



American Railway Engineering and
Maintenance-of-Way Association

CHAPTER 2

TRACK MEASURING SYSTEMS¹

Current until release of next edition

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INTRODUCTION

■ The Chapters of the AREMA Manual are divided into numbered Parts, each comprised of related documents (specifications, recommended practices, plans, etc.). Individual Parts are divided into Sections by centered headings set in capital letters and identified by a Section number. These Sections are subdivided into Articles designated by numbered side headings.

Page Numbers – In the page numbering of the Manual (2-2-1, for example) the first numeral designates the Chapter number, the second denotes the Part number in the Chapter, and the third numeral designates the page number in the Part. Thus, 2-2-1 means Chapter 2, Part 2, page 1.

In the Glossary and Bibliography, the Part number is replaced by either a “G” for Glossary or “B” for Bibliography.

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American Railway Engineering and
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Part 1

Definitions¹

— 1994 —

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¹ References, Vol. 88, 1987, pp. 54, 120; Vol. 91, 1990, p. 53; Vol. 93, 1992, p. 45; Vol. 94, 1994, p. 51.

SECTION 1.1 DEFINITIONS OF RAIL SURFACE CONDITIONS

1.1.1 GENERAL (1994)

- a. The purpose of this section is to provide a uniform set of definitions for various surface conditions so that specifications for their measurement and reporting can be drawn up.
- b. These definitions include rail conditions that can be addressed by rail maintenance techniques as opposed to track geometry maintenance techniques.
- c. The running surface anomalies can be divided into two broad categories: corrugations and discrete anomalies.

1.1.2 CORRUGATIONS (1994)

- a. Corrugations are rail head anomalies that appear on the surface of the rail in a repeatable i.e. periodic, manner along the length of the rail. They appear as “waves” or regularly spaced (periodic) discontinuities on the surface of the rail head. These waves are not always uniformly spaced, but rather tend to vary about some average wavelength.
- b. Corrugations are classed according to their wavelength, the peak to peak (or valley to valley) distance between the corrugation waves. These peak to peak distances are often measured with a straight edge in the field. The corresponding depth of the corrugation, which is commonly measured using a taper gage and straight edge, is the difference in height between the peak and the valley of the waves.

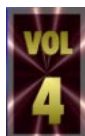
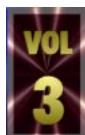
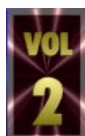
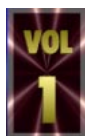
1.1.3 DISCRETE ANOMALIES (1994)

Discrete anomalies appear on the surface of the rail head in a random or arbitrary manner, i.e. without any characteristics of repeatability. These conditions often appear singularly. These conditions include:

- a. *Engine or Wheel Burns.* Discrete anomaly on the surface of the rail head caused by slipping or sliding of locomotive wheels. Usually found in pairs, with one on each rail. Can be of any depth, and usually .5 to 1.0 square inches in surface area.
- b. *Battered and/or Mismatched Joints.*
 - (1) Degradation of the ends of the rails, in the region of the joint bars, associated with repeated impact of wheels on the ends of the rails. Usually extend up to 18 inches from the rail ends in both directions. Batter also refers to any degradation of welded repairs at the ends of the rail.
 - (2) Mismatched joint refers to a joint in which the rail ends are not properly matched so as to produce a discontinuity in the running surfaces of the rail.
- c. *Weld Irregularities.*
 - (1) Non-uniformity of the running surface of the rail at welds, both plant and field welds. High welds are local high points at the weld usually the result of improper finishing of the weld at either the plant or field. Welds are often left nominally high (e.g. 0.020 inch) at the plant. Battered welds represent a degradation of the rail surface at the weld due to repeated impact loading by traffic. These conditions are usually located initially in the fusion zone or heat-affected zone of the weld, but can be extended beyond this region as degradation progresses.



- (2) These conditions also include misalignment (vertical and/or lateral) of the rails such as that resulting in peaked or dipped welds in the vertical plane.



- d. *Rail Head Damage*. Miscellaneous local damage to the surface of the rail such as caused by defective rolling stock (broken wheels, wheel flats, dragging equipment, etc.), derailments, or mishandling.
- e. *Spalling or Flaking (Shelly Spots)*. A localized degradation at the running surface of the rail, most commonly found at the gage corner of the high rail. This condition manifests itself initially as head checks (i.e. micro-cracks) at the gage corner which propagate and coalesce into larger areas which in turn break out of the rail surface. These surface cracks can also be found on the top of the rail, often in the low rail of curves.
- f. *Shelling (Gage Corner Shelling)*. A progressive internal separation that develops beneath the cold worked region in the gage corner of the rail head. This separation propagates longitudinally along the rail, and may crack out at any level on the gage side, generally near the upper gage corner. The shell can turn into a transverse defect (detail fracture).
- g. *Surface Batter/Crushed Head*. A flattening of the surface of the rail head, resulting in a downward distortion of the surface. Crushed head is distinguished from surface batter in that the entire head must have sagged. This is often associated with the presence of internal rail defects such as horizontal split head.
- h. *Plastic Flow (Lipped, Flowed Rail)*. A condition of deformation or flow of the rail steel at the field or gage sides of the rail head. Usually associated with very high contact stresses. The plastic flow is generally most noticeable on the field side of low rails in curves.
- i. *Rail Surface Roughness*. A condition of very fine non-uniformity or undulations (non-periodic) of the rail head of new rail. Usually associated with the mill scale layer of new rail. Usually too small to be detected by conventional straight edge and taper gage measurements.
- j. *Mill Defects*. Anomalies in the surface of the rail head due to improper rolling of the rail. Often does not manifest itself until after the rail has been in service. Includes mill scale, lines, seams, grooves, etc.

