



American Railway Engineering and
Maintenance-of-Way Association

CHAPTER 27

MAINTENANCE-OF-WAY WORK EQUIPMENT¹

FOREWORD

Part 3 Reports and Records was deleted in its entirety in 1996.

TABLE OF CONTENTS

Part/Section	Description	Page
1 General		27-1-1
1.1	Recommended Colors for Painting Motor Cars, Roadway Machines, Work Equipment and Rail Guide Wheel Equipment	27-1-3
1.2	General Care and Maintenance of Maintenance-of-Way Equipment (Including Rail Gear Equipment)	27-1-4
1.3	General Information Associated with Wire Rope as used on Roadway Work Equipment.	27-1-6
1.4	Bar Codes and Their Application for Roadway Work Equipment.	27-1-18
1.5	Equipment Operators Training and Certification	27-1-22
2 Roadway Machines		27-2-1
2.1	Specifications for Track Motor Cars.	27-2-4
2.2	Specifications for Railway Push Cars	27-2-23
2.3	Specifications for On-track Roadway Machines.	27-2-27
2.4	Axle, Wheel and Hub Specifications	27-2-43
2.5	Hydraulic Systems	27-2-43

¹ The material in this and other chapters in the AREMA *Manual for Railway Engineering* is published as recommended practice to railroads and others concerned with the engineering, design and construction of railroad fixed properties (except signals and communications), and allied services and facilities. For the purpose of this Manual, RECOMMENDED PRACTICE is defined as a material, device, design, plan, specification, principle or practice recommended to the railways for use as required, either exactly as presented or with such modifications as may be necessary or desirable to meet the needs of individual railways, but in either event, with a view to promoting efficiency and economy in the location, construction, operation or maintenance of railways. It is not intended to imply that other practices may not be equally acceptable.

TABLE OF CONTENTS (CONT)

Part/Section	Description	Page
2.6	Electrical Systems	27-2-46
2.7	Specifications for Rail Guide Wheel Equipment	27-2-47
2.8	Lockout/Tagout (LOTO) During Maintenance of Roadway Machines	27-2-58
2.9	Railway Track Equipment Operator Sightlines and Visibility Guideline for New On-Track Machinery 27-2-60	
2.10	Access Systems for Maintenance of Way Machines.	27-2-62
References.		27-R-1

INTRODUCTION

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

Page Numbers – In the page numbering of the Manual (27-2-1, for example) the first numeral designates the Chapter number, the second denotes the Part number in the Chapter, and the third numeral designates the page number in the Part. Thus, 27-2-1 means Chapter 27, Part 2, page 1.

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

Document Dates – The bold type date (Document Date) at the beginning of each document (Part) applies to the document as a whole and designates the year in which revisions were last made somewhere in the document, unless an attached footnote indicates that the document was adopted, reapproved, or rewritten in that year.

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Proceedings Footnote – The Proceedings footnote on the first page of each document gives references to all Association action with respect to the document.

Annual Updates – New manuals, as well as revision sets, will be printed and issued yearly.





American Railway Engineering and
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Part 1

General

— 2009 —

TABLE OF CONTENTS

Section/Article	Description	Page
1.1	Recommended Colors for Painting Motor Cars, Roadway Machines, Work Equipment and Rail Guide Wheel Equipment.....	27-1-3
1.1.1	General (1996).....	27-1-3
1.2	General Care and Maintenance of Maintenance-of-Way Equipment (Including Rail Gear Equipment)	27-1-4
1.2.1	General (2009).....	27-1-4
1.3	General Information Associated with Wire Rope as used on Roadway Work Equipment	27-1-6
1.3.1	Introduction (1991).....	27-1-6
1.3.2	General (1991).....	27-1-6
1.3.3	Diameter (1991).....	27-1-6
1.3.4	Construction (1991).....	27-1-7
1.3.5	Types of Strand Construction (1991).....	27-1-8
1.3.6	Classification of Wire Rope (1991).....	27-1-9
1.3.7	Wire Rope Lays (1991).....	27-1-11
1.3.8	Grades of Wire Rope (1991).....	27-1-12
1.3.9	Factor of Safety (1991).....	27-1-13
1.3.10	Lubrication of Wire Rope (1991).....	27-1-13
1.3.11	Cause of Failures (1991).....	27-1-13
1.3.12	Abrasion Versus Flexibility (1991).....	27-1-14
1.3.13	Wire Rope Connections (1991).....	27-1-15
1.3.14	References and Sources of Additional Information (1991).....	27-1-15
1.4	Bar Codes and Their Application for Roadway Work Equipment.....	27-1-18
1.4.1	Introduction (1992).....	27-1-18
1.4.2	Benefits of Bar Codes (1992).....	27-1-18
1.4.3	Equipment (1992).....	27-1-19
1.4.4	Bar Code Format (1992).....	27-1-19
1.4.5	Applications (1992).....	27-1-20
1.4.6	Manufacturers Requirements for Parts Books (1992).....	27-1-21

TABLE OF CONTENTS (CONT)

1.5 Equipment Operators Training and Certification	27-1-22
1.5.1 Introduction (2009)	27-1-22
1.5.2 Operator Training Methods - Background (2009)	27-1-22
1.5.3 Candidate Selection and Class Size Criteria (2009)	27-1-23
1.5.4 Operator Training Program Requirements (2009)	27-1-23
1.5.5 Retraining and Recertification (2009)	27-1-24



