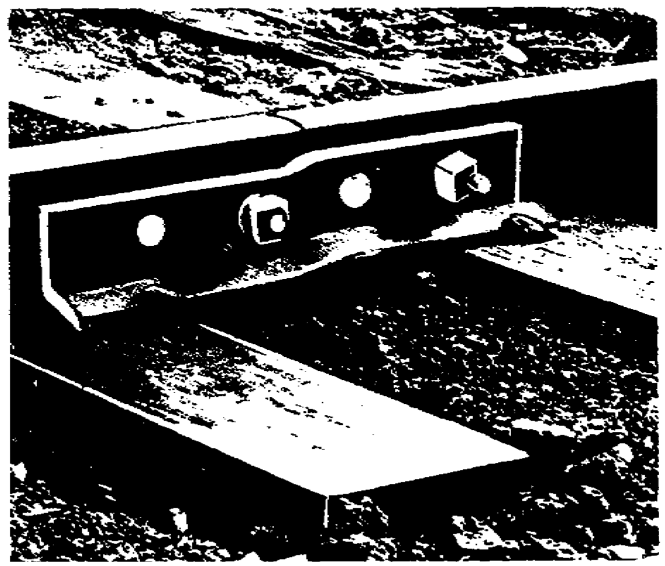
(3) Loose or missing bolts and nuts. Careless maintenance is obvious when an inspection reveals loose or missing bolts. On newly applied bars, the tension of the nuts should be checked at

least twice within the first 10 days after installation--first, within a day or so and again, within a week or 10 days.

Only when all bolts and nuts are in place and properly tightened can a rail joint provide the support that it is designed to give. Missing bolts and nuts should be replaced when their loss is first noticed.

3.30. COMPROMISE JOINTS

Often it is necessary to join tracks of different rail sections. Light-traffic branch lines must join main-line tracks; sidings and yard tracks of light rail must join heavy running tracks. In addition, replacing main-line rail often requires that rail of different weights be joined in the same track. These and other similar problems are solved with compromise joints.



The compromise joint, or the offset or step joint as it is sometimes called, is a variation of the simple bar joint, using bars made so that half the bar fits one rail section and the other half fits another. A typical compromise bar is shown at the right installed on the field side of a rail; another bar is installed on the gage side of the same rail. Compromise joints are designated either right or left handed. Standing inside the track and looking at the joint, if the larger and heavier rail is on your right, then the joint is right handed. If the larger, heavier rail is on your left, then the joint is left handed. These designations are diagramed in figure 3.22.

Compromise bars compensate for differences in web thickness, head width and depth, height, and location of boltholes. A pair of compromise joints holds the smaller rail so that its top and gage side meet those of the heavier rail. When compromise joints are ordered, the two rail weights and sections and the direction of the joints are specified. Compromise splices are common in theaters because they allow the use of any rail regardless of its section.

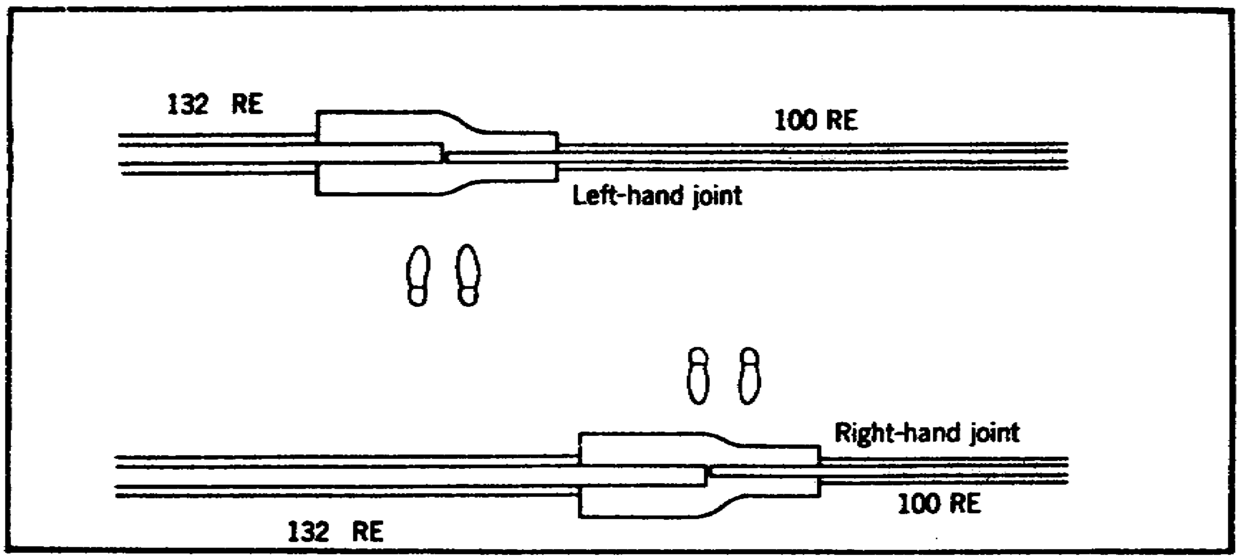


Figure 3.22. Designations of Compromise Bars.

3.31. INSULATED JOINTS

Insulated joints are found in automatic block territory on each track at block limits, on all crossovers and turnouts, and where highway crossing gates or lights are electrically operated. They are also used to isolate spurs on which gasoline is to be unloaded from track used in electric circuits. Joints connecting rail of the same section and those known as compromise joints are insulated where necessary. They are called insulated same-section joints and insulated compromise joints, respectively.

To insulate a joint, the procedure is as follows. A fiber insulator is placed between the rail base and the joint bar base; insulating bushings are placed around the bolts securing the bar; fiber washers are placed under the nuts; and fiber end post insulators, shaped like the rail, are placed between the two rail ends with no room for expansion.

Insulated joints are the source of continual maintenance annoyance; of all rail joints, they are said to be the weakest. To keep insulated joints in good. condition, the bolts must be kept tight and the ties under the joints should be the best; they must be well tamped with clean ballast and well drained to prevent the joint from pumping and churning and to prevent excessive wear of the fiber. Loose ties cause the fiber to wear out quickly, and this may cause failure of the signal.

3.32. BONDED JOINTS

In some track locations, copper bond wires connect rail ends to carry electric current across the joint. Such bonded joints are found where highway or train signals are actuated through track circuit and at gasoline-loading stations where the rails are grounded.