1.1.4 RAIL WEAR (1990)

- a. Deviation from the original rolled cross-sectional profile of the rail. These deviations result from either wear (abrasive, rolling, etc.) or plastic flow.
- b. Rail wear is often defined in terms of “critical” dimensions, which include:
 - (1) Gage face wear or rail head width at a defined point.
 - (2) Vertical head wear or rail head depth at the top of the rail.
 - (3) Lip size or width of top of head.
 - (4) Field side condition for transposed rail.
 - (5) Head area lost or head area remaining.

1.1.5 RAIL HEAD PROFILE (1990)

Transverse (cross-sectional) geometry of the rail head extending from one bottom fillet radius to the other bottom fillet radius of the rail head.



SECTION 1.2 DEFINITION OF TRACK QUALITY INDEX (TQI)

1.2.1 TRACK QUALITY INDEX (1990)

A number, derived from a formula, used to represent observed track data, and which relates to the ability of the track to perform its function.



SECTION 1.3 COMPILATION OF VARIOUS TRACK GEOMETRY PARAMETERS AND RELATED ELEMENTS, USED WHEN DESCRIBING TRACK GEOMETRY

1.3.1 GENERAL (1994)

- a. The purpose of this section is to describe the various track geometry parameters used by the railroads to describe track geometry. Included in this compilation is terminology for associated elements like rail, center line, etc.
- b. Track geometry describes the position that each rail, or the track center line, occupies in space.
- c. By projecting the track geometry into various planes, track geometry parameters can be specified. These parameters can be measured and used to describe track geometry.
- d. Depending upon which plane they reside in, track geometry parameters can be grouped as follows:
 - (1) parameters in the horizontal plane (a level plane defined by the horizon).
 - (2) parameters in the longitudinal vertical plane (a vertical plane through each rail or the track axis).
 - (3) parameters in the transverse vertical plane (a vertical plane normal to each rail or the track axis).
 - (4) parameters in the track plane (a plane located $\frac{5}{8}$ inch below the top of both rails along the track axis).



1.3.2 THE HORIZONTAL TRACK GEOMETRY (1994)

The horizontal track geometry is called Alignment ([Figure 2-1](#)). Alignment is the projection of the track geometry of each rail or the track center line onto the horizontal plane. When alignment describes a rail, a line along the rail gage side, $\frac{5}{8}$ inch below the top of the rail, is used for the projection. The following terms are used when describing alignment:

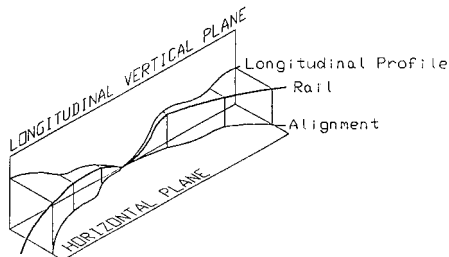


Figure 2-1. The Horizontal and Longitudinal Vertical Track Geometry

- a. Curvature.
- b. Line.
- c. Degree of Curve.
- d. Curve Radius.
- e. Horizontal Space Curve.
- f. Versine.

1.3.2.1 Measurements

The following measurements are used to quantify Alignment.

- a. *Absolute Horizontal Space Curve.* Absolute geophysical location of alignment which can be measured with conventional land surveying equipment, such as theodolite, transit, or unconventional land surveying equipment using electronic equipment and/or NAVSTAR Global Positioning System (GPS).
- b. *Chord Measurements.* A chord is a straight line between two points of the alignment. The chord measurement is the horizontal projected distance between a point on the chord and a point on the alignment, perpendicular to the chord. Chords can be measured using the string lining method. This method consists of stretching a string between two points on the rail and then measuring the offset between the rail and a point on the string (see Manual for reference). String lining methods can be performed manually (static) or with moving equipment (moving chord), using the offsets of three different points with respect to a reference plane.

