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U.S. Transit Track Restraining Rail
Volume II: Guidelines

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December 1981
Final Report

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16. Abstract

This report is sponsored by the Office of Rail and Construction Technology of the Urban Mass Transportation Administration (UMTA), and is a part of a program to assist transit properties in the development of track. This report covers a study of restraining rails in transit track, which is part of the current research program of UMTA and was initiated: 1) to assist in the analysis, design, and maintenance and operation of transit track; 2) to compile guidelines for the use of restraining rails; and 3) to devise concepts for possible improvements.

This report, Volume II, contains guidelines derived from the study of transit restraining rail requirements and practices, and includes consideration of practices in the railroad industry and other industries. It also includes recommended standards and practices for design, installation, maintenance and inspection, and suggestions for the evaluation of requirements for restraining rail installations. This report also presents descriptions and limits for measurable conditions, such as gage and flangeway width, and descriptions of conditions that normally are not measurable.

Volume I of this report describes current practices in the use of restraining rails and provides data from rail lubrication tests. It evaluates the benefits of alternative practices, presents concepts for advanced designs, discusses simplified analysis of the costs and benefits of restraining rail installations, recommends the design and fabrication of modifications and new concepts, and recommends tests to obtain additional information for improvements in track adjustment and practices in order to reduce rail wear.

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PREFACE

The Guidelines in this document were prepared by ENSCO, Inc. under contract DOT-TSC-1771, managed by the Transportation Systems Center. The contract was initiated following recommendations of the American Public Transit Association, as part of a program to assist Transit Properties to improve track performance. The program is sponsored by the Office of Rail and Construction Technology, Office of Technology Development and Deployment, Urban Mass Transportation Administration of the U.S. Department of Transportation. The objective of the project was to develop information to assist the design, installation maintenance and operation of transit track of increased integrity and safety, with emphasis on the cost-effective use of restraining rail.

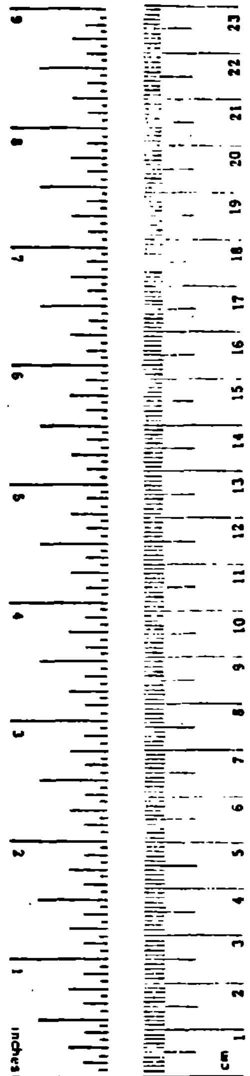
The information in the Guidelines was derived from a study of restraining rails and tests of the effects of lubrication performed under the same contract and reported under the title, "U.S. Transit Track Restraining Rail, Volume I, Study of Requirements and Practices". That report describes current practices in the use of restraining rail and rail lubrication, and provides data from rail lubrication tests. It includes discussion of the benefits of alternative practices, concepts for advanced designs, suggestions for simplified analysis of the costs and benefits of restraining rail installations, and recommendations on actions to improve the use of restraining rail and obtain additional information on the causes of wear. As a product of the research study, the Guidelines do not repeat information contained in the project report mentioned above, such as details of the information considered or a description of the investigation.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

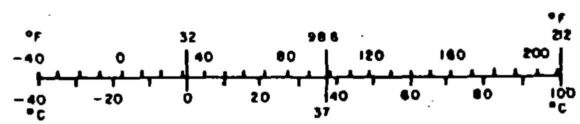
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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GUIDELINES FOR RESTRAINING RAILS

1. SUMMARY

Restraining rails are guardrails used to reduce rail wear and noise in sharp curves of transit track, and to increase the track resistance to derailment. They have been used in curves to over 1500-foot radius, in cases where the high rail had been wearing rapidly, as they are generally considered beneficial in reducing the frequency and cost of replacing the high rail.

These Guidelines recommend practices and standards for design, installation, maintenance and inspection; and recommended limits for some measurable features such as flangeway width. In general, however, exact standards cannot be applied industry wide, because the performances of rails in curves are affected greatly by the dynamic characteristics of the cars and other factors that vary widely among the Transit Properties. Accordingly many of the recommendations cover variable factors that should be considered in the investigations of conditions and requirements specific to an individual Transit Property.

The value of a restraining rail depends on the rate of wear of the high rail and the costs of rail replacement. These and other local factors cannot be generalized to provide accurate guidance but should be examined locally to support cost-effective decisions in specific cases. Further discussion and information on these and related matters are provided in the report, "U.S. Transit Track Restraining Rail, Volume I, Study of Requirements and Practices".

