



US Army Corps
of Engineers
Construction Engineering
Research Laboratories

USACERL Technical Report FM-93/14
September 1993
RAILER Engineered Management System

AD-A286 604



Condition Indexes for Low Volume Railroad Track: Condition Survey Inspection and Distress Manual

by
D.R. Uzarski

The U.S. Navy and U.S. Army together own over 5700 miles of railroad track that are vital to the mobilization and operational needs of the Department of Defense. Civilian local railroad companies control another 19,000 miles. Track managers need a method to assess current track conditions, predict future track conditions, establish track deterioration rates, formulate budgets, and determine and prioritize renewal projects.

In response to this need, the U.S. Army Construction Engineering Research Laboratories developed track component group condition indexes based primarily on visual inspection surveys and supplemented by inspection and operating criteria from various track standards.

This manual provides track inspectors with a standard reference for identifying track distresses and calculating condition indexes.



94-35863



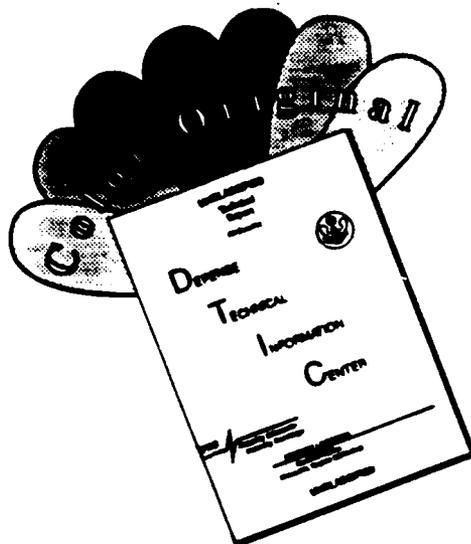
04 11 1994 7

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REPORT DOCUMENTATION PAGE

Form Approved
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Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Service, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave Blank) 2. REPORT DATE
September 1993 3. REPORT TYPE AND DATES COVERED
Final

4. TITLE AND SUBTITLE
Condition Indexes for Low Volume Railroad Track: Condition Survey Inspection and Distress Manual

5. FUNDING NUMBERS
FAD
N6247291MP00006
4A162784
AT41
C-CK1

6. AUTHOR(S)
D.R. Uzarski

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Construction Engineering Research Laboratories (USACERL)
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
FM-93/14

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Northern Division, Naval Facilities Engineering Command
ATTN: NORTHNAVFACENGCOM
U.S. Naval Base
Philadelphia, PA 19113-2090

U.S. Army Center for Public Works
ATTN: CECPW-FB-P
7701 Telegraph Road
Alexandria, VA 22310-3862

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
The U.S. Navy and U.S. Army together own over 5700 miles of railroad track that are vital to the mobilization and operational needs of the Department of Defense. Civilian local railroad companies control another 19,000 miles. Track managers need a method to assess current track conditions, predict future track conditions, establish track deterioration rates, formulate budgets, and determine and prioritize renewal projects.
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14. SUBJECT TERMS
condition indexes track inspection
railroad track
RAILER

15. NUMBER OF PAGES
140

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT
Unclassified

20. LIMITATION OF ABSTRACT
SAR

FOREWORD

This project was funded by the Northern Division, Naval Facilities Engineering Command (NORTHNAVFACENGCOC), U.S. Naval Base, Philadelphia, PA under Funding Authorization Document N6247291MP00006. The U.S. Navy Technical Monitor was Mr. William Gannon from the Southern Division, Naval Facilities Engineering Command (SOUTHNAVFACENGCOC). Funds were also provided by the Assistant Chief of Engineers, Office of Chief of Engineers (OCE), under Project 4A162784AT41, "Military Facilities Engineer Technology"; Task C, "Operations/Management/Repair"; Work Unit CK1, "RAILER Engineered Management System." The U.S. Army Center for Public Works technical monitor was Mr. Robert Williams, CECPW-FB-P.

The work was performed by the Engineering and Materials Division (FM), Infrastructure Laboratory (FL), U.S. Army Construction Engineering Research Laboratories (USACERL) in cooperation with the University of Illinois. Dr. Paul Howdysshell is Chief, CECER-FM, and Dr. Michael J. O'Connor is Chief, CECER-FL. The USACERL technical editor was Gloria J. Wienke, Information Management Office.

Much of this work was accomplished as the author's Ph.D. thesis in civil engineering from the University of Illinois. Special recognition is offered to Dr. Michael Darter and Dr. Marshall Thompson, who co-chaired the thesis committee and were extremely helpful and supportive. Dr. Samuel Carpenter's contribution is also appreciated.

Many individuals from USACERL contributed significantly to this work. First and foremost is Richard Harris II, who facilitated some of the data collection, provided feedback on ideas, and provided considerable support in many areas. Others who provided considerable support were Carole Bartholomew who also facilitated some of the data collection, created data files, and tracked down many of the needed literature references, and Jeff Mahoney who spent countless hours revising and remaking the deduct curves. The individuals have the author's heartfelt appreciation. The contributions of Tom Yu, Sue Wagers, Max Watkins, Magdy Abdelghaffar, Kevin Coyle, Rick Combs, Jim Field, and Edward Janeski in accomplishing countless tasks are acknowledged and appreciated.

By necessity, the members of the rating panel devoted many hours to providing rating information and feedback. Their patience, perseverance, and willingness to contribute time and expertise were the key to project success. Their assistance is greatly appreciated. Sincere thanks goes out to each and every member. Also, thanks goes to Dr. Dennis Cox from the University of Illinois for his efforts in developing the procedures for establishing the size of the rating panel.

LTC David J. Rehbein is Commander of USACERL, and Dr. L.R. Shaffer is Director.

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CONDITION INDEXES FOR LOW VOLUME RAILROAD TRACK: CONDITION SURVEY INSPECTION AND DISTRESS MANUAL

1 INTRODUCTION

Background

The U.S. Navy and the U.S. Army together own over 5700 miles¹ of railroad track that are vital to the mobilization and operational needs of the Department of Defense (Naval Facilities Engineering Command [NAVFAC] 1987; Hilsabek 1989; U.S. Army Corps of Engineers 1987). Civilian local (switching, terminal, and linehaul) railroad companies control another 19,000 miles of track which is approximately 10 percent of the entire commercial sector (Association of American Railroads 1988). This track is predominately low volume, carrying less than approximately 5 million gross tons per year (MGT/year). Also, the Class I and regional railroads have portions of their networks in low volume service. Low volume track serves a transportation niche essential to the economic well being of the United States.

Regardless of whether the primary motive is mission readiness (military) or profit (commercial), there is a need for a simple and practical condition assessment method that is objective and repeatable so that similar results are obtainable by different people. In response to the need, the U.S. Army Construction Engineering Research Laboratories (USACERL) developed objective and repeatable track component group condition indexes for rail, joints, and fastenings (RJCI); wooden crossties and switch ties (TCI); and ballast, subgrade, and roadway (BSCI) as well as an overall Track Structure Condition Index (TSCI). These indexes are based primarily on visual condition survey inspections (simply called "condition surveys" or "surveys") and are supplemented by other methods, when appropriate. The development of the indexes is described in technical report FM-93/13.

Each component group index is intended to reflect the component group's current physical ability to support typical military, short line, or industrial traffic, and the maintenance, repair, or rehabilitation needs to sustain that traffic. The TSCI is intended to do the same, but for the track structure as a whole.

The component group condition indexes are calculated based on the type, severity, and density of the distress as determined from the track condition survey. To obtain repeatable and meaningful condition index values, distress identification and measurement must be standardized.

The procedures described in this manual are intended for use in performing network level management tasks. They include: assessing current track conditions, predicting future track conditions, establishing track deterioration rates, formulating budgets, determining and prioritizing spot and major renewal (capital renewal) projects, and evaluating the effectiveness of those projects. They are not a substitute for routine safety inspections nor for detailed inspections required for project level management (Uzarski et al. 1993). These different inspections serve contrasting purposes and therefore, the level of effort (frequency and intensity) and the information collected differs.

Objectives

The objectives of this work effort were to develop low volume railroad track condition indexes for track evaluation and a condition survey procedure for computing these indexes. A secondary objective was to have the condition indexes computable from the detailed inspection procedure (ultimately published as Technical Report [TR] FM-94/01). This manual provides track inspectors with a standard reference for distress

¹A metric conversion table is on page 94.

identification for the component groups of rail, joints, and fastenings; ties; and ballast, subgrade, and roadway. The distress information is to be used in conjunction with the procedures in Chapter 2 to determine the RJCI, TCI, BSCI, and TSCI developed in TR FM-93/13.

Approach

A condition index methodology for low volume track that was based primarily on visual inspection methods and served the intended purposes cited above did not exist. Using inspection and operating restrictions criteria from various track standards (Federal Railroad Administration [FRA] 1982; NAVFAC 1993 [DRAFT]; ultimately published as Technical Manual [TM] 5-628 1991) as a starting point, procedures were developed for computing a meaningful RJCI, TCI, BSCI, and TSCI. A condition survey process was developed that structures the information collection to facilitate index computation, minimizes the amount of inspection information needed, and meshes with existing periodic safety inspection procedures.

The development of the condition indexes (described in Technical Report FM-93/13), this condition survey procedure, and a detailed inspection procedure (described in FM-94/01) were all developed concurrently to ensure compatibility. The indexes can be computed from both condition survey and detailed inspection procedures.

Using the Manual

Chapter 2 describes the condition survey procedures. Distresses for the rail, joints, and fastenings component group are presented in Chapter 3. Chapter 4 describes the tie component group distresses. Lastly, the ballast, subgrade, and roadway component group distresses are given in Chapter 5. These chapters present the name, description, severity levels, measurement criteria, density formulation, and cause for each distress.

Inspectors should study this manual and keep it handy as a ready reference when surveying track. Proper distress identification (type and severity) are essential to meaningful and consistent condition index values (Figure 1).

The results of each condition survey are to be used in conjunction with the distress deduct curves for determining the RJCI, TCI, and BSCI. These deduct curves are located in Appendix A through C, respectively. The RJCI, TCI, and BSCI values are used to compute the TSCI. Users of the RAILER Railroad Track Engineered Management System (RAILER EMS) will not manually compute the indexes because the computations are automatically performed.

A blank condition survey inspection worksheet and a blank calculation worksheet can be found in Appendixes D and E, respectively.

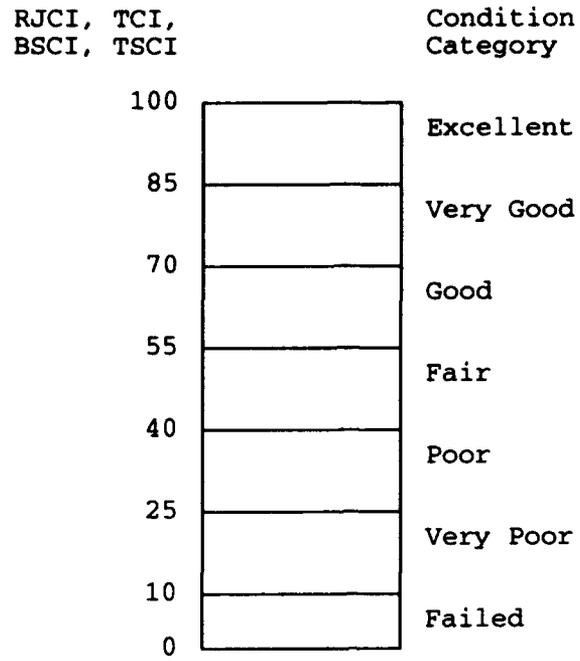


Figure 1. Condition Index Scale.

2 TRACK CONDITION SURVEY INSPECTION PROCEDURES AND CALCULATION OF INDEXES

Determining the condition indexes requires track condition survey so that the various distresses can be identified and quantified. Since sampling techniques are used to reduce the survey effort, the track network must be divided into track segments and sample units. Then, a condition survey program must be carefully planned and executed to gather distress information.

This chapter outlines the procedures for creating track segments and sample units, conducting condition surveys, and computing the condition indexes.

Dividing Track Into Track Segments and Sample Units

Track networks are typically divided into numbered or named distinct tracks with each having beginning and ending boundaries. Traffic, structure, curvature, and other parameters can vary greatly for a given track. Thus, dividing tracks into track segments is necessary to facilitate planning and decisionmaking for projects ranging from routine maintenance through spot repairs and renewals to major renewals or capital improvements. The procedures for creating track segments are described in detail elsewhere (Uzarski, Plotkin, and Brown 1988), but a summary is provided below. Also, once the track is divided into segments, each segment is further divided into sample units. The sample unit division process is described below.

Track Segments

Track segments represent "management units" upon which M&R decisions are made. Track work will be planned and scheduled for accomplishment over the entire segment. Therefore, the condition of the track segments drives, in part, the M&R decision process. The condition indexes must be computed at the track segment level.

A given track is divided into one or more segments depending on a number of factors. The basic criteria for segmenting is the goal of having relatively uniform key parameters within each segment. Example guideline criteria includes:

- Traffic
- Track structure
- Track use
- Condition

Distance (e.g., mileposts), curves, bridges, etc. may also be used for segment delineation. As a rule of thumb, short tracks (less than 1 mile) are segmented from turnout to turnout. Longer tracks may also use distance limits (e.g., mileposts) in addition to the turnout criteria.

There are no hard and fast rules for creating track segments. The only true criterion is that the size and divisional limits must reflect the physical requirements needed to support decisionmaking. Figure 2 displays an example track network divided into track segments.

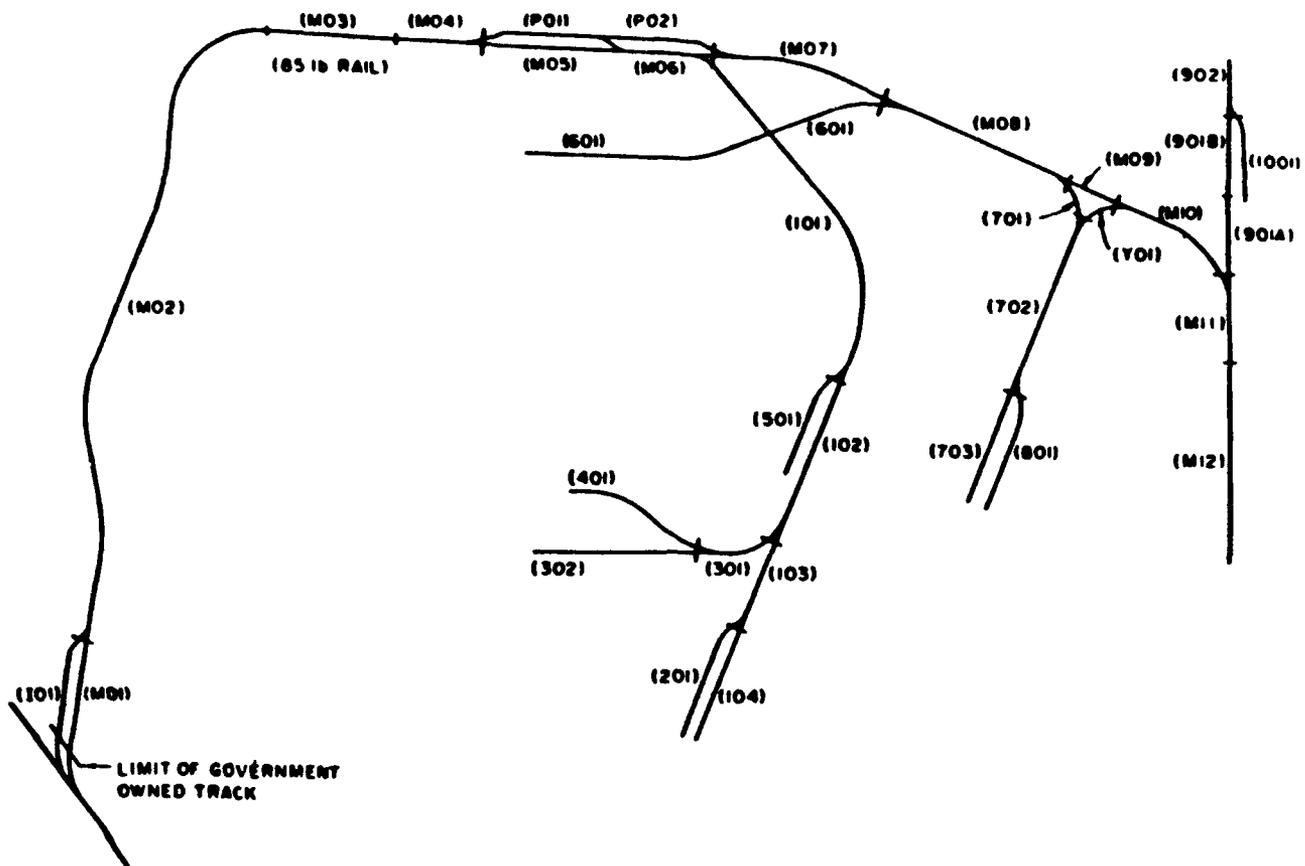


Figure 2. Example Segmented Track Network.

Sample Units

Sample units serve no purpose other than to facilitate the condition survey inspection process. A 100 percent track condition survey is not required to assess conditions through the use of these indexes, nor is it necessary to quantify "problems". The condition survey findings of selected sample units can be extrapolated and the compiled indexes can be averaged across the entire segment. This approach reduces the survey effort (and cost) while providing the necessary information for network level management, including: assessing condition, determining rates of deterioration, predicting condition, and planning M&R work and budgets.

Sampling does not apply to safety inspections nor for the detailed inspections needed before major renewal (capital improvement) projects. Technical Report FM-94/01 discusses the detailed inspection process.

Sample units are created as follows:

1. A location reference system should be applied to the entire track. The use of 100-ft "stations" or mileposts further divided into feet are recommended. Each track segment will have a beginning and ending station location.

2. Sample units may be any convenient length, but except as cited in the following text, they should be the same length within a given segment. Sample units that are 100-ft or 200-ft long are recommended, but field considerations (including station markings) may deem other lengths to be more practical. Sample units may not be shorter than 50 ft.

3. Each sample unit will begin at the X + 00 (X + YY00 for milepost stationing) station location (except for the first sample unit as noted in the following text).

4. Since track segments rarely begin and end at 00 stations, beginning and ending sample units must be adjusted, accordingly. If the distance from the beginning of the segment to the first 00 station is less than half of the desired sample unit length, this distance should be included with the first sample unit (that begins at the 00 station) forming a longer sample unit. If the distance from the beginning of the segment to the first 00 station is greater than or equal to half of the desired sample unit length, this portion of the segment will form its own sample unit. The same is true at the end of a segment.

5. Very short segments may only have one sample unit. Depending on where the 00 stations are located, the sample unit size may vary. They may be a minimum of 50 ft long.

6. A given turnout should reside in a single sample unit, but multiple turnouts may reside in a single sample unit. This may require that the sample units on either side of the turnout(s) be sized following the logic in 4 above.

7. Sample units will be numbered consecutively.

Rail, Joints, and Fastenings Component Group. Unfortunately, individual rails seldom begin and end at the limits of the sample unit. To properly manage with these differences, an entire rail (beginning at a joint) should be included for condition survey in a given sample unit if more than half of the rail resides in that sample unit. If less than half of a rail resides in the sample unit, it should not be surveyed. That rail is considered to be located in the adjacent sample unit.

The remaining components of the group are included for condition survey based on the normal sample unit boundaries.

Tie Component Group. Normally, the total number of ties to inspect per 100-ft sample unit will be between about 57 and 63. If sample unit limits are not marked in the field, simply assuming that 60 ties equals 100 ft affords a simple and practical solution for delineating sample unit limits.

If, by chance, a sample unit begins or ends in the middle of a defective or missing tie cluster, include the entire cluster either within that sample unit or in the adjacent one.

Ballast, Subgrade, and Roadway Component Group. The sample unit limits will correspond to the limits used for the rail, joints, and fastenings and tie component groups.

Figure 3 shows example track segment 702 from Figure 2 divided into 100-ft sample units.

Condition Survey Procedure

Crew Size

The condition surveys can be performed by a single trained person, although two will speed the process.

Transportation Mode

The condition survey of the sample units must be accomplished on foot. The use of a high-rail vehicle or other ground transportation for travel to the desired track segments and sample units will greatly increase inspector productivity.

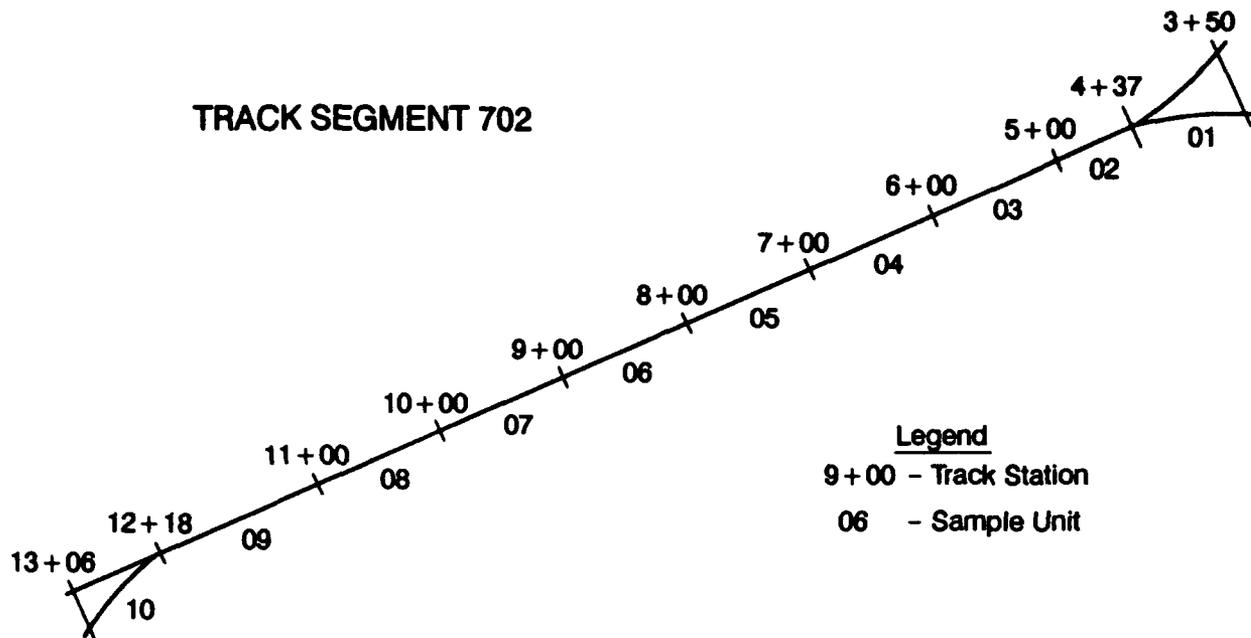


Figure 3. Track Segment Divided into 100-ft Sample Units.

Supplies

The following supplies are needed:

- Condition inspection worksheets (see Appendix D)
- Pencils
- Pointed metal rod (approximately 3 ft long)
- A 62-ft stringline or 100-ft tape measure
- A 6-ft (or equivalent) tape measure or folding rule
- Track level
- Spray paint or lumber crayons (optional)

Rail, Joints, and Fastenings (RJ & F) Component Group Condition Surveys

Most of the distresses can be found visually. However, not all of the defects that make up the distresses can be discovered this way. Some defects are internal to the rail (i.e., transverse fissures) and others are typically shielded from view because of joint bars and bolts (i.e., small bolt hole cracks and torch cut holes). Minute cracks, even those in plain view, can be nearly impossible to see.

Many of these hidden defects can only be discovered through rail flaw testing (*Rail Defect Manual 1964*). A rail flaw testing program is normally recommended based on operational levels and the history of defect

occurrence. This report does not attempt to establish rail flaw inspection cycle frequencies. However, track standards generally do address this testing topic (FRA 1982; NAVFAC 1993 [DRAFT]; TM 5-628 1991). The results of a rail flaw testing program should supplement the visual inspection.

As distresses are noted during the condition survey, they should be marked on the condition survey inspection worksheet (Figure 4). Defective rails and joints should be marked with paint to facilitate location by a section gang dispatched to repair the defect.

Tie Component Group Condition Surveys

All of the tie distresses can be discovered visually. The use of a pointed metal rod or something else to "thump" ties will help the inspector detect hollow and internally rotten ties. Marking defective ties with paint or crayon is optional. Normally, they would be marked if replacement is imminent so that tie or section gangs will know which ones to replace.

As distresses are noted during the condition survey inspection, they should be marked on the condition survey inspection worksheet (Figure 4).

Ballast, Subgrade, and Roadway (BS & R) Component Group Condition Surveys

All of the distresses can be found through visual means. They, too, are to be marked on the worksheet (Figure 4).

Condition Survey Guidelines

Several practical guidelines are offered below to assist in implementing these procedures.

Condition Survey Frequency

Since the primary purpose of the condition indexes is to aid in performing the network level management tasks of assessing current track conditions, predicting future track conditions, establishing track deterioration rates, determining and prioritizing current and long range work needs, formulating budgets, and measuring the effectiveness of spot and renewal projects, an inspection frequency needs to be established that best fits those needs. Typically, an annual frequency will be sufficient for these condition surveys.

Primarily for safety reasons, active track is inspected more often than annually. The condition surveys should be scheduled for accomplishment during one of the routine safety inspections.

Number and Selection of Sample Units to Survey

Every sample unit does not need to be surveyed. The number needed depends on how the condition varies throughout the length of the track segment. If the condition is relatively uniform throughout, Table 1 lists the recommended minimum number of sample units to survey.

These minimum numbers are for *representative* sample units. That is, there are no major noticeable differences in condition among them. If there are major differences in any component group, those sample units containing the differences should be surveyed as *additional* sample units. All selected sample units are surveyed the same, but they affect the condition indexes of the track segment differently. An example later in this chapter will illustrate this.

Table 1

**Recommended Minimum Numbers
of Sample Units to Condition Survey**

Number of Sample Units in the Track Segment	Minimum Number to Condition Survey
1 - 4	1
5 - 10	2
11 - 20	3
20 - 40	4
> 40	10%

The choice of which specific representative sample units to initially survey is left to the discretion of the inspector. It is recommended, however, that the units be distributed throughout the track segment. Subsequent condition surveys should be accomplished on the same sample units as long as they remain representative. This will reduce the inherent error in the condition indexes caused by sampling.

Sample Unit Size and Location

As described earlier in this report, sample units size may be any convenient length, but 100 or 200 ft is the recommended size. Except as noted earlier, the sample units should be the same size within a given segment but different segments may have sample units of different lengths, if practical. Sample units could be marked semipermanently in the field through the use of affixed station markers or by spraying paint on a rail web at the sample unit boundaries. They only need to be measured once and marked. Sample units can be measured with a 100-ft tape, a measuring wheel, or by any other reasonable method.

Often, the sample units will not be marked in the field. When that occurs, the inspector is faced with the challenge of deciding where to begin and end the condition survey. From a practical perspective, the inspector only needs to approximate within a few feet the beginning location of each sample unit. Then, rather than be faced with the task of measuring off a set distance, simply counting off ties (at the rate of 60 ties per 100 ft) to define the limits to the sample unit works extremely well.

Condition Survey Process

The condition survey process begins with a review of the most recent past condition survey or detailed inspection report, as appropriate (including rail flaw testing, if available) and any completed work orders. This review will help to prepare the inspector for what distresses may be found.

Figure 5 shows how the actual condition survey progresses. As can be seen, the inspector will travel the entire track segment. Safety inspections are performed until the first selected sample unit is reached. From here, the condition survey begins for the length of the sample unit. When the condition survey is completed for the sample unit, the inspector continues performing safety inspections until the next desired sample unit is encountered and the process repeats.

Three passes of each surveyed sample unit are recommended. Pass one should focus on the rail, joints, and fastenings component group. Pass two, performed from the end of the sample unit back to the beginning, concentrates on identifying defective, missing, and improperly positioned ties. The third pass looks for ballast, subgrade, and roadway component group distresses. Should there be very few distresses, an inspector may complete the condition survey with only one pass.

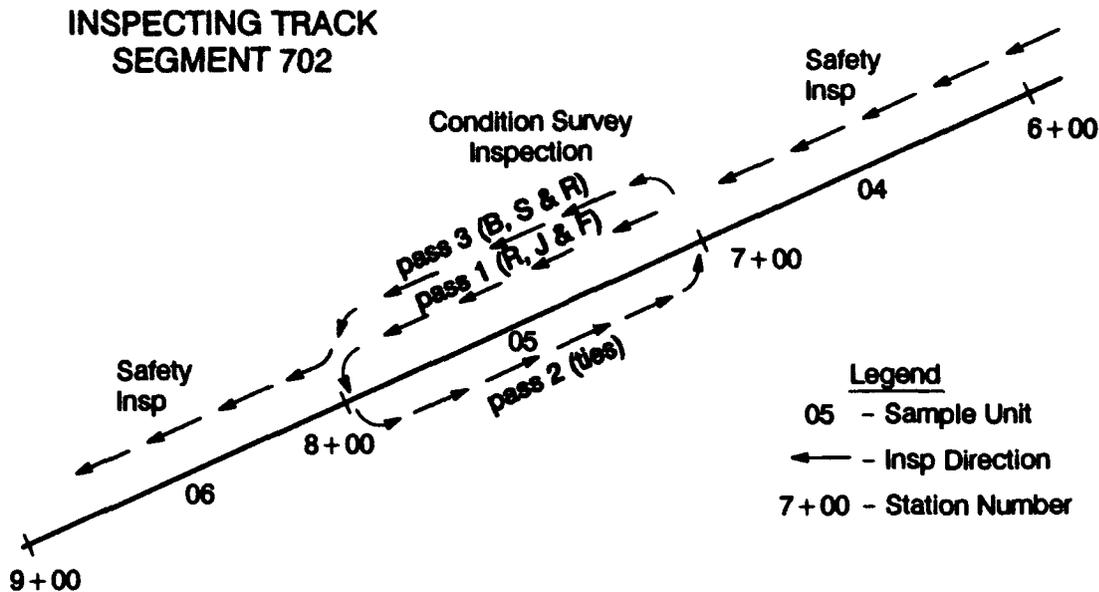


Figure 5. Condition Survey Inspection Process.

Use of this Manual

This manual is intended to serve as a ready distress identification reference for track inspectors. When an inspector is uncertain as to how to classify a "track problem," he/she should refer to the definitions and photographs in Chapters 3 through 5 and decide on the proper classification.

Recording Distress Information

A condition survey inspection worksheet, Appendix D, was designed to have the inspector record the required information so that a clear picture of condition results. Referring back to Figure 4, you can see specifically where the track problems are located.

Rail, Joints, and Fastenings Component Group. Rail and joint distresses should be marked by distress type number and severity level with an arrow to the affected rail or joint. Fastening distresses should be marked as follows:

- p = Hold-down device improper pattern (R3L)
- x = Hold-down device loose, missing, etc. (R3M)
- t = Tie plate defects (R4)
- g = Gauge rod defects (R5)
- = Rail anchor defects (R6)

Tie Component Group. Each defective, missing, or improperly positioned tie is marked as follows:

D = Defective

M = Missing

S = Skewed

R = Rotated

Ballast, Subgrade, and Roadway Component Group. Sketch the distresses and identify.

Summarizing the Condition Survey Findings

The right third of the condition survey worksheet is designed to summarize the condition survey findings. The quantities for each distress type/severity level are tallied. Figure 4 illustrates this.

Calculating the Indexes

The goal is to know the RJCI, TCI, BSCI, and TSCI for each track segment. This involves computing the RJCI, TCI, and BSCI for each surveyed sample unit and averaging the results. The TSCI is not computed at the sample unit level; rather, it is determined from the average RJCI, TCI, and BSCI. A worksheet (see Appendix E) has been developed to aid in the manual calculation process. Normally, the condition indexes will not be computed in the field. This is an office activity that is performed when convenient.

An example follows for sample unit 05 in track segment 702 (see Figure 3). A RJCI, TCI, and BSCI calculation worksheet, Figure 6, has been completed based on the condition survey information shown in Figure 4.

Calculating the RJCI for a Sample Unit

Using the deduct and correction curves provided in Appendix A, the RJCI for the example sample unit is 57. Table 2 shows, step-by-step, the computations accomplished in Figure 6 to arrive at the index value.

Calculating the TCI for a Sample Unit

Appendix B provides the deduct and correction curves for computing the TCI. For the example sample unit, the TCI is 50. Table 3 shows the computations accomplished in Figure 6 for this example sample unit.

Calculating the BSCI for a Sample Unit

The deduct and correction curves for computing the BSCI are provided in Appendix C. The BSCI for the example sample unit is 47. Table 4 shows the computations accomplished in Figure 6 used to arrive at the index value.

Calculating the Condition Indexes for a Track Segment

Once the requisite number of sample units have been inspected and the condition indexes computed, the condition indexes for the track segment as a whole can be computed using Equation 1.

$$CI_{ts} = \frac{(N - A)CI_1 + (A)CI_2}{N} \quad [\text{Eq 1}]$$

where CI_{ts} = RJCI, TCI, or BSCI of the track segment
N = total number of sample units in the track segment
A = number of additional sample units
 CI_1 = average RJCI, TCI, or BSCI of the representative sample units
 CI_2 = average RJCI, TCI, or BSCI, of the additional sample units

RJCI, TCI, and BSCI Calculation Worksheet

RJCI

Distress Type	Severity	Quantity	Density	Deduct Value
K1	L(1)	1	16.7	11
L2	L(1)	2	33.3	22
-	M(1)	1	16.7	11
K3	L	2	10	14
K6	-	7	37.5	11

$m = 1 + 9/98(100 - DV_{max}) = 6.97$

Row	Deduct Values						TDV	q	CDV	
1	35	22	14	11	11			93	5	37
2	35	22	14	11	2			84	4	35
3	35	22	14	2	2			75	3	40
4	35	2	2	2	2			63	2	40
5	35	2	2	2	2			43	1	43
6										
7										
8										
9										
10										

$RJCI = 100 - CDV_{max} = 100 - 43 = 57$

TCI

Distress Type	Severity	Quantity	Density	Deduct Value
T1	L	7	11.7	15
T1	M	1	1.67	4
T2	-	4	13.3	21
T2	M	2	5	19
T4	L	4	12.3	21

$m = 1 + 9/98(100 - DV_{max}) = 7.21$

Row	Deduct Values						TDV	q	CDV	
1	31	21	19	15	4			90	5	46
2	31	21	19	15	2			81	4	53
3	31	21	19	2	2			75	3	48
4	31	21	2	2	2			53	2	42
5	31	2	2	2	2			29	1	29
6										
7										
8										
9										
10										

$TCI = 100 - CDV_{max} = 100 - 50 = 50$

BSCI

Distress Type	Severity	Quantity	Density	Deduct Value
B1	-	100	100	20
B2	L	25	25	22
B8	-	100	52.3	24
B11	L	1	1	24

$m = 1 + 9/98(100 - DV_{max}) = 7.43$

Row	Deduct Values						TDV	q	CDV	
1	30	24	21	23				101	5	55
2	30	24	24	2				80	4	49
3	30	24	2	2				58	3	41
4	30	2	2	2				26	2	26
5										
6										
7										
8										
9										
10										

$BSCI = 100 - CDV_{max} = 100 - 45 = 55$

Figure 6. RJCI, TCI, and BSCI Calculation Worksheet.