Lugs at the end of the bond wire are driven into holes drilled in the rail's web until they fit firmly. Except in emergencies, the rail maintenance crew must be careful not to break wires or remove bonded rails unless a signal maintainer is present. If he is not there when a broken rail is to be replaced, tighten the joints to make as good contact as possible with the rails, and notify him that the bond wires have been broken.

3.33. SUMMARY

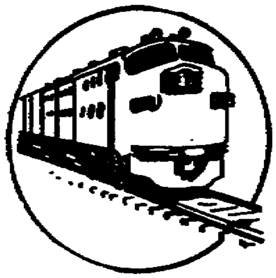
Rail joints are connected and strengthened by joint bars. Rails of different sizes are joined by compromise joints, a variation of the regular joint made to fit the different rail sections. Unless they are installed in very hot weather, space for expansion is left between the joints. Standard military practice is for a joint to be located opposite the center of the other rail of the track--a "broken joint." Joints in electric track-circuit territory must be insulated; in some locations, they must be bonded.

CORRESPONDENCE COURSE OF THE
U. S. ARMY
TRANSPORTATION SCHOOL

RAILWAY TRACK MAINTENANCE I

LESSON EXERCISES
TRANS SUBCOURSE 670

Fort Eustis, Virginia



TRANS SUBCOURSE 670

RAILWAY TRACK MAINTENANCE I

INTRODUCTION

Trans Subcourse 670, Railway Track Maintenance I, and Trans Sub-course 671, Railway Track Maintenance II, present information concerning maintenance and repair of railway track and its associated facilities. It is recommended that both subcourses be taken and that subcourse 670 precede 671. Only if you have had considerable working experience and desire information about a particular phase of this work should you take one subcourse without the other.

The information presented in the two subcourses is essential to a knowledge of maintenance of way, but even its complete assimilation will not qualify you as a track supervisor. Such qualification also depends upon extensive practical operating experience with railroads and with field engineering equipment. Knowledge of the material presented in the subcourses will enable you to understand the methods and procedures of track maintenance and prepare you to benefit rapidly from working experience.

Both subcourses treat fundamental ideas in some detail to assure you a common basic knowledge. An attempt is made to anticipate questions and to prevent misunderstandings which might arise if the texts presupposed fundamental technical knowledge of the subject.

In general, modern maintenance-of-way practices are universal and the largest portion of subject matter contained in the subcourses applies similarly to civilian and military railroads. Where differences as to specific operations occur, the military practice is emphasized and the reasons for variance are explained.

After studying the reference text to this subcourse, you should be able to identify the physical characteristics of a railroad; to define the terms used in maintenance of way and track; and to solve some of the varied problems of the track supervisor. In addition, you should be able to explain the relationship between roadbed and ballast, what materials are used for ballast, what their functions are, how they are used, and how they are cleaned. Also, you should be able to explain the importance of good drainage and the means by which it is obtained and maintained.

Finally, you should be able to describe the elements of track: rail, ties, track fastenings, and track devices. The subcourse consists of three lessons and an examination divided as follows:

		Credit hours
Lesson	1, Fundamentals of Railway Engineering	2
	2, Roadbed, Ballast, and Drainage	2
	3, Track Elements	3
Examination		3
	Total	10

Text and materials furnished: Reference Text 670, Railway Track Maintenance I, January 1971.

Upon completion of the subcourse, you are to retain the reference text; do not return it with your answer sheets.

LESSON 1..Fundamentals of Railway Engineering.

CREDIT HOURS ....2.

TEXT ASSIGNMENT...Reference Text 670, pars. 1.1-1.9.

MATERIALS REQUIRED.......................................None.

LESSON OBJECTIVE...To enable you to describe the physical characteristics of a railroad, to define the terms used in maintenance of way and track, and to solve the varied problems of the track supervisor.

SUGGESTIONS..None.

EXERCISES

Weight | True-False

(Mark a "T" for true and an "F" for false.)

3 1. Broadening the gage of track on sharp curves prevents derailment.

3 2. Developments reduce the percent of grade at the expense of increasing the route length.

3 3. The field side of a rail faces the centerline of the track.

3 4. A long train requires a long vertical curve.

3 5. Over a long distance, a change in the height of a rail line is described as a grade.

3 6. A profile shows the horizontal alinement as well as the vertical curves of a railroad.

Cluster True-False

(Each question of this kind consists of a series of statements related to the stem that precedes them. Indicate which are true and which false with respect to the stem)

7. What limitation does the use of smooth flanged wheels rolling on steel rails impose on a railroad? It:

2 a. Restricts it to a low tractive effort.

2 b. Restricts the roadbed to level terrain.

2 c. Requires it to use expensive installations to provide flexibility.

2 d. Restricts the number of cars per train.

2 e. Prohibits the use of superelevated track.

8. When you speak of a railroad's horizontal alinement, you are referring to its:

2 a. Curves and tangents.

2 b. Ups and downs.

2 c. Centerline.

2 d. Ground plan.

2 e. Grades.

9. Traffic density on a rail line should be used as a basis in determining:

2 a. If tangents should be superelevated.

2 b. The standard of maintenance for the line.

2 c. If curvature and gradient should be reduced by extensive construction.

2 d. The number of turnouts needed.

2 e. If vertical curves should be used.

Matching

10. In studying the fundamentals of railway engineering, you become familiar with certain terms and their definitions. Match the terms in column II with the definitions in column I. Terms in column II may be used once, more than once, or not at all.

	Column I	Column II
2	(1) Distance between the two rails of track.	A. Superelevation.
		B. Clearance.
2	(2) Relationship between the height of the two rails.	C. Cross level.
2	(3) Land on which the tracks are laid.	D. Profile.
		E. Alinement.
2	(4) The combination of curves and tangents which	F. Track surface.

(continued)

Weight

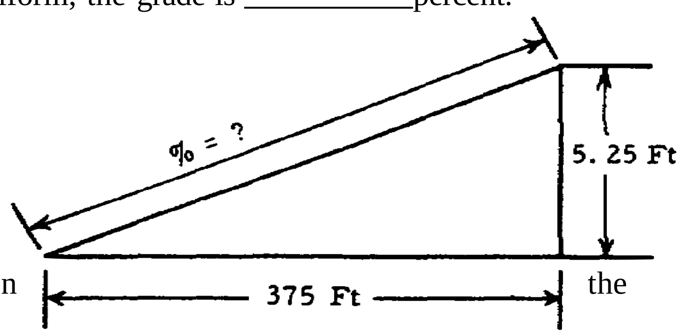
Weight		Column I		Column II
		lead a railroad to its destination.	G.	Gage.
			H.	Elevation.
2	(5)	Distance between obstructions bordering the track and any trains on it.	I.	Tangent.
			J.	Right of way.
2	(6)	Straight track.		
2	(7)	A side view of the surface of the rail.		
2	(8)	A railroad's ground plan.		