LIST OF FIGURES

Figure	Description	Page
27-1-1	Determining the True Diameter of Wire Rope	27-1-6
27-1-2	Component Parts of Wire Rope	27-1-7
27-1-3	Wire Rope Cores and Cross-sections	27-1-9
27-1-4	Common Lays	27-1-11
27-1-5	Abrasion and Fatigue Resistance	27-1-15
27-1-6	Clip Installation	27-1-16
27-1-7	Efficiency of Wire Rope Connections	27-1-17
27-1-8	Sample Bar Codes	27-1-20



LIST OF TABLES

Table	Description	Page
27-1-1	Recommended Colors for Painting Motor Cars, Roadway Machines, Work Equipment and Rail Guide Wheel Equipment	27-1-3
27-1-2	Recommended Colors for Painting of Parts/Components	27-1-3
27-1-3	Wire Rope Grades and Characteristics	27-1-12
27-1-4	Minimum Tread Diameter of Sheaves and Drums for Various Construction of Steel Rope	27-1-14
27-1-5	Clip Installation	27-1-16
27-1-6	Example Part Number Formats	27-1-22



SECTION 1.1 RECOMMENDED COLORS FOR PAINTING MOTOR CARS, ROADWAY MACHINES, WORK EQUIPMENT AND RAIL GUIDE WHEEL EQUIPMENT¹

— 1996 —



1.1.1 GENERAL (1996)

- a. The most suitable colors for painting Motor Cars, Roadway Machines, Work Equipment and Rail Guide Wheel Equipment are as shown in [Table 27-1-1](#).

Table 27-1-1. Recommended Colors for Painting Motor Cars, Roadway Machines, Work Equipment and Rail Guide Wheel Equipment

Equipment	Color	Standard Spec. No.
Motor Cars	Yellow	13538
Roadway Equipment	Yellow	13538
Roadway Work Equipment (cranes, etc.)	Yellow	13538
Work Equipment (Jordan Spreaders, etc.)	Mineral Red	10076
Rail Guide Wheel Equipment	Black	17038

- b. The predominant colors of equipment will be a specified color, but some parts or components may require custom painting (reference [Part 2, Roadway Machines, Section 2.3, Specifications for On-track Roadway Machines, Article 2.3.17](#)). Some of the more notable items are listed in [Table 27-1-2](#).

Table 27-1-2. Recommended Colors for Painting of Parts/Components

Component Area	Color	Standard Spec. No.
Gasoline Tank	Red	11086
Diesel Fuel Tank	Green	14110
Hydraulic Reservoir	Blue	15180
Coolant Reservoir	Gray	16251
Lifting Lugs	Black	17038
Safety Locks	Red	11086

- c. The colors listed under Standard Specification Numbers are consistent with those indicated in the “Federal Standard 595-B, Colors Used in Government Procurement.”

NOTE: It should be understood that some Railroads may have special painting requirements which will supersede the above recommended practices or guidelines.

¹ References, Vol. 32, 1931, pp. 472, 754; Vol. 43, 1942, pp. 213, 727; Vol. 44, 1943, pp. 251, 670; Vol. 54, 1953, pp. 638, 1373; Vol. 55, 1954, p. 1069; Vol. 62, 1961, pp. 454, 931; Vol. 92, 1991, p. 103; Vol. 94, 1993, p. 125, Vol. 97, p. 218.

SECTION 1.2 GENERAL CARE AND MAINTENANCE OF MAINTENANCE-OF-WAY EQUIPMENT (INCLUDING RAIL GEAR EQUIPMENT)¹ — 2009 —

1.2.1 GENERAL (2009)

- a. The varying conditions on different railroads do not permit the universal acceptance, in all details, of any specific outline or an organization for the use, maintenance, and repair of the equipment. To determine the proper organization best adapted to produce maximum service and productivity, at a minimum cost, from its fleet of equipment each railroad must review and analyze various conditions which will greatly influence these factors. Some of the more important areas are listed below.
 - (1) The quantity and age of the major and minor units of equipment.
 - (2) The level of mechanization and sophistication of the equipment.
 - (3) The type of managerial organization established for utilizing, supervising and maintaining the equipment.
 - (4) Geographic location and total trackage involved with the railroad.
 - (5) Organization of Equipment Repair Shops, i.e. centralized or decentralized, Engineering, Mechanical, or Fleet jurisdiction, manpower, etc.
- b. However, there are certain principles in the use and maintenance of machinery which will be found desirable, if not essential, if the equipment is to be maintained and used economically. Special attention should be directed to the following areas:
 - (1) The organization for supervising and maintaining the equipment should be headed by a practical railroad employee, with sufficient executive ability and solid mechanical knowledge to supervise the maintenance and operation of all equipment on the system. The appropriate department should have authority, and sufficient personnel to institute and enforce regulations for the maintenance and operation of the equipment. Duties should embrace direct or indirect control of mechanical details of the equipment, in both field and shop, the supervision of maintainers, involvement with necessary reports and managing data base information. He/she should work closely with the supervisory forces in the assignment and use of the equipment. He/she must also work very closely with the Purchasing and Material Department as it relates to acquisition of new equipment, component parts and the distribution of supplies required for the maintenance and repair of equipment.
 - (2) It is desirable that adequate instructions for the care and operation of the equipment be issued. Such instructions, developed by the AREA, were first published in the proceedings in 1947 and were later reprinted in handbook form under the title "Manual of Instructions for Care and Operation of Maintenance-of-Way Work Equipment."
 - (3) Cooperation on the part of supervisory officers in seeing the instructions are carried out are of the utmost importance. This cannot be secured unless each such officer recognizes the importance of the work he/she is supervising in an effort to keep the equipment in operation. In order to achieve maximum results of equipment productivity and availability, through proper operation and preventive maintenance procedures and practices, the local and upper management levels must give their full support to the program.