Table 2

Example RJCI Computation

Step 1: Inspect Rail, Joints, and Fastenings Component Group in Selected Sample Unit (see Figure 4)

Summary:

1 Rail, Low Severity, 1 Defect in Rail
2 Joints, Low Severity, 1 Defect in Each Joint
2 Joints, Medium Severity, 1 Defect in Each Joint
12 Occurrences of Improper Spiking Pattern
9 Rail Anchors Out-of-Position

Step 2: Compute Densities

60 Ties, 6 Rails, and 6 Joints in Sample Unit

R1L(1): Density = 1/6 = 16.7%
R2L(1): Density = 2/6 = 33.3%
R2M(1): Density = 1/6 = 16.7%
R3L: Density = 24/60x4 = 10.0%
R6: Density = 9/60x4 = 3.75%

Step 3: Compute Deduct Values (DV)

R1L: DV = 11 (from Figure A-1)
R2L: DV = 22 (from Figure A-5)
R2M: DV = 35 (from Figure A-6)
R3L: DV = 14 (from Figure A-9)
R6: DV = 10 (from Figure A-12)

Note: If, for example, there had been two defects in the rail for R1L the user must interpolate between the "1" and "3" curves on Figure A-1.

Step 4: List the Individual Deduct Values in Descending Order in Columns (see Figure 6)

Step 5: Determine "m" from Equation F1

$m = 1 + (9/98)(100 - HDV)$ where HDV = highest individual deduct value = 35
 $m = 6.97$ (maximum allowable number of deduct valves)
Note: m is greater than the actual number of deduct values (5).

Step 6: List Successive Rows of Individual Deduct Values Substituting the Value "2" for the Lowest (greater than 2) Value in Each Row (see Figure 6)

Step 7: Compute Total Deduct Value (TDV) for Each Row

Row 1: TDV = 93
Row 2: TDV = 84
Row 3: TDV = 75
Row 4: TDV = 63
Row 5: TDV = 43

Step 8: Determine "q" for Each Row

Row 1: q = 5 (total number of deduct values greater than 2 points)
Row 2: q = 4
Row 3: q = 3
Row 4: q = 2
Row 5: q = 1

Table 2 (Continued)

Step 9: Determine Corrected Deduct Value (CDV) for Each Row

- Row 1: CDV = 37 (from Figure A13)
- Row 2: CDV = 38
- Row 3: CDV = 40
- Row 4: CDV = 40
- Row 5: CDV = 43

Step 10: Compute RJC and Determine Condition Category

$RJC = 100 - CDV_{max} = 57$ - Good (from Figure 1)

Table 3

Example TCI Computation

Step 1: Inspect Tie Component Group in Selected Sample Units (See Figure 4)

Summary:

- 7 Single Defective Ties
- 1 Single Defective Tie at a Joint
- 4 Isolated Defective Tie Cluster, 2 Ties per Cluster
- 1 Isolated Defective Tie Cluster, 3 Ties per Cluster
- 4 Adjacent Defective Tie Cluster, 2 Ties per Cluster

Step 2: Compute Densities

60 Ties in Sample Unit

T1L:	Density =	7/60	=	11.7%
T1M:	Density =	1/60	=	1.67%
T2L:	Density =	8/60	=	13.3%
T2M:	Density =	3/60	=	5.0%
T4L:	Density =	8/60	=	13.3%

Step 3: Compute Deduct Values (DV)

T1L:	DV =	15 (from Figure B-1)
T1M:	DV =	4 (from Figure B-1)
T2L:	DV =	21 (from Figure B-2)
T2M:	DV =	19 (from Figure B-2)
T4L:	DV =	31 (from Figure B-4)

Step 4: List the Individual Deduct Values in Descending Order in Columns (see Figure 6)

Step 5: Determine "m" from Equation F1

$m = 1 = (9/98) (100 - HDV)$ where HDV - highest individual deduct value = 31
 $m = 7.34$ (maximum allowable number of deduct values)
Note: m is greater than the actual number of deduct values (5).

Step 6: List Successive Rows of Individual Deduct Values Substituting the Value "2" for the lowest (greater than 2) Value in Each Row (see Figure 6)

Step 7: Compute Total Deduct Value (DV) for Each Row

- Row 1: TDV = 90
- Row 2: TDV = 88
- Row 3: TDV = 75
- Row 4: TDV = 58
- Row 5: TDV = 39

Table 3 (Continued)

Step 8: Determine "q" for Each Row

- Row 1: q = 5 (total number of deduct values greater than 2 points)
- Row 2: q = 4
- Row 3: q = 3
- Row 4: q = 2
- Row 5: q = 1

Step 9: Determine Corrected Deduct Value (CDV) for Each Row

- Row 1: CDV = 46 (from Figure B9)
- Row 2: CDV = 50
- Row 3: CDV = 48
- Row 4: CDV = 42
- Row 5: CDV = 39

Step 10: Compute TCI and Determine Condition Category

$TCI = 100 - CDV_{max} = 50$ -Fair (from Figure 1)

Table 4

Example BSCI Computation

Step 1: Inspect Ballast, Subgrad, and Roadway Component Group in Selected Sample Unit (see Figure 4)

Summary

- 100 feet of Dirty Ballast
- 25 feet of Weeds not Affecting Inspection or Ops
- 100 feet of Insufficient Shoulder Ballast (one side)
- One Partially Clogged Culvert

Step 2: Compute Densities

- Sample Unit Length = 100 feet
- B1: Density = $100/100 = 100\%$
- B2L: Density = $25/100 = 25\%$
- B8: Density = $100/300 = 33.3\%$
- B11L: Density = N/A

Step 3: Compute Deduct Values (DV)

- B1: DV = 30 (from Figure C-1)
- B2L: DV = 24 (from Figure C-2)
- B8: DV = 24 (from Figure C-9)
- B11L: DV = 24 (from Figure C-12)

Step 4: List the Individual Deduct Values in Descending Order in Columns (see Figure 6)

Step 5: Determine "m" from Equation F1

- $m = 1 + (9/98) (100 - HDV)$ where HDV = highest individual deduct value = 3
- $m = 7.43$ (maximum allowable number of deduct values)
- Note: m is greater than the actual number of deduct values (4).

Step 6: List Successive Rows of Individual Deduct Values Substituting the Value "2" for the Lowest (greater than 2) Value in Each Row (see Figure 6)

Table 4 (Continued)

Step 7: Compute Total Deduct Value (TDV) for Each Row

Row 1: TDV	=	101
Row 2: TDV	=	80
Row 3: TDV	=	58
Row 4: TDV	=	36

Step 8: Determine "q" for Each Row

Row 1: q	=	4 (total number of deduct values greater than 4 points)
Row 2: q	=	3
Row 3: q	=	2
Row 4: q	=	1

Step 9: Determine Corrected Deduct Value (CDV) for Each Row

Row 1: CDV	=	53 (from Figure C13)
Row 2: CDV	=	49
Row 3: CDV	=	41
Row 4: CDV	=	36

Step 10: Compute BSCI and Determine Condition Category

$$\text{BSCI} = 100 - \text{CDV}_{\max} = 47 \rightarrow \text{Fair (from Figure 1)}$$

For the example track segment 702, three out of ten sample units were inspected and all of them were representative except for the ballast and subgrade component group for sample unit 05, which was considered "additional" because of the clogged culvert. That culvert was the only one present in the entire segment and, thus, not representative of the track segment as a whole. The RJCI, TCI, and BSCI computations for sample unit 05 are given in Tables 2 through 4, respectively. Those index values along with the computed indexes (details not provided) for sample units 03 and 08 are summarized in Table 5.

Substituting these values into Equation 1 yields the track segment RJCI = 67, TCI = 52, and BSCI = 60. The track segment TSCI is computed from Equation 2 and equals 57. The computations are provided in Table 6.

$$\text{TSCI} = 0.50(\text{Low}) + 0.35(\text{Mid}) + 0.15(\text{High}) \quad [\text{Eq 2}]$$

where TSCI = TSCI of the track segment
Low, Mid, High = RJCI, TCI, or BSCI of the track segment ranked low to high.

Table 5
Condition Index Values Summary

Index	Sample Unit 03	Sample Unit 05	Sample Unit 08
RJCI	70	57	75
TCI	55	50	50
BSCI	65	47	59

Table 6
Example Condition Index Computations for a Track Segment

Step 1: Substitute Sample Unit Indexes into Equation 1 and Compute RJCI

$$RJCI = \frac{(10)(70 + 57 + (75)/3)}{10} = 67 \text{ --> Good}$$

Step 2: Substitute Sample Unit Indexes into Equation 2 and Compute TCI

$$TCI = \frac{(10)(55 + 50 + 50)/3}{10} = 52 \text{ --> Fair}$$

Step 3: Substitute Sample Unit Indexes into Equation 2 and Compute BSCI

$$BSCI = \frac{(9)(65 + 59)/2 + (1)(47)/1}{10} = 60 \text{ --> Good}$$

Step 4: Rank Segment Indexes from Low to High

Low = 52
Mid = 60
High = 67

Step 5: Substitute Segment Indexes into Equation 1 and Compute TSCI

$$TSCI = 0.5(52) + 0.35(60) + 0.15(67) = 57 \text{ --> Good}$$

Use of RAILER EMS

The use of the computer-based RAILER Engineered Management System negates the need to manually compute the condition indexes. If RAILER is used, the reverse of the condition survey inspection worksheet will not be needed. Additionally, computer software (RAILER RED) has been developed for use in selected pen-based electronic clipboards for collecting condition survey information. If used, the paper worksheets will not be needed.

3 RAIL, JOINTS, AND FASTENINGS COMPONENT GROUP DISTRESSES

<u>Distress</u>	<u>Index</u>	<u>Page</u>
R1. Rail Defects		26
R2. Joint Defects		33
R3. Hold-Down Device Defects		38
R4. Tie Plate Defects		40
R5. Gauge Rod Defects		42
R6. Rail Anchor Defects		43

R1. Rail Defects

Description: Rail defects encompass everything that reduces the strength or functionality of rail. Thirty-three internal and external defects are possible and all are listed below within specific severity levels.

Severity Levels:

L - The following defects are low severity:

- Bent Rail**
- Chips or Dents in Head ≥ 0.25 in.**
- Corrugations**
- Engine Burns ≥ 0.25 in**
- Flaking**
- Mill Defects**
- Overflow ≥ 0.25 in**
- Rail Length < 13 ft**
- Shelling**
- Slivers**
- Head Checks (Surface Cracks)**
- Surface Spalls**

M - The following defects are medium severity:

- Bolt Hole Crack ≤ 0.5 in.**
- Broken Base ≤ 6.0 in.**
- Compound Fissure < 20 percent of area**
- Corroded Base**
- Crushed Head**
- Detail Fracture < 20 percent of area**
- End Batter > 0.25 in.**
- Engine Burn Fracture < 20 percent of area**
- Head Web Separation ≤ 0.5 in.**
- Horizontal Split Head ≤ 2.0 in.**
- Piped Rail ≤ 0.5 in.**
- Running Surface Damage**
- Side Wear**
- Split Web ≤ 0.5 in.**
- Torch Cut Rail**
- Transverse Fissure < 20 percent of area**
- Vertical Split Head ≤ 2.0 in.**
- Vertical Wear**

H - The following defects are high severity:

- Bolt Hole Crack > 0.5 in. and ≤ 1.5 in.**
- Broken Base > 6.0 in. and ≤ 12.0 in.**
- Compound Fissure ≥ 20 percent and < 40 percent of area**
- Detail Fracture ≥ 20 percent and < 40 percent of area**
- Engine Burn Fracture ≥ 20 percent and < 40 percent of area**
- Head Web Separation > 0.5 in. and ≤ 3.0 in.**
- Horizontal Split Head > 2.0 in. and ≤ 4.0 in.**
- Piped Rail > 0.5 in. and ≤ 3.0 in.**

Split Web > 0.5 in. and ≤ 3.0 in.
Torch Cut Hole
Transverse Fissure ≥ 20 percent and < 40 percent of area
Vertical Split Head > 2.0 in. and ≤ 4.0 in.
Weld Defects < 100 percent of area

VH - The following defects are very high severity:

Bolt Hole Crack > 1.5 in. or Break
Broken Base > 12.0 in.
Complete Break (clean and square or rough and angled)
Compound Fissure ≥ 40 percent of area
Detail Fracture ≥ 40 percent of area
Engine Burn Fracture ≥ 40 percent of area
Head Web Separation > 3.0 in. or Breakout
Horizontal Split Head > 4.0 in. or Breakout
Piped Rail > 3.0 in. or Breakout
Split Web > 3.0 in. or Breakout
Transverse Fissure ≥ 40 percent of area
Vertical Split Head > 4.0 in. or Breakout
Weld Defects = 100 percent of area

Measurement: Each Rail

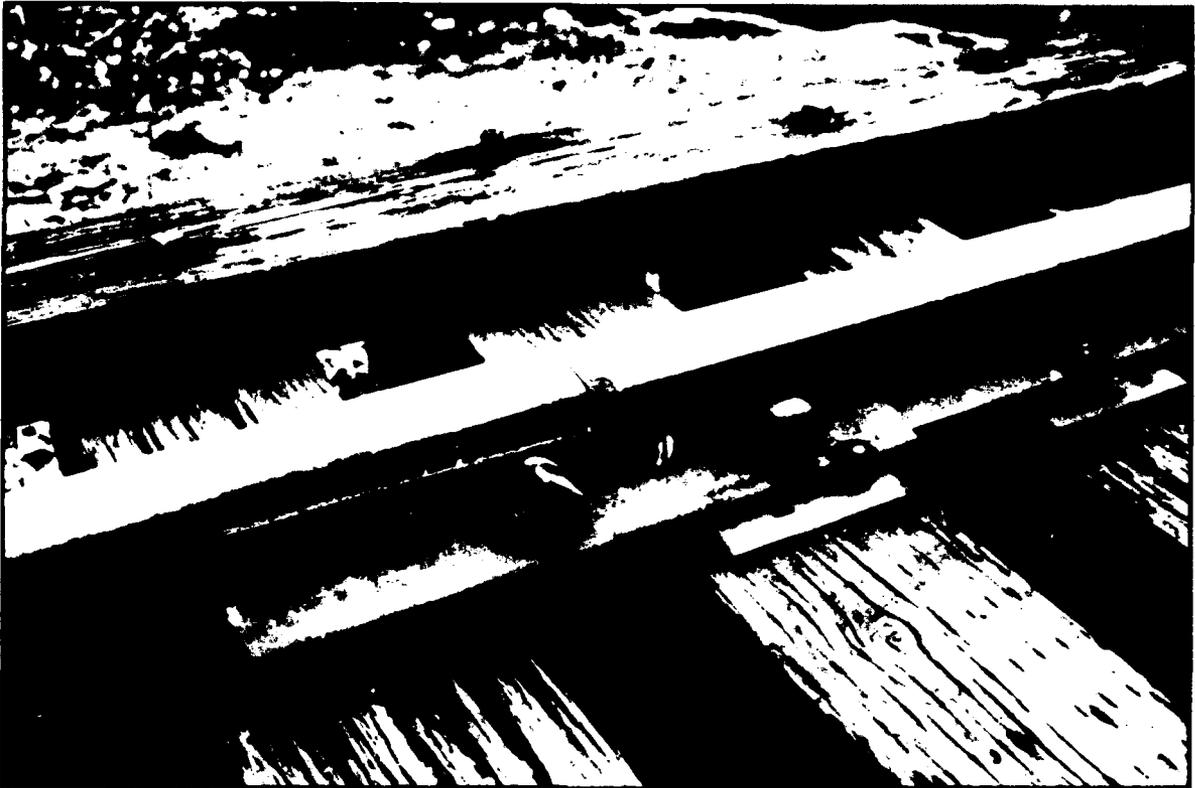
Notes: 1) Count the number of times each defect occurs in each rail except for low severity defects.

2) For low severity defects, only count the presence of different defects in a given rail (i.e., do not count the number of chips, shelly spots, etc.).

3) Rails longer than 39 ft shall be divided into the largest number of equivalent rail lengths of 39 ft or less. It shall be assumed that imaginary joints exist to link those rails.

Density:
$$\frac{\text{Number of Affected Rails with Given Number of Defect Occurrences}}{\text{Number of Rails in Sample Unit}}$$

Cause: Rail defects result from quality control problems in the manufacturing process of the rail, improper handling or installation, lack of maintenance, and environmental effects. Also, repeated wheel loads induce stresses and deflections leading to fatigue damage, wear and metal flow.



R1L
Rail Defect, Low Severity
(Chip in Head ≥ 0.25 in.)



R1L
Rail Defect, Low Severity
(Overflow ≥ 0.25 in.)



R1L
Rail Defect, Low Severity
(Shelling)



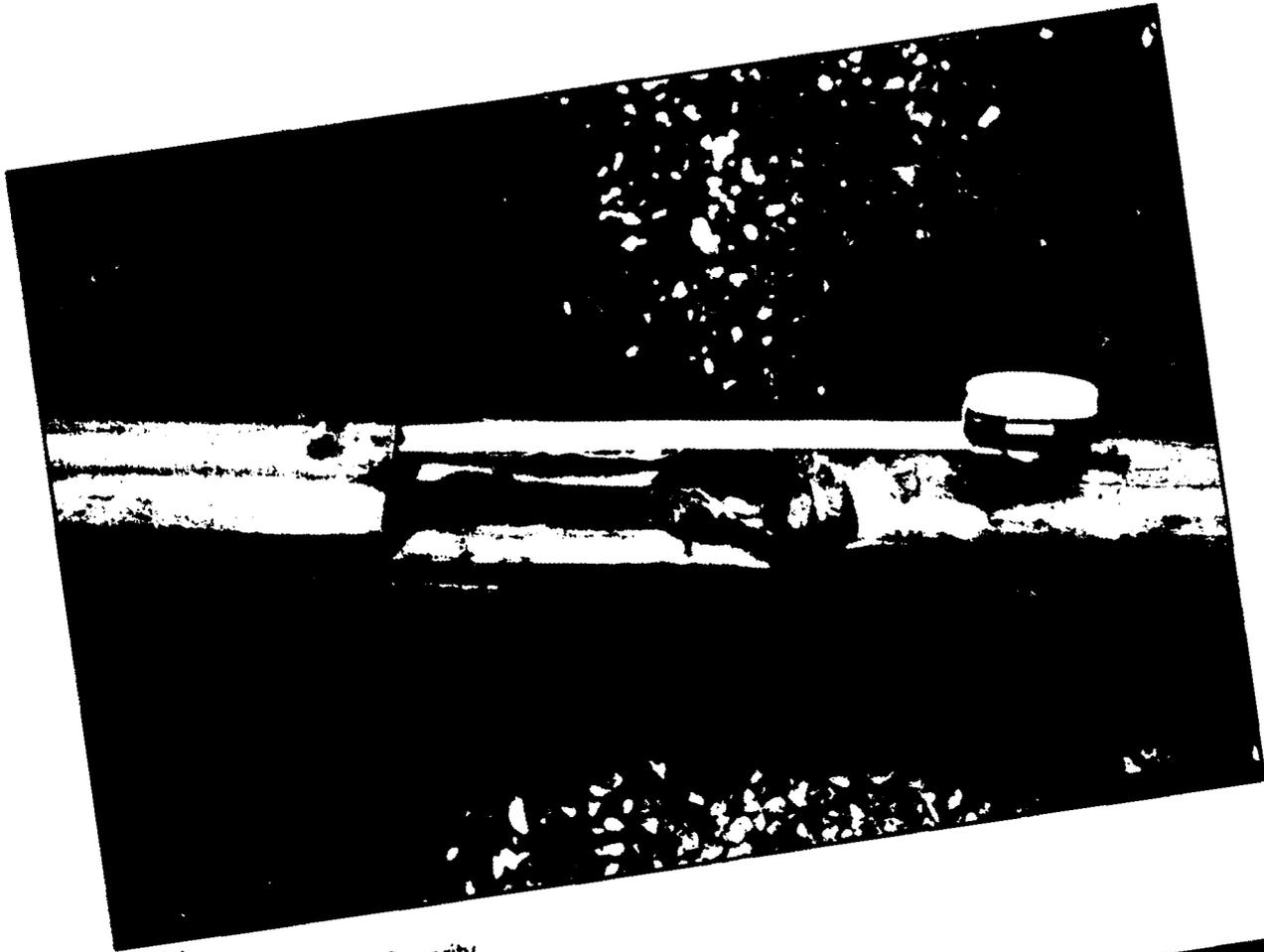
R1M
Rail Defect, Medium Severity
(Broken Base \leq 6.0 in.)



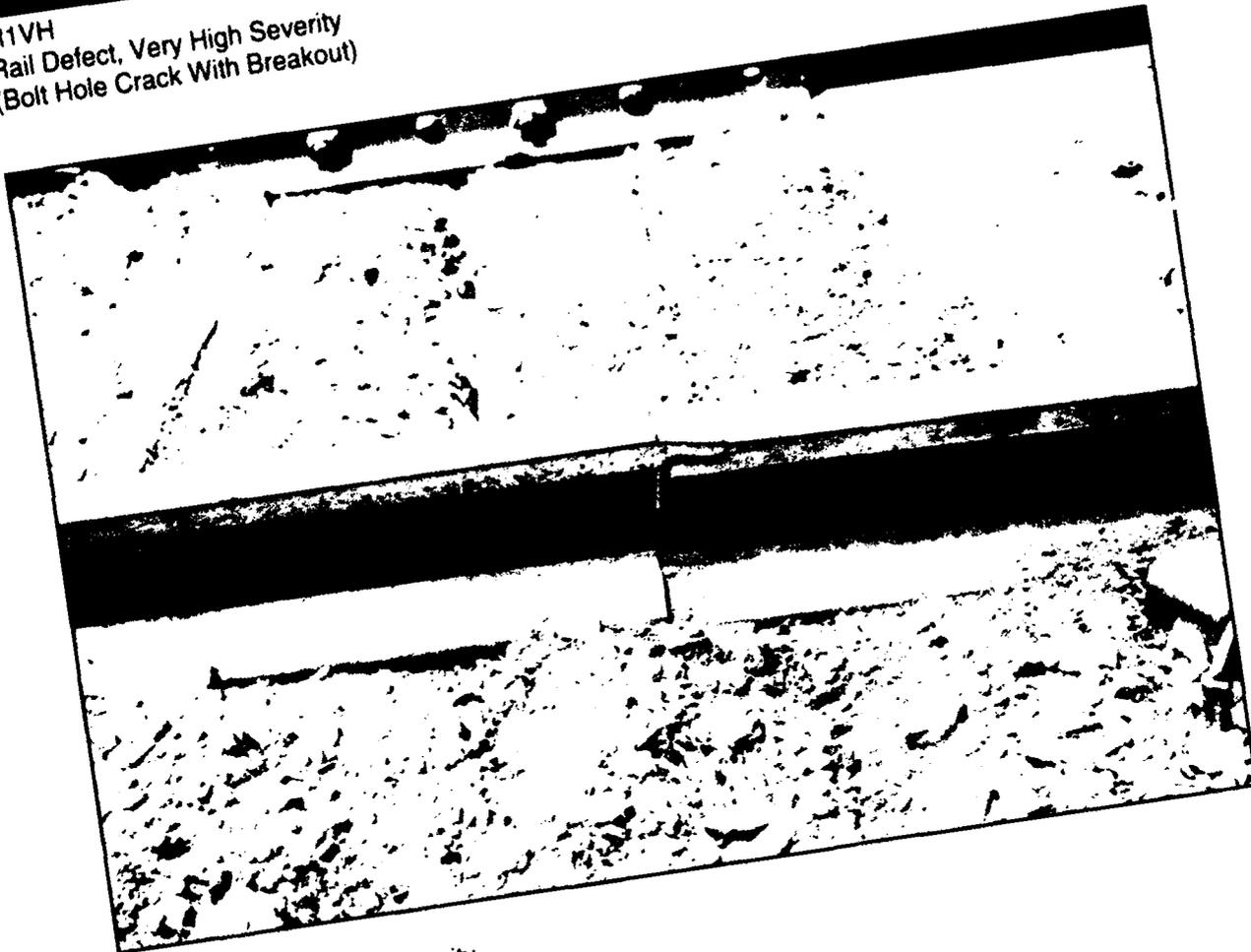
R1M
Rail Defect, Medium Severity
(Torch Cut Rail)



R1M
Rail Defect, Medium Severity
(Vertical Wear) [Note damage to joint bar from wheel flanges, which indicates wear]



R1VH
Rail Defect, Very High Severity
(Bolt Hole Crack With Breakout)



R1VH
Rail Defect, Very High Severity
(Complete Break)



R1VH
Rail Defect, Very High Severity
(Head Web Separation With Breakout)



R1VH
Rail Defects, Very High Severity
(Vertical Split Head With Breakout and Bolt Hole Crack > 1.5 in.)

R2. Joint Defects

Description: Joint defects include all items that reduce the strength or functionality of joints. Seventeen joint defects are possible. They are listed below within specific severity levels.

Severity Levels:

L - The following defects are low severity:

- Broken or Cracked Bar (not through center)
- Defective or Missing Bolt
- Improper Size or Type of Bar
- Improper Size or Type of Bolt
- Loose Bolt
- Torch Cut or Altered Bar

M - The following defects are medium severity:

- All Bolts at Joint Loose
- Corroded Bar
- One Bar Center Broken or Missing
- One Bar Center Cracked
- Only One Bolt per Rail End
- Rail End Gap > 1.0 in. and ≤ 2.0 in.
- Rail End Mismatch > 0.1875 in. and ≤ 0.25 in.

H - The following defect is high severity:

- Both Bars Center-cracked

VH - The following defects are very high severity:

- All Bolts on a Rail End Broken or Missing
- Both Bars Broken or Missing
- Loose Bars
- Rail End Gap > 2.0 in.
- Rail End Mismatch > 0.25 in.

Measurement: Each Joint

Notes: 1) Each loose bolt, etc. is considered a separate defect occurrence at a given joint. However, as applicable, only the highest severity level shall be recorded for a specific component (i.e., if the VH severity defect of all bolts on a rail end are broken or missing is present, the L severity defect of individual defective or missing bolts is not counted at same rail end).

2) Rails longer than 39 ft shall be divided into the largest number of equivalent rail lengths of 39 ft or less. It shall be assumed that imaginary joints exist linking those rails and that those joints are in perfect condition.

Density:
$$\frac{\text{Number of Affected Joints with Given Number of Defect Occurrences}}{\text{Number of Joints in Sample Unit}}$$

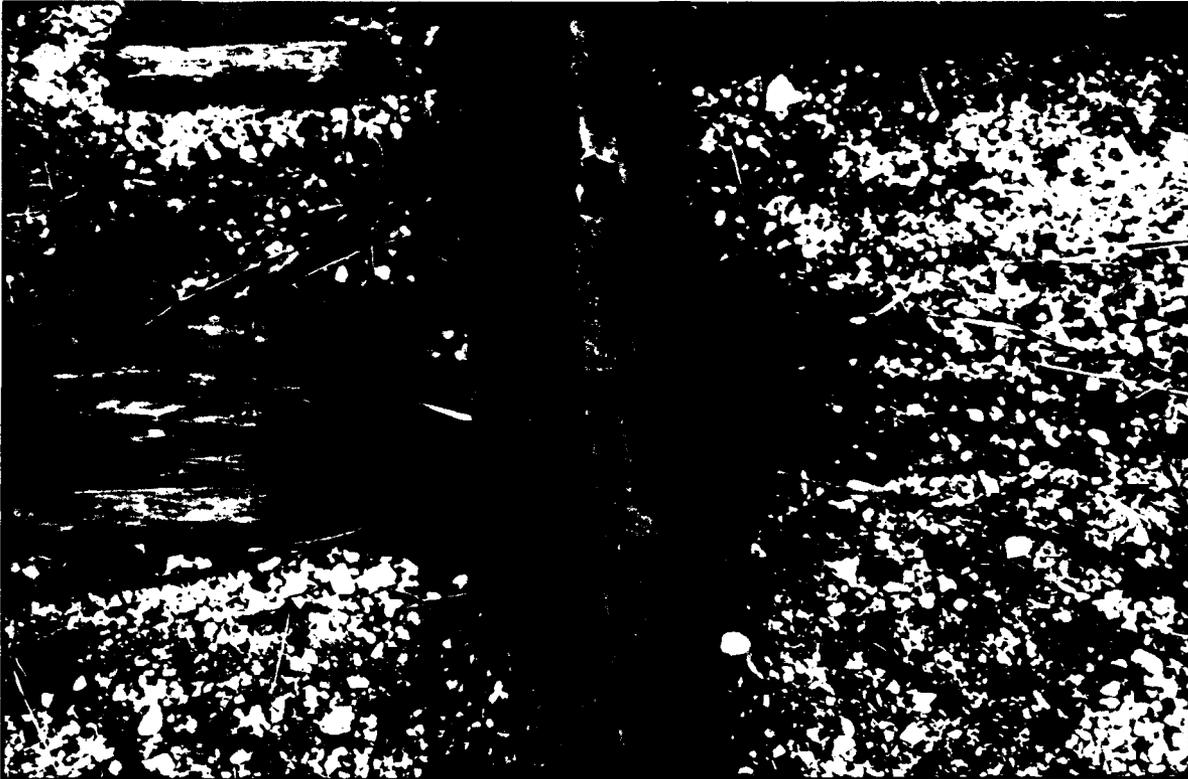
Cause: Joint defects result from improper installation, lack of maintenance, and environmental effects. Also, repeated wheel loads induce stresses, deflections, and vibrations leading to fatigue damage and loose bolts and bars.



R2L
Joint Defect, Low Severity
(Broken Bar [not through center])



R2L
Joint Defect, Low Severity
(Improper Type of Bolt)



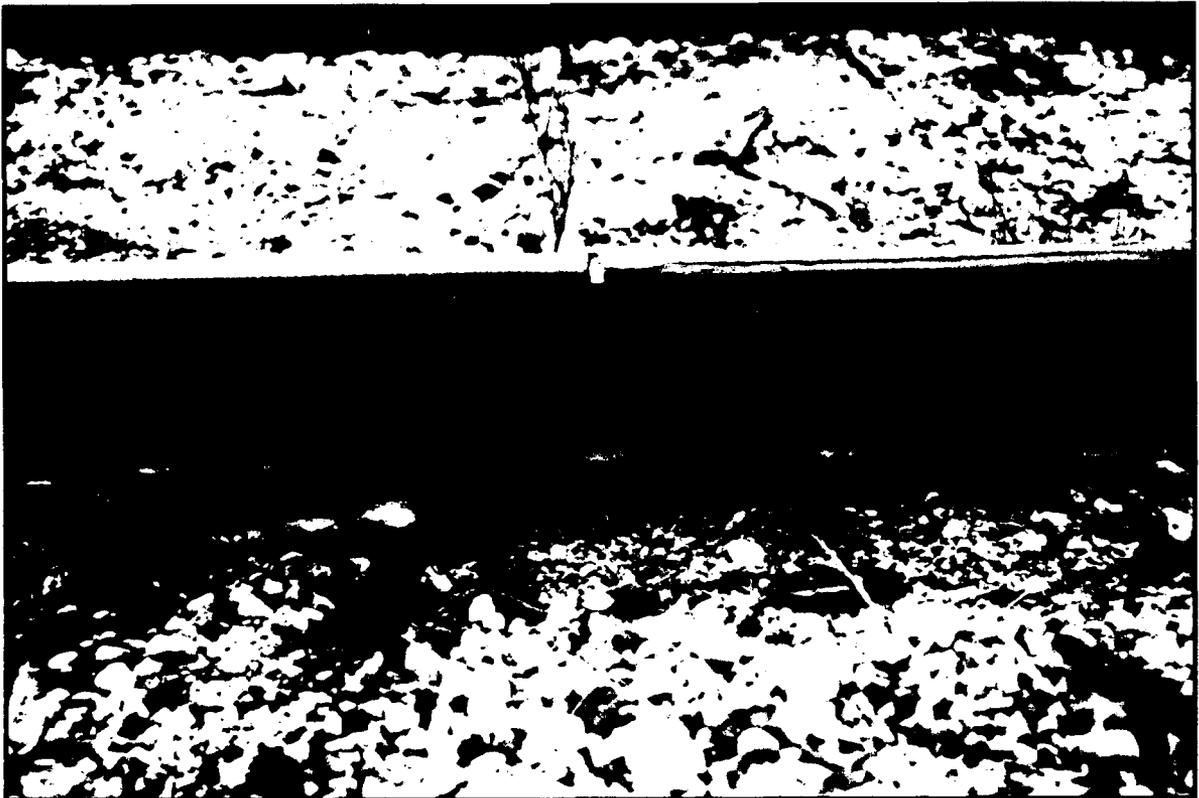
R2L
Joint Defect, Low Severity
(Loose Bolt)



R2M
Joint Defect, Medium Severity
(All Bolts at Joint Loose)



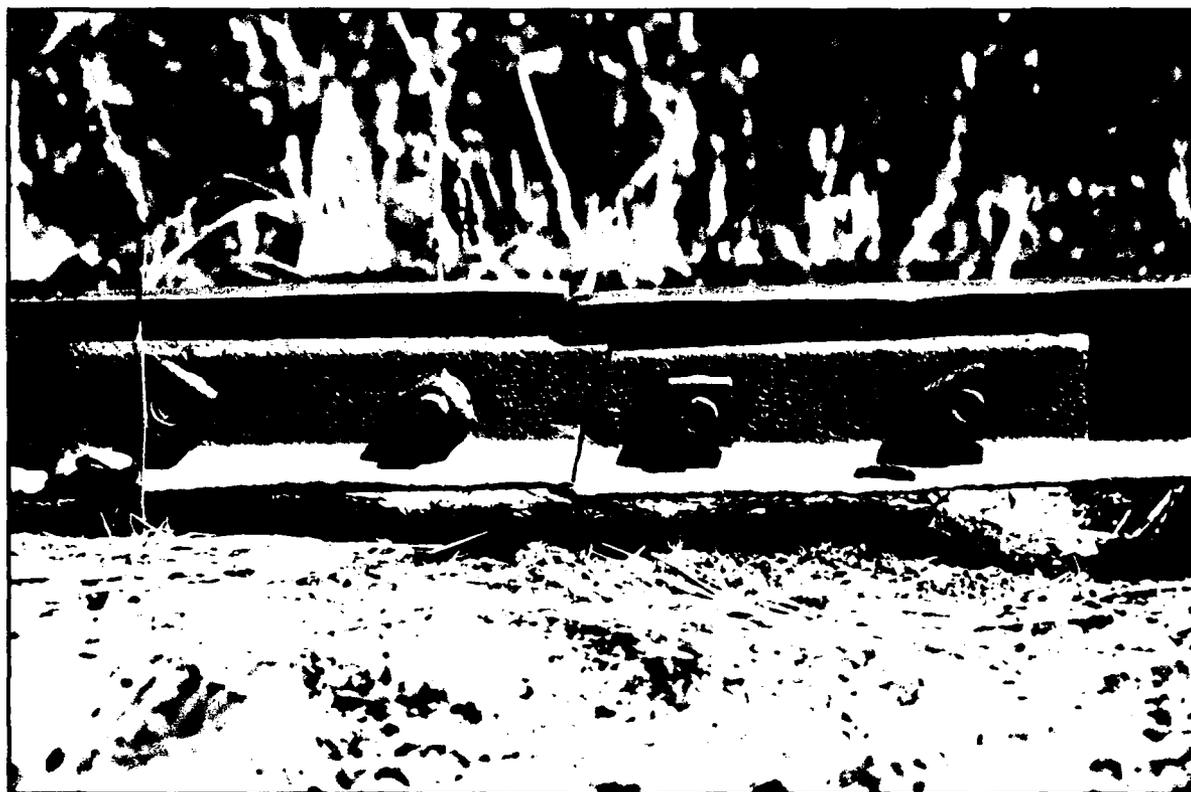
R2M
Joint Defect, Medium Severity
(Only One Bolt per Rail End)



R2H
Joint Defect, High Severity
(Both Bars Center Cracked [Other bar is hidden from view])



R2VH
Joint Defect, Very High Severity
(All Bolts on a Rail End Broken)



R2VH
Joint Defect, Very High Severity
(Both Bars Broken [Other bar is hidden from view])

R3. Hold-Down Device Defects

Description: Hold-down devices are considered defective if they fail to secure the rail properly to the tie or if they are placed in an improper pattern or position.