Multiple Choice

(Each question in this group contains one and only one correct answer. Circle the alternative which represents your choice.)

4 11. A railroad line gains 5.25 feet of elevation over a horizontal distance of 375 feet. If the gradient is uniform, the grade is ___________percent.

A. 1.40.
B. 1.62.
C. 1.71.
D. 1.83.



4 12. In the United States, curvature is measured on the basis of:

A. The length of the radius.
B. The length of the diameter.
C. The chord.
D. Degrees.

4 13. During an inspection, you find that one section of a standard-gage railroad has a gage of 56 3/8 inches

throughout its length. You would be justified in assuming that the:

A. Track was located on a sharp curve.
B. Track was to be used for high-speed traffic.
C. Traffic density was light.
D. Track's construction was faulty.

4 14. A line is tangent to a circle if it:

A. Touches the circumference of the circle at two points through its center.
B. Makes a right angle with any of the radii of the circle at its center.
C. Touches the circumference of the circle at two and only two points.
D. Makes a right angle with the radius of the circle at its circumference.

4 15. Standard gage ordinarily refers to track that, when measured at the gage line, is ____________inches between the rails.

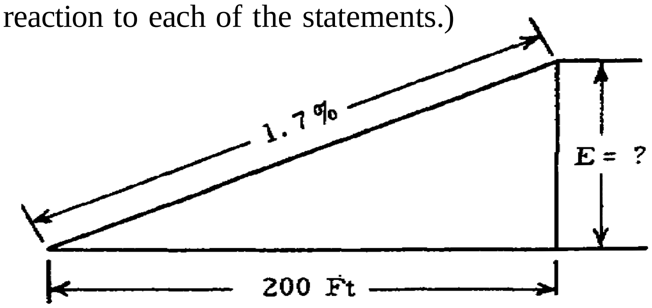
A. 54 1/8.
B. 54 1/4.
C. 56 1/2.
D. 60.

4 16. A railroad has a grade of 1.7 percent. If the horizontal distance between two points on the grade is 200 feet, what is the difference in elevation (E on the sketch) between them ?

A. 2.5 ft.
B. 3.4 ft.
C. 8.6 ft.
D. 10.7 ft.

Analytical

(Using the following key, indicate your reaction to each of the statements.)



Weight

A. The underscored statement is true, and the reason for it or result of it is true.

B. The underscored statement is true, but the reason or result is false.

C. The underscored statement is false.

4 17. A track with low traffic density requires extra maintenance because the lack of compacting weight from the trains allows ballast to spread.

4 18. In the United States, steepness of a grade is given in percent, arrived at by dividing the length of a grade by its radius.

4 19. The 56 1/2-inch gage is used on railroads in the United States because derailment is more frequent where smaller gages are used.

LESSON ASSIGNMENT SHEET

TRANS SUBCOURSE 670..............................Railway Track Maintenance I.

LESSON 2..Roadbed, Ballast, and Drainage.

CREDIT HOURS...2.

TEXT ASSIGNMENT...................................Reference Text 670, pars. 2.1-2.16.

MATERIALS REQUIRED............................None.

LESSON OBJECTIVE....................................To enable you to explain the relation-ship between roadbed and ballast; what materials are used for ballast, how they are selected, what their functions are, how they are used, and how they are cleaned; how important good drain-age is and how it is obtained and maintained.

SUGGESTIONS...None.

EXERCISES

Weight — True-False

(Mark a "T" for true and an "F" for false.)

3 1. Cinders are used for ballast on heavy tonnage, high-speed main lines because of their great economy.

3 2. Using an excellent ballast on an important rail supply line in a theater helps to compensate for the scarcity of maintenance men and machinery there.

3 3. The height and width of a longitudinal ditch are in direct proportion to the depth of the ballast section.

3 4. Scouring of a ditch prevents its being paved.

Weight

3 5. When vitrified sewer pipe is used to drain a side ditch, the pipe joints are closed tightly to prevent dirt from entering and clogging the pipe.

Cluster True-False

(Each question of this kind consists of a series of statements related to the stem that precedes them. Indicate which are true and which false with respect to the stem.)

6. Water pockets are a great nuisance to the track maintenance crew. They are often:

2 a. Created by operating numerous heavy trains over poor quality ballast.

2 b. Caused by pumping ties.

2 c. The cause of heaving roadbed.

2 d. The result of soil erosion.

2 e. Caused by porous material surrounded by impenetrable material.

7. A good roadbed is essential to a railroad because it:

2 a. Receives train weight from ballast above and transmits it to ground below.

2 b. Compensates for irregularities of terrain.

2 c. Supports ballast above adjacent ground to provide run-off for water.

2 d. Provides the stability that a track needs.

2 e. Should be spongy to reduce shock to rails and provide a comfortable ride.

8. As a track supervisor in an oversea area, you would select new ballast on the basis of the:

Weight

2 a. Traffic density.

2 b. Availability of materials.

2 c. Maximum track curvature.

2 d. Depth of subgrade.

2 e. Height of ties used.

9. Drainage of the track structure over part of a heavy traffic line is being hampered by contaminated ballast. The crushed stone ballast was put down 4 years ago. To solve the problem, you would:

2 a. Remove the dirty ballast, clean and replace it, and add any new amount needed.

2 b. Undertake a large-scale program of grouting.

2 c. Schedule it to be cleaned in 2 years.

2 d. Clean the ballast by hand or by mechanical ballast cleaners.

2 e. Remove the dirty ballast and replace it with new, clean ballast.

10. As a track supervisor, you would expect good ballast to:

2 a. Hold moisture near crossties.

2 b. Maintain proper track alinement.

2 c. Drain the track structure.

2 d. Maintain correct track gage.

2 e. Help in maintaining track surface.

11. As a track supervisor, you decide to use cinders for ballast in a certain yard because of:

2 a. Their resistance to being ground into dust.

2 b. Their economical first cost.

Weight

2 c. Their low maintenance requirements.

2 d. The low traffic density of the yard.

2 e. Their ease in handling.

12. On your section, the walls of a certain cut have presented a constant problem because of erosion and crumbling. At present, the slope is one unit horizontal to one unit vertical. The procedures that would solve the problem are:

2 a. Change the slope to 1 1/2 horizontal to 1 vertical.