2. DEFINITION AND FUNCTIONS

2.1 DEFINITION

A restraining rail is a guardrail that provides a flangeway for car wheels on the gage side of the low rail in a curve; it contacts the backs of the wheels in order to guide them through the curve and improve the performance of the track structure.

2.2 FUNCTIONS

2.2.1 Primary Functions

- Improve system safety by increasing the track resistance to derailment.
- Reduce noise by keeping wheels from flanging on an unlubricated high rail.
- Reduce costs by reducing the rate of wear of the high rail.

2.2.2 Secondary Functions

- Reduce track maintenance.
- Transfer wear to the backs of the wheel flanges and reduce the rate of wear.
- Substitute for inner guardrails where they would otherwise be installed on curves at wayside obstacles or other potential hazards.

3. USE IN TRANSIT TRACK

3.1 LOCATIONS

3.1.1 Mainline Track

Restraining rails should be considered for installation in mainline curves where:

- Speeds cannot be restricted to levels that will be acceptable without a restraining rail.
- Extra protection against derailment is desirable.
- An inner guardrail would otherwise be used on a curve to minimize potentially serious results in the event of a derailment from any cause.
- Noise levels are unacceptable, and the high rail cannot be lubricated.
- Rail maintenance and replacement costs should be reduced.

- Reduction of track maintenance costs plus small values in added safety and other measurable benefits will provide overall savings.

3.1.2 Secondary and Yard Track

Restraining rails should be considered for installation in secondary and yard track where:

- Speeds cannot be restricted to levels that will be acceptable without a restraining rail.
- Noise levels should be reduced, and the high rail cannot be lubricated.
- Savings will be produced by reduction of overall replacement and maintenance costs.

3.2 EVALUATION

3.2.1 General

In all cases, both the potential advantages and disadvantages of a restraining rail installation should be considered. The potential advantages are indicated by the functions listed in Section 2.2. Potential disadvantages are:

- Higher noise levels may result, if restraining rail is not properly lubricated.
- Additional installation and maintenance costs.
- Additional lubricant required, if high rail is also lubricated.
- Additional work in changing our worn rails.
- Interference with ballast tamping.
- Development of sharp wheel flanges in some cases.
- Hazard in the remote case of a car derailing as it approaches an unprotected end of a restraining rail.

3.2.2 Safety

Restraining rails are considered advisable:

- In all mainline curves of a 500-foot radius or less; except where cars are operated at or below balanced speed and periodic inspections show that the wheels do not have tendencies to climb the high rail.

- In mainline curves above 500-foot radius where periodic inspections indicate that the car wheels have a tendency to climb the high rail.
- In mainline curves on bridges and elevated track, in subways, at wayside obstacles, and in other situations where an inner guardrail would otherwise be required, and a restraining rail is an acceptable substitute.
- In yard and secondary track where curvature and operating conditions warrant it.

3.2.3 Noise

Restraining rails are considered advisable when the high rail cannot be lubricated, and noise from flange contact on the high rail exceeds allowable limits, or when complaints reach a level of significance that has been established by the Transit Property.

3.2.4 Costs

Decisions on restraining rails that are not dictated by safety or noise reduction requirements should be based on complete cost analysis of all acceptable alternatives. All costs and overhead and rates of wear of the rails should be analyzed over the life cycle of the track. The analysis should also include factors at the work site that affect job costs and estimates of any changes in costs (such as operating costs) that will result from the work done.

4. DESIGN

4.1 MATERIALS

4.1.1 Rail Steel

Regular AREA rail steel is satisfactory for lubricated restraining rails. Heat-treated rails are difficult to bend to curvature, and they exert more spring action towards straightening segments of a curve, compared to rails of regular steel.

4.1.2 Fasteners

Cast steel, rolled sections, and weldments have given satisfactory service except where abrupt transitions built into fixtures caused stress concentrations. Cast steel plates were observed to have cracked frequently on wood ties. High strength steel bolts reduce breakage in vertical restraining rail assemblies. Adhesives resist the loosening that occurs frequently in bolted fasteners.

4.2 RAIL

4.2.1 Rail Section

The rails may be Tee rails, other structural shapes or special composite rails; with strength, stiffness and resistance to wear adequate for the service. Relay rail may be used if its wear pattern and the amount of wear do not affect satisfactory service as restraining rail.