¹ References, Vol. 27, 1926, pp. 1028, 1449; Vol. 49, 1948, pp. 148, 593; Vol. 53, 1952, pp. 366, 1088; Vol. 54, 1953, pp. 638, 1373; Vol. 58, 1957, pp. 580, 1218; Vol. 62, 1961, pp. 455, 931; Vol. 63, 1962, pp. 352, 738; Vol. 92, 1991, p. 103, Vol. 97, p. 218.





- (4) Prevention of disabling conditions in any machine is as truly maintenance as is the correction of such conditions after they have developed; and prevention will save the loss of time and money required for repairs.
- (5) As a result of following a thorough preventive maintenance program, the need for emergency and/or unscheduled repairs can be substantially reduced. A preventive maintenance program is basically a repair prior to failure philosophy and can be characterized by the following:
 - (a) Keeping equipment clean.
 - (b) Operating the equipment safely and within its limit of capacity.
 - (c) Well controlled lubrication program.
 - (d) Performing required inspection, adjustment, and scheduled maintenance at the proper intervals.
 - (e) Utilizing a formal record keeping system, i.e. operators and maintenance personnel, daily log, machine history file, failure reporting system, cost involved with equipment use, which will provide a solid foundation for a computerized record keeping and cost capturing system.
 - (f) Ongoing training program for operator and service/maintenance personnel.
- (6) Material Department operations should be properly located and adequately stocked so that repair parts, when needed, can be supplied with the least delay. This area can be streamlined with the use of highway type van trailers, properly sized, well organized, and adequately stocked to eliminate some of the current problems associated with using rolling stock tool cars. Some of these problems are delay in timely spotting of the car at the work site and damages to the parts inventory due to rough handling. The use of relief equipment and power plants will reduce delays in the event of equipment failures.
- (7) In scheduling the shopping of equipment for major repairs, consideration should be given to the capacity of the shop as well as the conditions of the equipment. In so far as possible, the equipment used in seasonal work should be overhauled during the slack season.
- (8) Shops for the repair of equipment should be centrally located and under the control of the appropriate department. These shops should be equipped with the necessary tools, shop machinery, and in general provide repairs in the most timely and cost effective method.
- (9) The expense of maintaining the equipment can be reduced through the adoption by each railroad, of the fewest number of makes and type of the equipment required to meet its needs. Such a restriction to adopt its standards will reduce investment in stock parts and lower maintenance costs.
- (10) Adequate reports and records should be prepared as a means of maintaining close check on the use being made of the equipment, the care of it, and to assist in passing judgment on purchase of new equipment.

SECTION 1.3 GENERAL INFORMATION ASSOCIATED WITH WIRE ROPE AS USED ON ROADWAY WORK EQUIPMENT¹

— 1991 —

1.3.1 INTRODUCTION (1991)

- Wire rope is a much more complex mechanism than one generally realizes. But when its fundamentals and capabilities are understood, wire rope can perform with economy, dependability and safety.
- It consists of many wires capable of transmitting dynamic stresses or supporting static loads. Wire rope is one of the strongest products manufactured for its size and weight. Wire rope is made to withstand the demands of tensile and bending stresses and abrasive wear, present in practically all job applications. It is available for a wide variety of applications and ever expanding number of operating conditions.

1.3.2 GENERAL (1991)

Wire rope is a piece of flexible, multi-wired, stranded machinery made of many precision parts. The usual type of wire rope consists of a core member, around which any number of multi-wired strands are “laid” or helically bent. In general, the greater the number of wires in the strand and the greater number of strands for a given size rope, the more flexible it will be.

1.3.3 DIAMETER (1991)

The true diameter of a wire rope is the diameter of a circle which will enclose it. In using a caliper to determine the diameter, be careful to measure across the crowns or the widest diameter at any given point, and avoid measuring across adjacent strands ([Figure 27-1-1](#)).

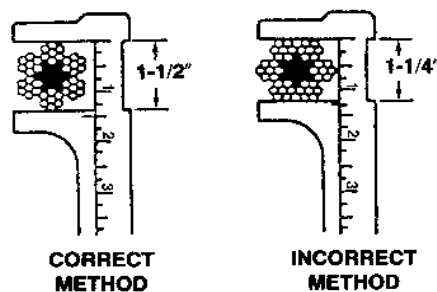


Figure 27-1-1. Determining the True Diameter of Wire Rope

¹ References, Vol. 44, 1943, p. 256; Vol. 45, 1944, pp. 110, 609; Vol. 54, 1953, pp. 638, 1373; Vol. 63, 1962, pp. 352, 738; Vol. 92, 1991, p. 102. Revised 1991.

1.3.4 CONSTRUCTION (1991)

Wire rope has three main component parts consisting of core, strands and wires, of which each is indicated in Figure 27-1-2.

1.3.4.1 Core

Supports the outer strands and also maintains position of strands during movement involving bending and load stresses.