2 b. Install a lateral drainage system on top of the sub-grade.

2 c. Construct a French drain.

2 d. Introduce plant growth.

2 e. Erect a retaining wall.

Multiple Choice

(Each question in this group contains one and only one correct answer. Circle the alternative that represents your choice.)

3 13. Severe scouring has occurred in a drainage ditch cut through soil. To correct this condition, you would:

A. Introduce plant growth.
B. Increase the gradient.
C. Construct a double ditch.
D. Pave the ditch.

3 14. Although subballast may not be used on your line, you should know how, why, and when it should be used. It:

A. Should be omitted when the top ballast consists of slag.

B. Reduces the unit pressure on the roadbed.

C. Is primarily used on low-traffic, branch-line track.

Weight

D. Is a high-quality ballast used under the top ballast where the subgrade is particularly spongy.

3 15. Grouting is one way to get rid of a water pocket. To apply this method, you would:

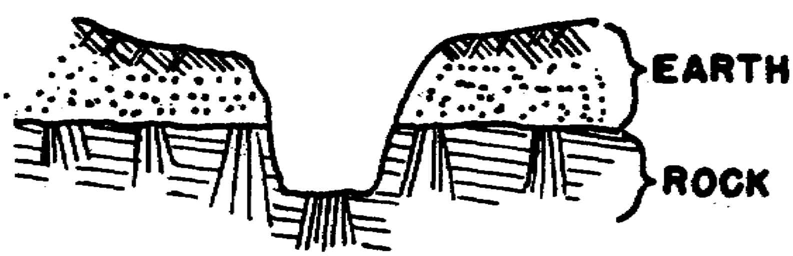
A. Construct an intercepting ditch or dike.
B. Dig trenches under rail joints and fill them with cinders.
C. Install a French drain in the water pocket.
D. Inject a cement-water mixture, under pressure, into the water pocket.

3 16. A stretch of main-line track subject to a heavy volume of high-speed traffic is to be reballasted, Crushed stone is not available for the job, but several other kinds of ballast materials are. Your second choice, comparable in quality to crushed stone, would be:

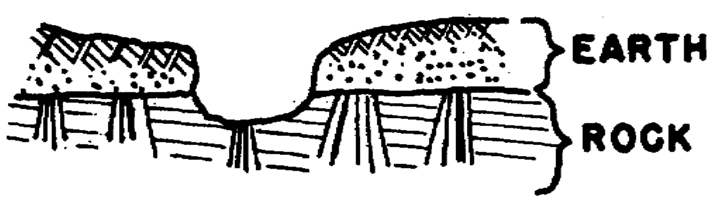
A. Cinders.
B. A sand and gravel mixture.
C. A good-quality slag.
D. Pit-run gravel.

3 17. A typical cross section of an earth and rock cut is shown in sketch:

A.

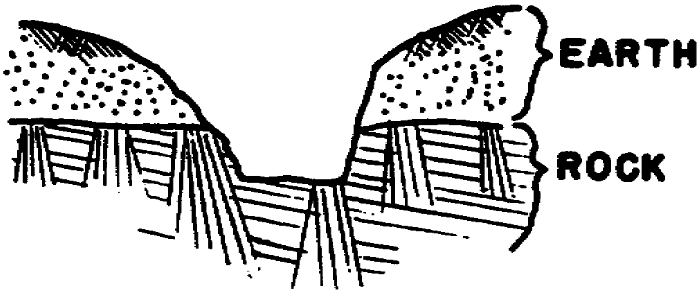


B.

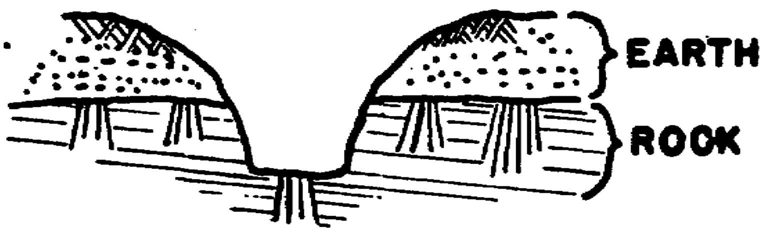


Weight

C.



D.



LESSON ASSIGNMENT SHEET

TRANS SUBCOURSE 670..Railway Track Maintenance I.

LESSON 3 ....Track Elements.

CREDIT HOURS...3.

TEXT ASSIGNMENT...Reference Text 670, pars. 3.1-3.33.

MATERIALS REQUIRED..None.

LESSON OBJECTIVE...To enable you/to identify the elements of track including rail–its development, . manufacture, characteristics, and common failures and their detection; crossties–their preservation, size, and spacing; track fastenings; and rail joints–design, types, location, and problems.

SUGGESTIONS...None.

EXERCISES

Weight		True-False (Mark a "T" for true and an "F" for false.)
2	1.	In comparing 60 -and 75-pound ASCE rail, you would find that the 75-pound rail is the stiffer of the two.
2	2.	The military standard 33-foot rail requires screw spikes for its installation.
2	3.	Concrete ties are preferred to wooden ones because of their resistance to impact loads.

Weight | Cluster True-False

(Each question of this kind consists of a series of statements related to the stem that precedes them. Indicate which are true and which are false with respect to the stem)

4. A detail of untrained men has been assigned to you to assist in handling creosoted ties before a large-scale renewal program. You would caution the men to:

2 a. Stack the ties so that only the adzed surfaces come in contact with each other.

2 b. Prevent creosote from coming in contact with their skin.

2 c. Stack ties to prevent water from being constantly in touch with them.

2 d. Handle the ties with tongs.

2 e. Remove any dirt found on the stacked ties.

5. The life of ties can be increased by:

2 a. Using antisplitting irons.

2 b. Treating them with creosote.

2 c. Adzing after treatment.

2 d. Treating them with calcium chloride.

2 e. Boring before treatment.

6. Each section of rail has its heat number impressed on its side. Heat numbers:

2 a. Are usually noted when rails with transverse fissures are removed from service.

2 b. Always contain five numbers followed by two letters, such as 11225 RE.

Weight

2 c. Are recorded when the rails are put in service.

2 d. Designate all the rails made from the same ladle of molten steel.

2 e. Are found on the opposite side of a rail from that on which the weight and section appear.

2 f. Tell the highest temperature to which the rail was heated during the end-hardening process.

7. Wooden crossties have a number of advantages, some of which are their:

2 a. Resistance to rot in damp climates.

2 b. Resistance to impact loads.

2 c. Resistance to abrasive wear.

2 d. General availability.