4.2.2 Vertical Tee Rail

Advantages:

- They are less stiff than horizontal restraining rails and therefore easier to bend and less likely to warp parts of a curve by their spring action.
- They are convenient in ballasted track where rails should be fastened at every tie, or between each pair of ties, to produce uniform load on the roadbed; the individual fasteners are not as expensive as those used with horizontal rail.
- They suit conditions where traffic and other factors favor the replacement of all three curve rails at the same time, and where the high rail can be lubricated.
- Tee rails suitable for use as vertical restraining rails are readily available. Any rail the approximate size of the running rail can be used, either new or relay rail.

- The non-adjustable fastenings that are often used require very little maintenance.

Disadvantages:

- One side of the flange must be sheared at additional cost; the unsymmetrical rail is then difficult to bend, and a worn rail cannot be rotated or moved to a reverse curve.
- Some shops have difficulty in replacing a worn vertical restraining rail alone, when many holes have to be drilled on site for bolts to fasten it to the low rail.
- Fasteners that permit adjustment of a vertical restraining rail are costly and tedious to adjust.
- The low rail may have to be replaced before surface wear would otherwise require it, if wheel flanges begin to hit spacer blocks between the rails.

4.2.3 Horizontal Tee Rail

Advantages:

- On Slab or open-deck track, the strength of the support structure and the stiffness of the rail in the plane of its web permit the use of few, widely separated fasteners.
- The flange need not be sheared unless cars and equipment have unusually low clearance envelopes.
- When not sheared, symmetrical rail can be bent uniformly. When worn, it may be rotated and moved to a reverse curve of similar radius, or rotated and turned end for end and reused in the same curve.
- The fasteners for horizontal restraining rail are relatively easy to adjust; so the rail can be used to prevent the wheels from flanging on the high rail where it is not lubricated.
- The restraining rail is relatively easy to replace by itself.
- Tee rails suitable for use as horizontal restraining rails are readily available. Rails the same or smaller than the running rail can be used, both new and relay rail.

Disadvantages:

- The rail is difficult to bend but must be bent closely to required curvature, because it acts as a very stiff spring and tends to warp the curve track when cars vibrate it.
- It is not suited to ballasted track because the relatively expensive fasteners should be placed close together on every tie in order to prevent overloading of any single tie.
- Adjustable fastenings tend to loosen more easily than non-adjustable fastenings and require more frequent inspection and maintenance.

4.2.4 Other Restraining Rail Sections

Structural shapes and composite shapes with adequate lateral and vertical stiffness are acceptable.

4.3 DIMENSIONS

4.3.1 Length

A restraining rail should extend a minimum of 10 feet beyond the ends of the transition curves in order to help control oscillations as cars enter and leave the curves. Needs for longer extensions can be determined from observation of the dynamic behavior of the cars and evidence of spot wear on rails.

4.3.2 Height

The top of the restraining rail should be between 0.25 and 0.50 inch above the track surface of the low rail. Additional height is desirable if feasible, for it will place the bottom of the guard face above the low point of the flange, so that undesirable "step" wear will not occur.

4.3.3 Flangeway Width

The width of the flangeway is determined from the radius of the curve, the wheel base, wheel diameter and the cross section shape of the wheel flange. It should permit the wheels of a truck to pass through the curve without flange contact under free wheeling conditions. With both wheels in flange contact with the low rail, the clearance between the back of the wheel flanges should not be less than 0.75 inch as installed or more than 1.25 inch before worn rails are adjusted/replaced. The flangeway width plus guard distance equal the track gage.

4.3.4 Guard Distance

In an installation designed for the restraining rail to wear at the approximate rate of the lubricated high rail, the guard distance from the guard face of the restraining rail to the gage side of the high rail should equal the back-to-back distance between wheels plus one flange thickness. Both the restraining rail and the high rail should be lubricated to equalize the wear.

In an installation designed for the restraining rail to prevent wear of the high rail, the guard distance should be 0.6 inch more than the back-to-back of wheels distance plus flange thickness. The restraining rail should then be lubricated.

4.3.5 Support Spacing

Fasteners may be spaced as far apart as the rail stiffness will permit, while not exceeding allowable deflections under load and the allowable load on the fasteners.

In ballasted track, where high lateral forces are expected, fasteners installed on every tie will tend to impose uniform and therefore lower lateral loads on the ballast layer. In track supported by a slab or open-deck structure, higher lateral support strength is available; fasteners can be spaced farther apart, and they should be installed at the locations of running rail fasteners.

4.3.6 Track Geometry

Bending and installing the restraining rail to a smooth curve are essential to good ride quality and low rates of wear in guarded curves. In addition, maintaining a uniform distance between the restraining rail and the high rail will avoid erratic transfer of lateral forces between the rails. It is recommended that unloaded deviations from a smooth curve not exceed the limits stated in Table 1.