1.3.4.1.1 Fiber Core – (FC)

Are generally sisal, manila, or man-made synthetic fiber rope as polypropylene, polyester or nylon. It is treated with a special lubricant and recommended for high duty service. The limitations of fiber core ropes are reached when pressure such as crushing results in core collapse and distortion of the rope strands.

1.3.4.1.2 Independent Wire Rope Core – (IWRC)

Generally used under severe conditions. The wire core can be independent wire rope, steel strand or armored core. The independent wire rope core is composed of a separate 7×7 wire rope. It is recommended for heavy-duty service because of its ability to minimize crushing and distortion.

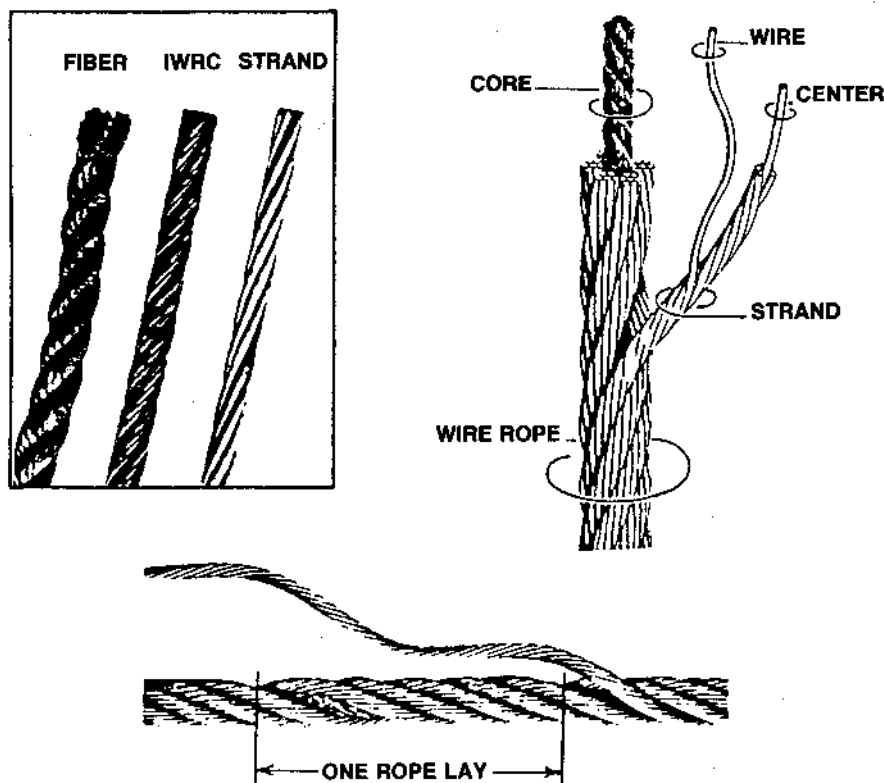


Figure 27-1-2. Component Parts of Wire Rope

1.3.4.1.3 Wire Strand Core – (WSC)

Are normally used on small diameter ropes and aircraft cords. A WSC consists of a single strand, either of the same construction or sometimes more flexible than the main rope strands.

1.3.4.2 Strands

These are supported by a core. Size, strength and number of strands depends upon the job the wire rope has to perform. Also, strands are laid around the core with a length of lay (or pitch) suitable to form the finished wire rope best suited for the job. Strands are composed of wires, varying in number from 3-91 with the majority being 7, 19, 25, or 37. These are laid helically around the core.

1.3.4.3 Wires

THESE MAKE UP THE STRANDS. They are produced in various grades such as “plow steel,” “improved plow steel” and “extra improved plow steel.”

1.3.5 TYPES OF STRAND CONSTRUCTION (1991)

There are two general types: round strands and strands that have been shaped or formed.

1.3.5.1 Round Strand Ropes

1.3.5.1.1 Ordinary

Wires are all of the same size.

1.3.5.1.2 Seale

Strands have larger diameter wires on the outside of the strand to resist abrasion and smaller wires inside to improve flexibility.

1.3.5.1.3 Warrington

Alternate wires are larger and smaller to combine flexibility with resistance to abrasion.

1.3.5.1.4 Filler

Has many small wires in the valleys between the outer and inner rows of wires to provide good abrasion and fatigue resistance.

1.3.5.2 Flat or Formed Strand Ropes

- a. This is a special rope construction made up of triangular-shaped strands providing outstanding service for special heavy-duty jobs. This design forms an outer rope surface more nearly approaching a smooth continuous cylinder of steel, as compared with round strand rope.
- b. These formed strand ropes have a “flat” strand surface for greater load support and more contact area on sheaves and drums, and is provided in three “styles.” First, seven large strand wires formed over a single triangle center wire is a 6 × 8 Style D ([Figure 27-1-3](#)); second, multiple strand wires formed over a single triangular center wire is a 6 × 25 Style B and third, 6 × 30 Style G has six smaller wires forming the triangular center. The visual comparison shown on [Figure 27-1-3](#) indicates that flattened strand provides a sheave point bearing much greater than round strands, and this principal of greater wear distribution applies equally to strand wear.