2 e. Suitability for holding rails by spikes.

Matching

8. Match the equipment in column II with the function it carries out in column I. Choices in column II may be used once, more than once, or not at all.)

Weight	Column I	Column II
1	(1) Prevents rail from overturning.	A. Tie plate.
		B. C-iron.
1	(2) Prevents rail from moving longitudinally.	C. Flange plate.
1	(3) Prevents rail from moving away from center-line of track (spreading).	D. Gage rod.
		E. Angle bar.
	(continued)	F. Hook head spike.

Weight

Weight		Column I		Column II
1	(4)	Spreads rail weight over tie.	G.	Rail brace.
			H.	Rail anchor.
1	(5)	Resists lateral thrust on rail.		

9. Typical markings to be found on the web of a rail are shown in column I; column II lists their explanations. "Read" the markings by selecting choices from column II that identify the numbered parts in column I.

Weight	Column I		Column II
8*	(1) (2) (3) (4)	A.	Weight per yard.
	100 RE Illinois USA 1967	B.	Ingot number.
	(5) (6) (7) (8)	C.	Which rail of a specific ingot.
	///// 56341 D 15	D.	Fillet curve number
		E.	Controlled cooling.
		F.	Week of manufacture.
		G.	Place of manufacture.
		H.	Heat number.
		I.	Web height.
		J.	Month of manufacture.
		K.	Branding symbol.
		L.	Year of manufacture.

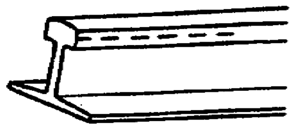
*1 point for each choice.

Weight

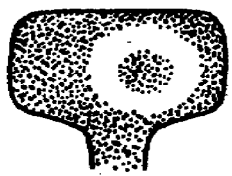
10. Column II lists types of rail failures and column I illustrates six of them. Match the failure in column II to the illustration in column I that shows it.

Column I

1 (1)



1 (2)



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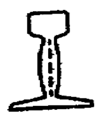

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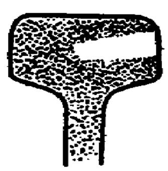


Column II

A. Web fracture.

B. Transverse fissure.

C. Vertical split head.

D. Horizontal split head.

E. Broken base.

F. Compound fissure.

G. Crushed head.

H. Vertical fissure.

I. Piped rail.

J. Split web.

Weight

11. In column 1, several track locations are listed. Column II lists several types of joints. Match the two columns.

Column I Column II

Weight	Column I	Column II
1	(1) 112-RE rail joins 100-RA rail in automatic block territory at block limits.	A. Bridge joint.
		B. Insulated same-section joint.
	(2) 75-AS rail joins grounded 75-AS rail in a petroleum loading area.	C. Insulated compromise joint.
		D. Bonded joint.
	(3) 152-RA rail joins 152-RA rail in automatic block territory where highway crossing gates are electrically operated.	E. Suspended joint.
1	(4) 75-AS rail joins 80-AS at boundary of two blocks in automatic block territory.	
1	(5) 100-RE rail joins 100-RE rail at boundary of two blocks in automatic block territory.	

Multiple Choice

(Each question in this group contains only one correct answer. Circle the alternative of your Choice).

2 12. Rail anchors are used to restrain the movement of track where there is:

A. Excessive lateral thrust.
B. Continually spreading track on a curve.

Weight

C. Excessive vertical thrust.
D. Longitudinal movement.

2 13. The space left between ties should not exceed ___________inches.

A. 12.
B. 16.
C. 18.
D. 20.

2 14. If a joint is located directly across from one in the other rail, it is called a _________joint.

A. Square.
B. Broken.
C. Perpendicular.
D. Parallel.

2 15. Both rails in a mile-long siding are to be replaced with 85-AS rail. What will be the total weight in pounds of the new rails ? (Remember, there are 5,280 feet in a mile.)

A. 85,850.
B. 99,734.
C. 130,600.
D. 299, 200.

2 16. When a base plate is added to a suspended joint, it is called a ____joint.

A. Foot.
B. One-tie.
C. Three-tie.
D. Bridge.

2 17. The spikes used to hold T-rail in place at a rail joint are driven through the _____________of the joint.

A. Web.
B. Flange slots.
C. Rod.
D. Fishing space.

Weight

2 18. A main-line running track is constructed of 39-foot rails to Corps of Engineers specifications. If the ties used are 9 inches wide, approximately what percent of the total rail length rests on tie surface?

A. 18.
B. 24.
C. 32.
D. 40.

2 19. When 39-foot rails are laid at a temperature of 400 F., what is the difference between their rail gap and that of 33-foot rails laid at the same temperature?

A. 1/16 inch more.
B. 1/8 inch less.
C. 1/4 inch less.
D. 3/16 inch more.

2 20. If angle, head-free, and head-contact bars were placed before you, you could easily identify the angle bar by its:

A. Head.
B. Flange.
C. Web.
D. Square boltholes.

2 21. When a rail joint is installed in cold weather, the gap left between rail sections, in comparison with that left in warm weather, is:

A. Smaller.
B. The same.
C. Greater.
D. Governed by the humidity.

2 22. End wear on a rail is referred to as:

A. Abrasion.
B. Batter.
C. Crushing.
D. Grinding.

Weight

2 23. The gage of the track on a particularly sharp curve in your section was increased slightly to prevent binding. The passage of trains, however, is spreading the gage even farther. To correct the situation, you should install:

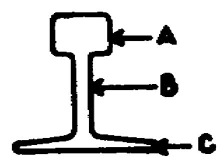
A. Gage rods.
B. Track gages.
C. Rail braces.
D. Rail anchors.

2 24. Modern railroad rails are usually made of:

A. Rolled iron.
B. Wrought iron.
C. Open-hearth alloyed steel.
D. Bessemer steel.

2 25. The sketch shows a typical rail section. Which of the following correctly identifies its three main parts ?

A. A, head; B, web; C, base.
B. A, base; B, head; C, web.
C. A, head; B, base, C, web.
D. A, base; B, web; C, head.



CORRESPONDENCE COURSE OF THE
U. S. ARMY TRANSPORTATION SCHOOL
SOLUTIONS

TRANS SUBCOURSE 670..Railway Track Maintenance I.

(All references are to Reference Text 670.)