Severity Levels:

L - Improper pattern or position

M - Loose, bent, broken, missing or otherwise defective

Note: If spikes or other devices are loose or missing due to the tie being defective, this distress is not counted.

Measurement: Each spike, clip, etc.

Density:
$$\frac{\text{Number of Defective Spikes, etc.}}{\text{Number of Ties in Sample Unit} \times 4}$$

Cause: Hold-down device defects occur from improper installation, defective ties, and vibrations and deflections imposed from train operations.



R3L
Hold-Down Device Defect, Low Severity
(Improper Pattern)



R3M
Hold-Down Device Defect, Medium Severity (Missing Spike)

R4. Tie Plate Defects

Description: Tie plates are considered defective if they are in an improper position, cracked, bent, broken, or corroded.

Severity Levels:

None

Measurement: Each plate

Density
$$\frac{\text{Number of Defective Plates}}{\text{Number of Ties in Sample Unit} + 2}$$

Cause: Tie plate defects generally occur from improper handling or installation, defective ties, and missing hold-down devices. Vibrations, deflections, and excessive wheel loads imposed from train operations can cause plates to break, bend, or crack from fatigue.



R4
Tie Plate Defect
(Broken)



R4
Tie Plate Defect
(Improper Position)

R5. Gauge Rod Defects

Description: Gauge rods are considered defective if they are cracked, broken, loose, or bent (resulting in improper gauge).

Severity Levels:

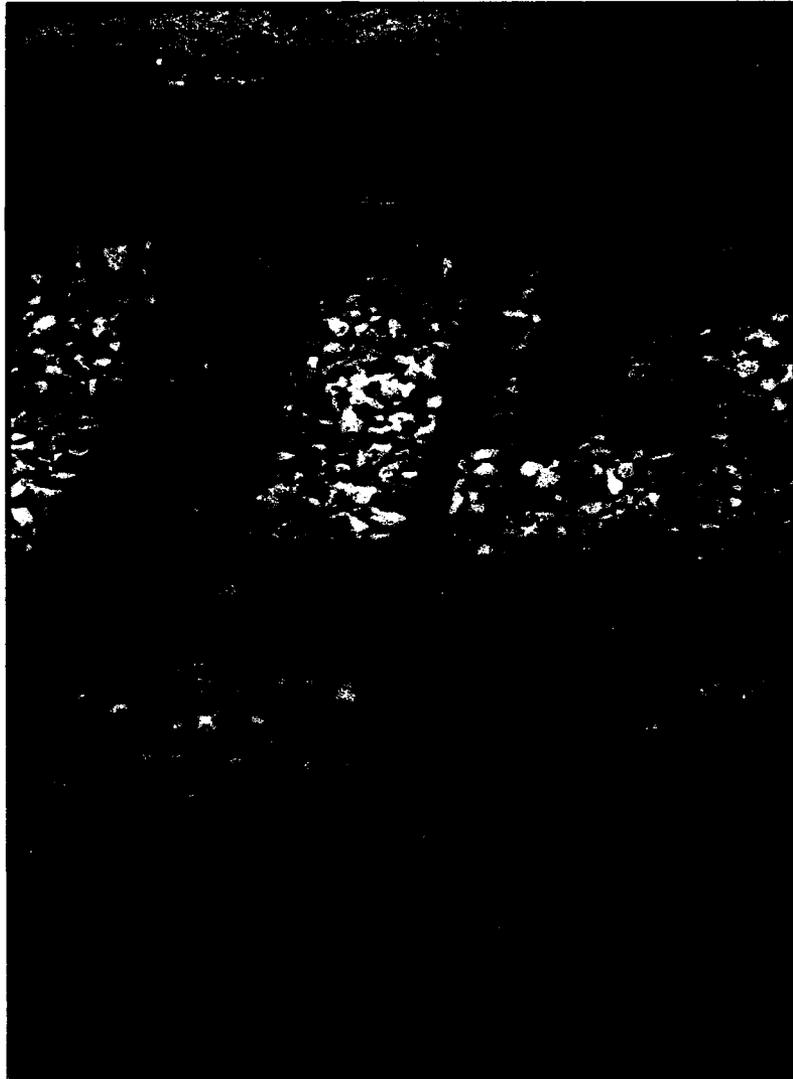
None

Measurement: Each gauge rod

Density:
$$\frac{\text{Number of Defective Gauge Rods}}{\text{Sample Unit Length}}$$

Cause: Gauge rod defects generally occur from improper handling or installation, vibrations from train operations, fatigue from wheel loads, and derailments.

Note: This distress is only counted if the use of a gauge rod is still warranted.



**R5
Gauge Rod Defect (Broken)**

R6. Rail Anchor Defects

Description: Rail anchors are considered defective if they are improperly positioned, loose, or missing (if originally installed).

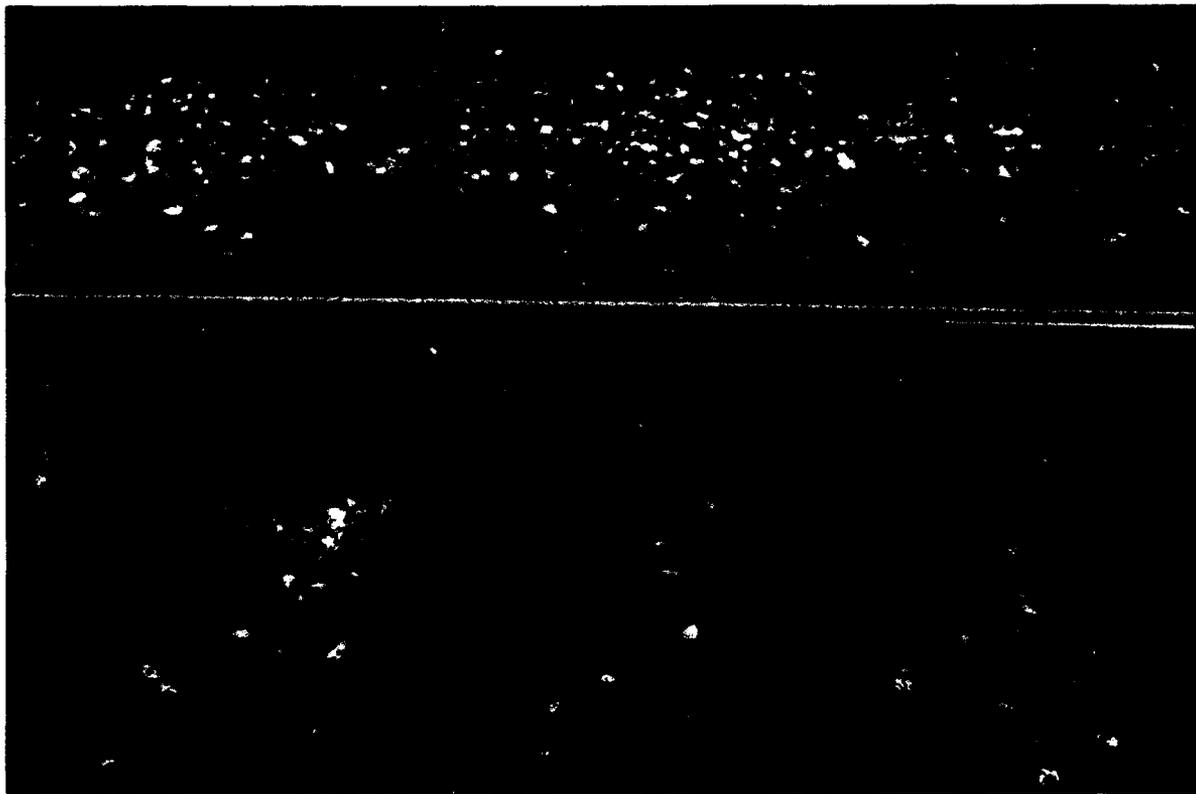
Severity Level:

None

Measurement: Each anchor

Density:
$$\frac{\text{Number of Defective Anchors}}{\text{Number of Ties in Sample Unit} + 4}$$

Cause: Rail anchor defects generally occur from improper installation and rail and/or tie movement.



**R6
Rail Anchor Defect
(Improper Position)**

4 TIE COMPONENT GROUP DISTRESSES

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T1. Single Defective Ties

Description: A tie is considered defective if it is rotten, hollow, split, or impaired to the extent that spikes or other hold-down devices cannot be secured; broken through; cut more than 2 in.; permits tie plate movement more than 0.5 in.; or is generally deteriorated to a degree that it no longer performs as desired.

Severity Levels:

L - Tie located anywhere except at a joint

M - Joint tie when a nondefective tie exists at the same joint

Note: If a single defective tie is the only joint tie, distress T5 governs.

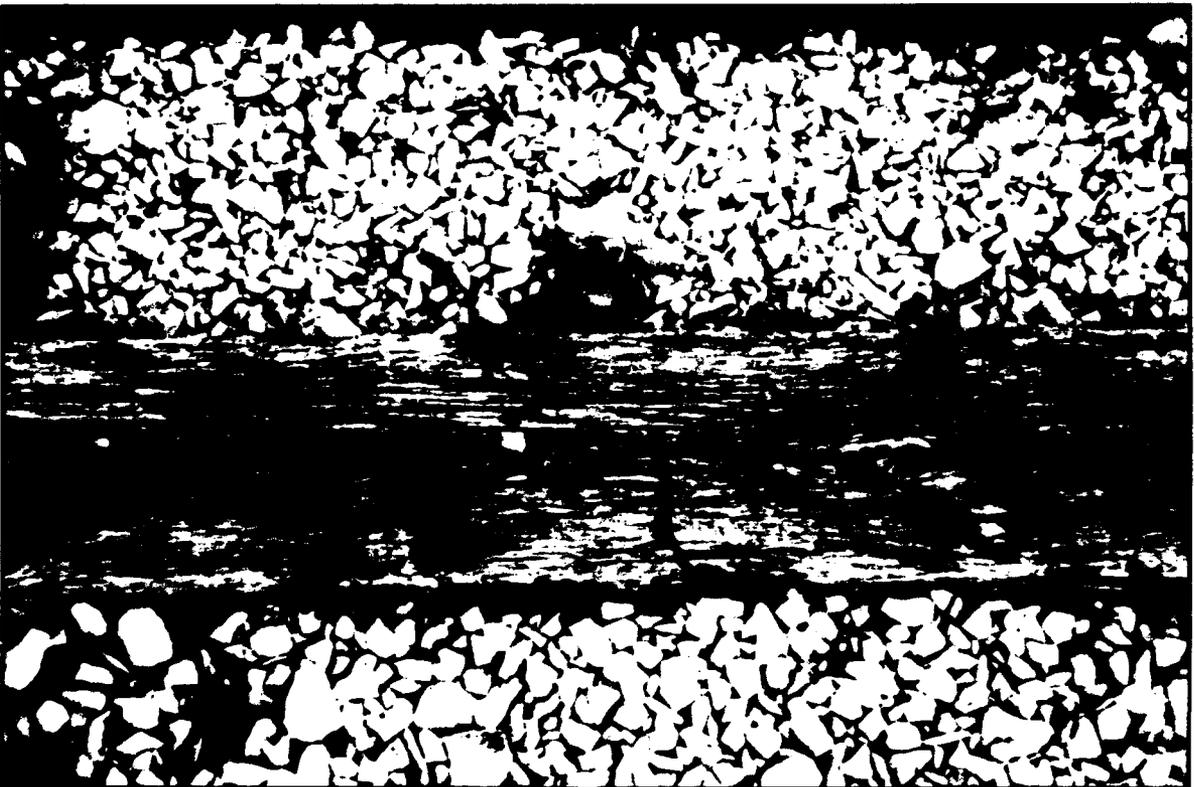
Measurement: Each Tie

Density:
$$\frac{\text{Number of Defective Ties}}{\text{Number of Ties in Sample Unit}}$$

Cause: Ties become defective from natural causes, use, and abuse. Decay, rot, insect infestation, and splitting from aging and drying are natural causes of wood deterioration. Climatic factors and poor drainage add to the deterioration. Wheel loads crush wood fibers, lead to mechanical wear, and loosen hold-down devices. Coupled with poor ballast support, ties can break under load. Abuse in handling, installation, and maintenance diminishes the wood treatment and leads to spike-kill. Derailments can severely damage ties.



T1L
Single Defective Tie, Low Severity
(Broken Under Rail Seat)



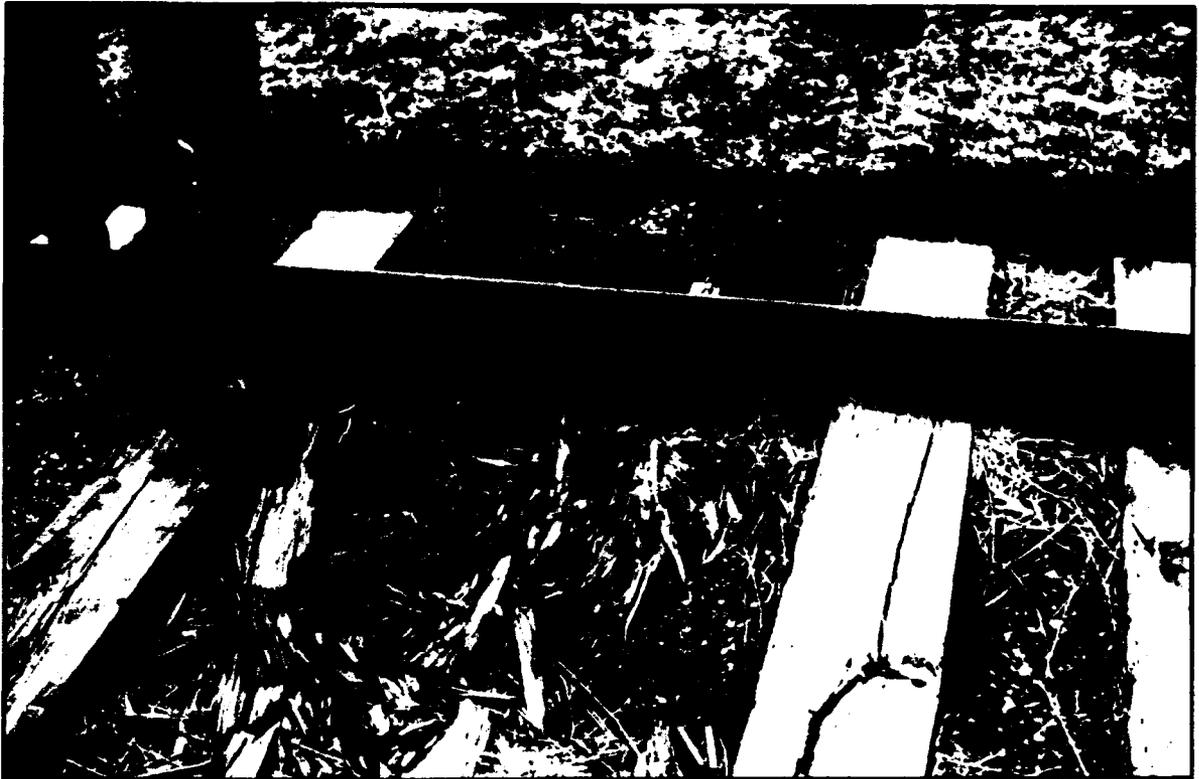
T1L
Single Defective Tie, Low Severity
(Broken at Center)



T1L
Single Defective Tie, Low Severity
(Cut More Than 2 in.)



T1L
Single Defective Tie, Low Severity
(Split)



T1L
Single Defective Tie, Low Severity
(Rotten)



T1M
Single Defective Tie, Medium Severity

T2. Isolated Defective Tie Clusters

Description: A defective tie cluster of any size is considered isolated if two or more nondefective ties separate it from any other cluster.

- Notes:**
- 1) If distress T3 or T5 is counted, this distress is not counted for the same cluster.
 - 2) If six-in-a-row defective ties are present in the same cluster, the cluster shall be divided into a cluster of five and the remaining tie treated as distress T1L.

Severity Levels:

L - Two-in-a-row defective ties

M - Three-in-a-row defective ties

H - Four-in-a-row defective ties

VH - Five-in-a-row defective ties

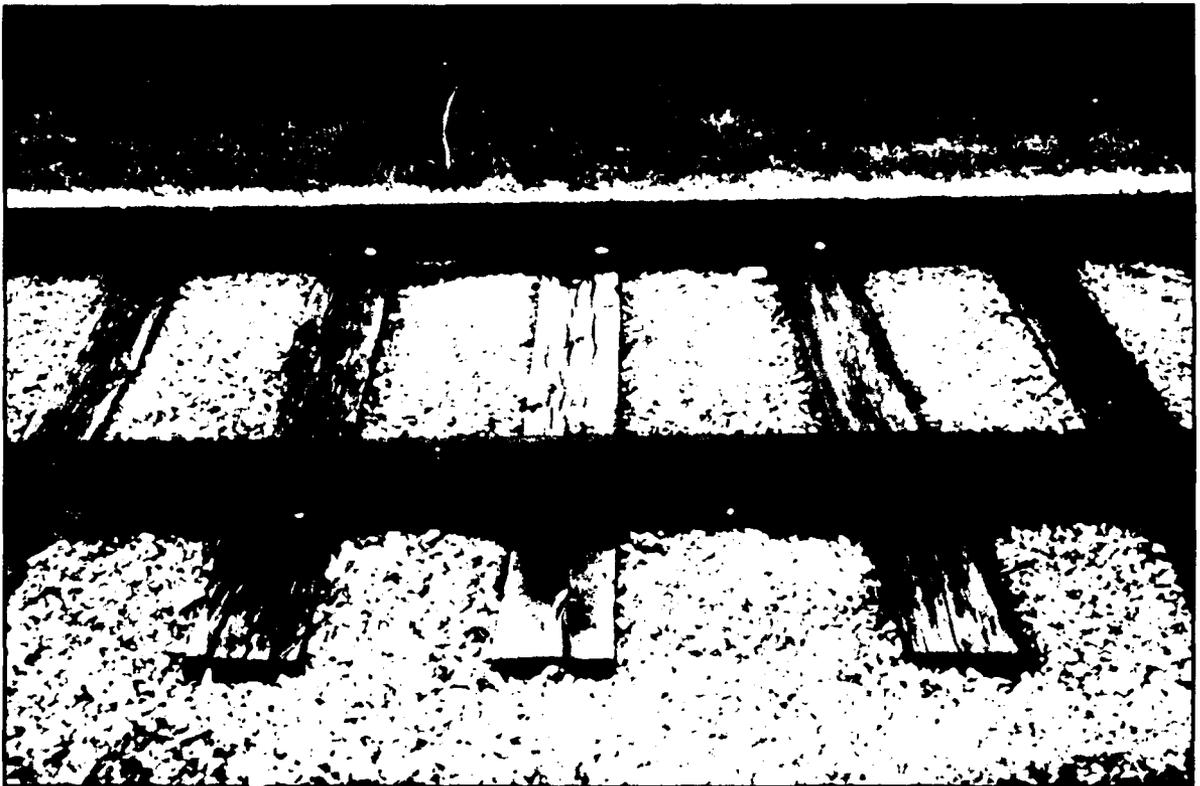
Measurement: Each Cluster

Density:
$$\frac{\text{Number of Clusters} * 2, 3, 4, \text{ or } 5 (\text{depending on severity level})}{\text{Number of Ties in Sample Unit}}$$

Cause: Same as for single defective ties. As ties deteriorate, wheel loads are transferred to adjacent ties, thus accelerating their deterioration.



T2L
Isolated Defective Tie Cluster,
Low Severity



T2M
Isolated Defective Tie Cluster,
Medium Severity



T2H
Isolated Defective Tie Cluster,
High Severity



T2VH
Isolated Defective Tie Cluster,
Very High Severity

T3. Isolated Defective Tie Clusters That Include One Joint Tie

Description: A defective tie cluster of any size is considered isolated if two or more nondefective ties separate it from any other cluster. One joint tie will be either the first or last tie of the cluster.

Notes: 1) This distress assumes that a nondefective joint tie accompanies the defective joint tie. If not, the cluster should be divided so that distresses T4 and T5 pertain.

2) If six-in-a-row defective ties are present in the same cluster, the cluster shall be divided into a cluster of five and the remaining tie treated as distress T1L.

Severity Levels:

L - Two-in-a-row defective ties

M - Three-in-a-row defective ties

H - Four-in-a-row defective ties

VH - Five-in-a-row defective ties

Measurement: Each Cluster

Density:
$$\frac{\text{Number of Clusters} \times 2, 3, 4, \text{ or } 5 \text{ (depending on severity level)}}{\text{Number of Ties in Sample Unit}}$$

Cause: Same as for single defective ties. As ties deteriorate, wheel loads are transferred to adjacent ties, thus accelerating their deterioration.



T3L
Isolated Defective Cluster That Includes One Joint Tie, Low Severity



T3M
Isolated Defective Cluster That Includes One Joint Tie, Medium Severity



T3H
Isolated Defective Cluster That Includes One Joint Tie, High Severity



T3VH
Isolated Defective Cluster That Includes One Joint Tie, Very High Severity

T4. Adjacent Defective Tie Clusters

Description: A defective tie cluster of any size is considered adjacent if one or no nondefective ties separate it from any other cluster.

Notes: 1) If more than six-in-a-row defective ties are present in the same cluster, the cluster shall be divided into smaller clusters in groups of five with any remainder constituting a final appropriately sized cluster of this distress type.

2) If a cluster contains more than two-in-a-row defective ties and that cluster includes all joint ties, the cluster shall be divided into smaller clusters beginning with distress T5. Remaining ties shall be treated as this distress and/or distress T1 (low severity).

Severity Levels:

L - Two-in-a-row defective ties

M - Three-in-a-row defective ties

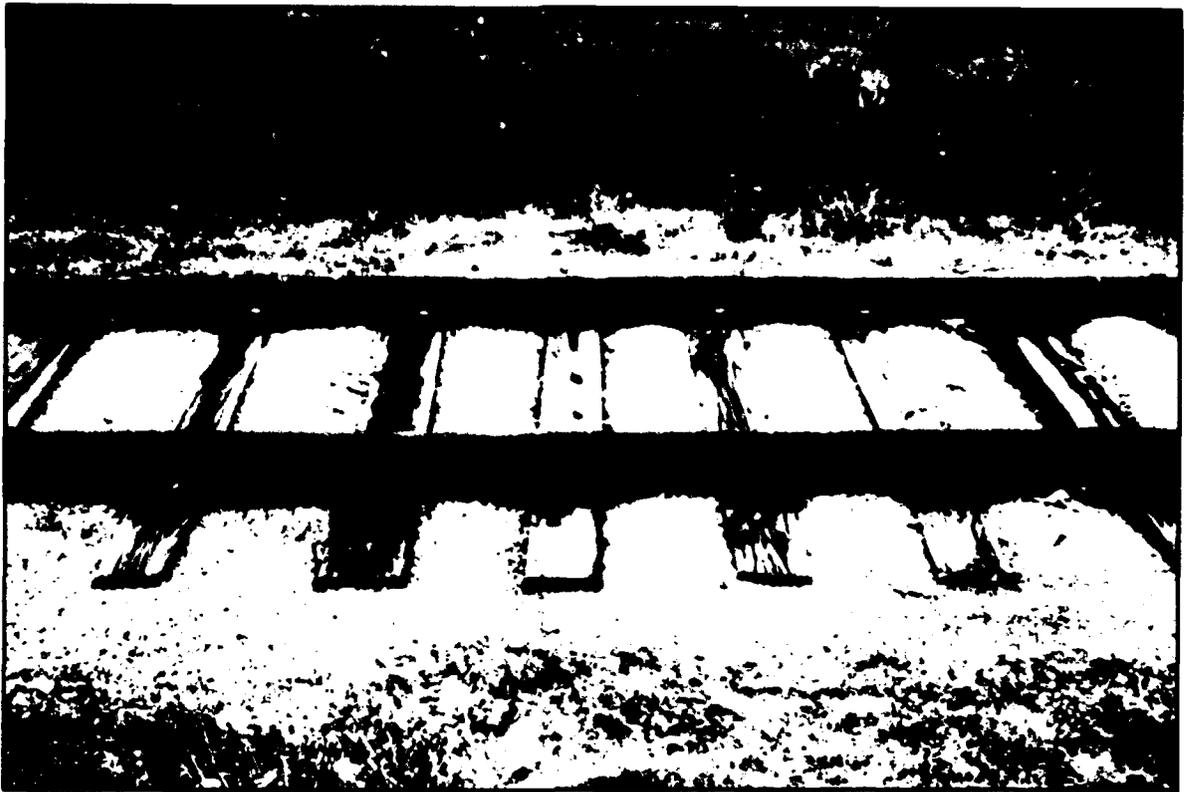
H - Four-in-a-row defective ties

VH - Five-in-a-row defective ties

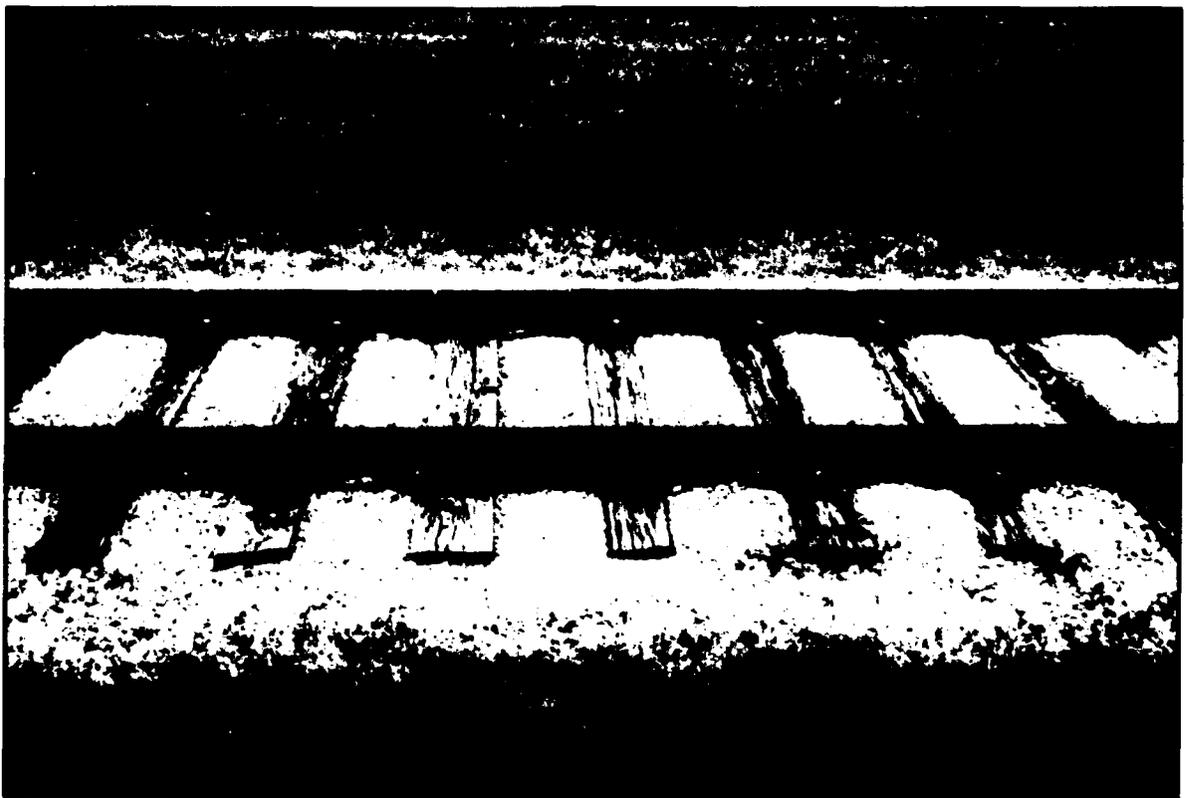
Measurement: Each Cluster

Density:
$$\frac{\text{Number of Clusters} * 2, 3, 4, \text{ or } 5 \text{ (depending on severity level)}}{\text{Number of Ties in Sample Unit}}$$

Cause: Same as for single defective ties. As ties deteriorate, wheel loads are transferred to adjacent ties, thus accelerating their deterioration.



T4L/T4L
Adjacent Defective Tie Clusters,
Low Severity and Low Severity



T4M/T4L
Adjacent Defective Tie Clusters,
Low Severity and Medium Severity



T4HT4M
Adjacent Defective Tie Clusters,
High Severity and Medium Severity

T5. All Joint Ties Defective

Description: Depending on tie positioning in relation to a joint, one or two ties will be considered joint ties. If these one or two ties are defective, this distress pertains.

Note: If more than two-in-a-row defective ties are present in the same cluster and that cluster includes all joint ties, the cluster shall be divided into smaller clusters beginning with this distress. Remaining ties shall be treated as distress T4 and/or distress T1 (low severity).

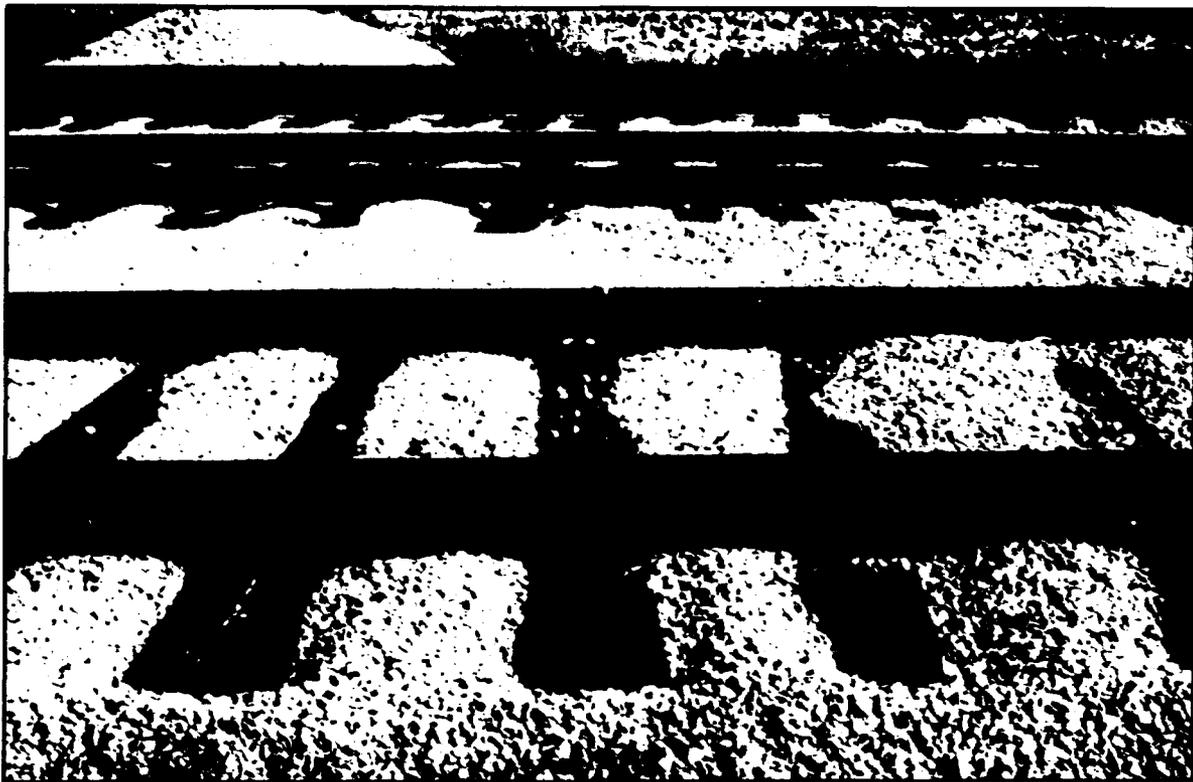
Severity Levels:

None

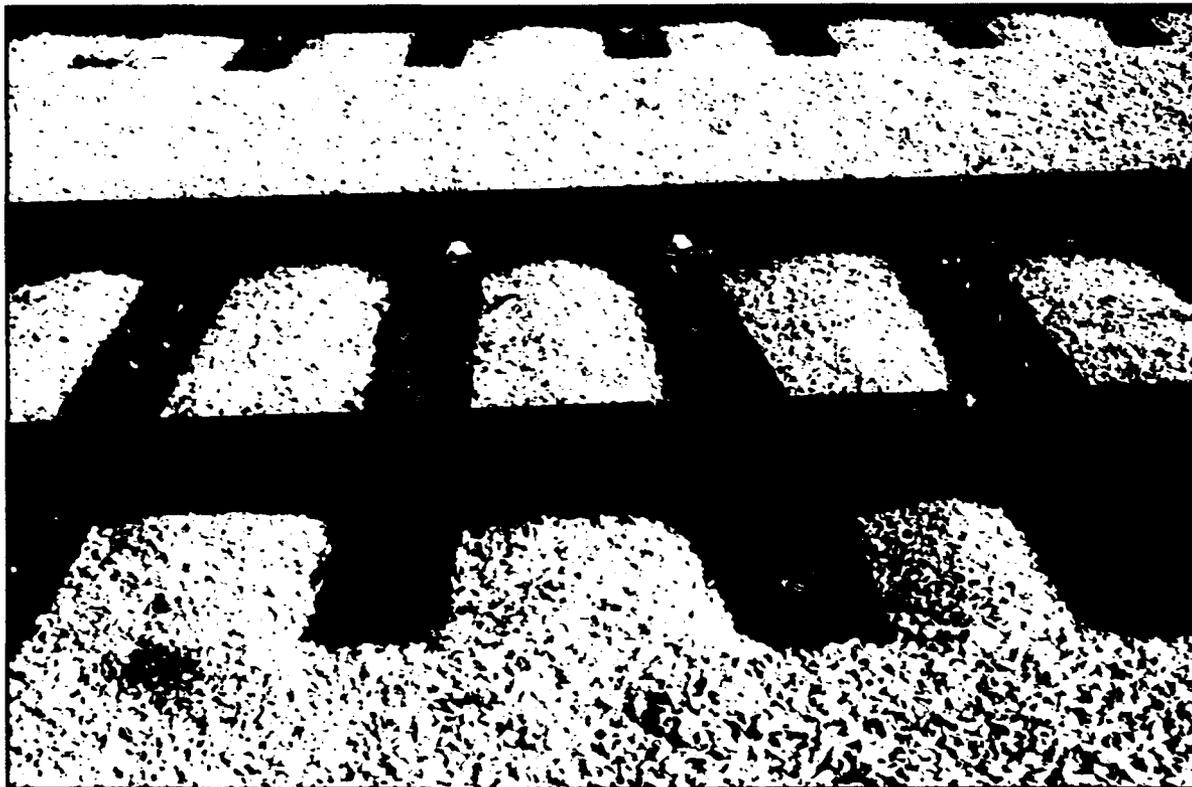
Measurement: Each Tie

Density:
$$\frac{\text{Number of Defective Ties}}{\text{Number of Ties in Sample Unit}}$$

Cause: Same as for single defective ties. However, since joints in the rail are structurally weak points, joint ties are subject to increased loading, which can accelerate deterioration.