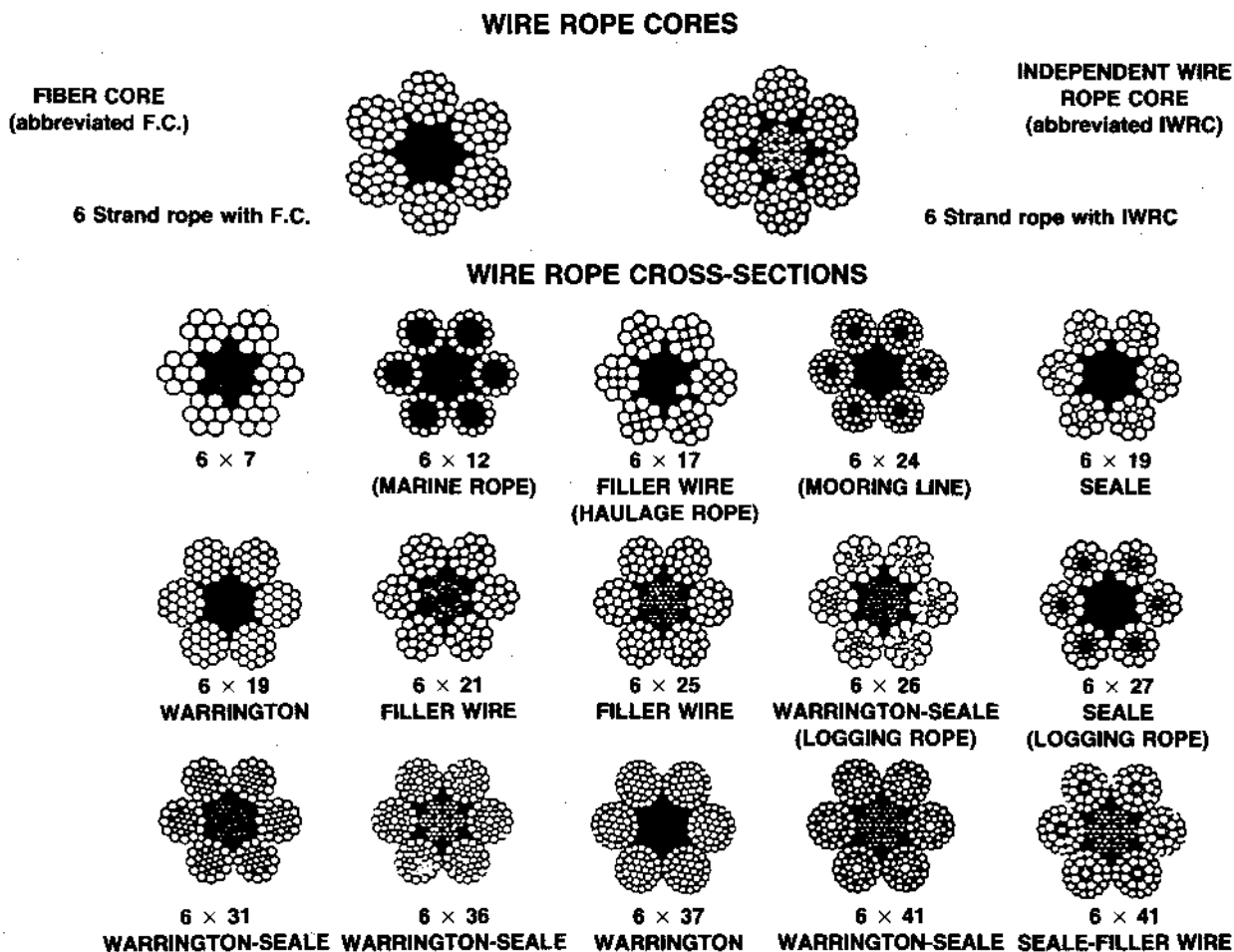


*Figure 27-1-3. Wire Rope Cores and Cross-sections
(Sheet 1 of 2)*

1.3.6 CLASSIFICATION OF WIRE ROPE (1991)

- a. This design or arrangement of wire rope, consisting of wire, strands and core is called the construction, The classification of wire rope is the numerical designation of construction. It defines the number of strands placed around the core as well as the number of wires in each individual strand.
- b. For example, 6×7 means that there are 6 strands, each strand composed of 7 wires; 6×19 means 6 strands composed of 19 wires; 6×37 denotes 6 strands composed of 37 wires. Note the cross section of a 7-wire strand that forms a part of 6×7 rope. (See [Figure 27-1-2](#).) Each of the wires are the same diameter, and 6 wires fit snugly around the wire in the center. For this reason, a 6-strand rope with center core is most common today. With bigger and heavier-duty equipment and the demand for maximum efficiency on many more applications, extra qualities of resistance to abrasion, increased flexibility and resistance to bending fatigue are now being required of wire rope. The 19-wire classification fulfills these requirements with twelve or less outer wires and combinations of inner wire arrangement.