TABLE 1. LIMITS FOR DEVIATIONS OF UNLOADED RESTRAINING RAIL FROM A SMOOTH CURVE

	Distance or Length	
Speed, mph	5 Feet	20 Feet
0 to 10	0.30 inch	0.50 inch
10+ to 15	0.20	0.40
15+ to 25	0.10	0.20
Over 25	0.05	0.10

Along with the limits in Table 1, the guard distance (from the guard face of the restraining rail to the gage side of the high rail) should not vary more than 0.10 inch in 5 feet and 0.20 inch in 20 feet.

4.4 LOADS

4.4.1 Peak Forces

Track irregularities may develop; and, for some reason, a car may some day be operated at excessive speed. Such conditions will result in large peak forces between the lead wheel on the inside of a curve and the restraining rail. Accordingly, a restraining rail should be adequate to withstand a peak lateral force at least 1.5 times the maximum vertical wheel load and a peak vertical force at least 0.5 times the maximum vertical wheel load.

4.4.2 Deflections

Under design loads for regular operating speed, a restraining rail should not deflect more than 0.10 inch laterally or vertically at fasteners.

Between fasteners, in addition to the deflection at fasteners, a restraining rail should not deflect laterally more than the smaller of 0.20 inch, or 0.006 times the distance between fasteners; and the rail should not deflect vertically more than the smaller of 0.25 inch, or 0.008 times the distance between fasteners.

4.5 COMPONENTS

4.5.1 Adequacy

Components proven adequate for guardrails in turnouts and crossings are adequate for restraining rails. Special, uncommon components usually cost more.

4.5.2 Joints

Bolted joints facilitate replacement of the restraining rail by itself. Four-hole joint bars are adequate for horizontal restraining rail. Vertical restraining rail should be bolted to the low rail through spacer blocks at the joints. High strength bolts should be used to fasten the rails together. Adhesive or lock nuts are recommended for bolts to resist frequent loosening under vibrating loads. It should be noted that standard joint bars are not made with curvatures in either direction; they tend to kink under forces transmitted by adjacent rail ends.

4.5.3 Bonds

Restraining rails should be bonded at joints and to the running rail where required to reduce resistance to return electric current.

4.5.4 Braces

Non-adjustable braces are relatively low cost and are suitable for use with a restraining rail that is bolted to the low rail, so that it wears at the same rate as the high rail.

Adjustable braces that provide firm lateral support should be used where a function of the restraining rail is to keep wheels from flanging on the high rail.

4.5.5 Clamps

Clamps are easier to install than through bolts to the low rail, but they are much more expensive. Adjustable clamps and spacer blocks permit adjustment of the restraining rail to compensate for wear.

4.5.6 Insulation

Transit Properties that use the rails to return electric current, or use the track as part of the signal circuit, should analyze the effects of new or redesigned restraining rail installations to ensure that the electrical characteristics are not adversely affected.

5. INSTALLATION

When feasible, restraining rails should be installed at the time a track is constructed or rebuilt in order to minimize the costs of installation.

5.1 BENDING RAILS

Restraining rails should be bent to track curvature before installation in cases where their spring action under traffic vibrations would otherwise degrade track geometry. In general, Tee rails should be bent to track curvature for curves to 300-foot radius if installed vertically, and for curves to 500-foot radius if installed horizontally.

5.2 ASSEMBLIES

When a vertical restraining rail and a low rail are to be installed at one time, it is preferable to bend, cut, drill and bolt the rails together at the shop in as long an assembly as can be handed, and install them as a unit.

5.3 MEASUREMENTS

The specified gage, guard distance, flangeway width and rail height should be measured frequently during installation. Since the restraining rail guides the car through the curve and determines ride quality, the smoothness of the restraining rail in curve alignment is more important than the exact guard distance and flangeway width mentioned above. To check smoothness, midchord offsets from 5- and-20-foot chords to the restraining rail curve should be measured at the fastener, and adjustments should be made to correct irregularities that exceed the limits stated in Table 1, Section 4.3.6.

5.4 TORQUING BOLTS

All bolts should be lubricated and torqued to specified levels. Where an adhesive is used, it serves initially as a thread lubricant.

6. MAINTENANCE

Maintenance is considered to include inspection and lubrication as well as routine maintenance, repairs and replacements.

6.1 INSPECTION

Restraining rails should be inspected carefully at the times of regular, periodic track inspections. Debris should be removed from flangeways and loose nuts should be tightened to specified torques. Looseness of any fastenings that is not corrected, excessive or insufficient lubricant, signs of gage widening or unusual wear, and other defects should be reported in writing for appropriate corrective action.