T5
All Joint Ties Defective
(One Tie)



T5
All Joint Ties Defective
(Two Ties)

T6. Missing Ties

Description: This distress occurs when ties are physically missing from the track structure. This may include one joint tie when another tie is present at the same joint.

Note: If more than three-in-a-row missing ties are present in the same cluster, the cluster shall be divided into smaller clusters of three with any remainder constituting a final appropriately sized cluster or single tie.

Severity Levels:

L - Single missing tie

M - Two-in-a-row missing ties

H - Three-in-a-row missing ties

Measurement: Each Cluster

Density:
$$\frac{\text{Number of Clusters} * 1, 2, \text{ or } 3 \text{ (depending on severity level)}}{\text{Number of Ties in Sample Unit}}$$

Cause: Ties may be missing because they were never installed or they may have been removed for use elsewhere.



T6L
Missing Tie, Low Severity



T6L
Missing Tie, Low Severity



T6M
Missing Ties, Medium Severity



T6H
Missing Ties, High Severity

T7. All Joint Ties Missing

Description: Depending on tie positioning in relation to a joint, one or two ties will be considered joint ties. If these one or two ties are missing, this distress pertains.

Note: If two-in-a-row or more missing ties are present in the same cluster and that cluster includes all joint ties, the cluster shall be divided into smaller clusters beginning with this distress. Remaining ties shall be treated as distress T6.

Severity Levels:

None

Measurement: Each Tie

Density:
$$\frac{\text{Number of Missing Ties}}{\text{Number of Ties in Sample Unit}}$$

Cause: Ties may be missing because they were never installed or they may have been removed for use elsewhere.

T8. Improperly Positioned Ties

Description: Ties are improperly positioned if they are skewed, rotated, or bunched.

Severity Levels:

L - Any of the following: Tie rotated on its longitudinal axis to the point where the rail does not sit flush on the tie plate and/or tie; tie skewed over 8 in. or a standard tie width; or tie bunched over 8 in. or standard tie width.

Note: This distress is not counted if the tie is also defective.

M - Center-to-center spacing between any two ties along either rail greater than 48 in., but spacing does not span a joint.

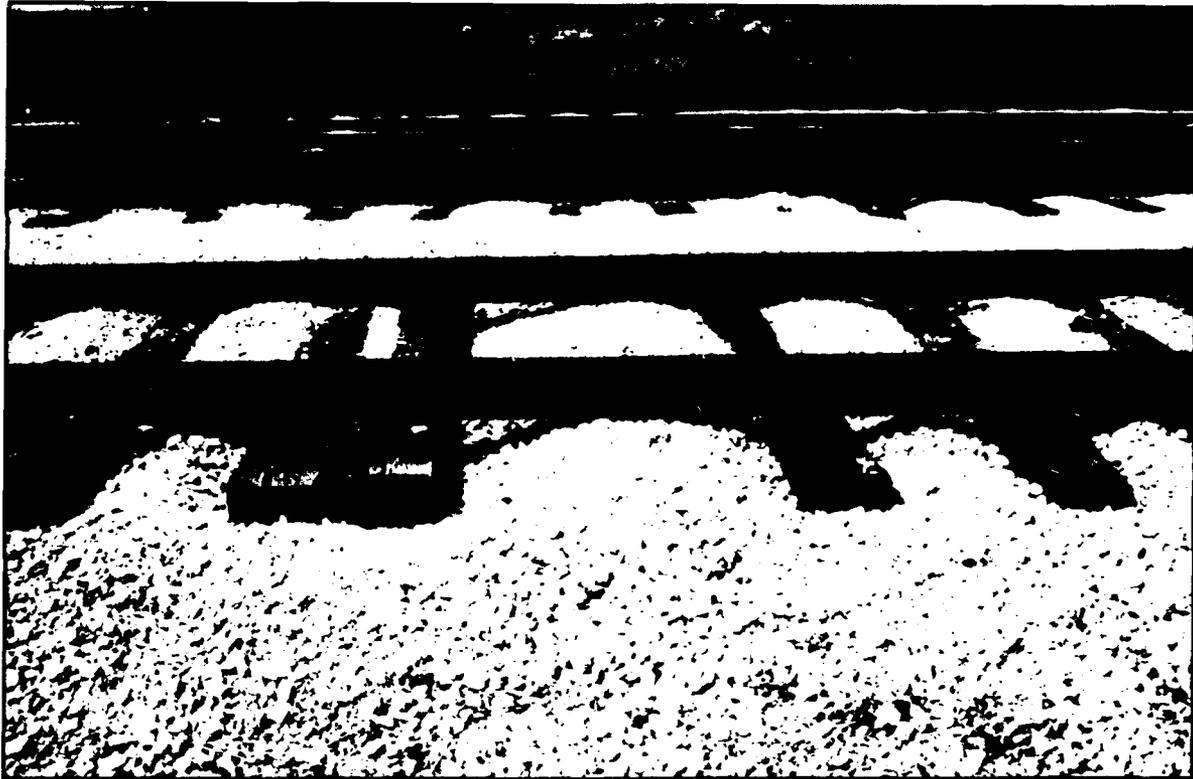
H - Center-to-center spacing between any two ties along either rail greater than 48 in., and spacing spans a joint.

Note: If excessive center-to-center spacing is due to two or more missing ties, only distress T6 or T7 pertains. If the excessive spacing is due to a combination of a single missing tie and skewing or bunching, include the missing tie (distress T6 or T7) as a separate distress.

Measurement: Each Tie or Wide Spacing, as appropriate

Density:
$$\frac{\text{Number of Improperly Positioned Ties or Wide Spaces}}{\text{Number of Ties in Sample Unit}}$$

Cause: Ties may be improperly positioned due to improper installation, poor ballast support, lack of crib ballast, rail movement, and vibrations and deflections from train operations.



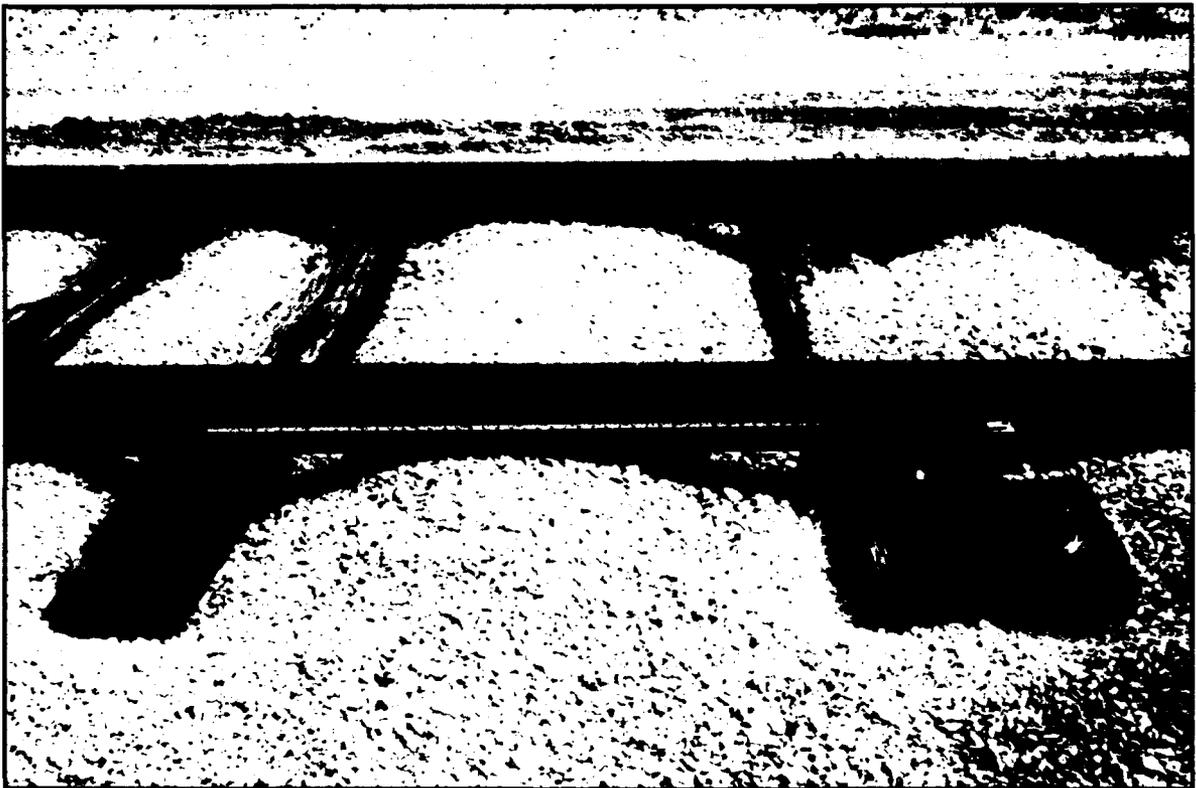
T8L
Improperly Positioned Tie, Low Severity (Bunched)



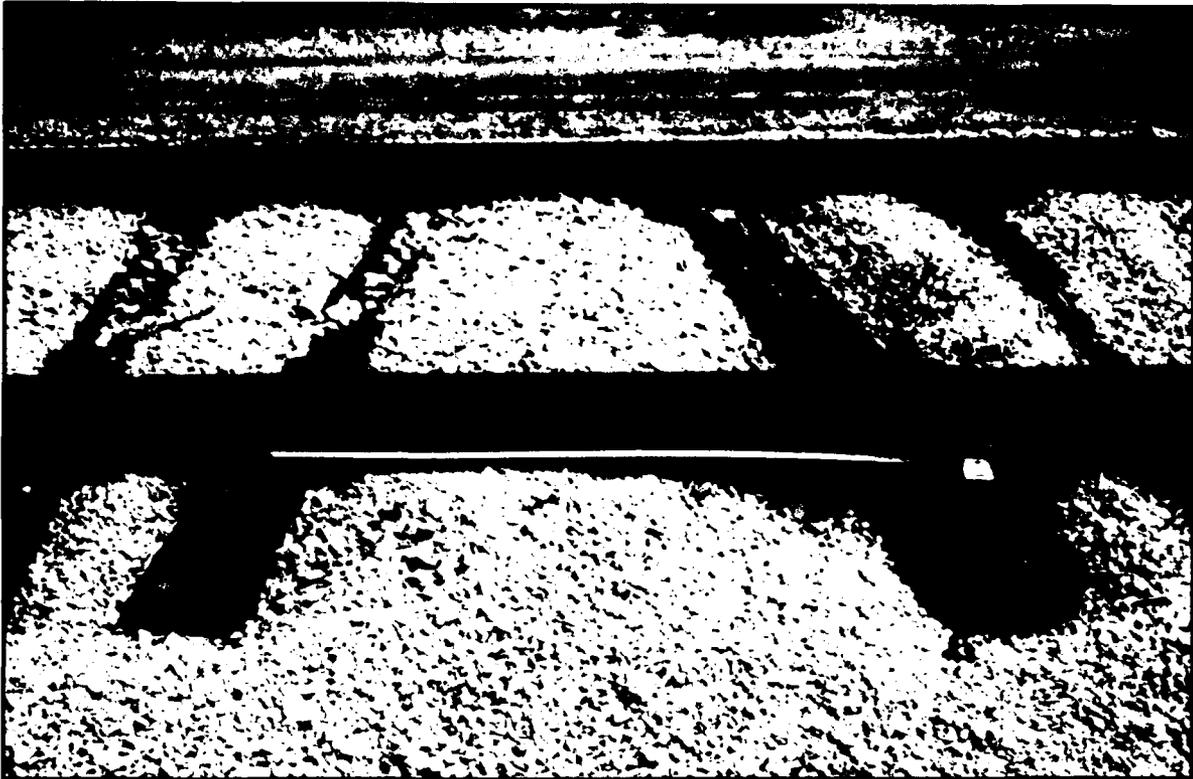
T8L
Improperly Positioned Tie, Low Severity
(Rotated)



T8L
Improperly Positioned Tie, Low Severity
(Skewed)



T8M
Improperly Positioned Ties,
Medium Severity



T8H
Improperly Positioned Ties, High Severity

5 BALLAST, SUBGRADE, AND ROADWAY COMPONENT GROUP DISTRESSES

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B1. Dirty (Fouled) Ballast

Description: Ballast is considered dirty if fine material is present filling the voids between the large aggregate particles. Drainage through ballast is seriously impaired and/or intergranular contact between large aggregate particles is not maintained.

Severity Levels:

None

Measurement: Linear Feet of Track

Density:
$$\frac{\text{Distress Linear Feet}}{\text{Sample Unit Length}}$$

Cause: Ballast becomes dirty or fouled from several sources. Contamination results from subgrade intrusion, droppings from cars of coal, sand, etc., and wind or water deposition of fine material. Also, ballast may wear or disintegrate from mechanical abrasion and weathering causing fine material to form in place.



B1
Dirty (Fouled) Ballast



B1
Dirty (Fouled) Ballast

B2. Vegetation Growth

Description: This distress occurs when plant life is growing in the track structure.

Severity Levels:

L - Growing in ballast, obstructing vision, making walking difficult within 8 ft of the track centerline, brushing sides or bottoms of cars, or presenting fire hazard at timber bridges or trestles

M - Interferes with track inspection

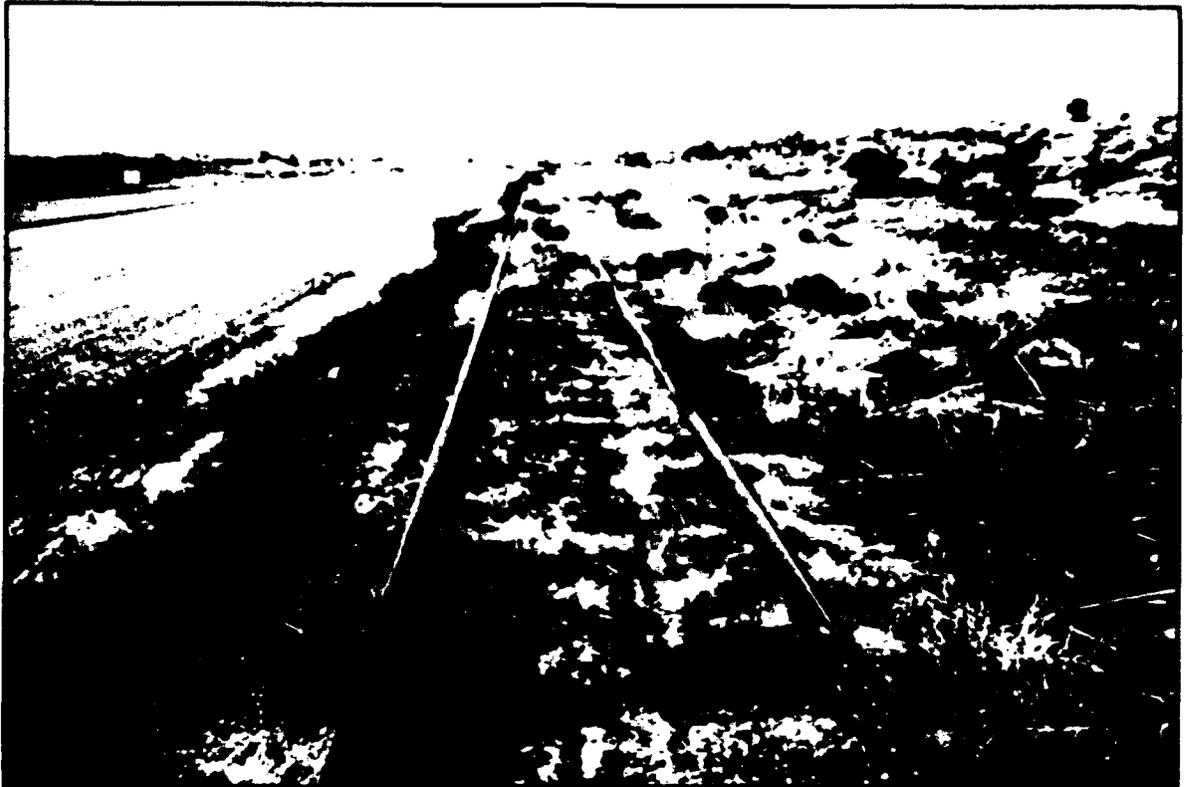
H - Interferes with train movements

VH - Prevents train movements

Measurement: Linear Feet of Track

Density:
$$\frac{\text{Distress Linear Feet}}{\text{Sample Unit Length}}$$

Cause: Seeds may be blown in by the wind, deposited by water, or dropped from freight cars. Extensive root structure from vegetation growing along right-of-way may cause sprouting in track structure. Combinations of water and fine material in ballast and/or subgrade are needed to sustain growth.



B2L
Vegetation Growth, Low Severity



B2M
Vegetation Growth, Medium Severity



B2H
Vegetation Growth, High Severity



B2VH
Vegetation Growth, Very High Severity

B3. Settlement of Ballast and/or Subgrade

Description: Settlement consists of a permanent deformation of the ballast or subgrade resulting in profile, warp, or crosslevel deviations in the track.

Severity Levels:

Maximum profile, crosslevel, or warp measurements for a given geometry deviation as shown below:

Sev Level	Profile	Crosslevel	Warp
L	≥0.75 in. ≤2.25 in.	≥0.50 in. ≤1.50 in.	≥0.50 in. ≤1.75 in.
M	>2.25 in. ≤2.75 in.	>1.50 in. ≤2.25 in.	>1.75 ≤2.25 in.
H	>2.75 in. ≤3.00 in.	>2.25 in. ≤3.00 in.	>2.25 in. ≤3.00 in.
VH	>3.00 in.	>3.00 in.	>3.00 in.

Measurement: Linear Feet of Track Associated with a Given Geometry Deviation

Notes:

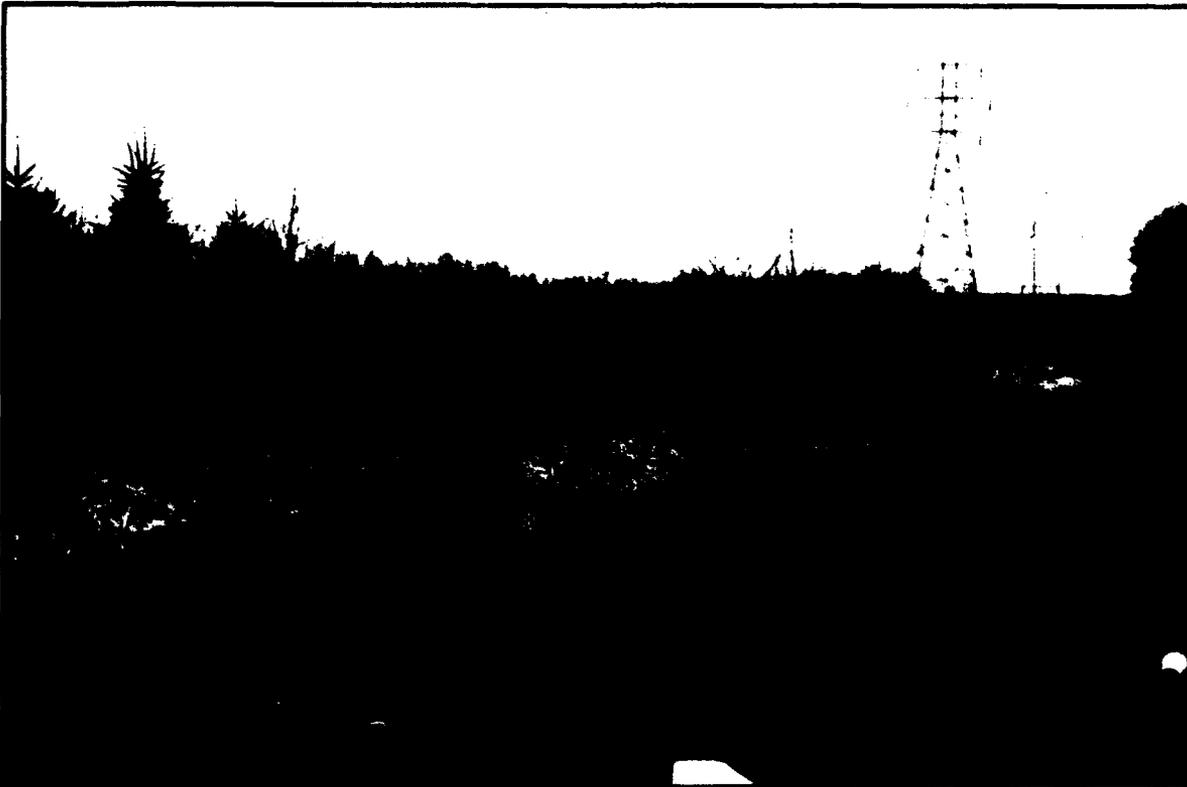
- 1) Record the type of geometry deviation along with its maximum value.
- 2) Only record the deviation type having the greatest measurement value for a given geometry deviation.
- 3) Record each geometry deviation occurrence separately.
- 4) Locations on bridges or at bridge approaches or other track structures should be specifically noted.

Density:

$$\frac{\text{Distress Linear Feet}}{\text{Sample Unit Length}}$$

Cause: Permanent deformation of the support ballast and/or subgrade is caused by a combination of weak materials and repetitive wheel loads. The support ballast and/or subgrade will compact, consolidate, or move under load. Settlement will normally be irregular due to variances in track structure and subgrade strength.

Note: If geometry problems are due to defective ties do not count this distress.



B3
Settlement of Ballast and/or Subgrade
(Geometry measurement determines severity level)



B3L
Settlement of Ballast and/or subgrade,
Low Severity
(Profile measurement)



B3L
Settlement of Ballast and/or Subgrade,
Low Severity



B3M
Settlement of Ballast and/or Subgrade at a Bridge, Medium Severity

B4. Hanging Ties at Bridge Approach

Description: A hanging tie situation exists when a depression is present under one or more ties at a bridge abutment. The size of the depression may result in ties being partially or completely unsupported by the ballast. If the fastener between a given tie and the rail is intact, the tie will "hang" from the rail. If the fastener between a given tie and the rail has failed, the tie may have dropped into the depression.

Severity Levels:

None

Measurement: Each Tie

Density:

$$\frac{\text{Number of Hanging Ties}}{\text{Number of Ties in Sample Unit}}$$

Cause: This distress occurs when settlement or consolidation of fill material behind a bridge abutment results in a lack of tie support.

Note: If hanging ties occur due to erosion, distress B9 governs.



B4
Hanging Ties at Bridge Approach



B4
Hanging Ties at Bridge Approach

B5. Center Bound Track

Description: A center bound track condition exists when a loss of contact area between the ballast and outer portion of the tie has occurred. Depending on the tie condition, a loss of contact area may exist between the tie and the rail. The tie end will deflect or rock when stepped on, giving the impression that the tie is loose.

Note: If tie deflections result in Distress B6, Pumping Ties, do not count this distress.

Severity Levels:

L - Condition occurs at any tie except a joint tie

M - Condition occurs at a joint resulting in a hanging joint

Measurement: Each Tie

Density:
$$\frac{\text{Number of Affected Ties}}{\text{Number of Ties in Sample Unit}}$$

Cause: Wheel loads result in deflections of the outer portions of ties. Over time, the ballast under the tie ends may become compacted or a plastic deformation may occur resulting in a permanent deformation in the ballast section. Since the center of the tie is virtually unloaded, a loss of contact area between the tie and ballast occurs at the outer portions of the tie.



B5L
Center Bound Track, Low Severity
(Note shadow under tie)



B5M
Center Bound Track, Medium Severity
(Note gap between rail and tie plate)

B6. Pumping Ties

Description: Muddy track or a hard mass of soil material that has formed around ties as a result of being forced out of the ballast section due to tie deflections and water accumulation.

Notes:

- 1) If this distress is present, do not count distress B5, Center Bound Track.
- 2) Distress B1, Dirty Ballast, must be counted in addition to this distress.

Severity Levels:

L - Pumping at only one end of any tie

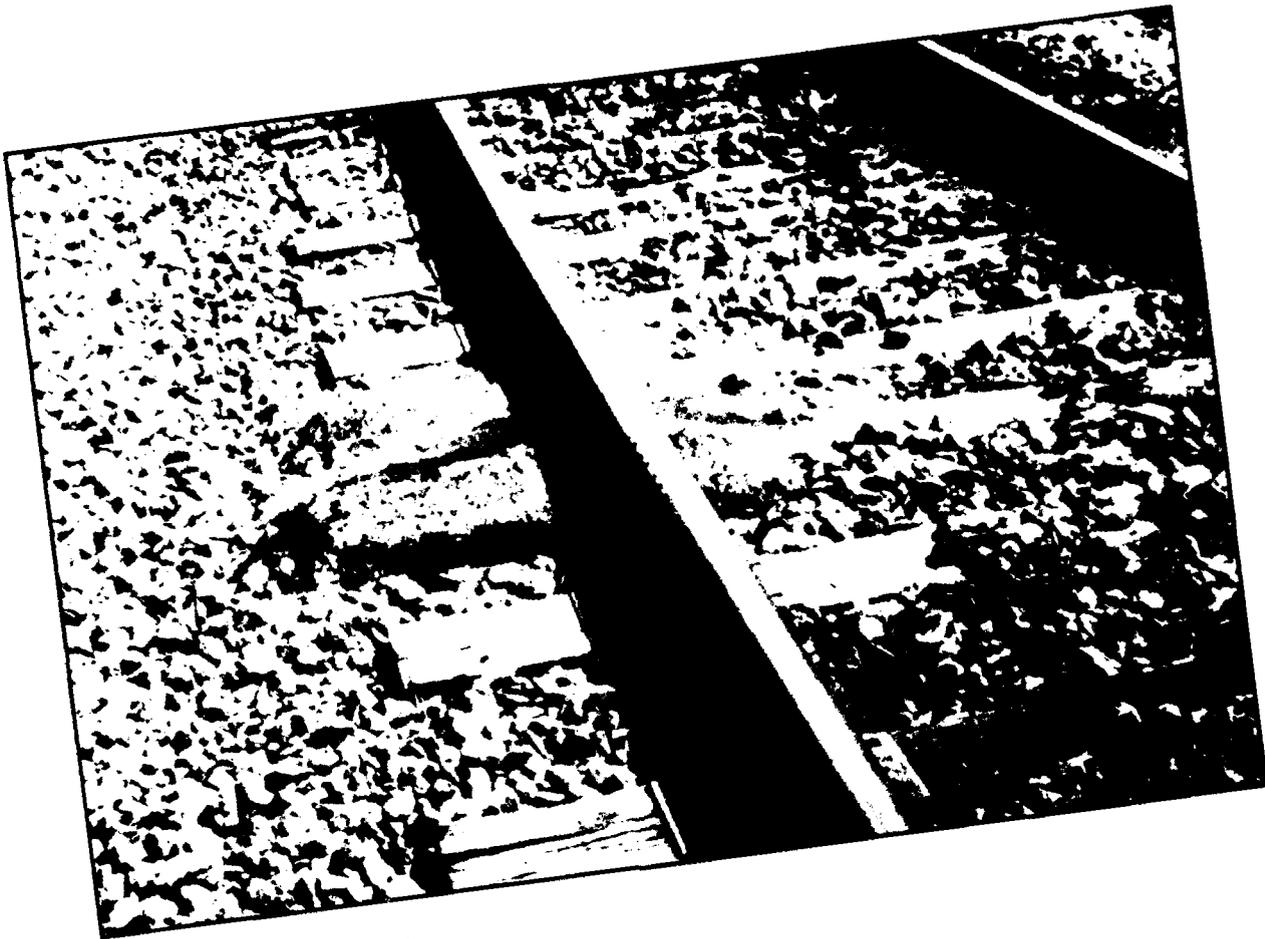
M - Pumping at both ends of any tie

H - Pumping at only the end of a joint tie supporting the joint

Measurement: Each Tie

Density:
$$\frac{\text{Number of Pumping Ties}}{\text{Number of Ties in Sample Unit}}$$

Cause: A combination of dirty ballast, water, and traffic results in fine material being liquified from tie deflection and forced through the ballast section leaving a muddy condition that may harden into an impermeable mass.



B6L
Pumping Ties, Low Severity



B6L
Pumping Ties, Low Severity



B6M
Pumping Ties, Medium Severity



B6H
Pumping Ties, High Severity

B7. Alignment Deviation

Description: Track that has moved in a lateral direction from its designated position.

Severity Levels:

Maximum alignment deviation at a given location as shown below:

Sev Level	Alignment Deviation
L	≥0.50 in. to ≤2.00 in.
M	>2.00 in. to ≤3.00 in.
H	>3.00 in. to ≤5.00 in.
VH	>5.00 in.

Measurement: Linear Feet of Track Associated with a Given Maximum Deviation

Note: Record the maximum deviation measurement value.

Density:
$$\frac{\text{Distress Linear Feet}}{\text{Sample Unit Length}}$$

Cause: An alignment deviation may occur due to insufficient shoulder ballast needed to resist lateral train forces on track, insufficient support ballast and/or weak subgrade material causing track movement from repetitive wheel loads, and climatic or natural factors such as thermal expansion of rail and earth movement associated with slope stability or other factors.

Note: If geometry problems are caused by defective ties, do not count this distress.



B7
Alignment Deviation (Geometry measurement determines severity level)



B7M
Alignment Deviation, Medium Severity
(Alignment measurement)

B8. Insufficient Crib/Shoulder Ballast

Description: A lack or shortage of ballast in the shoulder and/or crib areas of track results in this distress.

Severity Levels:

None

Measurement: Linear Feet of Track

Note: Each shoulder and the crib area are measured separately. The results are totaled for the density calculation.

Density:
$$\frac{\text{Distress Linear Feet}}{\text{Sample Unit Length} \times 3}$$

Cause: A lack of crib or shoulder ballast may occur due to lack of placement during construction or rehabilitation. Shoulder ballast may have been removed or reduced due to construction, rehabilitation, or other work adjacent to the track.



B8
Insufficient Crib/Shoulder Ballast
(Crib)



B8
Insufficient Crib/Shoulder Ballast
(Shoulder - One Side)

B9. Erosion of Ballast

Description: Erosion consists of the loss of ballast from the shoulder, crib, or both areas resulting in a reduction in ballast cross section.

Severity Levels:

L - Erosion of shoulder ballast (single side), but no undermining of the track structure has resulted

M - Erosion of crib and shoulder ballast (one side or both sides at the same location), but no undermining of the track structure has resulted

H - Removal of a portion of the support ballast resulting in restricted train movements

VH - Ballast or ballast and subgrade partially or completely washed out resulting in no train movements

Note: At any given location record only the highest severity level present.

Measurement: Linear Feet of Track

Density:
$$\frac{\text{Distress Linear Feet}}{\text{Sample Unit Length}}$$

Cause: Excessive water flowing either along the track shoulder or over the track with sufficient velocity to carry aggregate away.



B9H
Erosion of Ballast, High Severity



B9VH
Erosion of Ballast, Very High Severity

B10. Inadequate Trackside Drainage

Description: The restriction or prevention of water flow in ditches paralleling the track. Also, the erosion of ditches and/or side slopes.

Note: If ditch or slope erosion has resulted in erosion of the track structure, distress B8 should also be counted.