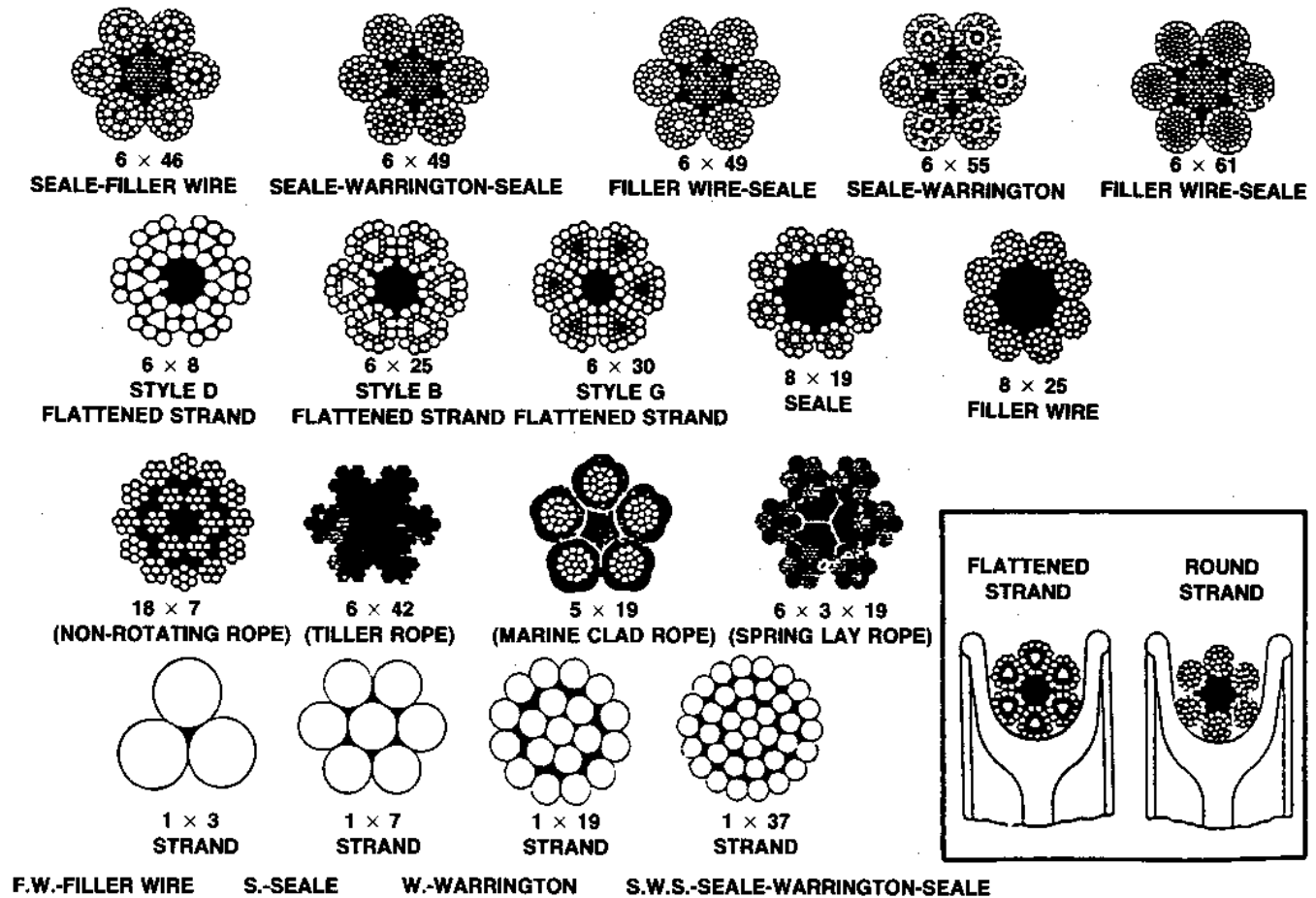


Figure 27-1-3. Wire Rope Cores and Cross-sections
(Sheet 2 of 2)

- c. The 37-wire classification was created because of the requirements of extreme flexibility in ropes. Generally speaking, the more wires per strand, the greater the flexibility of the rope. Many varieties of classifications of strand construction are designed for all types of applications. To avoid confusion, a simplified method to identify wire rope constructions has been adopted. Although the “6 × 19 classification” and “6 × 37 classification” are not factually descriptive of one classification, they do cover the largest variation of wire ropes of similar weight and strength. Note the many end views on Figure 27-1-3, showing wire rope classifications to suit most every wire rope application.

- 6 × 19 CLASSIFICATION—Six strands having 16 through 26 wires but not more than 12 outer wires in each strand.
- 6 × 37 CLASSIFICATION—Six strands having 27 through 49 wires, but not more than 18 outer wires in each strand.

1.3.7 WIRE ROPE LAYS (1991)

Chap
TOC

VOL
1

VOL
2

VOL
3

VOL
4

- a. The term “lay” means direction in which wires are laid into strands or strands into rope. The most common are indicated on [Figure 27-1-4](#).
- b. Each one offers variations and flexibility in resistance to wear and crushing. The direction strands “lay” in the rope are either RIGHT or LEFT. When you look along a rope, strands of the right lay rope follow the right-turning pattern. Left lay rope follows the left-turning pattern. It makes no difference which direction you look to determine the lay rotation.
 - (1) *Right Lay Rope*. When the strands of a rope are laid in a right-turning or helical twist pattern.
 - (2) *Left Lay Rope*. When the strands of a rope are laid in a left-turning or helical twist pattern.
 - (3) *Regular Lay Rope*. The wires which make up the strands are spirally laid in the opposite direction to the rope lay.
 - (4) *Lang Lay Rope*. When the wires which make up the strands are spirally laid in the same direction as the rope lay or strands themselves.
- c. The difference between “Regular” and “Lang” lay is easily recognized. The outer wires in Lang lay appear to run at an angle to the axis of the rope. The outer wires in Regular lay appear to run in the same direction as the rope axis.
- d. Regular Lay Ropes have better resistance to crushing, rotation and distortion than Lang lay ropes under load. The difference in direction of the wire and strand lays offer these advantages and also applications where only one end of the rope may be secured.
- e. Regular Lay Applications include winch lines, overhead crane ropes, holding and closing lines on clam shells, rotary drilling and cable tool lines in the oil and gas market, logging ropes, elevator ropes, mining machine ropes, hoist lines on railroad wreckers and cranes, hoists on small shovels, boom lines, tendons and slings.
- f. Lang Lay Ropes are generally more flexible and have more resistance to abrasion and bending fatigue than regular ropes.