At least semi-annually, and often for heavy traffic and sharp curves, alignment deviations should be checked as midchord offsets from a 20-foot stringline and from a 5-foot straight edge. Deviations from a smooth curve that exceed the limits stated in Table 1, Section 4.3.6 should be corrected promptly.

6.2 LUBRICATION

6.2.1 Lubricant

In selecting a lubricant, the engineer should guide on the experience of other transit properties and railroads in the same weather region. In general, the satisfactory lubricants adhere to the rails, resist water, do not have large changes in viscosity within the temperature range expected, do not produce much smoke under traffic, and have additives such as molybdenum disulphide or graphite to improve their performance under severe conditions.

Water-glycol mixes may be used to lubricate rails in locations where noise reduction is important or where the drip of an oily lubricant would cause problems.

6.2.2 Application

Pressure-type lubricators are recommended which will accept connections to the manufacturers' containers of lubricant. Spray lubricators should be used with water-glycol mixtures. The lubricators should be adjusted to apply the minimum amount of lubricant that will reduce wear and noise satisfactorily under the expected traffic density and frequency.

Manual lubrication is acceptable as a temporary measure, and in locations where installation of an automatic lubricator is not feasible or not suitable. An applicator with a control orifice is preferred. Grease can be applied in predetermined quantities at measured intervals with a stick by a trained and careful track mechanic. Application with a brush is not satisfactory.

6.3 ROUTINE MAINTENANCE AND REPAIRS

6.3.1 Requirements

Maintenance requirements for restraining rails develop along with requirements for other maintenance as a track deteriorates because of traffic and conditions that cause wear, corrosion, rot, and the clogging of the ballast with dust and mud. The requirements are identified by inspection of the track and from reports of trouble or bad conditions. Maintenance requirements should also be derived from the evaluation of data in inspection reports, equipment records, production schedules, construction plans, and other documents. Study of such data enables engineers to predict requirements long before they can be identified by inspection of the track.

6.3.2 Planning

The maintenance of restraining rail should be planned with other track maintenance on the basis of rail condition, rate of wear and projected traffic in relation to available resources. The planning actions required include:

- Study of records, authorized work, and other information to identify all restraining rail installations and their conditions.
- Evaluation of current and projected levels of use, and other factors that affect restraining rails.
- Forecasting changes in rates of wear and future problems.
- Determining maintenance requirements.
- Evaluating alternative maintenance actions for cost effectiveness.
- Integrating the planning of restraining rail maintenance with all other track maintenance.

6.3.3 Methods

The methods used in maintaining restraining rails are similar to those used in installing and maintaining other parts of the track. Adjustable restraining rail should be adjusted laterally to a smooth curve, the guardface to gage distance and the flangeway width stated in Section 4.3, whenever the wear approaches 0.30 inch. When irregularities develop from causes other than wear of the restraining rail, adjustments should be made with equipment used for lining track, or with jacks and hand tools.

When a used restraining rail is to be relaid, several precautions should be observed:

- The rail should be inspected carefully; defective rail and rail that cannot be bent to a smooth curve should not be used.
- The rail should be matched to the adjacent rail lengths in track by weight, cross section, and the amount of wear; the guardface should make a smooth fit. The rail should be ground as necessary to obtain this fit.

- The rail should be cut with a saw to the exact length required, and burrs should be ground off; bolt holes should be drilled.
- Badly worn restraining rails should be used only where needed in sidings and secondary tracks and yards.

Rail ends that are damaged slightly by batter or metal flow (lips) can be repaired in place by welding and grinding. Severe batter, cracked rail, or broken rail can be corrected by replacing the affected lengths or by cropping. In the latter case, the damaged ends are cut off, and new holes are drilled for joint bars. The joint bars should be held in place with clamps while the holes are being drilled. Holes should never be drilled in the space between existing holes.

When lengths of damaged or worn restraining rail are to be replaced, no parts should be removed until the new rail or relay rail is ready to be placed. The replacement rail should be fitted carefully to the ends of the adjacent lengths of rail in the track. Special joint bars may be needed with fishing surfaces ground to fit both the old and new rail.

In every case of cropping or replacing rail, the rail ends should be ground or built up by welding, as necessary, to provide smooth alignment at the joints.

7. RECORD KEEPING

Accurate evaluation of the cost effectiveness of restraining rail depends largely on accurate and complete records of all pertinent information over the periods through which restraining rails are expected to last. Information to be maintained should include:

Date of installation, costs and notes on any unusual conditions.

Installation data: exact location in track, length and geometry of curve, length of facing and trailing spirals, length and type of restraining rail, steel characteristics, height above low rail, guard to gage distance, flangeway width, joint types, bolt torque, fastener types and spacing.

Inspections.

Maintenance activities and costs.