Severity Levels:

L - Water cannot freely flow along side ditches

M - Erosion of side ditches and/or side slopes, but no erosion or undermining of the track structure has resulted

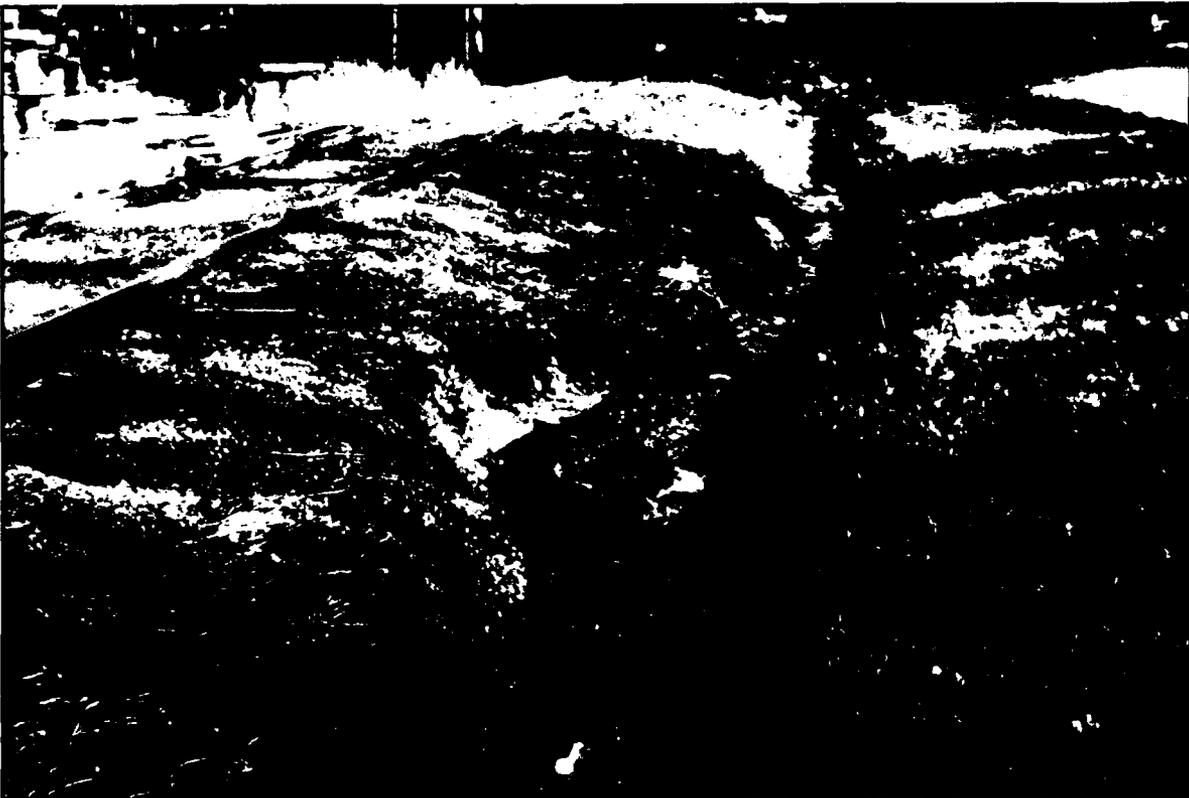
Measurement: Linear Feet of Ditch or Slope

Density:
$$\frac{\text{Distress Linear Feet}}{\text{Sample Unit Length} \times 2}$$

Cause: Flow can become restricted or prevented due to clogging from vegetation, debris, soil, or the deposition of other extraneous material. Excessive water flowing in the ditch with sufficient velocity may lead to erosion.



B10L
Inadequate Trackside Drainage,
Low Severity



B10M
Inadequate Trackside Drainage,
Medium Severity

B11. Inadequate Water Flow Through Drainage Structures

Description: The restriction or prevention of water flow through culverts under the track, through culverts paralleling the track under grade crossings, or through other drainage structures.

Severity Levels:

L - Restricted flow

M - Flow almost or entirely blocked

Measurement: Each Affected Culvert, etc.

Density:
$$\frac{\text{Number of Affected Culverts, etc.}}{\text{Sample Unit Length}}$$

Cause: Flow can become restricted or prevented due to clogging from vegetation, debris, soil, or the deposition of other extraneous material. Drainage structures may become damaged (e.g., ends of corrugated metal pipe culverts) from equipment or the deposition of extraneous material.



B11L
Inadequate Water Flow Through Drainage Structures, Low Severity



B11M
Inadequate Water Flow Through Drainage Structures, Medium Severity

METRIC CONVERSION FACTORS

1 in.	=	25.4 mm
1 ft	=	0.305 m
1 lb	=	0.453 kg
1 mi	=	1.61 km
1 yd	=	0.9144 m

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Uzarski, D.R., D.G. Brown, R. Harris, and D.E. Plotkin, *Maintenance Management of U.S. Army Railroad Networks - The RAILER System: Detailed Track Inspection Manual*, Technical Report FM-94/01/ADA274459 (USACERL, October 1993).

**APPENDIX A: DEDUCT VALUE CURVES FOR RAIL, JOINTS,
AND FASTENINGS COMPONENT GROUP**

R1 L
RAIL DEFECTS (Low Severity)

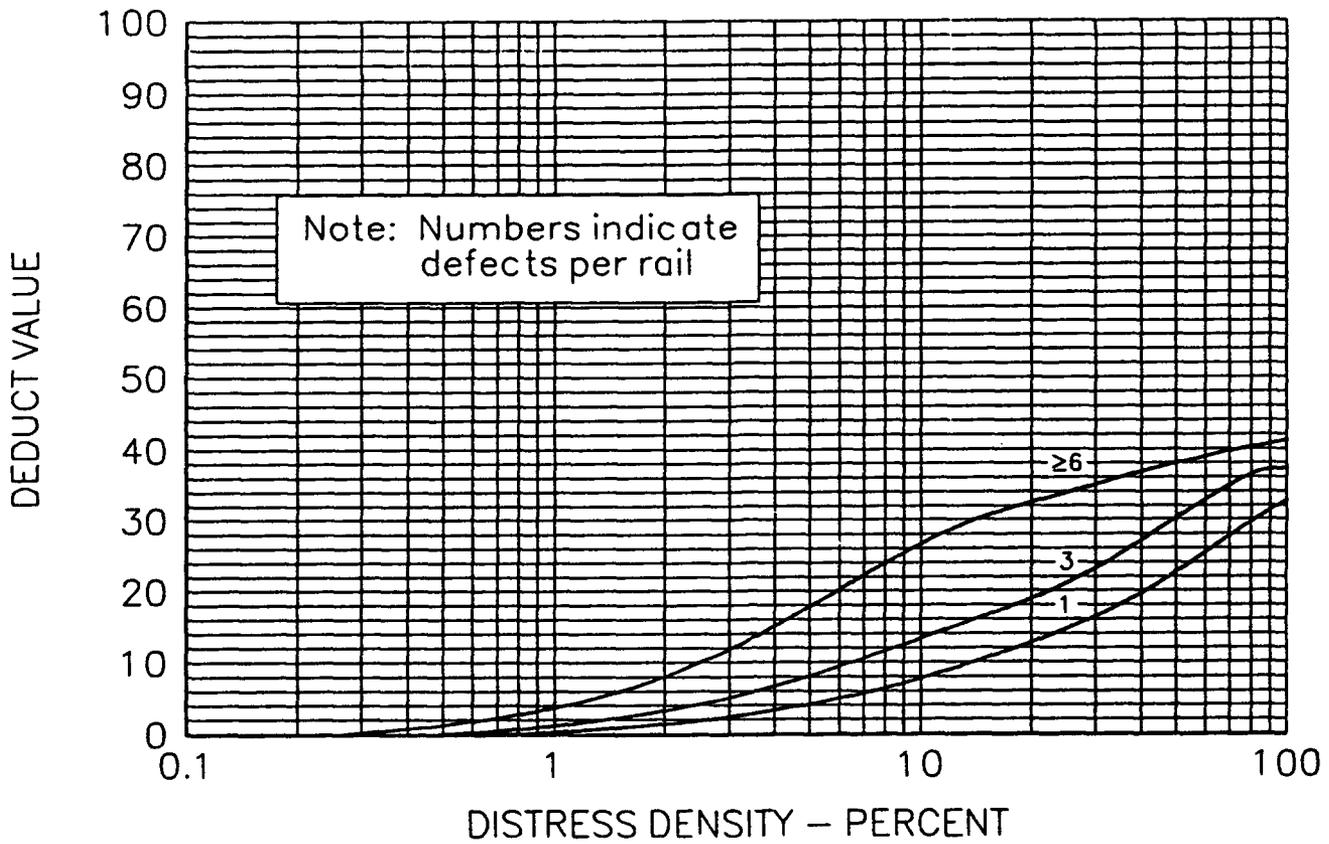


Figure A1. Rail Defects (R1) - Low Severity Deduct Curves.

R1 M
RAIL DEFECTS (Medium Severity)

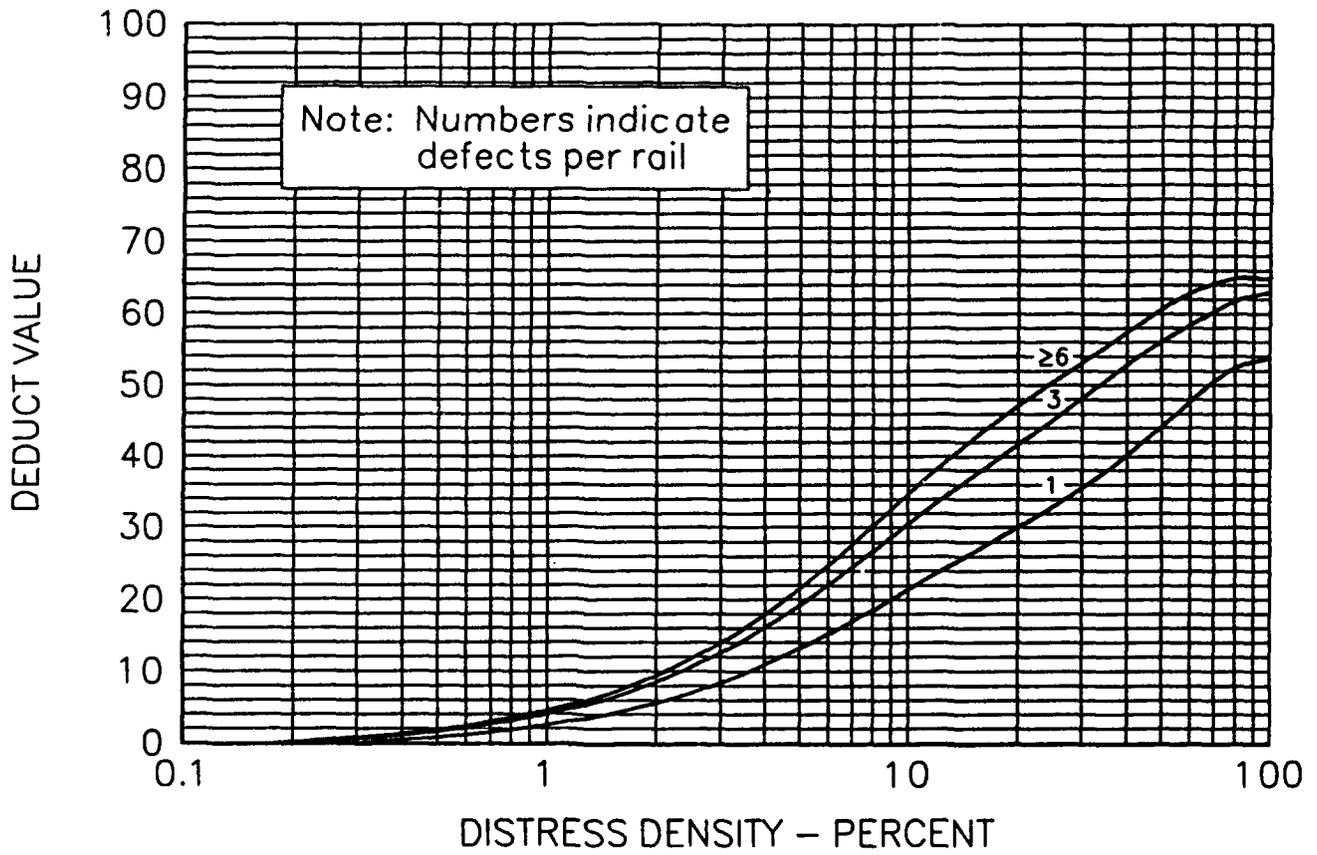


Figure A2. Rail Defects (R1) - Medium Severity Deduct Curves.

R1 H
RAIL DEFECTS (High Severity)

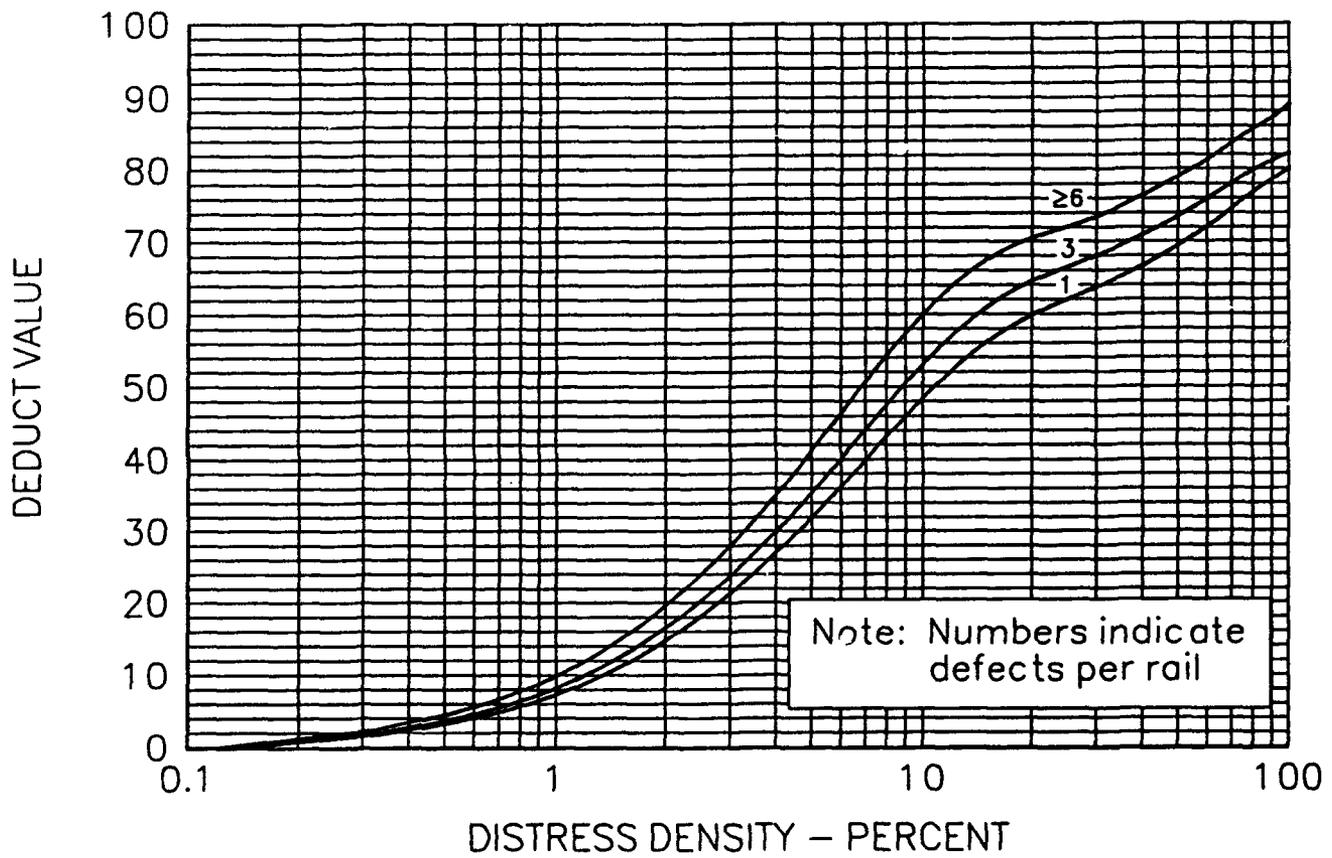


Figure A3. Rail Defects (R1) - High Severity Deduct Curves.

R1 VH
RAIL DEFECTS (Very High Severity)

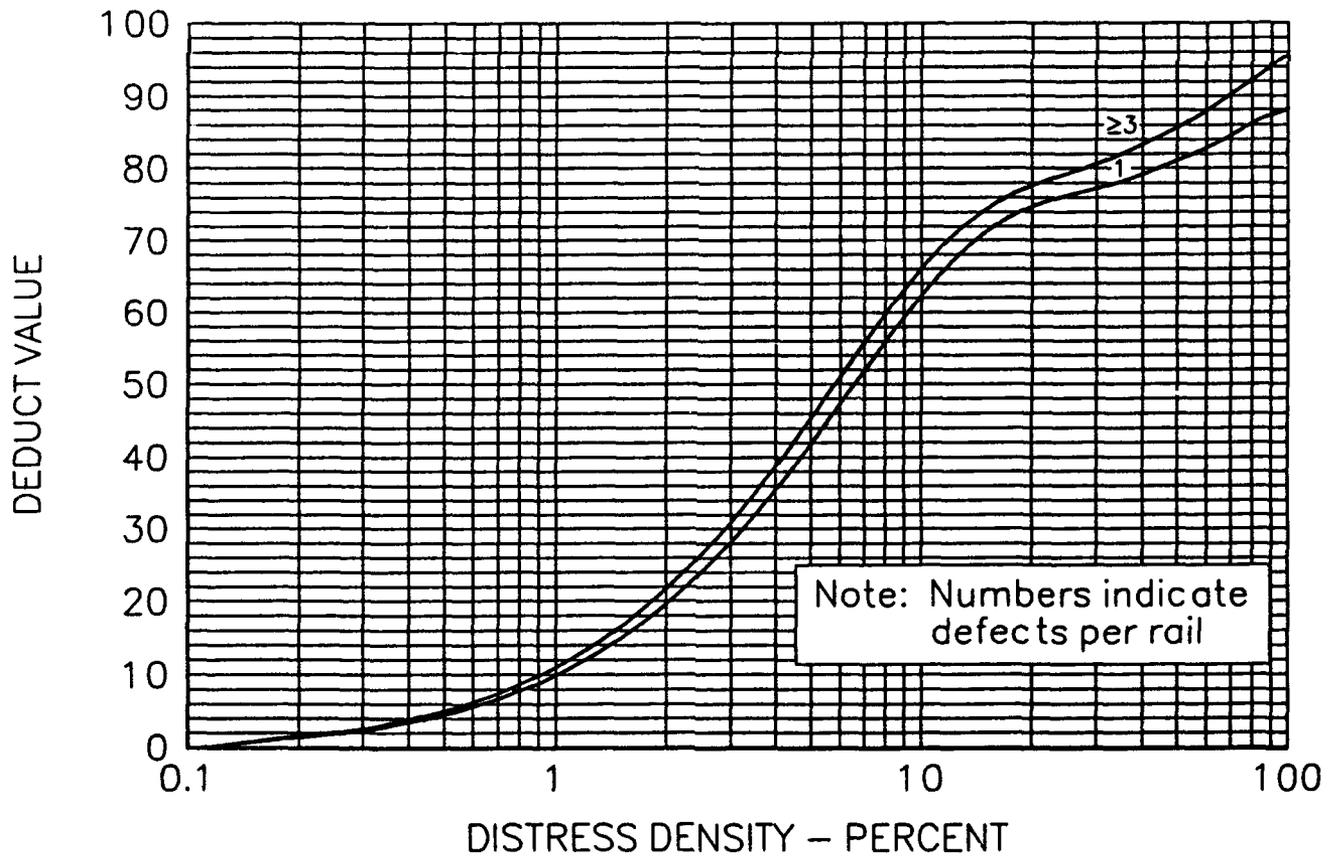


Figure A4. Rail Defects (R1) - Very High Severity Deduct Curves.

R2L
JOINT DEFECTS (Low Severity)

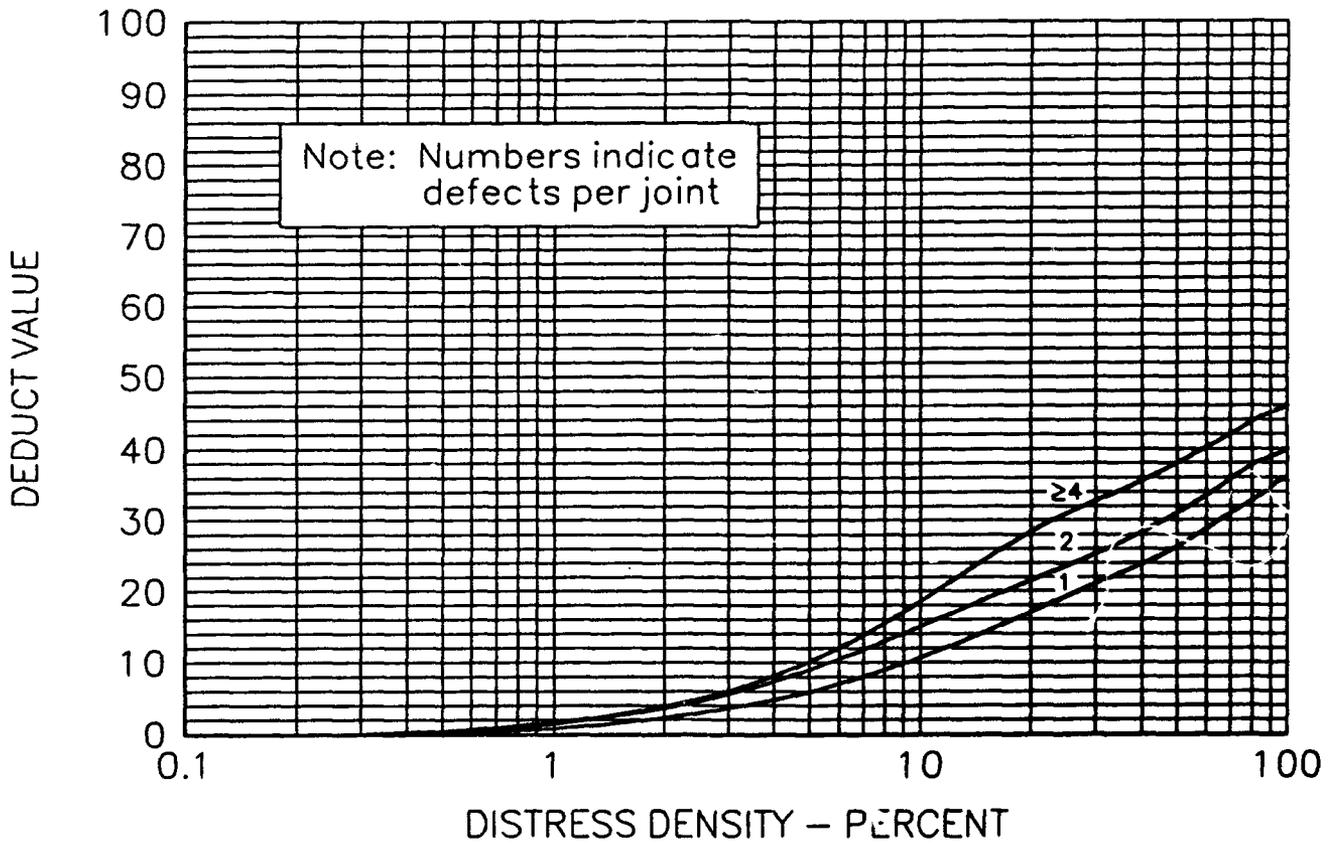


Figure A5. Joint Defects (R2) - Low Severity Deduct Curves.

R2M
JOINT DEFECTS (Medium Severity)

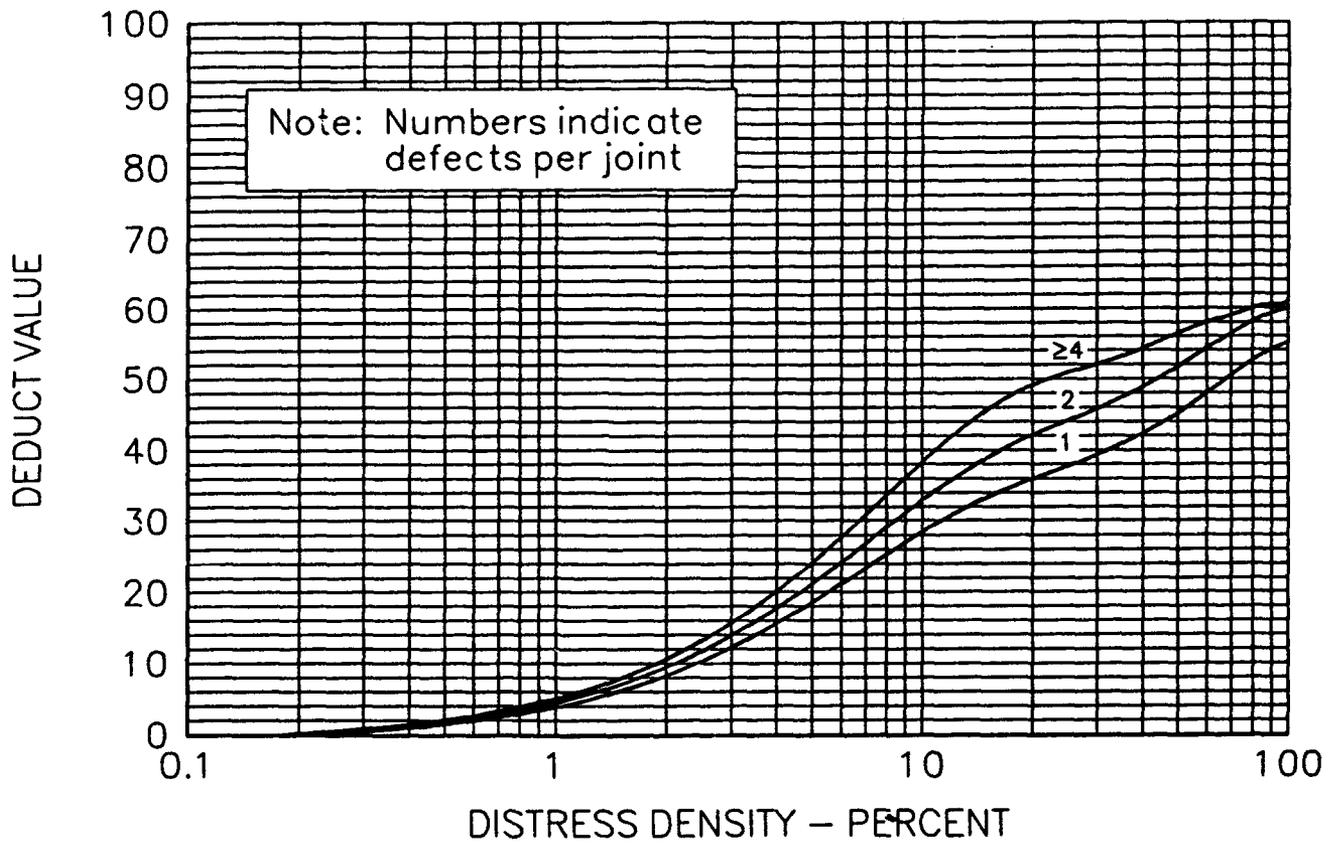


Figure A6. Joint Defects (R2) - Medium Severity Deduct Curves.

R2H
JOINT DEFECTS (High Severity)

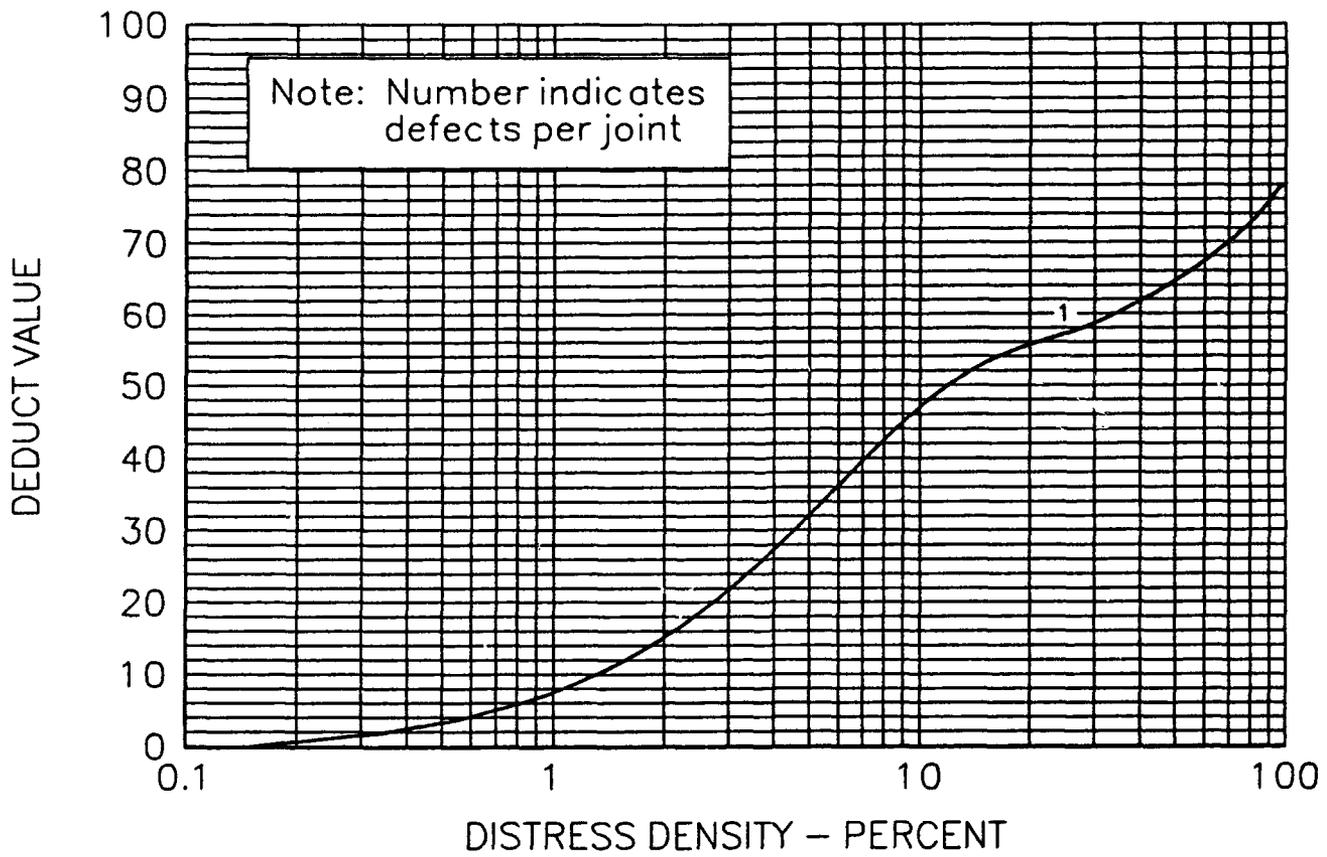


Figure A7. Joint Defects (R2) - High Severity Deduct Curve.

R2VH
JOINT DEFECTS (Very High Severity)

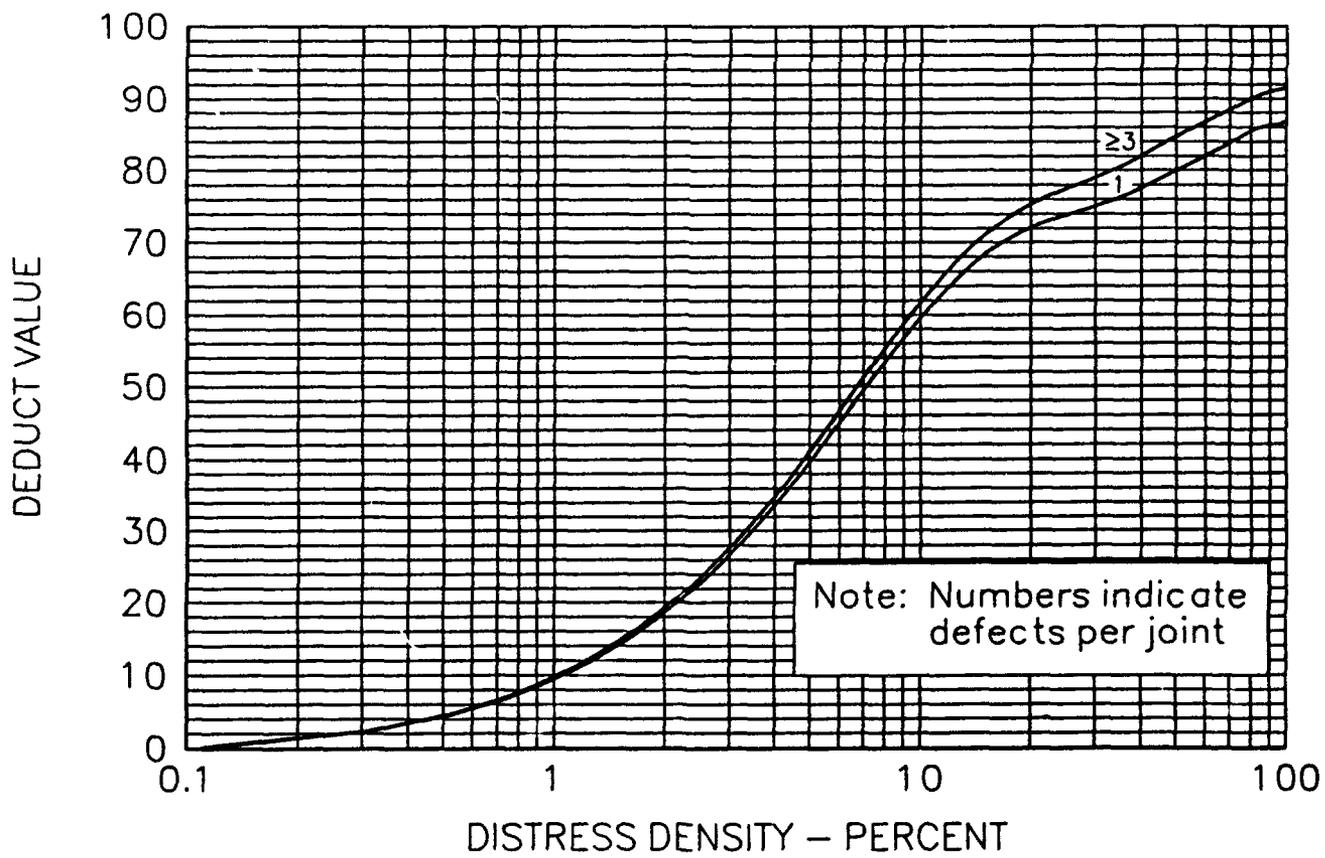


Figure A8. Joint Defects (R2) - Very High Severity Deduct Curves.