LESSON 1

Weight	Exercise
3	1. F. (par. 1.6d)
3	2. T. (par. 1.3b)
3	3. F. (par. 1.6a)
3	4. T. (par. 1.5b)
3	5. T. (par. 1.7)
3	6. F. (pars. 1.4, 1.5)
2	7. a. T. (par. 1.2)
2	b. F. (par. 1.3a)
2	c. T. (par. 1.2)
2	d. F. (par. 1.2)
2	e. F. (par. 1.7)
2	8. a. T. (par. 1.4)
2	b. F. (par. 1.4)
2	c. F. (par. 1.4)
2	d. T. (par. 1.4)
2	e. F. (par. 1.4)
2	9. a. F. (par. 1.7)
2	b. T. (par. 1.2)
2	c. T. (par. 1.2)
2	d. T. (par. 1.2)
2	e. F. (par. 1.5b)
2	10. (1) G. (par. 1.6)
2	(2) C. (par. 1.7)
2	(3) J. (par. 1.4c)
2	(4) E. (par. 1.4) .
2	(5) B. (par. 1.8)
2	(6) I. (par. 1.4)
2	(7) D. (par. 1.5)
2	(8) E. (par. 1.4)
4	11. A. (par. 1.5)

$\frac{5.25}{375} \times 100 = 1.40$

All concerned will be careful that neither this solution nor information conc[...] the possession of students or prospective students who have not completed the work to which it pertains.

Weight	Exercise
4	12. D. (par. 1.4a)
4	13. B. (par. 1.6d)
4	14. D. (par. 1.4)
4	15. C. (par. 1.6)
4	16. B. (par. 1.5)

$$\frac{E}{200} \times 100 = 1.7$$

$$E = \frac{200}{100} \times 1.7$$

E = 3.4

Weight	Exercise
4	17. C. (par. 1.2)

Low traffic density on a line requires <u>less</u> maintenance.

Weight	Exercise
4	18. B. (par. 1.5)

To find percent of grade, divide the vertical rise by the horizontal length of the grade and multiply by 100.

Weight	Exercise
4	19. B. (par. 1.6)

No reason for adopting the U.S. standard gage is known.

LESSON 2

Weight	Exercise	Weight	Exercise
3	1. F. (par. 2.5a, d)	2	6. a. T. (par. 2.10b(3))
3	2. T. (par. 2.6)	2	b. T. (par. 2.10a)
3	3. F. (par. 2.14)	2	c. T. (par. 2.10b(4))
3	4. F. (par. 2.14)	2	d. F. (par. 2.3e)
3	5. F. (par. 2.14a)	2	e. T. (par. 2.10b)

Weight	Exercise		
2	7.	a.	T. (par. 2.2; fig. 2.1)
2		b.	T. (par. 2.3)
2		c.	T. (par. 2.2)
2		d.	T. (par. 2.1)
2		e.	F. (par. 2.1)
2	8.	a.	T. (par. 2.6)
2		b.	T. (par. 2.6)
2		c.	F. (par. 2.6)
2		d.	F. (par. 2.6)
2		e.	F. (par. 2.6)
2	9.	a.	T. (par. 2.13a)
2		b.	F. (pars. 2.13a, 2.15d)
2		c.	F. (par. 2.13d)
2		d.	T. (par. 2.13a, c)
2		e.	F. (par. 2.13)
2	10.	a.	F. (par. 2.4)
2		b.	T. (par. 2.4)
2		c.	T. (par. 2.4

Weight	Exercise		
2		d.	F. (par. 2.4)
2		e.	T. (par. 2.4)
2	11.	a.	F. (par. 2.5d)
2		b.	T. (par. 2.5d)
2		c.	F. (par. 2.6)
2		d.	T. (par. 2.6)
2		e.	T. (par. 2.5d)
2	12.	a.	T. (par. 2.3d(1))
2		b.	F. (par. 2.15a, b)
2		c.	F. (pars. 2.3e, 2.15e)
2		d.	T. (par. 2.3e(2))
2		e.	T. (par. 2.3e(3)) "
3	13.	D.	(par. 2.14)
3	14.	B.	(par. 2.7a)
3	15.	D.	(par. 2.15d)
3	16.	C.	(pars. 2.5c, 2.6)
3	17.	D.	(par. 2.3d; fig. 2.2C)

LESSON 3

Weight	Exercise
2	1. T. (par. 3.6)
2	2. F. (pars. 3.9, 3.21)

Weight	Exercise		
2	3.	F.	(pars. 3.12, 3.14b)
2	4.	a.	F. (par. 3.17c)
2		b.	T. (par. 3.17a)
2		c.	T. (par. 3.17c)
2		d.	T. (par. 3.17c)
2		e.	F. (par. 3.17c)
2	5.	a.	T. (par. 3.17b)
2		b.	T. (par. 3.17a)
2		c.	F. (par. 3.17a)
2		d.	F. (par. 3.17a)
2		e.	T. (par. 3.17a)
2	6.	a.	T. (par. 3.10a)
2		b.	F. (par. 3.8)
2		c.	T. (par. 3.10a)
2		d.	T. (pars. 3.4, 3.8)
2		e.	T. (par. 3.8)
2		f.	F. (par. 3.8)
2	7.	a.	F. (par. 3.12)
2		b.	T. (par. 3.12)
2		c.	F. (par. 3.12)
2		d.	T. (par. 3.12)

Weight	Exercise		
2		e.	T. (par. 3.12)
1	8.	(1)	F. (par. 3.21)
1		(2)	H. (par. 3.22)
1		(3)	D. (par. 3.22)
1		(4)	A. (par. 3.20)
1		(5)	G. (par. 3.22)
1	9.	(1)	A. (par. 3.8)
1		(2)	K. (pars. 3.5, 3.8)
1		(3)	G. (par. 3.8)
1		(4)	L. (par. 3.8)
1		(5)	J. (par. 3.8)
1		(6)	H. (par. 3.8)
1		(7)	C. (par. 3.8)
1		(8)	B. (par. 3.8)
1	10.	(1)	D. (par. 3.10b; fig. 3.2D)
1		(2)	B. (par. 3.10a; fig. 3.2A)
1		(3)	I. (par. 3.10i; fig. 3.2 C)
1		(4)	G. (par. 3.10e; fig. 3.2F)
1		(5)	J. (par. 3.10f; fig. 3.2G)

Weight	Exercise
1	(6) D. (par. 3.10b; fig. 3.2D)
1	11. (1) C. (pars. 3.30, 3.31)
1	(2) D. (par. 3.32)
1	(3) B. (par. 3.31)
1	(4) C. (pars. 3.30, 3.31)
1	(5) B. (par. 3.31)
2	12. D. (par. 3.22)
2	13. C. (par. 3.16)
2	14. A. (par. 3.27b)
2	15. D. (par; 3.5)

$$\frac{5,280\text{ ft}}{3\text{ ft}} = 1,760 \text{ yards per mile of rail}$$

3,520 x 85 = 299, 200 lb.