Lubrication, type, method of application and quantity used.

Wear rate.

Gross tons of traffic per year and data on the cars operated to include: maximum wheel loads, wheel taper, back-to-back distance and flange thickness, distance between axles and distance between trucks.

Speed control and operating modes.

Problems and solutions.

Concise and simple forms should be used to record inspection data and all other data. Clear forms will facilitate understanding and use of the data in maintenance planning and control and in the analysis of the alternatives available for the effective use of restraining rail.

APPENDIX A
COMMENTS ON THE GUIDELINES

A.1 SUMMARY

The comments in this appendix are offered to help clarify certain requirements of the Guidelines and provide information on actions to comply with them that may be useful to some transit engineers.

Section numbers and headings for which there are no comments have been omitted from this appendix.

Restraining rails are considered valuable in those mainline curves where they reduce the frequency and cost of replacing worn high rails and increase the resistance of the track to derailments. However they would have little or no value in many curves, if cars were operated at speeds so low as to cause negligible wear of the high rail and not produce objectional noise. This is often the case in yard tracks and flat curves of turnouts but not in mainline curves. The speeds that are necessary for efficient mainline operations may result in high rates of wear in curves; objectional noise is produced when the gage side of the high rail is not lubricated; and, in some cases, wear patterns indicate tendencies of the car wheels to climb the high rails.

Speed is only one of the many factors that affect the rate of wear of the high rail. The dynamic characteristics of the transit cars have large effects, and the cars vary greatly among the Transit Properties and even among the separate lines of some Properties. At the same time, other local factors, such as the availability of skills and distances from suppliers, have large effects on costs. The result is that you cannot predict what curve radius and operating speed will justify a restraining rail without study of the rates of wear in the specific curves under consideration and study of local factors that affect costs.

A.2 DEFINITIONS

Restraining rails are called check rails in some countries and are often called guardrails.

The short guards installed to protect switch points, frogs and crossings also are often called guardrails.

An inner guardrail is a Tee rail, structural shape or timber installed on the gage side of a running rail at a distance where it will not jam the wheels of a derailed car against the running rail but will guide them. Thus it prevents the car from leaving the track or hitting obstacles on the opposite side. An inner guardrail is also called a guardrail, an inner guard, an emergency guardrail, or a safety guard.

Guard timbers are bolted to the ties on the field sides of the running rails on many elevated tracks. Primarily, they serve as spacers to hold the ties in position.

A.3 USE

A.3.1 LOCATIONS

Effective decisions on the use of restraining rail in any location on a Transit Property require:

Knowledge of the track and operating conditions that indicate restraining rails may be desirable.

Measurements of rail wear and estimates of the useful lives of the rails.

Determination of alternative actions that will be acceptable in each case.

Accurate information on all factors that significantly affect costs.

Accurate information on factors that significantly affect benefits.

Systematic analyses of the available alternatives, with their costs and benefits, at specific sites in the track system.

The actions that may be taken in any one case depend on their relative costs, local conditions and preferences, and availability of funds.

A.3.2 EVALUATION

A.3.2.2 Safety

A tendency for car wheels to climb a high rail is often indicated by an angle of wear below 65^{o} from the track surface, "step" wear or marks of heavy scuffing and abrasive wear on the gage side of the high rail.

A.3.2.3 Noise

Noise levels can be checked with a sound pressure meter held at a consistent elevation, angle and distance from the track and in similar locations on the different curves.

A.3.2.4 Costs

Good cost data and analysis help direct attention to the more effective actions that can be taken in track maintenance/replacement. They form a basis for rational discussions with supervisors of other departments, so that agreements can be reached which will benefit the entire system.

A.4 DESIGN

A.4.1 MATERIALS

A.4.1.1 Rail Steel

Heat-treated steels and alloy steels used in rails have superior resistance to wear; but so far, little evidence has been accumulated to show that these materials last much longer than regular AREA steel when used in lubricated restraining rails. Heat-treated and alloy steel rails are very difficult to bend to track curvature. Many railroad and transit engineers consider them to be cost effective when used as running rails in curves.

A.4.2 RAIL

A.4.2.4 Other Restraining Rail Sections

Structural steel shapes may be favorable for restraining rails in some applications, because they can be designed to weigh less than Tee rails of the same stiffness. Composite shapes would permit the use of rubbing strips of expensive alloys such as high manganese steel which has shown superior wear-resistant qualities in sharp curves and turnouts.

A.4.3 DIMENSIONS

A.4.3.2 Height

Raising the height of the top of the guard face of the restraining rail increases the area that contacts the backs of the wheels. This is advantageous where clearance permits, as it reduces the rate at which the rail and wheel wear in depth. However it increases the downward component of the rotational velocity of the wheel, as the contact patch is moved farther ahead of the tread contact. Raising the height of the rail may also have other serious disadvantages that cannot be defined without tests. Surface wear of the adjacent low rail gradually raises the effective height of a restraining rail.