R3
HOLD DOWN DEVICE DEFECTS

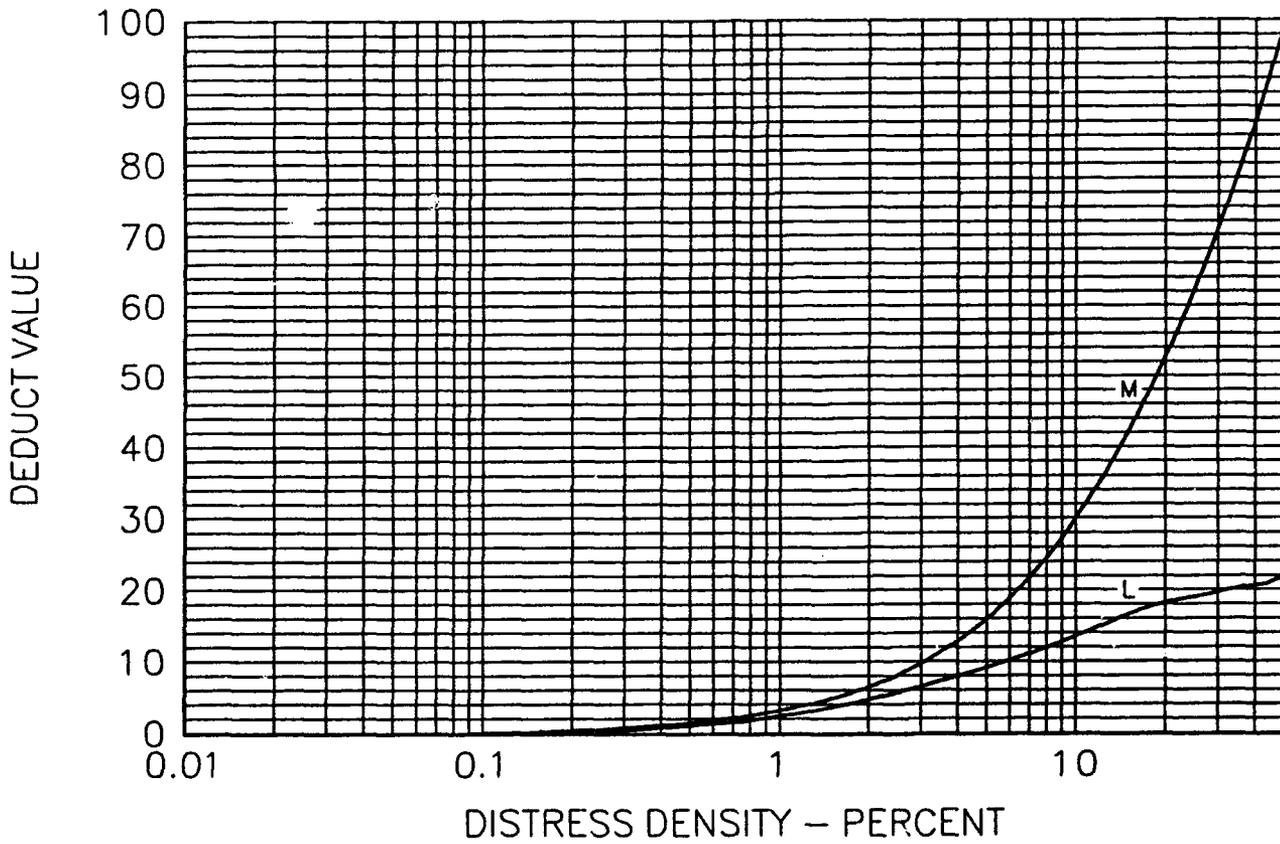


Figure A9. Hold-Down Device Defects (R3), Deduct Curves.

R4
TIE PLATE DEFECTS

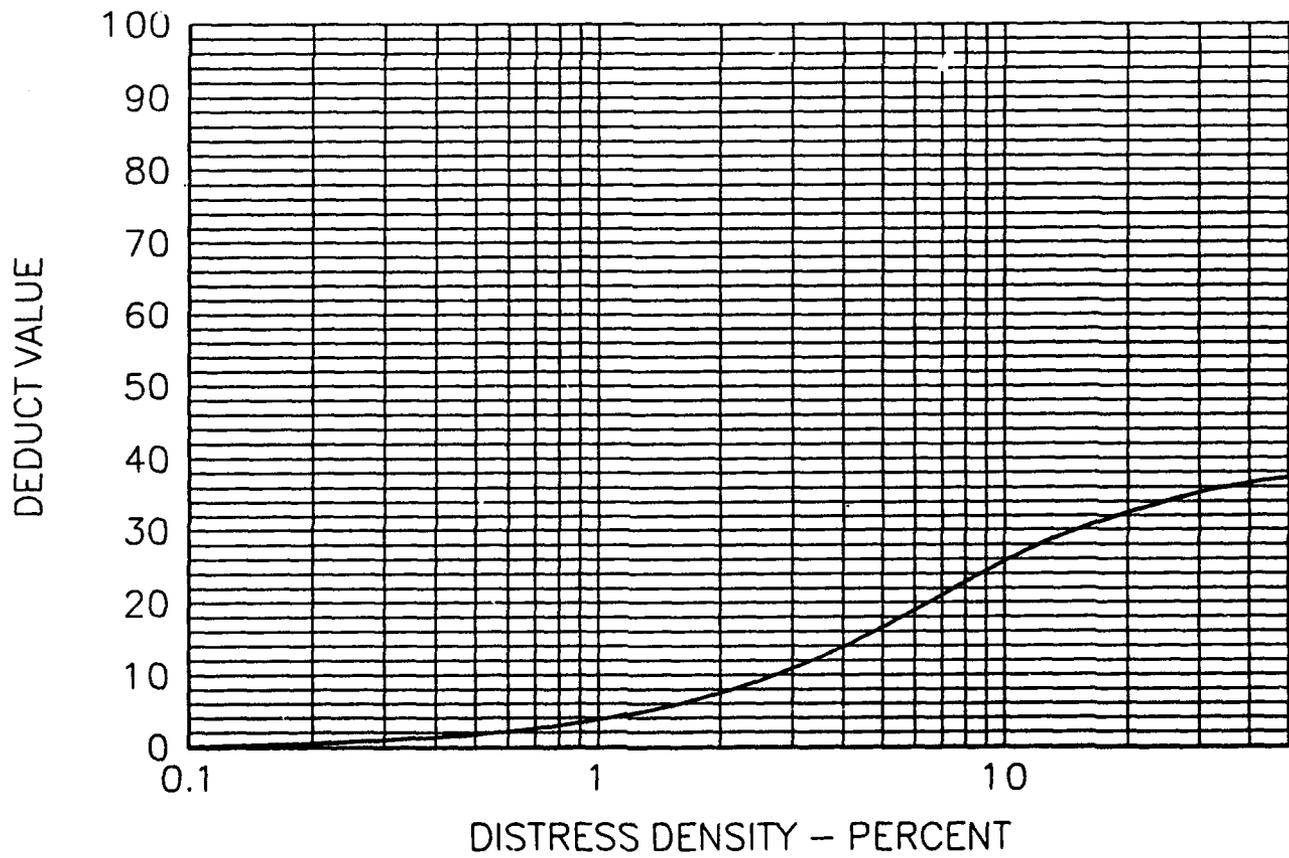


Figure A10. Tie Plate Defects (R4) Deduct Curve.

R5
GAUGE ROD DEFECTS

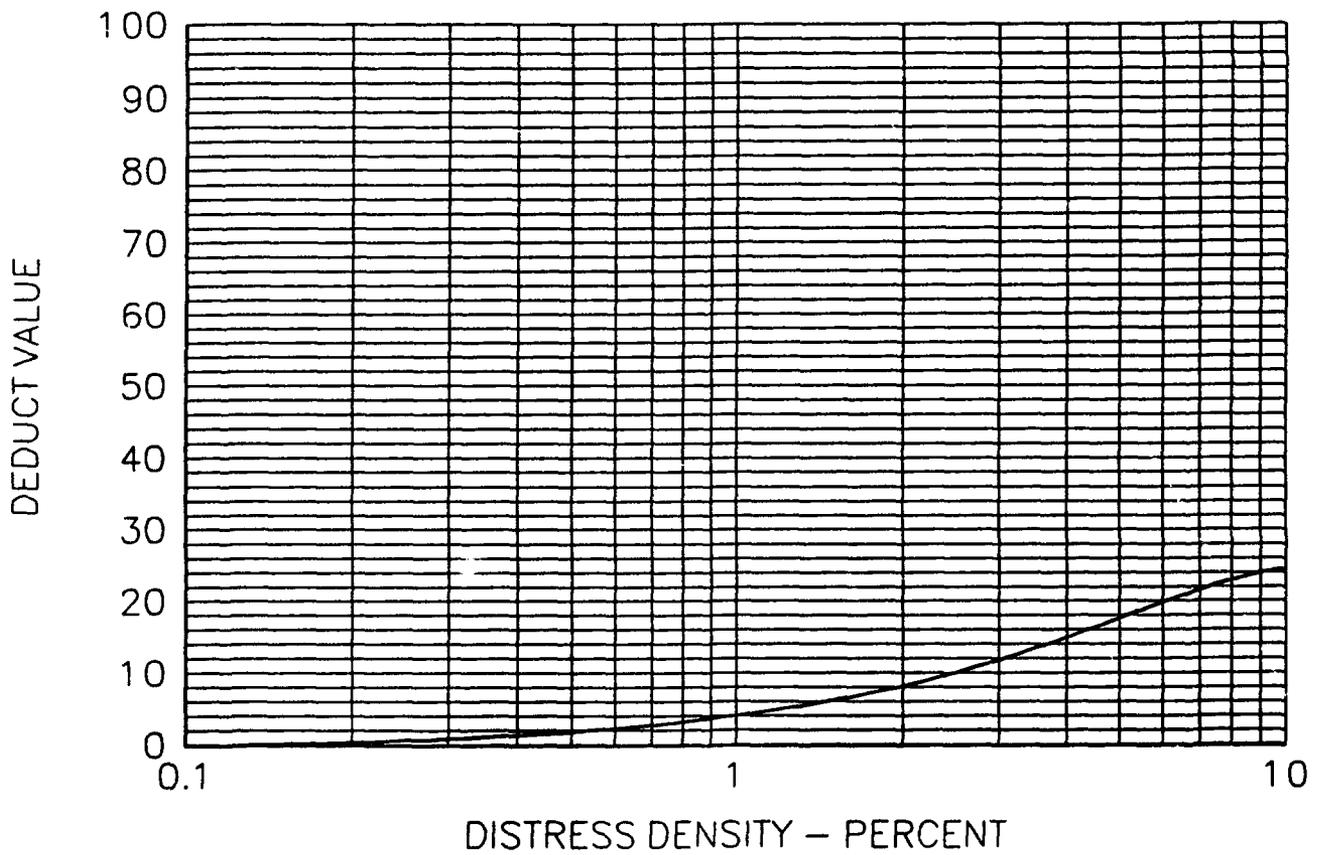


Figure A11. Gauge Rod Defects (R5) Deduct Curve.

R6
RAIL ANCHOR DEFECTS

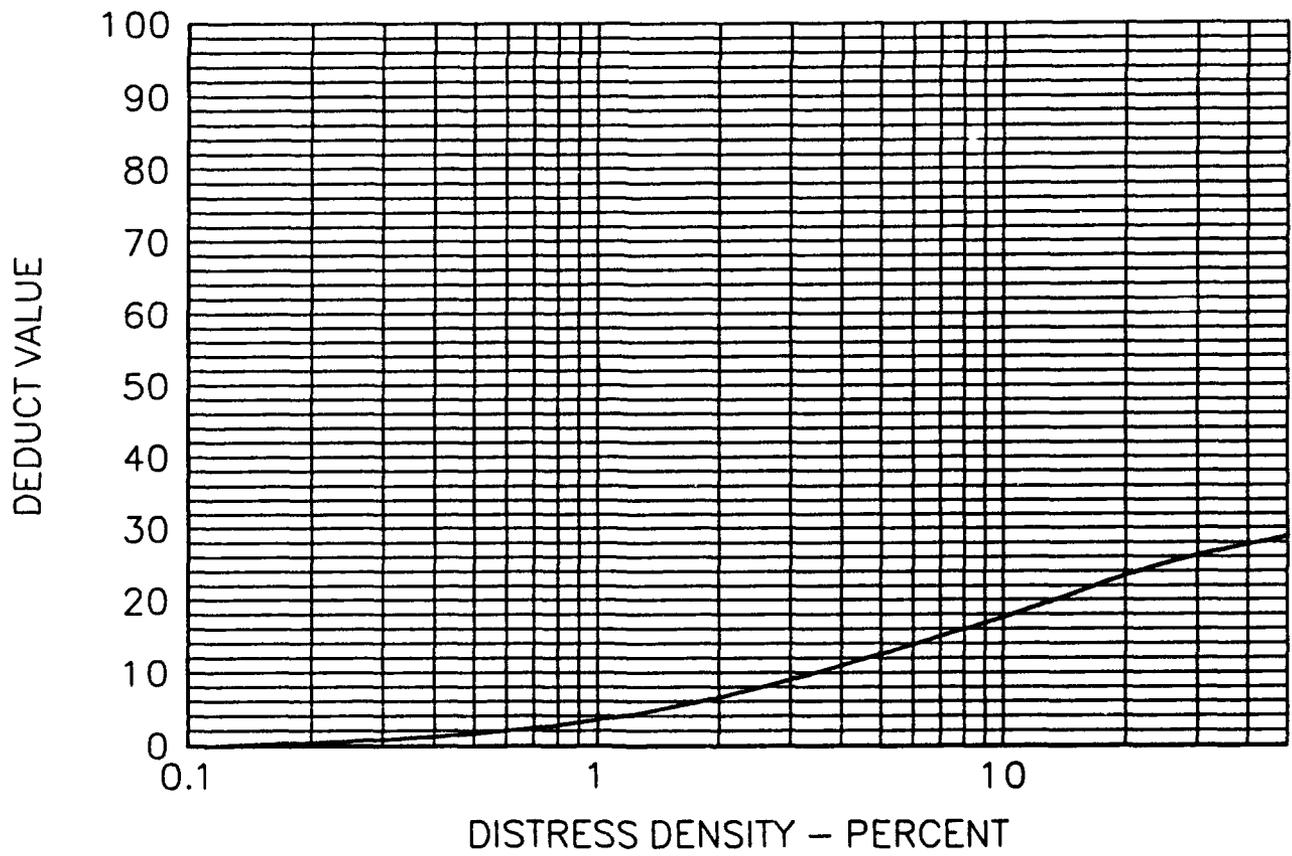


Figure A12. Rail Anchor Defects (R6) Deduct Curve.

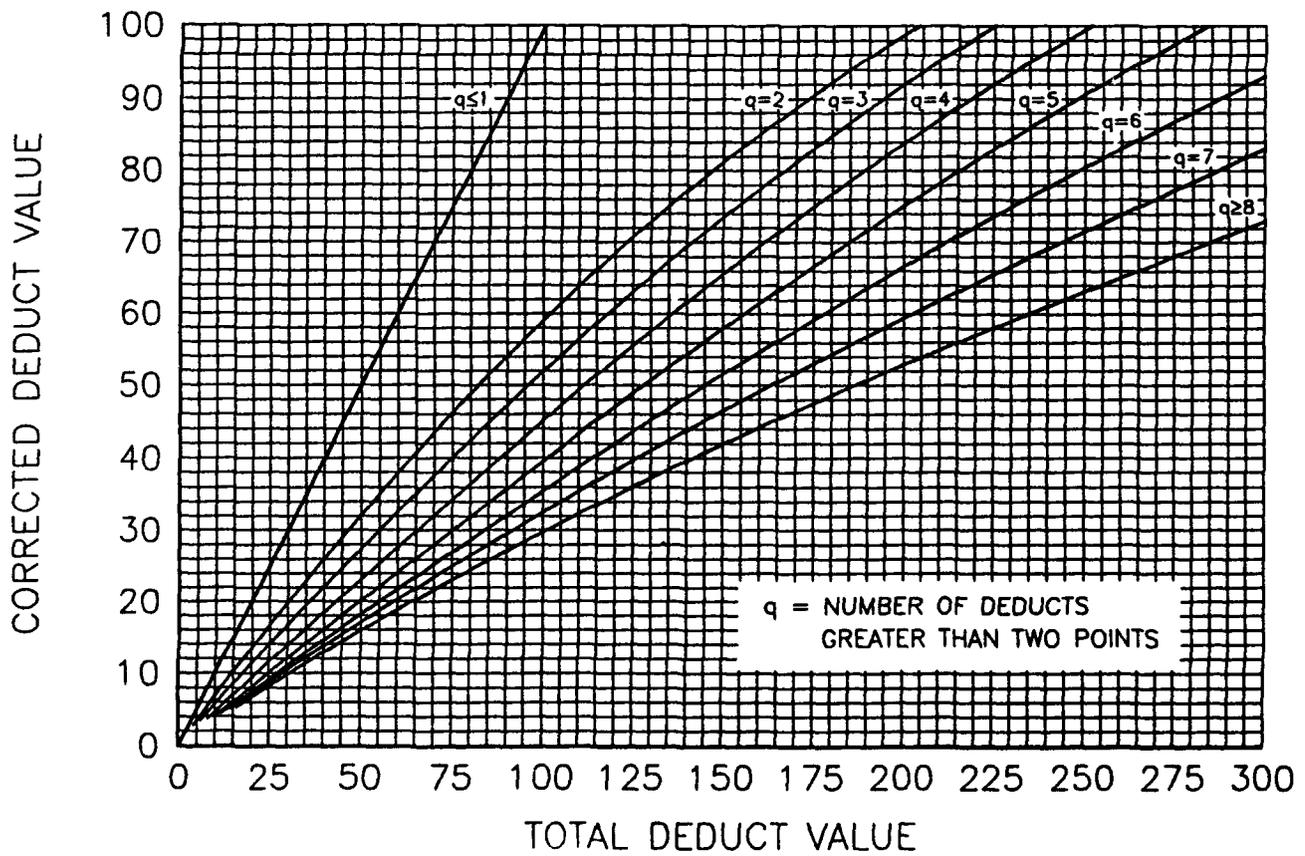


Figure A13. Rail, Joints, and Fastenings Component Group Correction Curves.

APPENDIX B: DEDUCT VALUE CURVES FOR TIE COMPONENT GROUP

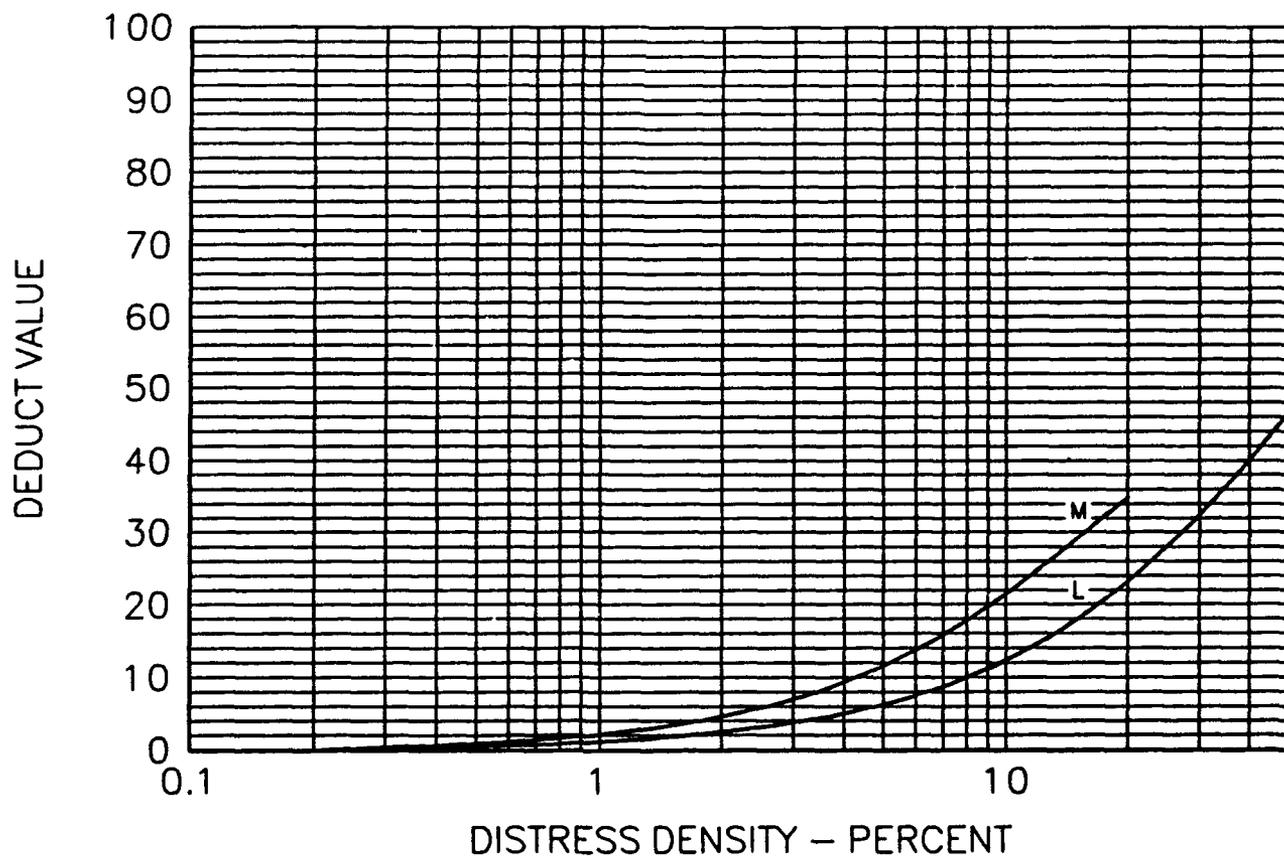


Figure B1. Single Defective Ties (T1) Deduct Curves.

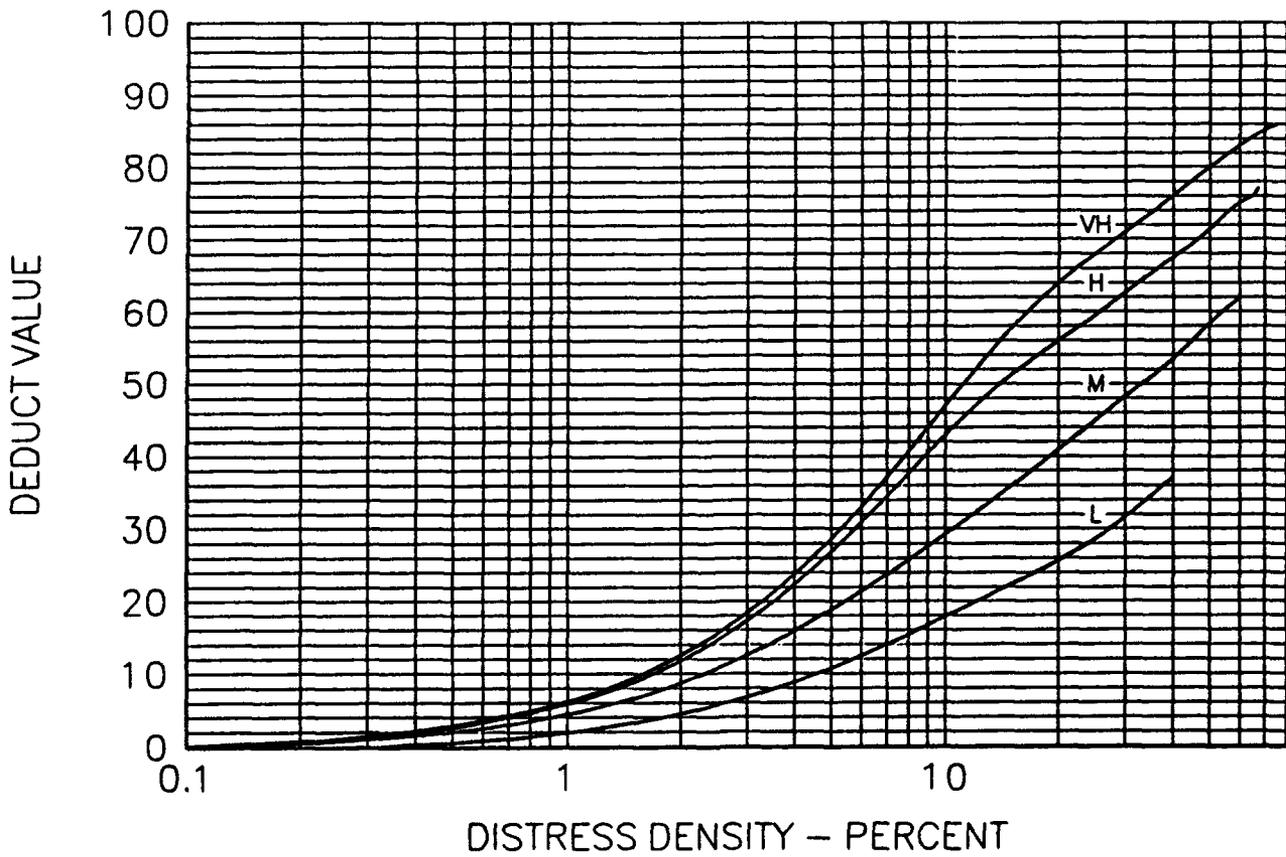


Figure B2. Isolated Defective Tie Cluster (T2) Deduct Curves.

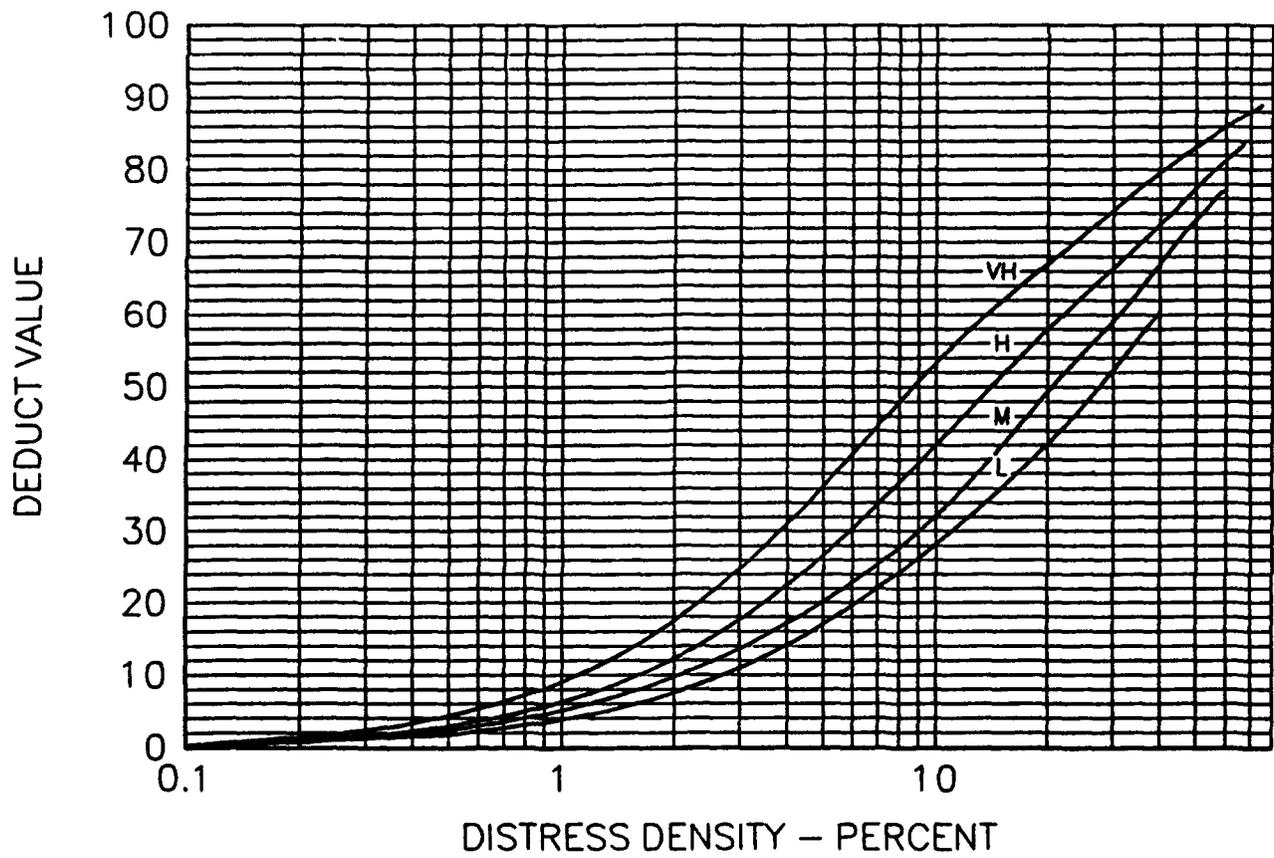


Figure B3. Isolated Defective Tie Cluster That Includes One Joint Tie (T3) Deduct Curves.

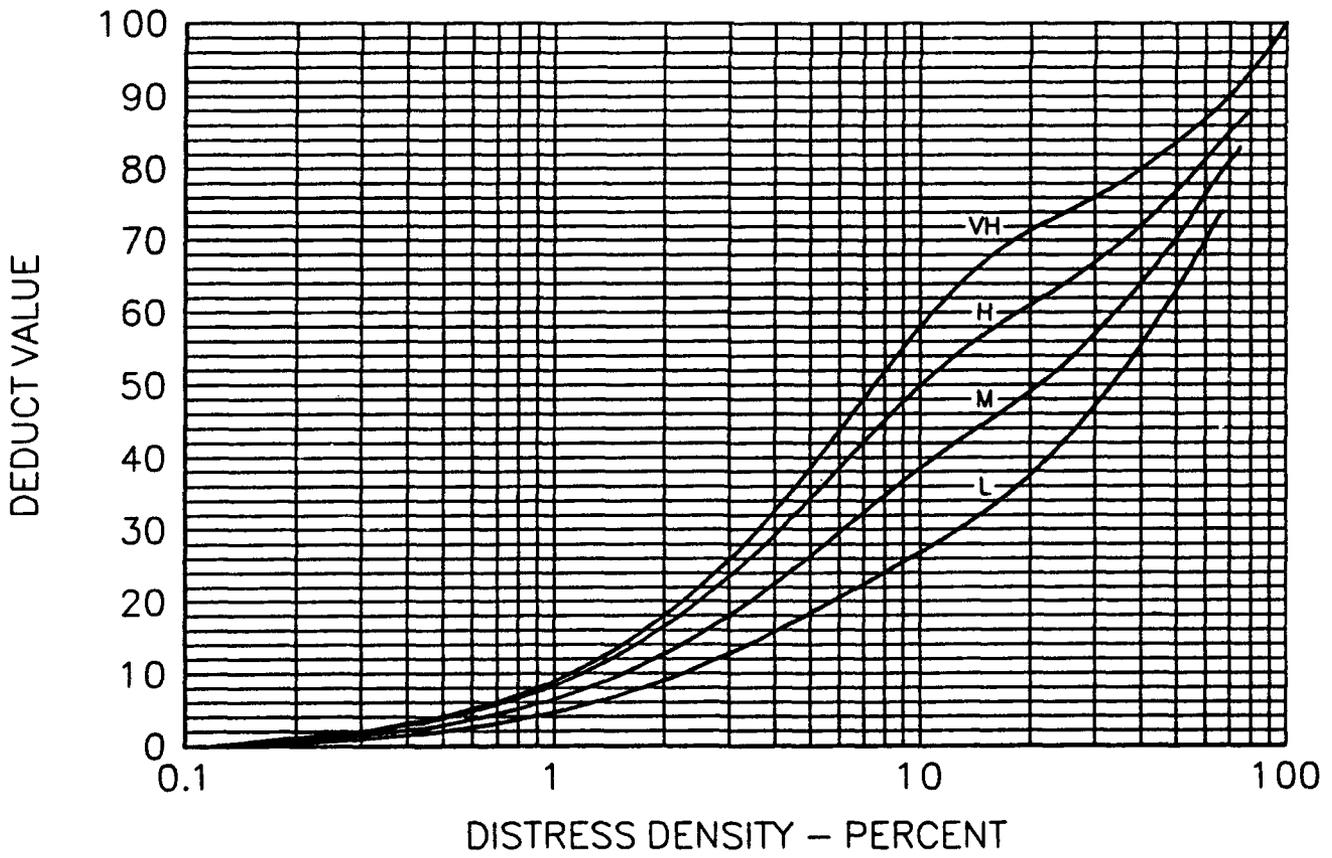


Figure B4. Adjacent Defective Tie Cluster (T4) Deduct Curves.

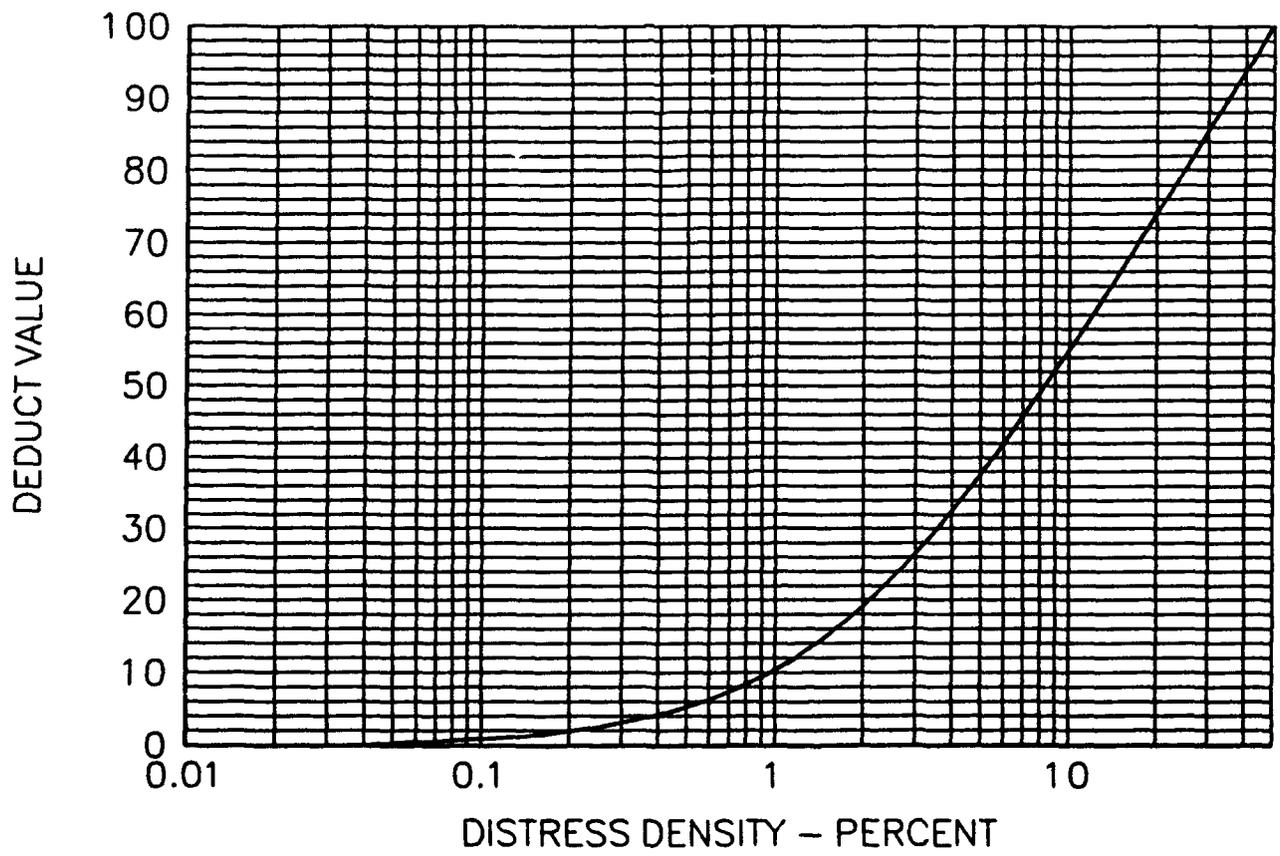


Figure B5. All Joint Ties Defective (T5) Deduct Curve.