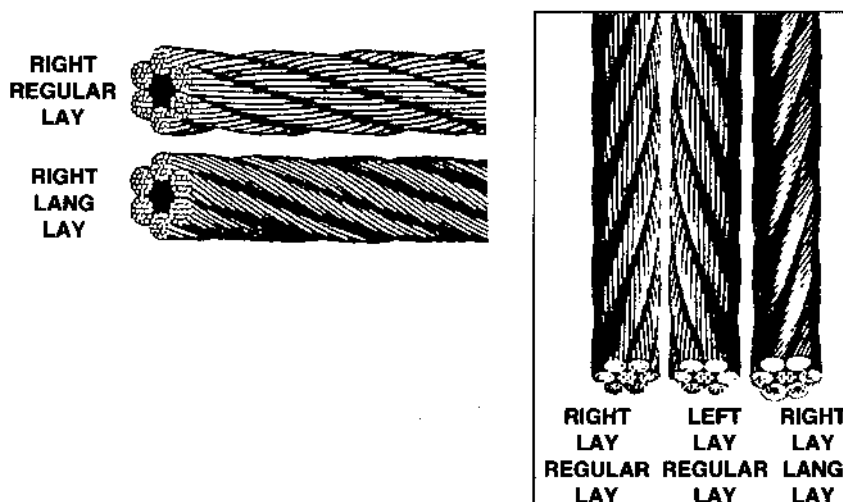


Figure 27-1-4. Common Lays

- g. Lang Lay Applications include scraper and dozer ropes, drag line crowd, retract and hoist lines on shovels, and many other applications subject to heavy abrasion conditions when both ends of the rope are tied down or anchored.

1.3.8 GRADES OF WIRE ROPE (1991)

- a. One of the primary points to consider in selecting wire rope is the material from which the rope is constructed. This is known as the *grade* of the wire rope.
- b. Quite obviously, the grade of wire will affect such things as strength, resistance to wear, fatigue resistance, corrosion resistance, etc. Today, the greatest portion of all wire rope is made from two grades of wire – improved plow steel (IPS) and extra improved plow steel (XIP). Both are tough, strong, wear-resisting carbon steel, with XIP providing about 15% greater tensile strength.
- c. Some of the other grades of rope wire, along with the distinctive characteristics of each, are shown in [Table 27-1-3](#).

Table 27-1-3. Wire Rope Grades and Characteristics

Grade of Wire	Characteristics
“POWERSTEEL” Extra Improved Plow Steel	Special grade of high-carbon steel wire unexcelled in strength, toughness and uniformity. Used in “POWERSTEEL” rope for severe conditions.
YELLOW STRAND Improved Plow Steel	The quality used in Yellow Strand is surpassed in strength and toughness only by “POWERSTEEL.” Recommended for a wide variety of applications.
PLOW STEEL	Lower in carbon content and tensile strength, this grade of rope will not resist abrasion as well as “Yellow Strand.” Should be limited to applications where service is less severe.
GALVANIZED “BROGAL”	All ropes may be made up either bright (not galvanized) or “BROGAL” galvanized. Used for many marine and industrial applications as protection against the corrosive effects such as usually-present moist or wet weather, salt water and many industrial atmospheres.
STAINLESS STEEL	Stainless Steel ropes have breaking strengths approximately equal to ropes of similar size in the “Yellow Strand” grade. The 18% chromium, 8% nickel alloy stainless has found wide acceptance in both marine and industrial applications for corrosion-resisting ropes with high tensile strength.
TRACTION STEEL	This is a special grade of steel. Traction steel ropes are used on elevators, both passenger and freight.
IRON	This is a special type of low-carbon wire. Its major uses are for sash cord, serving strand, iron tiller rope and on some older type, slow speed elevators.
NON-FERROUS	Corrosion resistance to marine and industrial atmospheres are the main functions of bronze and monel ropes. Not recommended where heavy loads or abrasion is present.



1.3.9 FACTOR OF SAFETY (1991)



- a. The factor of safety, applying to a wire rope installation, may be defined as the ratio of the ultimate strength of the rope to the actual load that has been imposed upon it by service conditions.
- b. For all practical purposes, the rated catalog strength for a size and grade of rope in question may be used for this calculation if the rope is a new one. However, if the end fittings on the rope are less than 100% efficient, this value should be reduced by the efficiency of a particular fitting used. The actual load on the rope should include the static load, as well as any dynamic or live loads.
- c. The factor of safety should be determined after consideration of such data as types of loads; acceleration and deceleration; rope speed; rope attachments; number, size, and arrangements of drums and sheaves; conditions causing corrosion and abrasion; and the time the rope has been in service.
- d. The working load on a wire rope will vary depending on the application, from approximately a safety factor of 3 to perhaps 12 or more. However, for general hoisting service, a safety factor of 5 usually is adequate for a preliminary determination of the rope size.