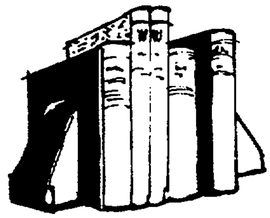
Weight	Exercise
2	16. D. (par. 3.27a(2))
2	17. B. (par. 3.28c)
2	18. D. (par. 3.16)

21 x 9 = 189 in. of tie surface
39 x 12 = 468 in. of rail

$$\frac{189}{468} \times 100 = 40.3 \text{ or approximately 40 percent}$$

Weight	Exercise
2	19. A. (par. 3.28a)
2	20. B. (par. 3.26a)
2	21. C. (par. 3.28a; table V)

Weight	Exercise
2	22. B. (par. 3.29b(1))
2	23. A. (par. 3.22; fig. 3.17)
2	24. C. (par. 3.4)
2	25. A. (par. 3.5; fig. 3.1)



Appendix I

REFERENCES

Army Regulations

AR 310-25	Dictionary of United States Army Terms
AR 310-50	Authorized Abbreviations and Brevity Codes

Field Manuals

FM 21-30	Military Symbols

Technical Manuals

TM 5-370	Railroad Construction
TM 5-627	Railway Track Maintenance; Repairs and Utilities
TM 55-204	Maintenance of Railroad Way and Structures

Commercial Publications

Henry, Robert S., This Fascinating Railroad Business, Indianapolis, The Bobbs-Merrill Co., 1946.

Raymond, William G., Riggs, Henry E., and Sadler, Walter C., Elements of Railroad Engineering, New York, John Wiley & Sons, Inc., 1947.

Rench, Walter F., Roadway and Track, New York, Simmons-Boardman Publishing Corp., 1946.

Stevers, Martin D., Steel Trails, New York, Milton, Balch and Company, 1933.

Tratman, E. E. R., Trackwork, and the Section Foreman, Scranton, International Textbook Co., 1935.

Webb, Walter L., Railroad Construction, Theory and Practice, New York, John Wiley & Sons, Inc., 1944.

Appendix II

GLOSSARY

Adzing--cutting or planing a crosstie enough to provide a smooth, satisfactory seat for rail or tie plate.

Adzing machine--portable power-operated machine designed to adz crossties to provide proper bearing for rails or tie plates.

Alinement--horizontal location of a railroad, with reference to curves and tangents.

Angle bar--rail joint bar. See Joint bar.

Antichecking iron--piece of flat iron sharpened on one edge driven into the end of a tie to prevent checking and splitting. It is bent to special designs or to the shape of C, S, or Z, and called C-iron, S-iron, or Z-iron. Also called antisplitting iron.

Anticreeper--see Rail anchor.

Ballast--selected material placed on the roadbed to hold track in line and surface. Consists of hard particles easily handled in tamping, which distribute the load, drain well, and resist plant growth. Materials used include broken or crushed stone, gravel, slag, sand.

Ballast section--cross section of a track between and above the toes of the ballast slopes, whether or not this section includes subballast.

Ballast shoulder--that portion of ballast between the end of the tie and the toe of the ballast slope. It distributes the traffic load over a greater width of roadway and helps hold the track in alinement.

Ballast tamper--portable power-operated machine for compacting ballast under crossties.

Ballast tamping--compacting ballast under crossties to maintain the line and surface of track.

Batter--mashing of the surface of the railhead close to the end of the rail.

Bolt, track--metal fastener, 7 to 10 inches long and 7/8, 1, or 1 1/4 inches in diameter, used to fasten joint bars to rail ends.

Brace, rail--device used at such places as switches and movable-point frogs, with switch, tie, or gage plates, for holding rail in place. Also used on rails at sharp curves to maintain the gage and prevent rail overturning.

Brace, track--auxiliary fastening designed to be used both as a rail brace and a gage rod.

Check--small lengthwise crack or separation of wood fibers, caused by superficial shrinkage of a timber.

Circuit, track--low-voltage electric circuit of which the rails of a track form a part when bonded at the joints for this purpose.

Clearance diagram--chart diagraming the limitations imposed by permanent railway structures above track level on the maximum dimensions of cargo or equipment.

Clearance limitation--restrictions imposed by permanent railway structures on the maximum dimensions of cargo and equipment.

Compromise bars--special joint bars to connect rails of different section in such a way that the gage sides and running surfaces are held in line. Also called offset bars.

Creosote--oily aromatic compound distilled from tars, used in preserving wood used in exposed locations.

Crib--ballast or the open space between two adjacent crossties; also, a crisscross structure of logs, timber, concrete, or other members used to retain a fill or as a bridge support.

Crossing, grade--crossing or intersection of a railroad and a highway at the same level or grade.

Crosstie--see Tie.

Curvature--measure of the sharpness of a curve.

Curve, easement--alinement curve, the degree of which varies in some definitely determined manner, to give a gradual transition between a tangent and a simple curve or between two simple curves.

Curve, vertical--curve in the profile of a track to connect intersecting grade lines and to permit safe and smooth operation of trains over summits and across sags (depressions).

Drill, track--machine tool designed to operate horizontally to drill holes through webs of track rails, especially for track bolts.

Easement curve--see Curve, easement.

Expansion shim--spacer inserted between ends of abutting rails while track is being laid, to provide allowance for expansion of steel when temperature changes.

Fastenings, auxiliary track--spring washers, tie plates, rail braces, rail anchors, and other accessories.

Fastenings, track--term commonly applied to splice bars, bolts, and spikes.

Fishing space--space between head and base of a rail occupied by a splice bar.

Flange--projecting edge, rib, or rim on any object. Examples: on a rail, the base; on a car wheel, the inside rim which projects below the tread.

French drain--rock drain located higher than a drainage ditch to help in correcting water pockets.

Frog--device used where two running rails intersect, providing flangeways to permit wheels and wheel flanges on either rail to cross the other.

Gage line--line five-eighths inch below the running surface of a rail on the side of the head nearest the track center; the line from which measurements of gage are made.

Gage, narrow--gage narrower than standard gage.

Gage of track--distance between gage lines of rails laid in track.

Gage rod--device for holding track to correct gage. Also called a tie rod.

Gaging of track--bringing two rails into their correct relative positions as regards gage.

Grade--rate of rise or fall of the grade line, expressed as a percentage of length; feet of rise or fall per 100 feet of length. Also referred to as gradient.