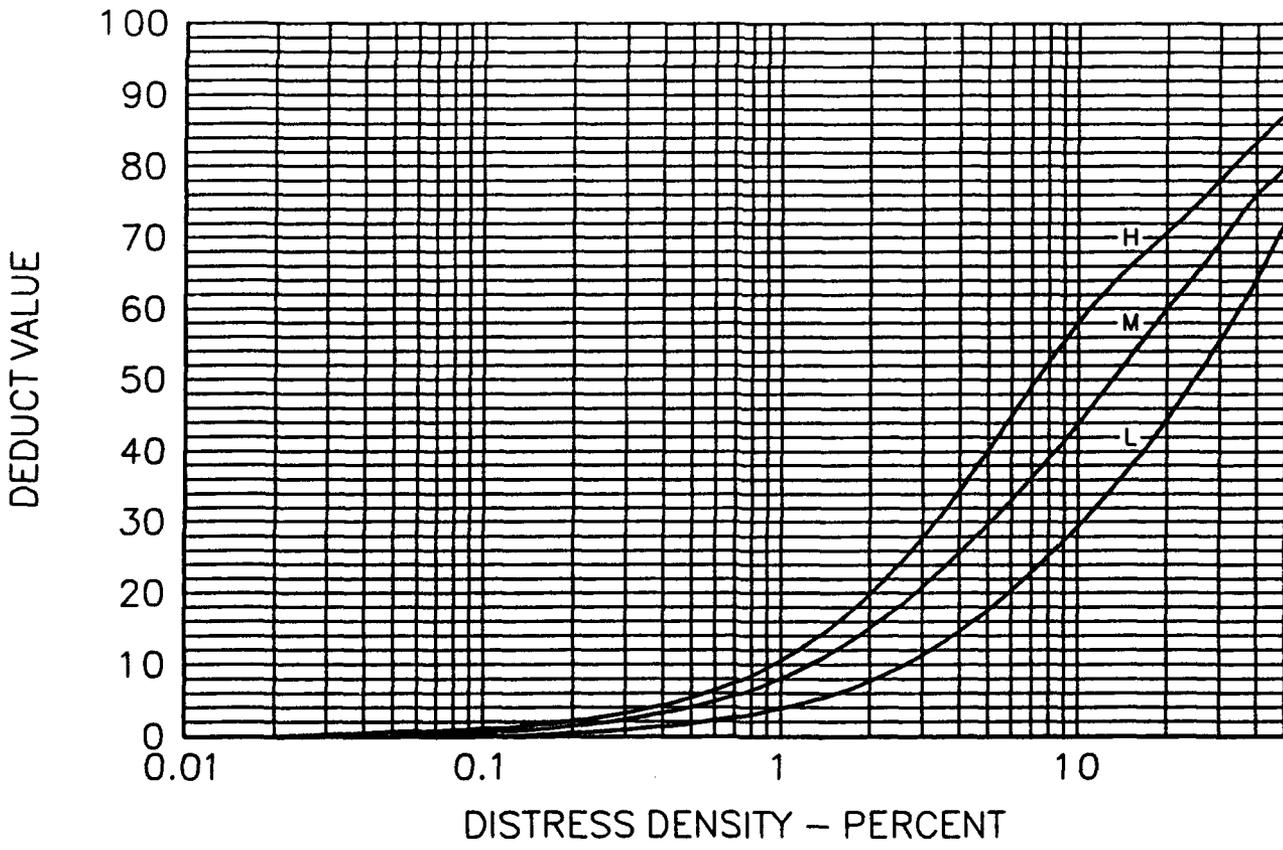


Figure B6. Missing Ties (T6) Deduct Curves.

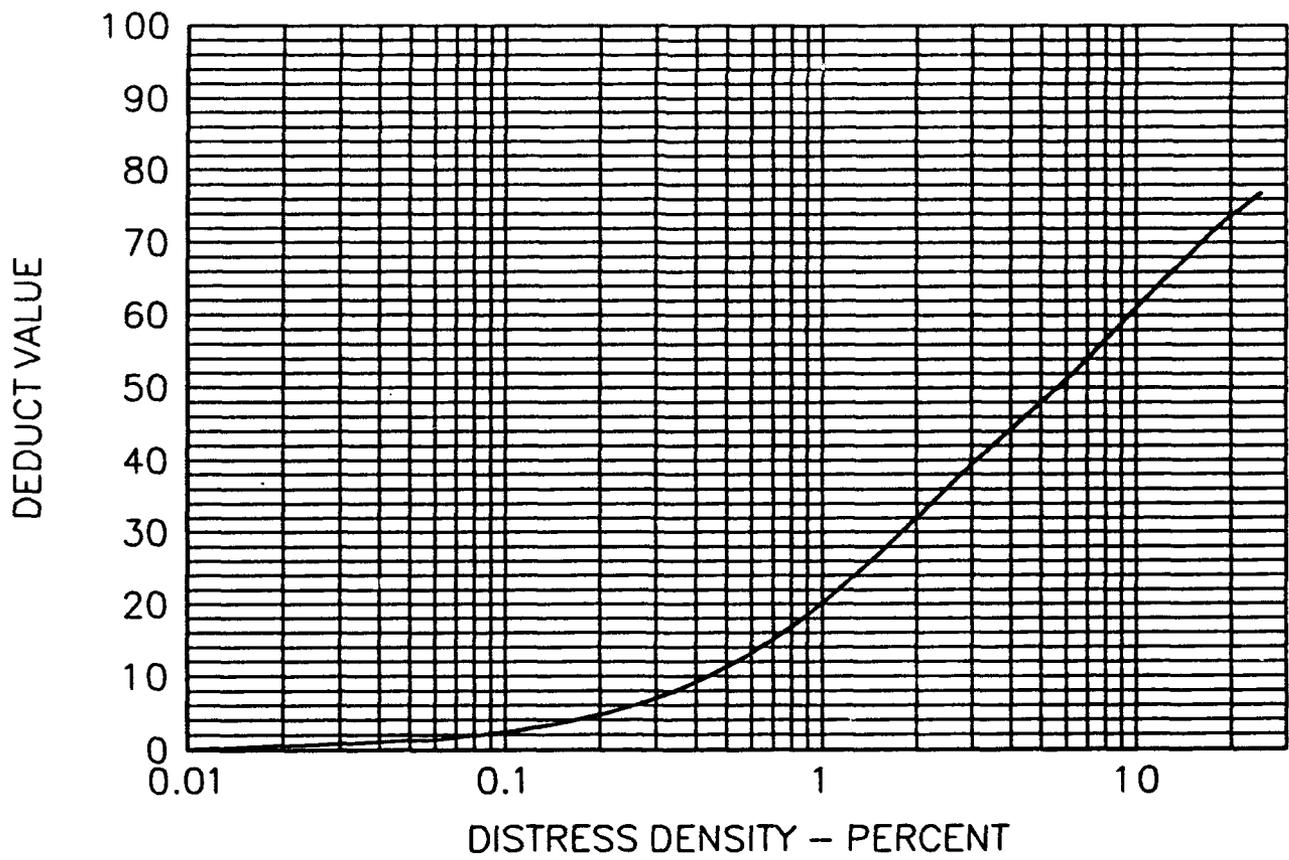


Figure B7. All Joint Ties Missing (T7) Deduct Curve.

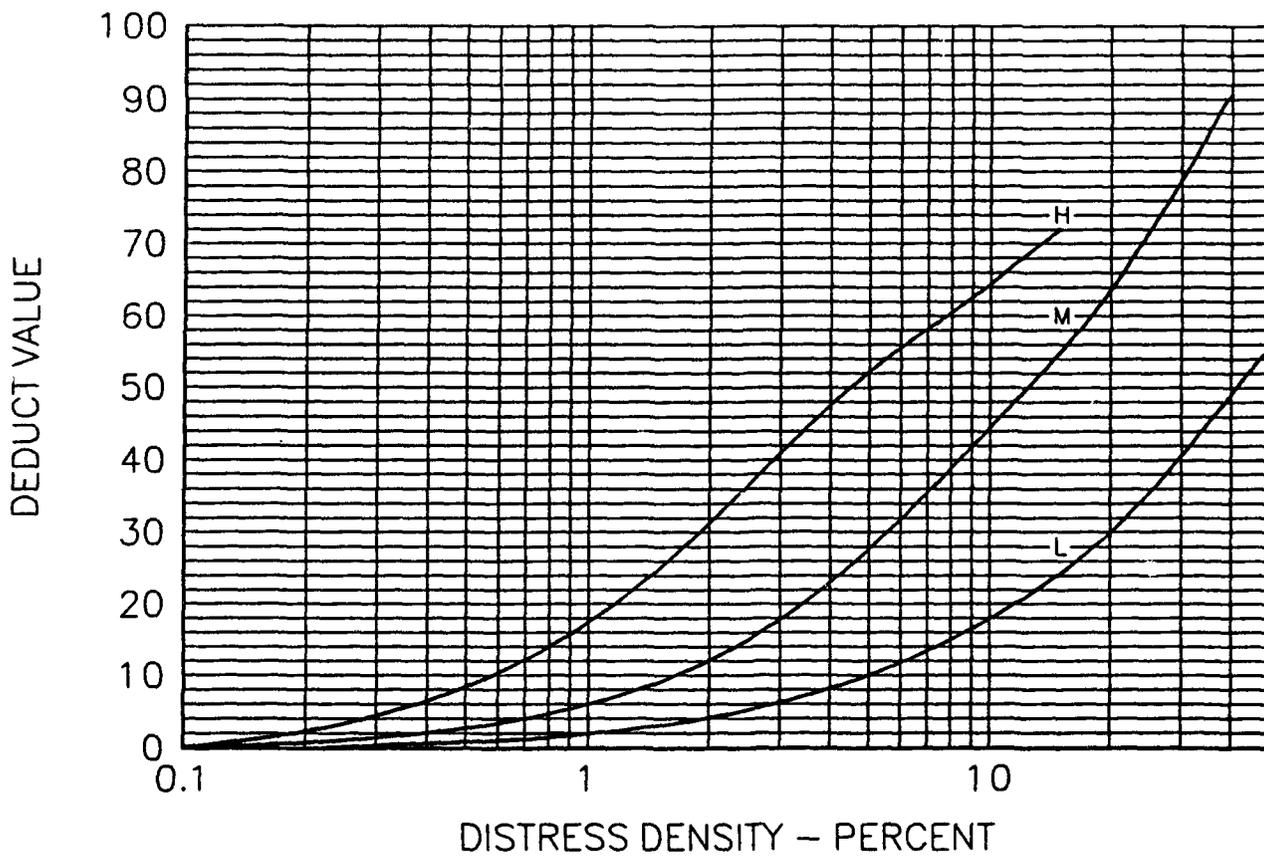


Figure B8. Improperly Positioned Ties (T8) Deduct Curves.

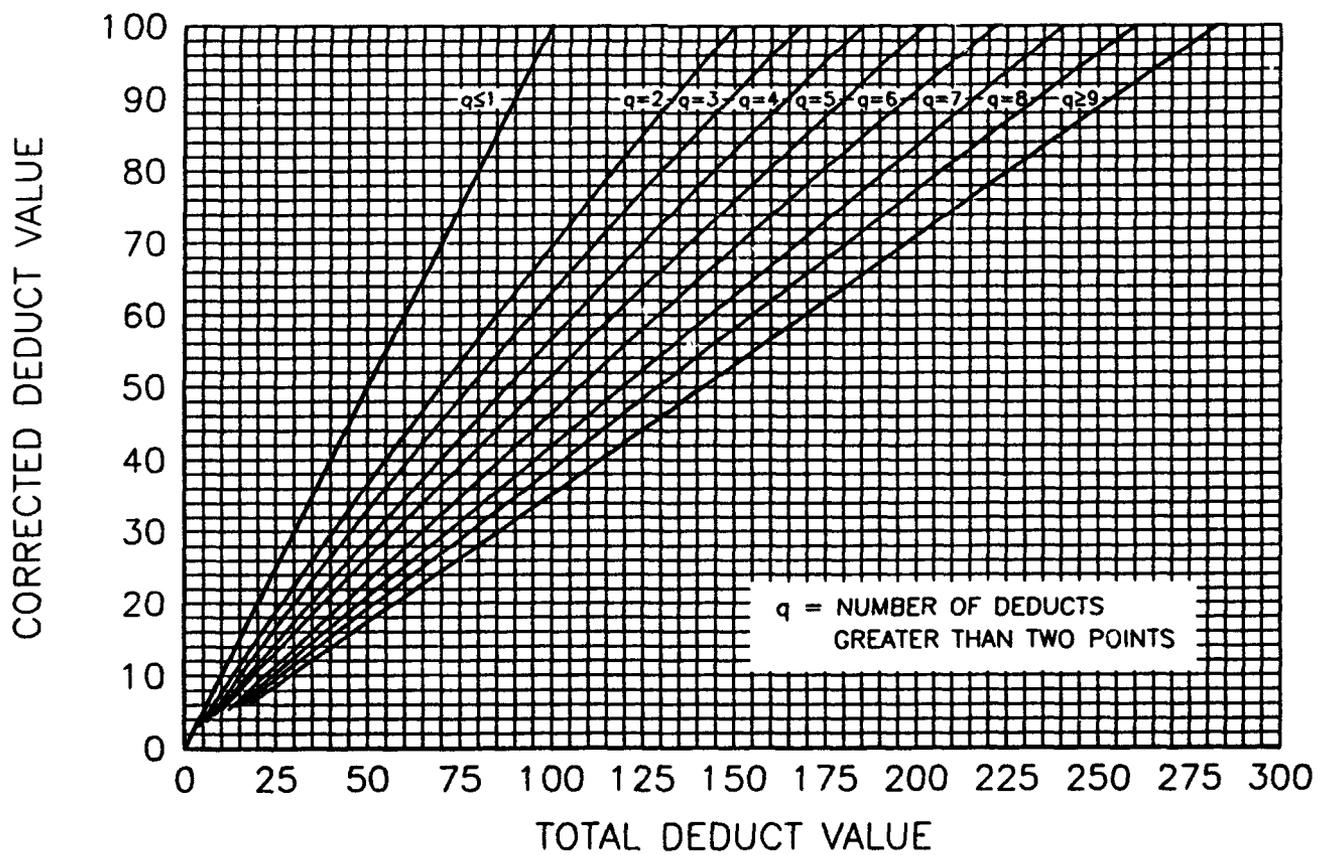


Figure B9. Tie Component Group Correction Curves.

**APPENDIX C: DEDUCT VALUE CURVES FOR BALLAST, SUBGRADE,
AND ROADWAY COMPONENT GROUP**

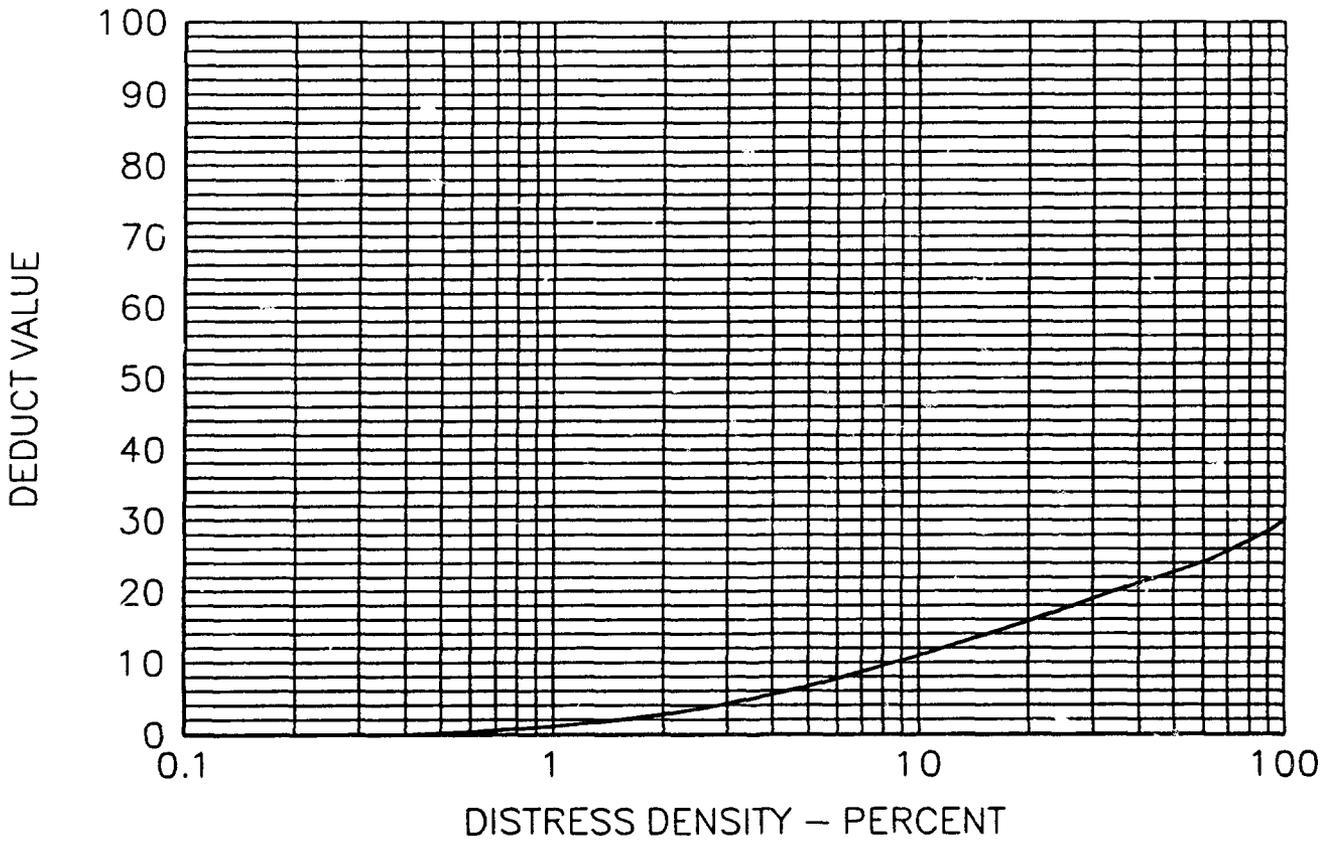


Figure C1. Dirty (Fouled) Ballast (B1) Deduct Curve.

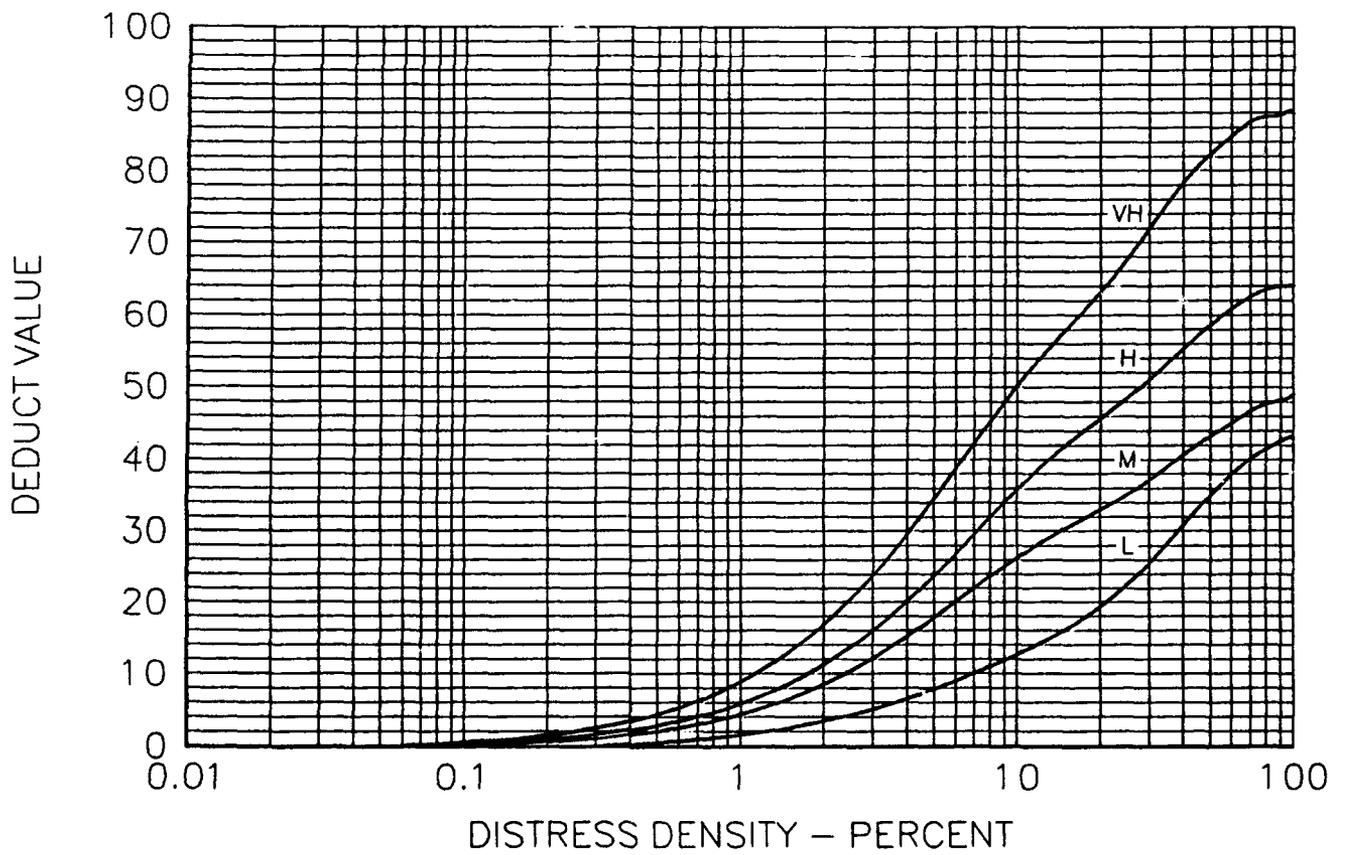


Figure C2. Vegetation Growth (B2) Deduct Curves.

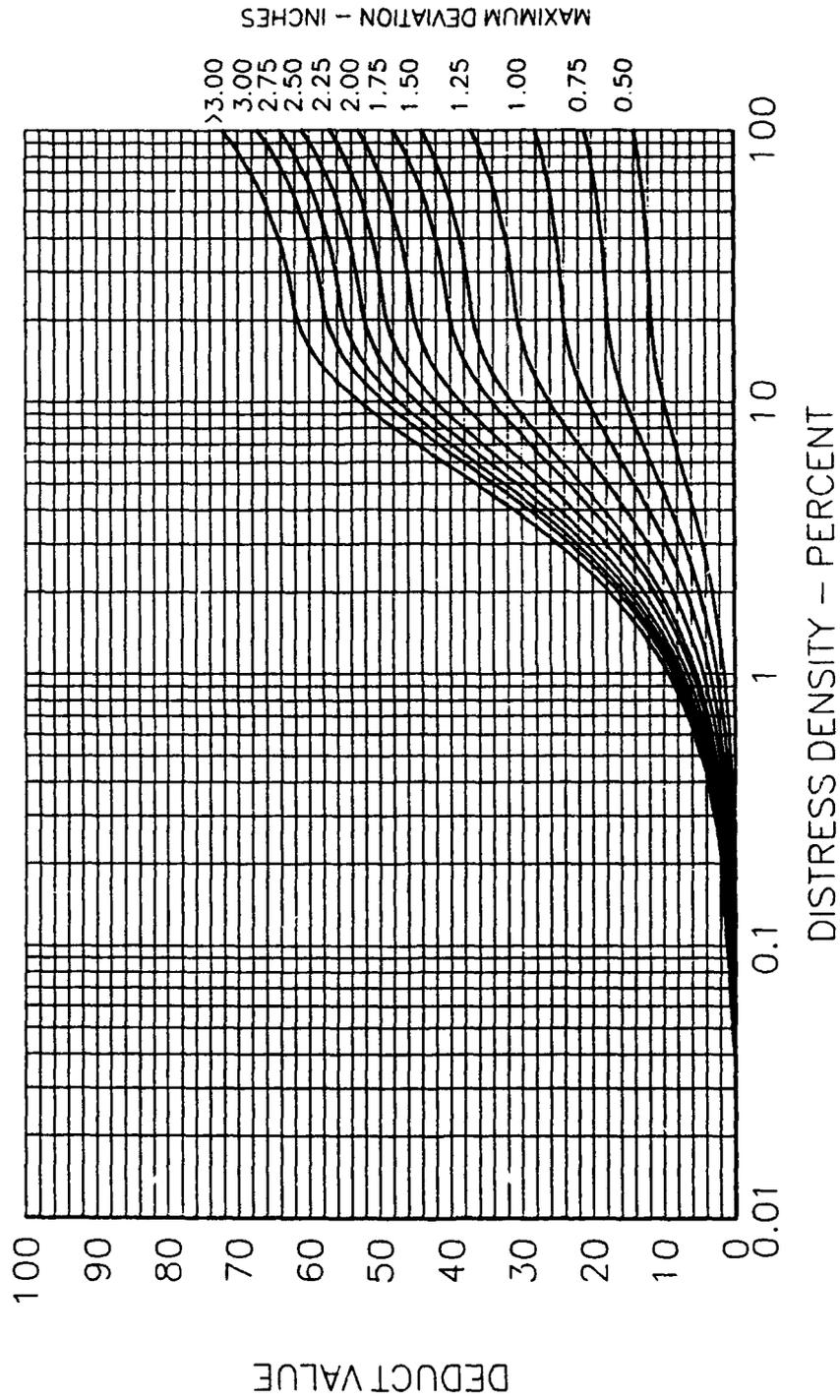


Figure C3. Settlement of Ballast and/or Subgrade (B3) Deduct Curves.

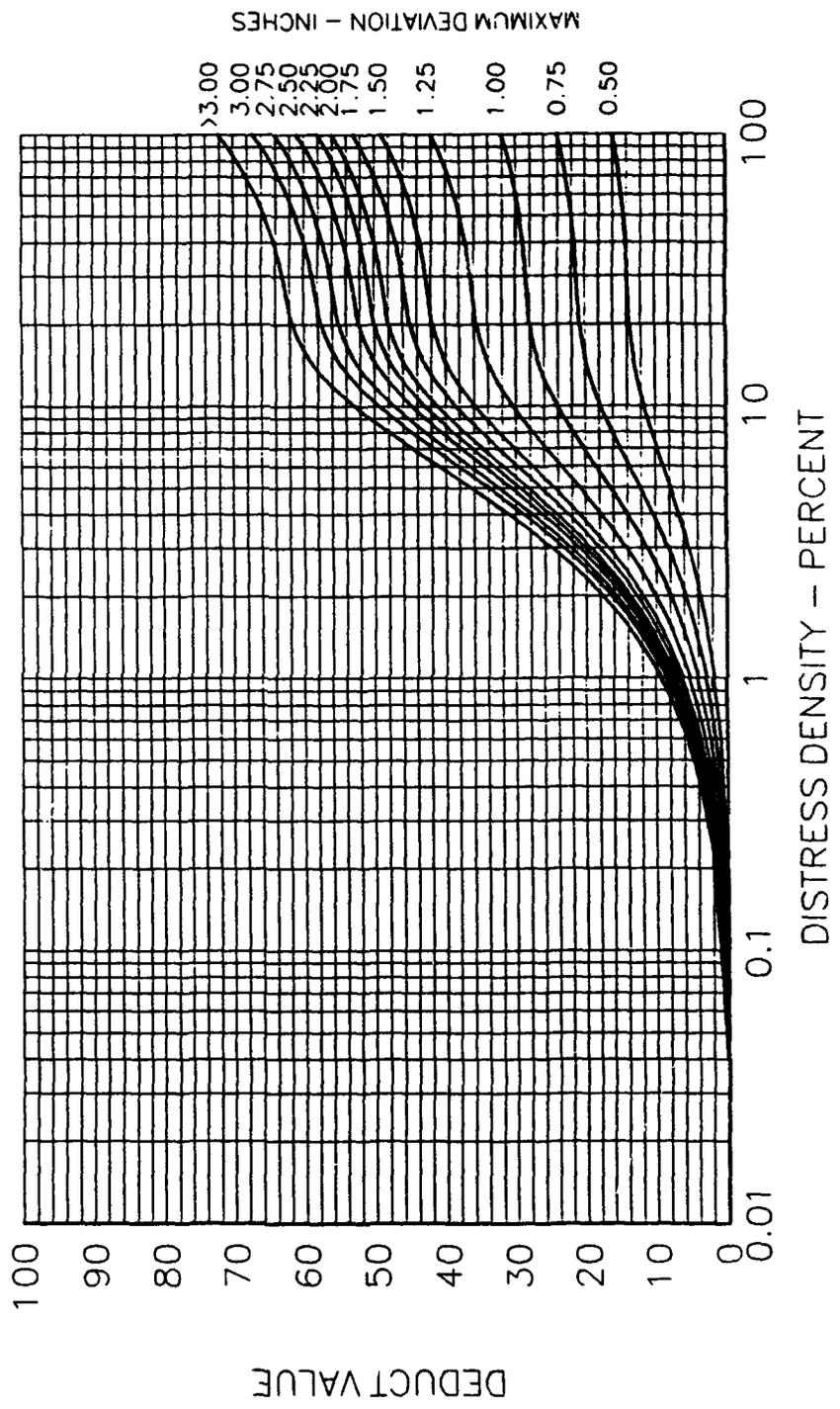


Figure C4. Settlement of Ballast and/or Subgrade (B3) at Bridge or Other Track Structure Deduct Curves.

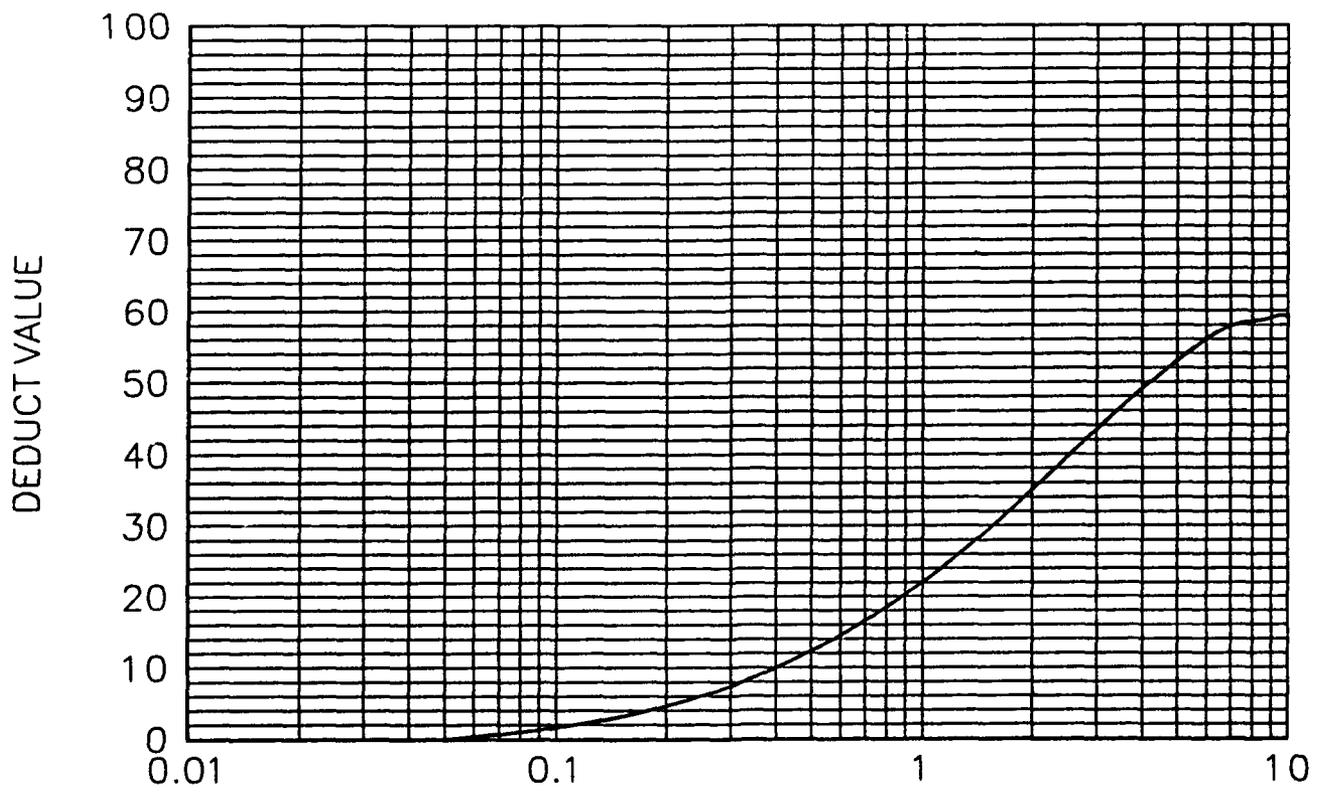


Figure C5. Hanging Ties at Bridge Approach (B4) Deduct Curve.