The following terms are synonyms for chord measurements:

- (1) Versine.
- (2) Offset, Asymmetrical Offset, Symmetrical Offset, Mid-offset.
- (3) Ordinate, Asymmetrical Ordinate, Symmetrical Ordinate, Mid-ordinate.
- c. *Degree of Curve.* The angle subtended at the center of a simple curve by a 100-foot chord, which can be measured using either conventional (transit) or unconventional (NAVSTAR GPS) land surveying equipment, or the string lining method, using a 62-foot long chord. (The value of the mid-ordinate (mid-chord offset), in inches, of a 62-foot chord equals the degree of curve) computed from the measurement of

truck yaw in relation to the car frame, or computed from the car body yaw rate and the vehicle's longitudinal velocity.

- d. *Horizontal Rate of Change.* The horizontal difference between two alignment measurements of two points a preselected distance apart, measured with conventional land surveying equipment, such as theodolite, transit or unconventional land surveying equipment using electronic equipment and/or NAVSTAR Global Positioning System (GPS).
- e. *Quasi Horizontal Space Curve.* Absolute geophysical location of alignment with its mean removed. The mean is calculated from alignment over a preselected distance.
- f. *Tangential Deflection.* The angle between the chord and the tangent to the curve at one end point of the chord as measured using a theodolite, transit, electronic equipment or NAVSTAR Global Positioning System (GPS).
- g. *Tangential Offset.* The distance measured perpendicular to the tangent between a point on the curve and the tangent as measured using a theodolite, transit, electronic equipment or NAVSTAR Global Positioning System (GPS).



1.3.3 THE LONGITUDINAL VERTICAL TRACK GEOMETRY (1994)

- a. The longitudinal vertical track geometry is called Longitudinal Profile ([Figure 2-1](#)).
- b. Longitudinal Profile is the track geometry of each rail or the track center line projected onto the longitudinal vertical plane. When Longitudinal Profile describes a rail, a line along the top of the rail is used for the projection.
- c. The following terms are used when describing Longitudinal Profile:
 - (1) Profile, Surface, Top Vertical Alignment.
 - (2) Dip, Sag, Hump.
 - (3) Grade, Slope.
 - (4) Ramps, Runoff.
 - (5) Vertical Space Curve.
 - (6) Vertical Curve.

1.3.3.1 Measurements

The following measurements are used to quantify Longitudinal Profile.

- a. *Absolute Vertical Space Curve.* Absolute elevation of each geophysical location of the Longitudinal Profile usually measured with conventional land surveying equipment, such as theodolite, transit, or unconventional land surveying equipment using electronic equipment and/or NAVSTAR Global Positioning System (GPS).
- b. *Chord Measurements.* A chord is a straight line between two points of the Longitudinal Profile. The chord measurement is the vertical projected distance between a point on the chord and a point on the Longitudinal Profile, perpendicular to the chord. Chord measurements can be made using the string



lining method. This method consists of stretching a string between two points on the rail and then measuring the offset between the rail and a point on the string (see Manual for reference). String lining methods can be performed manually (static) or with moving equipment (moving chord), using the offsets of three different points with respect to a reference plane.

- c. The following terms are used when describing chord measurements:

- (1) Versine.
- (2) Offset, Asymmetrical Offset, Symmetrical offset, Mid-offset.
- (3) Ordinate, Asymmetrical Ordinate, Symmetrical Ordinate, Mid-ordinate.
- (4) Dip or Hump is used on one rail only.



- d. *Dip, Sag, Hump*. The deviation of the vertical parameter of both rails from uniformity over a specified distance. Dip, Sag and Hump can be measured by string lining both rails (see above) with the starting point (end of the string) in the same transverse plane. The smaller of the offsets (both offsets must have the same sign) represents the dip, sag or hump, or by measuring the vertical displacement of the four journal box points with reference to the car frame.



- e. *Grade, Slope*. The elevation difference between two points of the Absolute Vertical Space Curve a preselected distance apart. Grade and slope can be measured using the same methods shown under *absolute vertical space curve*, or by measuring the inclination of the car frame over a horizontal reference plane with corrections to compensate for the vehicle's vertical accelerations and car body pitch.



- f. *Ramp, Vertical Runoff*. The established change of elevation from one point to another along the track. These can be measured using the same methods shown under Absolute Vertical Space Curve.



- g. *Vertical Rate of Change*. The vertical difference between two Longitudinal Profile measurement of two points a preselected distance apart, and is measured the same as grade or slope.

1.3.4 THE TRACK GEOMETRY IN THE TRANSVERSE VERTICAL PLANE (1994)

- a. *Superelevation* (Figure 2-2). The difference in elevation between the top of one rail and the top of the other rail measured along a line perpendicular to the track center line. Superelevation can be measured using a levelboard, pendulum or inclinometer, or a gyroscope with compensation for vehicle speed and car body movement.

The following terms are synonyms for superelevation:

- (1) Elevation.
 - (2) Cant.
 - (3) Crosslevel.
- b. *Twist*. The difference in superelevation between two points a fixed distance apart along the track (twist base). Twist (or warp) can be measured by computing the difference between two levelboard measurements taken at each end of the twist base or computed from the measurements of vertical displacements of the journal box points with respect to the car frame.