A.4.3.4 Guard Distance

The guard distance and other check distances are indicated in Figure 1.

A.4.4 LOADS

A.4.4.1 Peak Forces

High peak forces which may develop because of track irregularities and other factors, and which the track should be designed

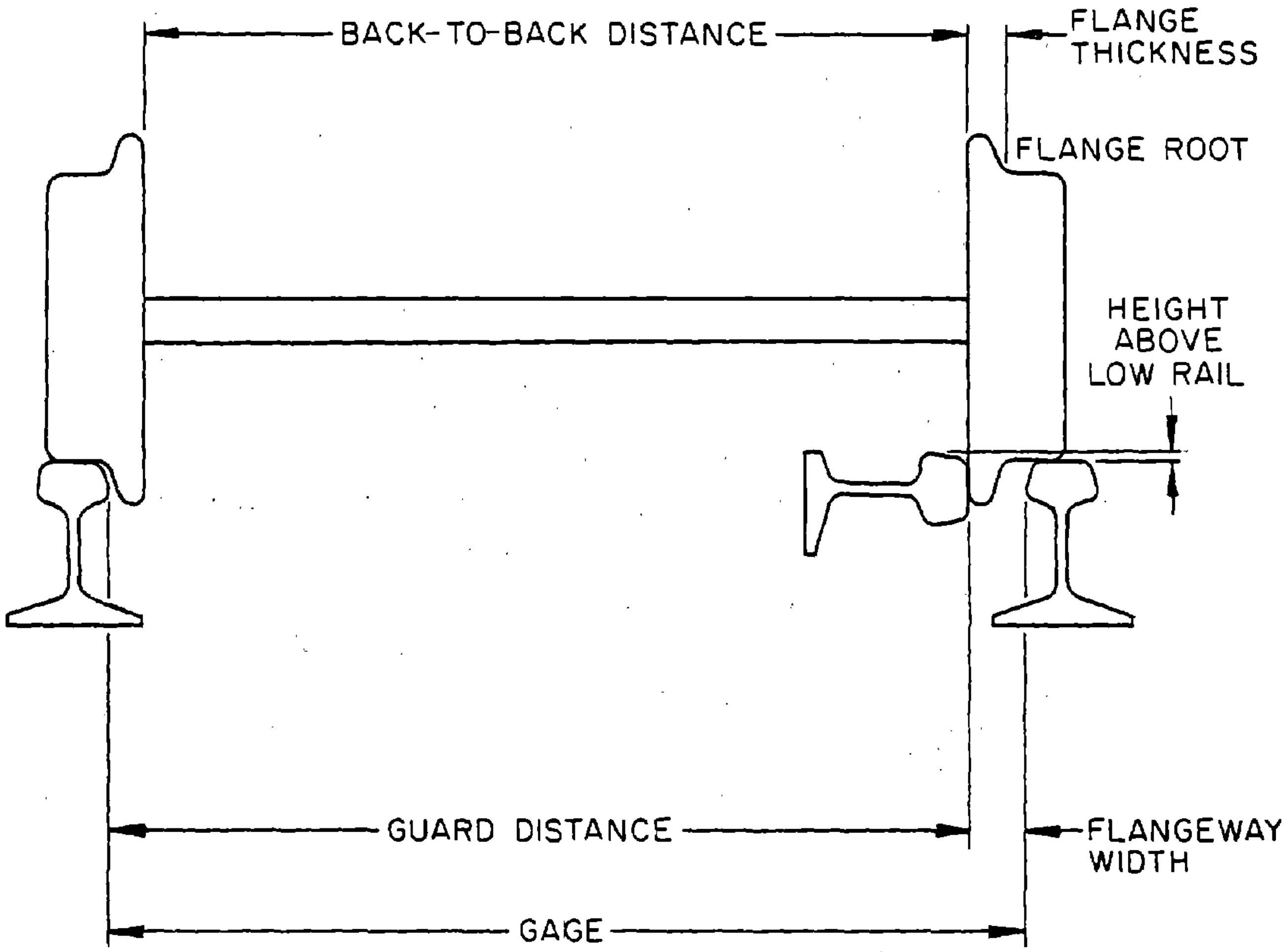

Fig. 1

Check Distances for Restraining Rail.

to withstand, are of short duration. They do not normally cause excessive wear or other problems unless the conditions that caused them are left uncorrected over a long period of time. A restraining rail with non-adjustable fasteners will not share lateral forces equally with the high rail because of the tolerance in the length of car axles. Wheels on long axles will flange on the high rail only, while wheels on short axles will flange on the restraining rail.