Grade crossing--see Crossing, grade.

Grade line or grade--line on a profile representing top-of-rail elevations of track; also a series of staked elevations transferring this line to the ground or roadbed.

Insulated joint--rail joint designed to stop the flow of electric current from rail to rail, as at the end of a track circuit, by placing nonconductors so as to separate rail ends and other metal parts.

Joint bar--steel angle bar or other shape used to fasten together the ends of rails in a track. Used in pairs, they are designed to fit the space between head and flange (fishing space) closely and are held in place by track bolts. Also called angle or splice bar.

Joint bar, head-contact--type of symmetrical joint bar, used on heavy rail, which bears against the underside of the rail head.

Joint bar, head-free--type of symmetrical joint bar, used on heavy rail, which contacts the rail at the fillet curve between the head and web.

Joint, bonded--that joint in which copper bond wiring is used to carry electric current across the joint.

Joint, broken--term applied to a joint located across from the center of the rail section opposite it.

Joint, compromise--special rail joint, sometimes called a step or offset joint, for uniting rails of different sections; so made that it brings gage sides and joined railheads into line to provide continuous smooth surfaces for treads and flanges of passing wheels.

Joint, square--term applied to a joint located directly across from another in the opposite rail.

Joint, supported--rail joint in which the rail ends are placed on a single tie.

Joint, suspended--rail joint in which the rail ends meet between two consecutive ties. When a base plate is added to a suspended joint, it is called a bridge joint.

Joint tie--tie used under a rail joint.

Level, cross--condition of a track in which the elevation of the rails is transversely equal.

Main track--track extending through yards and between stations upon which trains are operated by timetable or train order or both, or the use of which is governed by block signals.

Passing track--track auxiliary to the main track for meeting or passing trains.

Profile--longitudinal section through a track that shows elevation and depression. Also, a drawing showing grade line of a railroad, usually obtained from levels taken on top of the rail.

Rail--rolled steel shape designed to be laid end-to-end in two parallel lines on ties, to form a track for railroad rolling stock, traveling cranes, and the like.

Rail anchor--device attached to a rail to keep it from moving longitudinally under traffic; also called anticreeper.

Rail bond--electrical conductor for bridging rail joints.

Rail brace--metal casting made to fit against the side of a rail or guard rail and to be spiked to the tie on the outside of a track or the inside of a guard rail to prevent the rail from inclining backward with the thrust of wheels.

Rail brand--identification mark, including manufacturer's name or initials, month and year the rail was rolled, weight per linear yard, initials of section, number of the heat, portion of the ingot, and process of manufacture.

Rail creeping--intermittent, longitudinal movement of rails in track under traffic or because of temperature changes. Effect is resisted by anticreepers or similar devices.

Rail joint base plate--special tie plate used under some types of rail joints. See Joint, suspended.

Rail joint, insulated--rail joint which arrests the flow of electric current from rail to rail, as at the end of a track circuit, by using nonconductors to separate rail ends and other metal parts.

Rail joint, pumping--rail joint so poorly supported that mud is churned by passage of wheels and pumped up through ballast.

Rail section--pattern or dimensional details of rail, such as width of base, height of rail, thickness of web, width and thickness of head, angle of head, and angle of base. Each particular pattern is identified by a brand name or symbol, such as ASCE, AREA, ARA, and others.

Rail stiffness--resistance a rail offers to being bent vertically.

Right of way--land or water rights necessary for the roadbed and its accessories.

Roadbed--finished surface of roadway upon which track and ballast rest.

Roadbed shoulder--portion of subgrade lying between the ballast-covered portion and the ditch in cuts, and the top of slope on embankments. A roadbed shoulder not less than 18 inches wide should be maintained outside the toe of the ballast slope.

Roadway--that part of a railway prepared to receive track which during construction is often referred to as the grade.

Screw spike--cylindrical threaded steel spike with a special head, designed to be turned with a special wrench into holes bored in ties, to secure rails or to act as a tie plate holder in tie plates with holes intended for this use.

Section (of a railway)--portion of a rail division assigned to one of the six track maintenance sections in a track maintenance platoon. The two track maintenance platoons of a railway engineering company are responsible for maintaining 90 to 150 miles (144 to 240 kilometers) of railway.

Shim, track--bearing piece, usually of wood, placed between rail and tie or between tie plate and tie, to raise rail to a desired elevation.

Slot spiking--driving track spikes so that they engage with slots or notches at edges of joint bars to resist against creeping of rails.

Spike, cut--large hook head nail, 9/16 or 5/8 inch square, 5 1/2 to 6 inches long below the head; used to fasten rails to ties or to tie plates. See Screw spike.

Splice bar--type of joint bar.

Spring lock washer--washer designed to prevent the nut of a track bolt from loosening under vibration; also called nutlock.

Spur track--dead end branch track diverging from a main or other track.

Subballast--gravel, crushed rock, or the like, usually inferior to the ballast used in the track, spread on the surface of a cut or fill before distributing ties. If spread over the full width of roadbed, it is part of the roadbed or subgrade; if spread between the toes of the ballast slopes only, it is part of the ballast section.

Subgrade--elevation of a roadbed.

Superelevation--height the outer rail is raised above the inner or grade rail, on curves, to resist the centrifugal force of moving trains.

Surface (of track)--condition of a track as to vertical evenness or smoothness over short distances.

T-rail--term applied to the solid iron rail Robert L. Stevens invented.

Tamper--air-, electric-, or power-driven tool used for compacting ballast under ties.

Tie--transverse support to which rails are fastened to keep them in line, gage, and surface. Also called crosstie.

Tie plate--metal plate at least 6 inches wide and long enough to provide a safe bearing area on the tie, with a shoulder to restrain outward movement of the rail.

Tie plug--wooden pin driven in to fill an unused spike hole in a tie, to exclude moisture, prevent decay, and provide solid wood for redriving the spike.

Tie rod--see Gage rod.

Tie spacing--distances between tie centers in a track or turnout.

Toe--lowest part of the slope of an earth embankment.

Track brace--auxiliary fastening designed to be used as a rail brace and a gage rod.

Track fastenings--see Fastenings, track.

Track fastenings, auxiliary--see Fastenings, auxiliary track.

Turnout--arrangement of a switch and a frog with closure rails, by which rolling stock can be diverted from one track to another.

Water pocket--cavity formed in the roadbed because of improper surface drainage in which water collects; an uneven, spongy track results.

Zinc chloride--one wood preservative with which ties are treated.

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