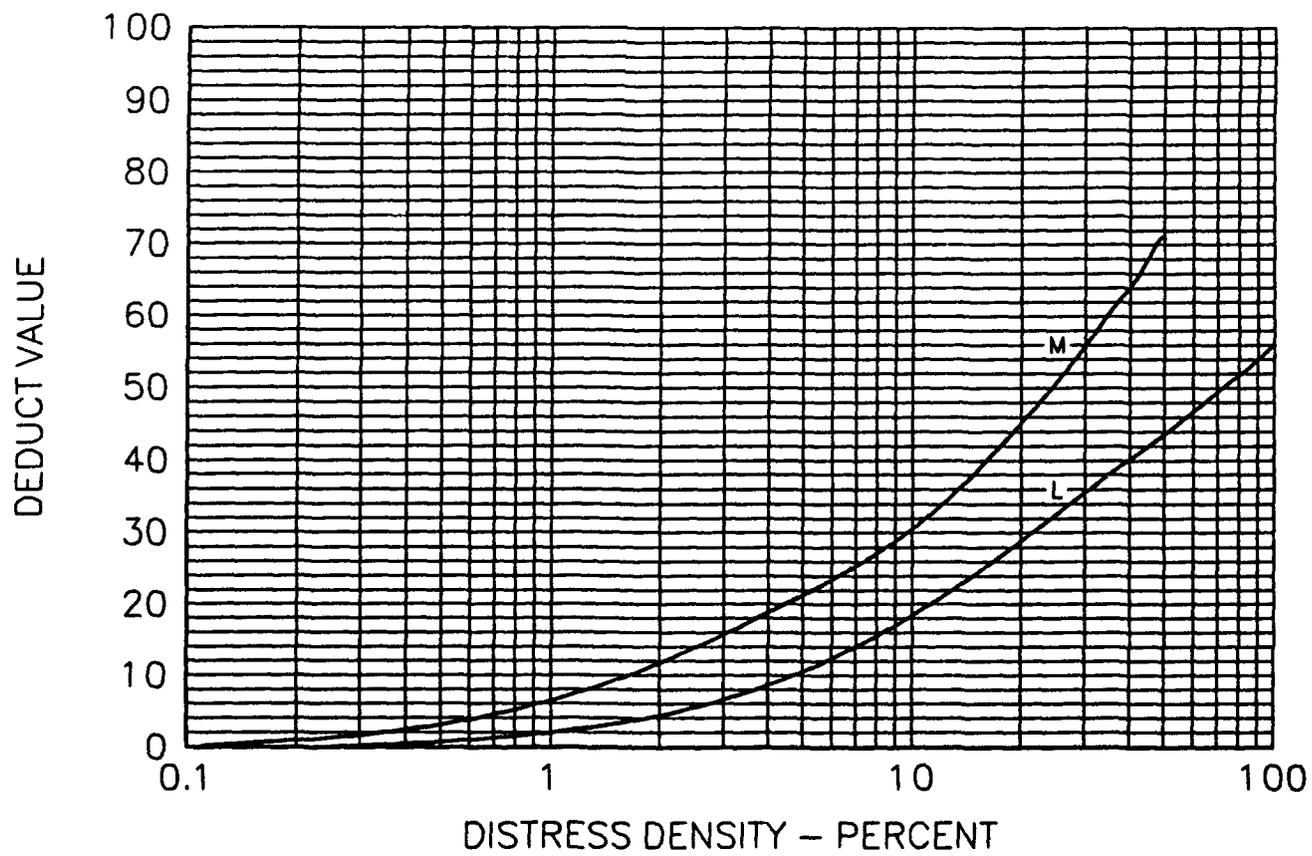


Figure C6. Center Bound Track (B5) Deduct Curves.

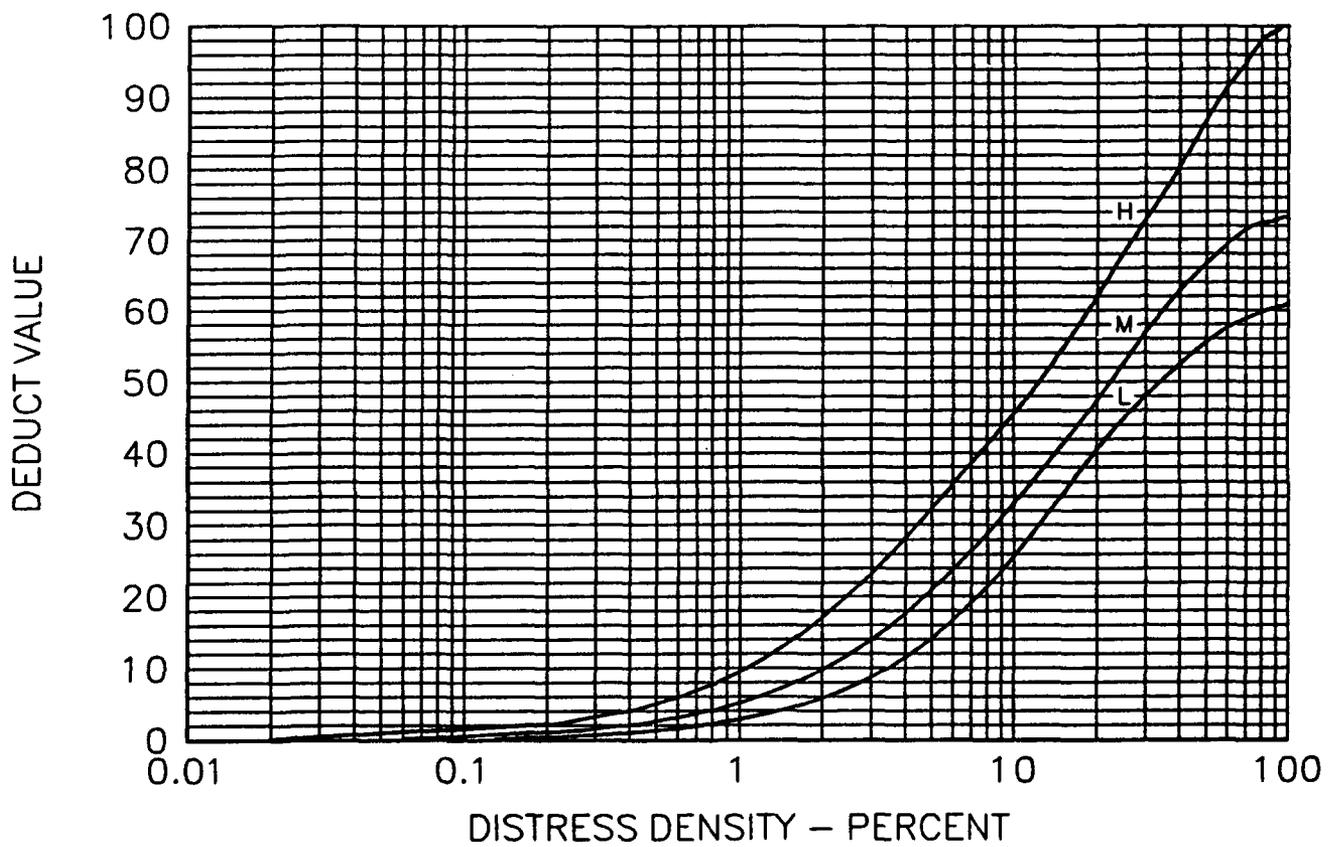


Figure C7. Pumping Ties (B6) Deduct Curves.

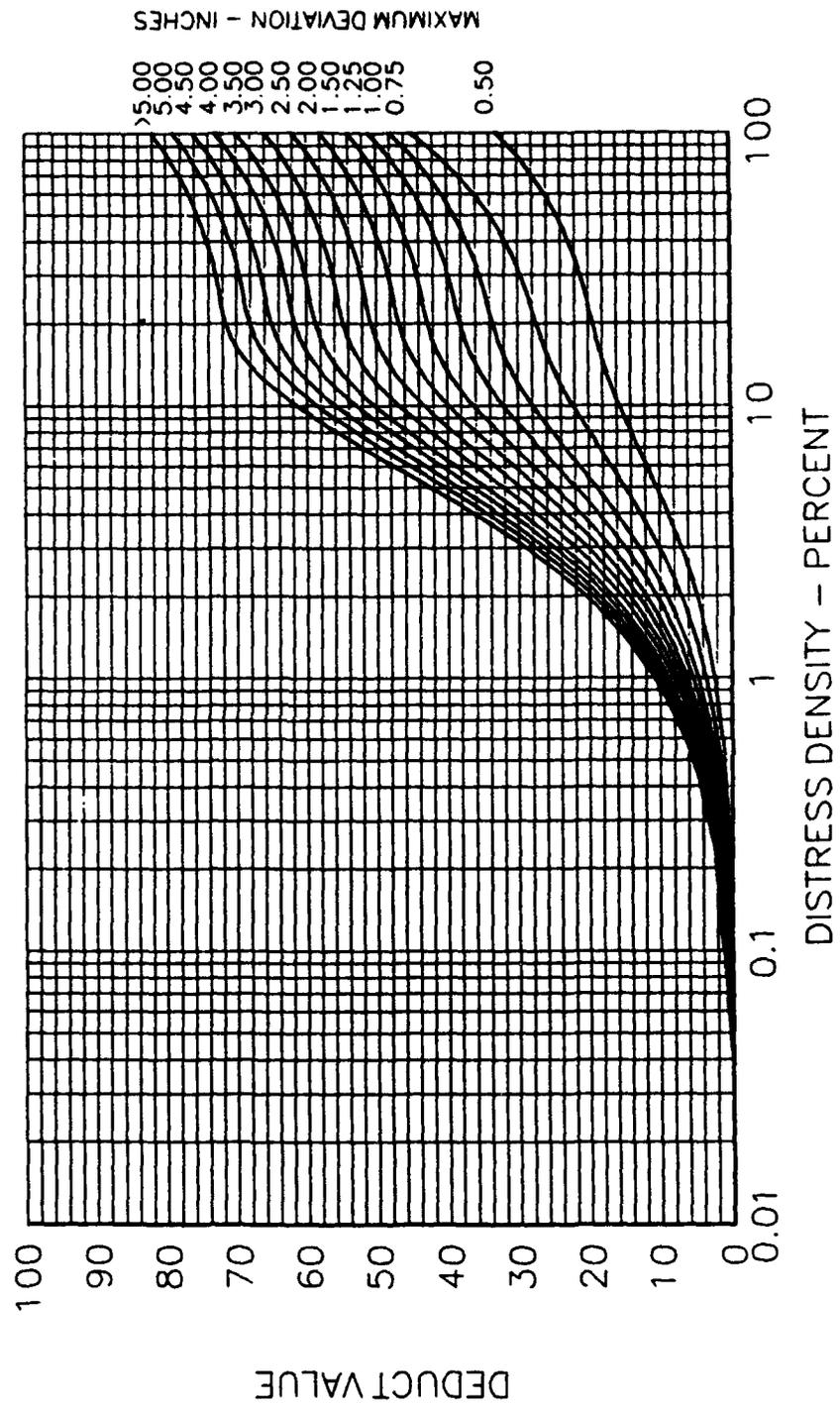


Figure C8. Alignment Deviation (B7) Deduct Curves.

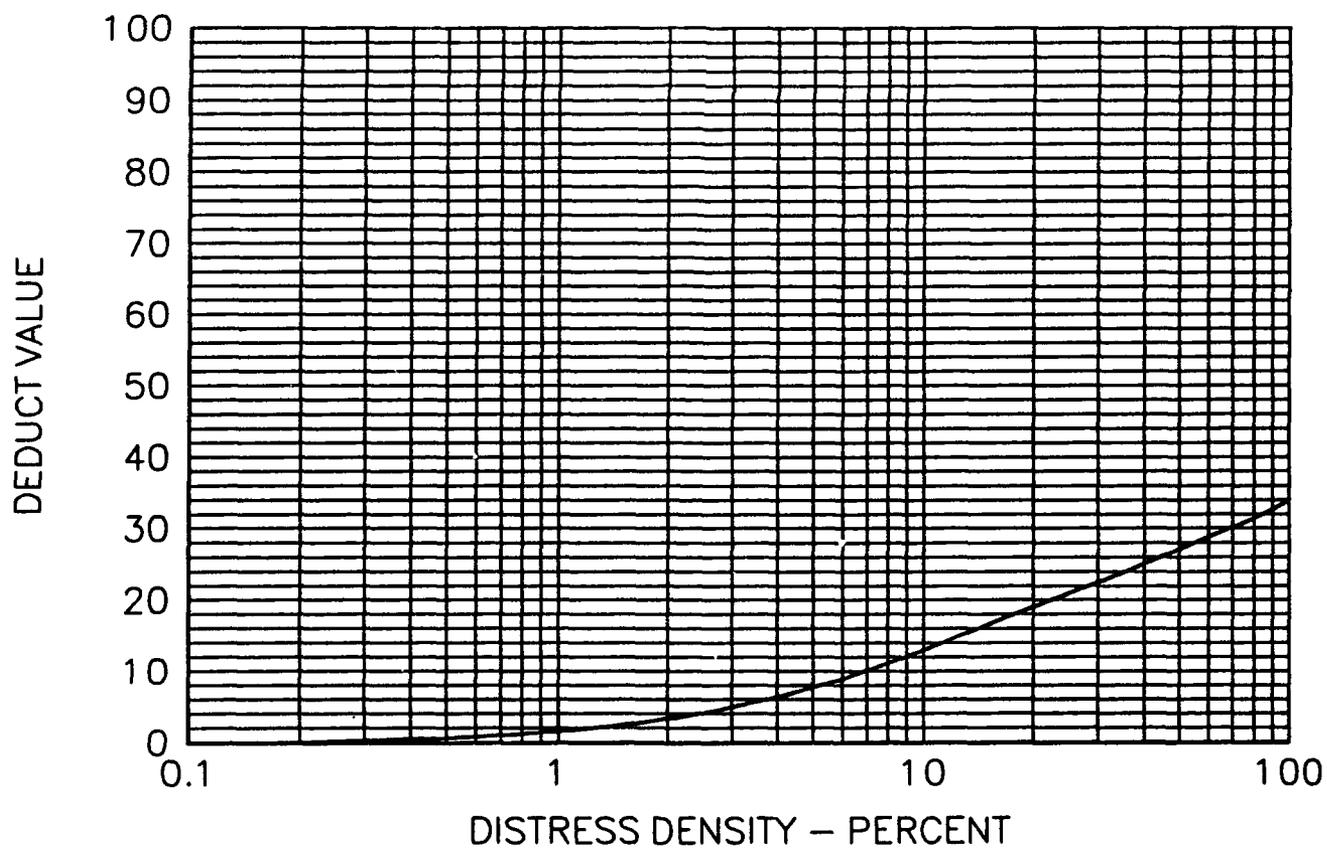


Figure C9. Insufficient Crib/Shoulder Ballast (B8) Deduct Curve.

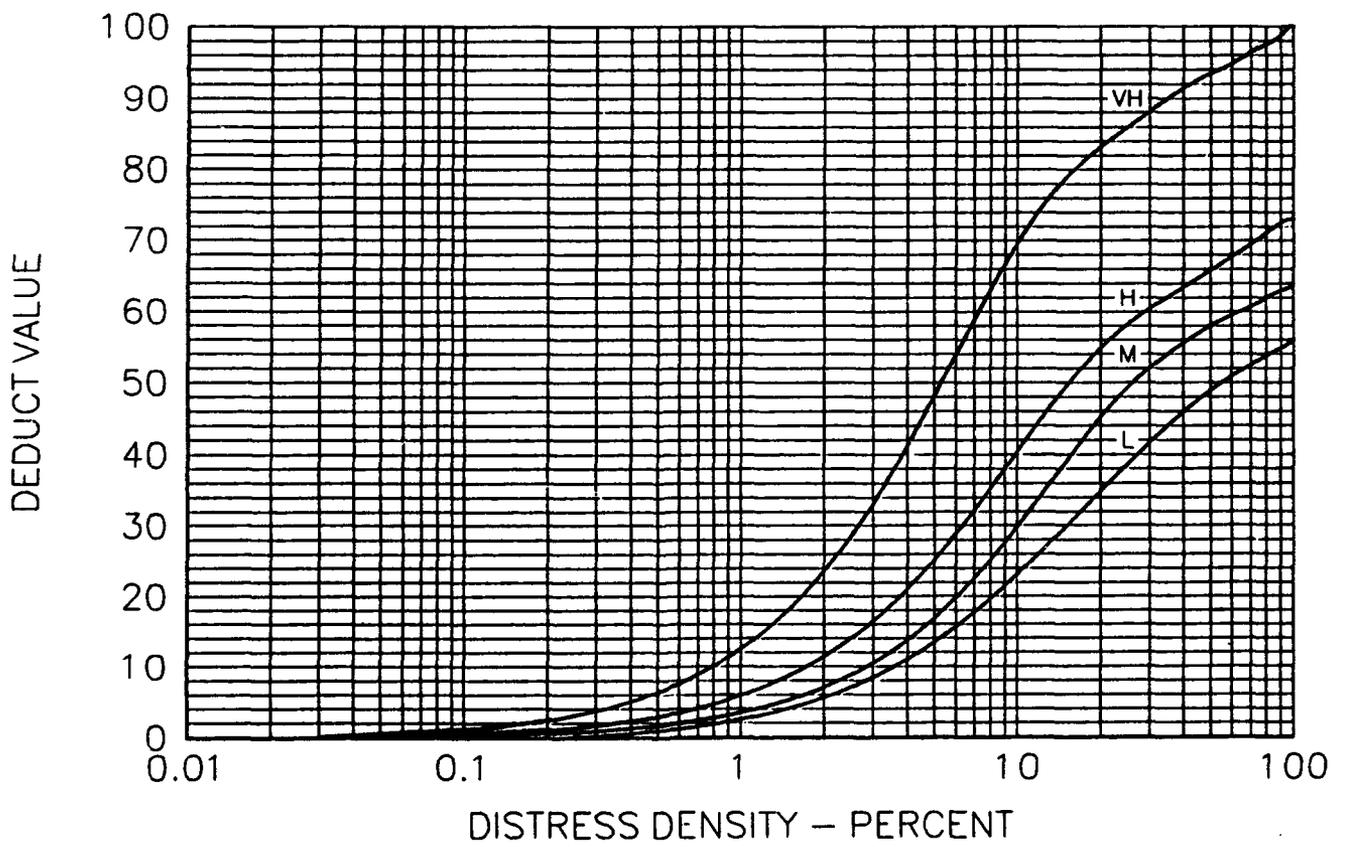


Figure C10. Erosion of Ballast (B9) Deduct Curves.

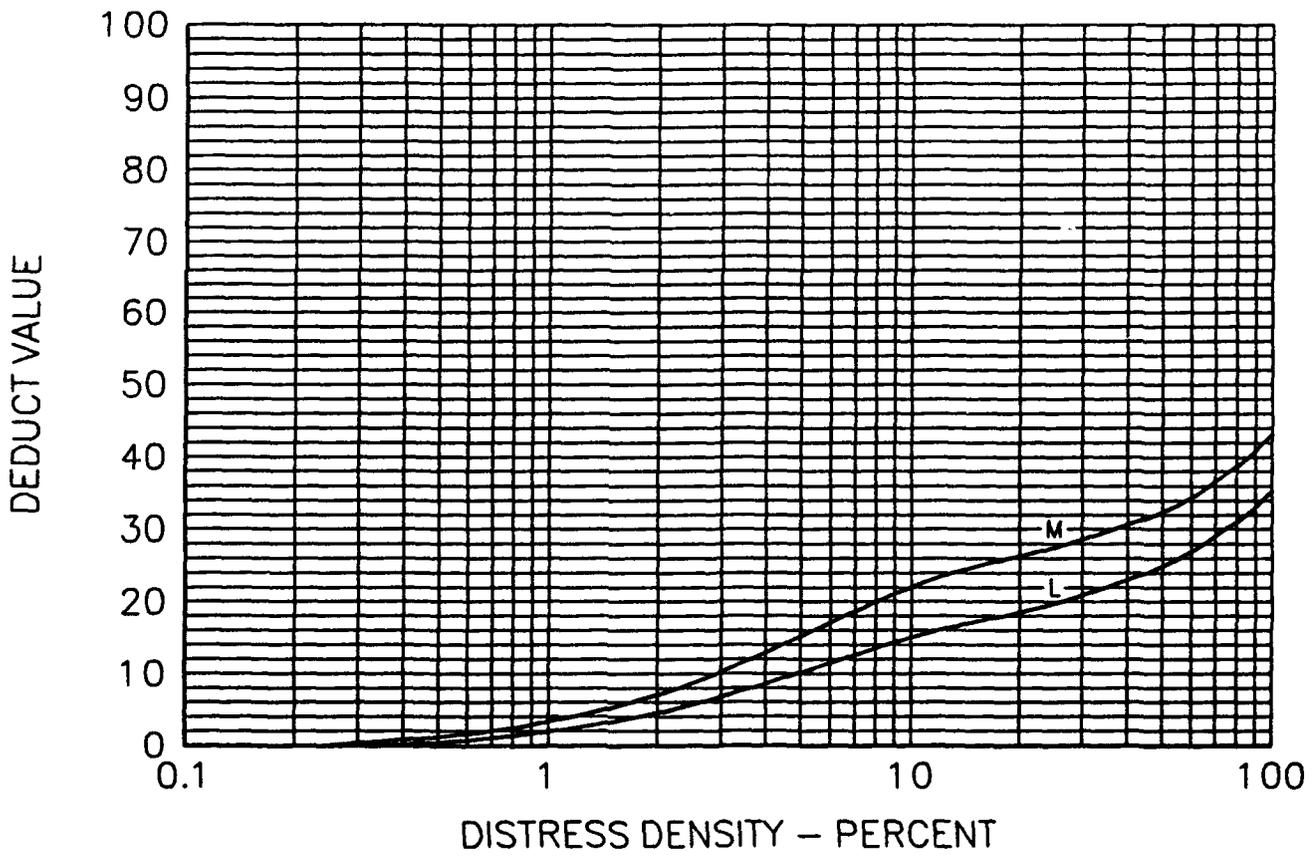


Figure C11. Inadequate Trackside Drainage (B10) Deduct Curves.

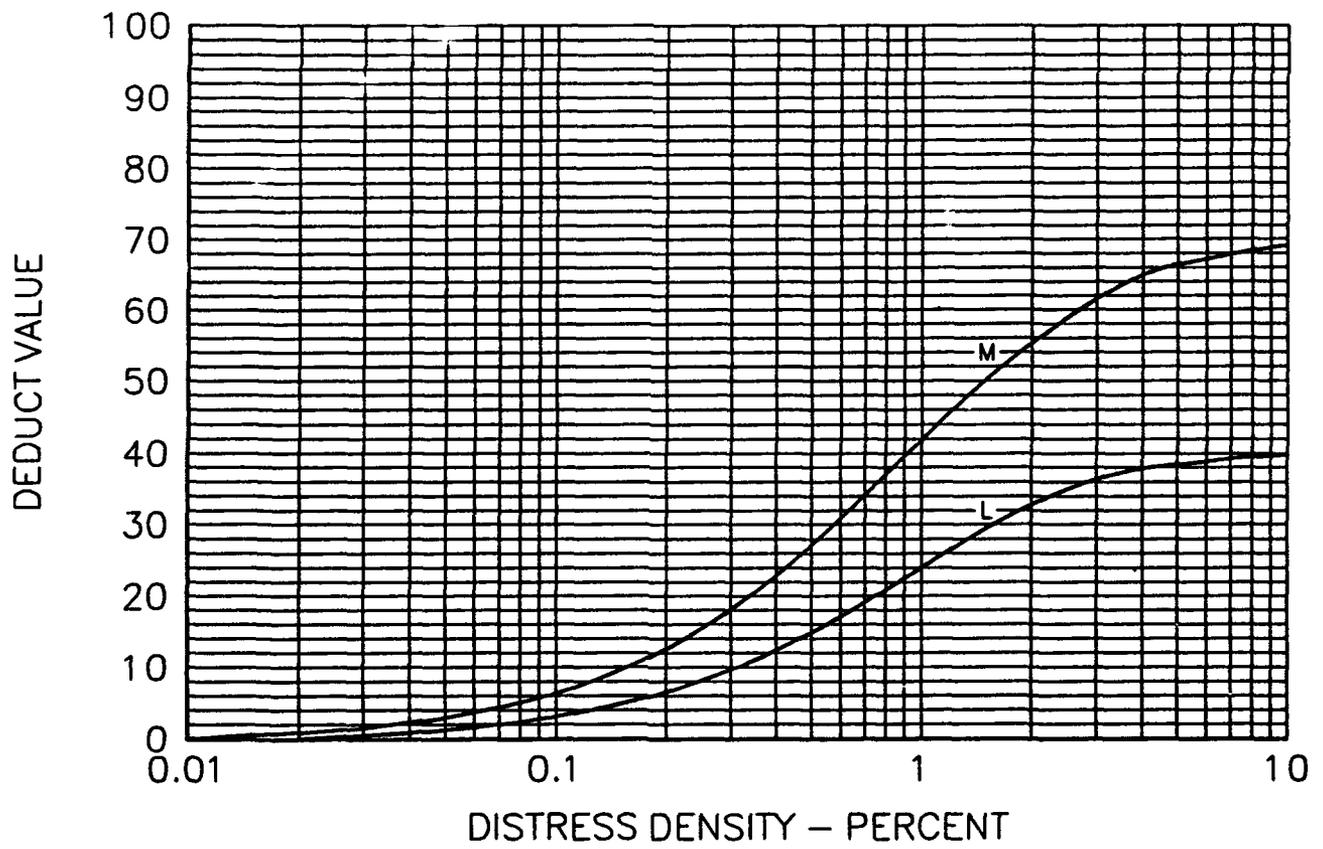


Figure C12. Inadequate Water Flow Through Drainage Structures (B11) Deduct Curves.

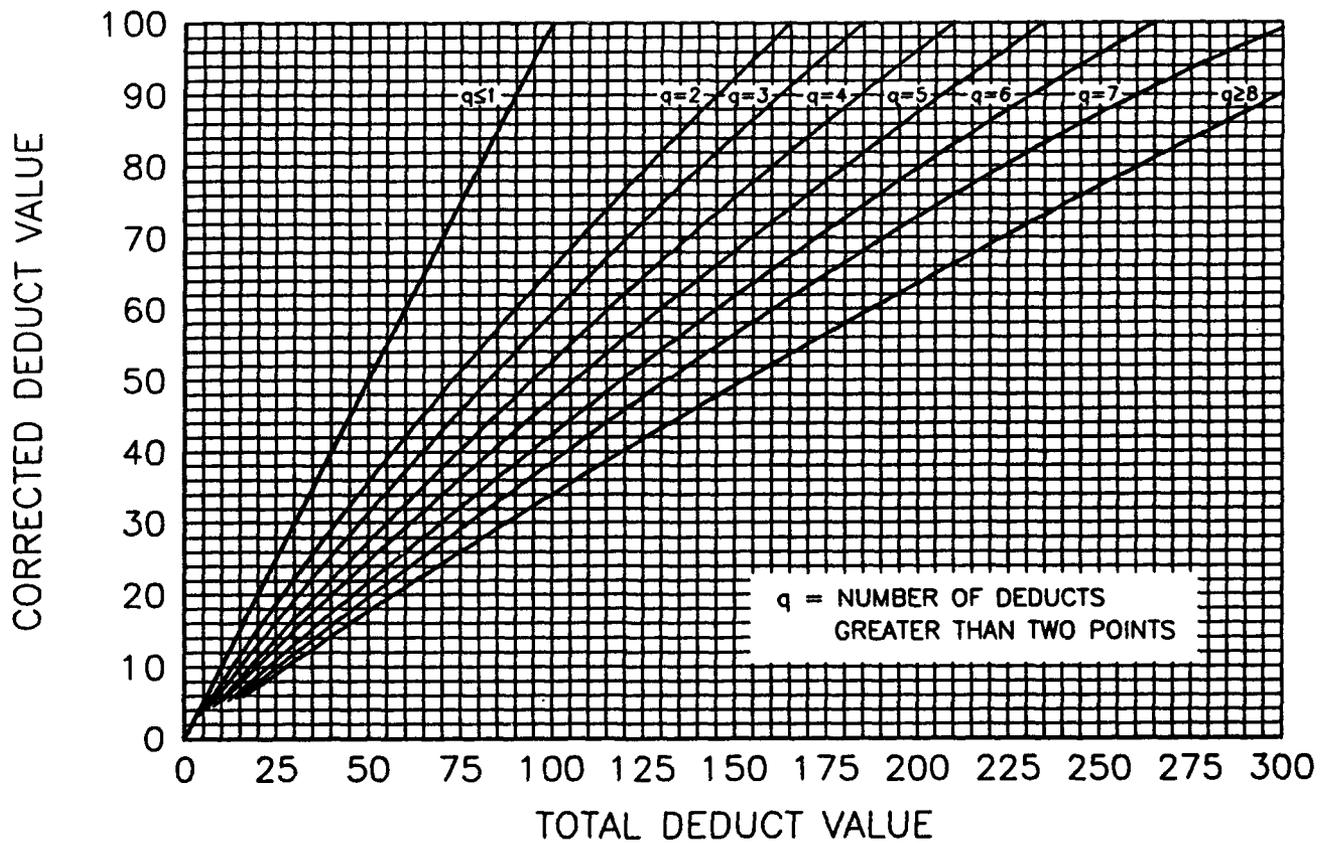


Figure C13. Ballast, Subgrade, and Roadway Component Group Correction Curves.

APPENDIX D: BLANK RAILROAD TRACK CONDITION SURVEY INSPECTION WORKSHEET

APPENDIX E: BLANK RJCI, TCI, AND BSCI CALCULATION WORKSHEET

RJCI, TCI, and BSCI Calculation Worksheet

RJCI

Distress Type	Severity	Quantity	Density	Deduct Value

$m = 1 + 9/98(100 - DV_{max}) =$

Row	Deduct Values								TDV	q	CDV
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
RJCI = 100 - CDV _{max} =											

TCI

Distress Type	Severity	Quantity	Density	Deduct Value

$m = 1 + 9/98(100 - DV_{max}) =$

Row	Deduct Values								TDV	q	CDV
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
TCI = 100 - CDV _{max} =											

BSCI

Distress Type	Severity	Quantity	Density	Deduct Value

$m = 1 + 9/98(100 - DV_{max}) =$

Row	Deduct Values								TDV	q	CDV
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
BSCI = 100 - CDV _{max} =											

APPENDIX F: CORRECTED DEDUCT VALUE (CDV) DETERMINATION DISCUSSION

The corrected deduct value (CDV) determination procedure follows the methodology described in ASTM D 5340 - 93.

The CDV determination procedure is identical for the RJCI, TCI, and BSCI. It involves examining and ranking all of the individual deduct values, establishing the maximum number to use, and deciding which of those deduct values are to be used in the CDV determination.

The maximum number of deducts to use is found using Equation F1.

$$m = 1.00 + (9/x)(100 - HDV) \leq 10 \quad [\text{Eq F1}]$$

where $9/x = \text{Constant}$
 $x = 98$ based on the cutoff deduct value of 2
HDV = Highest Deduct Value

Equation F1 is presented graphically as Figure F1.

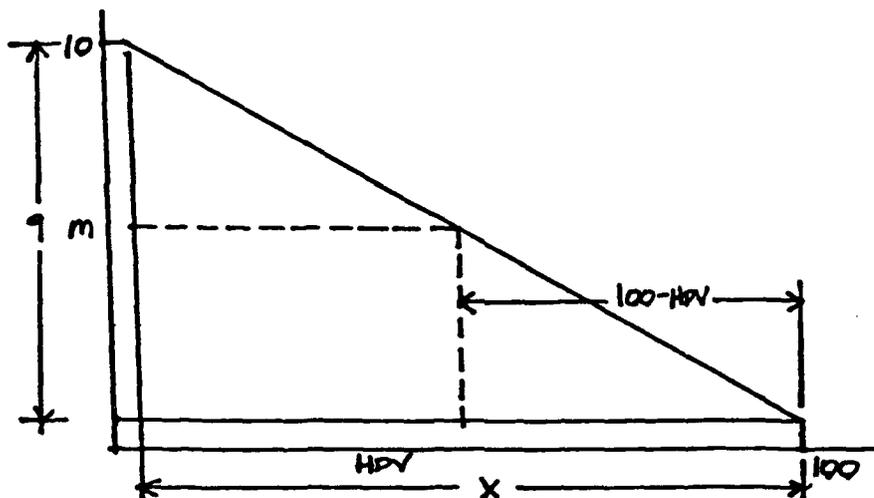


Figure F1. Determination of Maximum Allowable Deducts

If the number of individual deducts exceeds the maximum allowable, the number to use is reduced to "m," including the decimal (fractional) portion. This is accomplished as follows:

1. Compute "m."
 - Use Equation F1.
 - For example, if the HDV is 32, "m" equals 7.24.
2. Determine which individual deduct values to use in CDV calculation.
 - Rank individual deduct values, high to low.

- If the actual number of individual deduct values is less than or equal to "m," all of the values will be used in the analysis.
- If the actual number of individual deduct values is greater than "m," reduce the number of deduct values to "m" by eliminating individual deduct values, low to high. The fractional value of "m," if applicable, is multiplied by the "m + 1" deduct value and the resulting product is used along with the other "m" highest deduct values.

For example, use m of 7.24 as calculated previously, for computing the BSCI. There are nine individual deduct values ranked, high to low, as 32, 29, 23, 21, 13, 10, 8, 6, 5. This means that the value 5 is dropped and the seven values 32 through 8 will be used. The value 6 is reduced by multiplying 6 by .24. This results in a revised value of 1 (rounded to the nearest whole integer). The individual deduct values that will carry forward in the analysis are 32, 29, 23, 21, 13, 10, 8, 1.

The CDV is computed using the individual deduct values. They should be placed in a table with the first row consisting of the ranked values. Successive rows are created substituting the value "2" for the lowest value in each row that exceeds 2. Each row is then totalled. This is shown in Table F1.

Once the individual deduct table is created, CDVs are computed for each row. This is accomplished using the appropriate correction curves (e.g, Figure C13 for the BSCI). The "q" values to use are the number of individual deduct values greater than two points. This is illustrated in Table F2.

The largest CDV is used to compute the condition index. For this example the CDV is 50.

Table F1

Example Individual Deduct Value Table

Individual Deduct Values								Total
32	29	23	21	13	10	8	1	137
32	29	23	21	13	10	2	1	131
32	29	23	21	13	2	2	1	123
32	29	23	21	2	2	2	1	112
32	29	23	2	2	2	2	1	93
32	29	2	2	2	2	2	1	72
32	2	2	2	2	2	2	1	45

Table F2

Example Corrected Deduct Value (CDV) Table

Total	q	CDV
137	7	43
131	6	46
123	5	48
112	4	50
93	3	49
72	2	44
45	1	45

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