A.4.4.2 Deflections

Deflections should be calculated for the forces expected on the rails under standard operating procedures with the track maintained in good condition.

A.5 INSTALLATION

A.5.1 BENDING RAILS

Rails may be bent in the shops of the supplier or the Transit Property. Great care and many operations with a press are necessary to produce a smooth curve rather than a series of tangents. Rail ends are particularly difficult to bend; if not bent to design curvature, they will produce kinks at the joints. For small-radius curves, it may be necessary to heat the rail ends with joint bars in place, bend them and hold them until they cool. Generally, with a good roadbed or slab and strong fasteners, straight vertical restraining rail can be used in curves above 300-foot radius and straight horizontal restraining rail can be used in curves above 500-foot radius. When rails are bent after one flange has been sheared, bending moment must be applied to both bending axes in order to produce the proper deformation. The procedure has to be developed through experiments for each curvature and each type of rail.

A.5.2 ASSEMBLIES

Where a restraining rail is to be matched to fasteners on a low rail already installed, it may be necessary to drill holes and make final cuts at the job site.

A.5.3 MEASUREMENTS

The convenient practice is to install and adjust the high rail to the design curvature and profile and use it as the line rail for the installation of the low rail and restraining rail with a level and gage. However small tolerances in adjusting the high rail and in measuring gage may accumulate to produce small irregularities in the curve of the restraining rail.

In curve track, alignment deviations are difficult to find by sighting along the side of the rail, and midchord offsets should be measured to find irregularities that may exceed the limits stated in Table 1, Section 4.3.6. Normally midchord offsets are measured in the plane of the gage line but offsets to a restraining rail may have to be measured at the height of the top of the low rail for the stringline or straightedge to clear the low rail.

The midchord offsets from 5- and 20-foot chords should be calculated in advance for the design curve at the guard face of the restraining rail, so that they can be subtracted from measured offsets to find the actual deviations from a smooth curve. The curve radius at the guard face should be equal to the track centerline radius, minus half the track gage, plus the flangeway width at the height of the offset measurements.

The midchord offset to a smooth, circular curve should be:

$$\delta = 3L\ /2R$$

where, δ is the offset in inches
L is the chord length in feet, and,
R is the radius of the curve in feet.

When used to calculate offsets, this approximation produces errors of less than 0.05 inch for a 20-foot chord and curves above 65-foot radius. The errors in calculation are smaller for a 5-foot chord, but the measurement errors are relatively larger.

A.6 MAINTENANCE

A.6.1 INSPECTION

An alert inspector can often find indications of wide gage in curves including: grease streaks on the outside of the low rail, excessive gage wear (especially stepped wear) on the high rail, outward canting of rails as when tie plates cut into ties on the outside of the rail, marks of lateral movement on fasteners or ties, a series of straight chords in the rail instead of a smooth curve, and flange marks at excessive distances from the rails in places where dirt has collected.

The inspector should sight along the line of the rail to spot deviations from a smooth curve and misalignments that may develop at joints. As noted in Section A.5.3, alignment deviations are difficult to see in curve track and midchord offsets should be measured to find irregularities that may exceed the limits stated in Table 1, Section 4.3.6. The comments on offset measurements apply; but the restraining rail may have worn or the track may have shifted to the extent that adjusting a portion of the curve to the original design may produce unacceptable irregularities at the ends of the adjusted portion. Adjustments are desirable that will smooth the curve to the required standard (not necessarily the original design) with minimum effort. The midchord ordinate can be measured at several places where the rail is smooth each side of the irregularity; the average of several of the measurements can be taken as the midchord ordinate of the smooth curve; and the rail can be adjusted to this ordinate at the irregularity.

Bolted joints in the restraining rails and adjacent running rails should be given special attention. Many defects develop at bolted joints and will accelerate the deterioration of the track unless corrected promptly. These include: loose or floating ties, loose or broken bolts, misalignment, low joints, mud pumping, worn tie plates that cannot be fastened firmly, rail end batter, cracked or broken joint bars and cracked or broken rail ends. Voids in ballast or other poor support of fasteners are especially serious.

Wear and damage of components are often associated with loosening of fasteners. Adhesives are useful in keeping threaded fasteners tight.

A.6.2 LUBRICATION

A.6.2.1 Lubricant

Complete general specifications have not been developed for rail lubricants, although many lubricants are available that have given results considered satisfactory by the users. Weather, exposure, ventilation and the characteristics of the lubricator affect the results obtained from a lubricant. Accordingly the experience of other users in the same area can provide useful information.

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