1.3.10 LUBRICATION OF WIRE ROPE (1991)



- a. Lubrication is necessary for wire rope to increase its service life, similar to any other machine. When one realizes that in a 6×19 rope there are 114 wires and a fiber core totaling 115 working parts, the necessity for lubrication is evident. A second important reason for lubricating iron and steel ropes is to prevent corrosion of the wires. A rusty rope is a liability, since there is no known means of inspection which will even approximate the strength of a corroded rope.
- b. Crude oil should not be used for rope lubrication as it is very apt to contain impurities that are harmful to both the core and the steel wire. Whenever possible, hot lubricants should be used and applied when the rope is under a very light load so as to get the most penetrating effect possible. The frequency of lubrication must be determined by judgment based on the service being performed, and often enough to keep the rope pliable with evidence of lubrication in the valleys between the strands. The types of lubricant used, the amount, and the method of application depend upon the size and construction of the rope and the service it is performing. Special lubricants are available for most all unusual applications.

1.3.11 CAUSE OF FAILURES (1991)

The following are some of the more common causes of wire rope failures.

- a. Use of ropes of incorrect size, construction or grade.
- b. Allowing ropes to drag over obstacles. In this manner, rope is exposed to unnecessary wear, kinking, etc.
- c. Lack of proper lubrication, which causes heating and excessive friction wear.
- d. Sheaves and drums of inadequate size that cause short radius bends. The largest practical size of drums, sheaves and pulleys should be utilized, and high speed should be avoided. The tread diameter of a drum or sheave should be in accordance with [Table 27-1-4](#).

Table 27-1-4. Minimum Tread Diameter of Sheaves and Drums for Various Construction of Steel Rope

Rope Construction	Average Recommended Tread Diameter	Minimum Recommended Tread Diameter
6 × 7	72 d	42 d
6 × 19	45 d	30 d
6 × 31	33 d	22 d
6 × 37	27 d	18 d
8 × 19	31 d	21 d
d = Diameter of rope in inches		

- e. Over winding or cross winding drums.
- f. Sheaves and drums defective or out of alignment. Badly worn sheaves cause winding and cutting of strands. Poor alignment of sheaves causes excessive wear and often over stresses the rope.
- g. Ropes jumping sheave flanges. Rope should be let out slowly in order to be taut at all times.
- h. Effects of heat moisture or acid fumes.
- i. Improper fittings. Clamps, thimble and other rope fittings should be of proper size.
- j. Permitting rope to untwist. This can be avoided if the ends are properly seized.
- k. Kinking. Rope should be allowed to twist when slack; if a kink is formed, it should be straightened out before it enters a sheave or a strain is placed on the rope.
- l. Severe overloads, reverse bends, and other excessive strains.
- m. Internal wear because of grit penetrating between strands and wires. Unless absolutely necessary, ropes should not be allowed to drag along the ground or through piles of material where they are likely to pick up grit.
- n. The angle between center line of the sheaves and the rope as it winds on and off the drum is called the fleet angle. Keep the fleet angle as low as possible (1-1/2 degrees). A large fleet angle may cause the rope to spool loosely on the drum or crowd itself until it jumps back to the previous layer, and also cause the rope to rub against the flanges of the sheave and thus produce undue wear.

1.3.12 ABRASION VERSUS FLEXIBILITY (1991)

- a. The best illustration of the *design compromise* mentioned above is the inter-relationship between resistance to abrasion and fatigue resistance.
- b. Fatigue resistance – which is the measure of the capability of bending repeatedly under stress – is accomplished by using many flexible wires in the rope strands. Resistance to abrasion or metal loss is achieved primarily with a rope design which uses fewer, larger wires so that the outer layer of wire can better withstand scrapes.
- c. So when anything is done from an engineering standpoint to alter either abrasion resistance (resistance to metal loss) or fatigue resistance, *both* of these characteristics are affected – and possibly rope strength also. (See [Figure 27-1-5.](#))



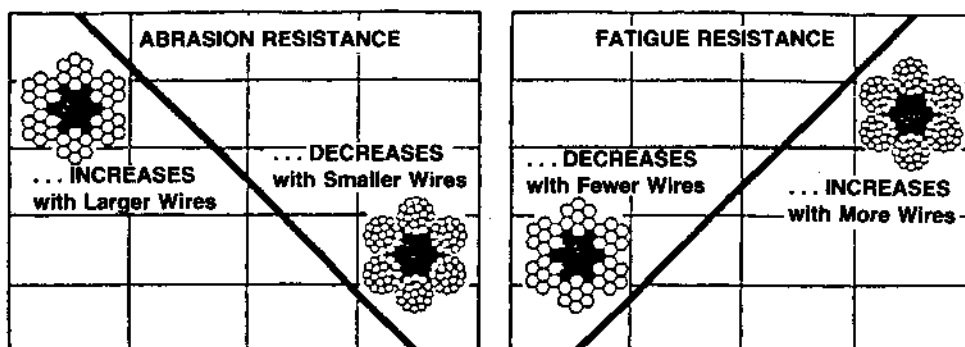


Figure 27-1-5. Abrasion and Fatigue Resistance

1.3.13 WIRE ROPE CONNECTIONS (1991)

1.3.13.1 Typical Cable Connections Using Wire Rope Clips

- Clips are made of drop-forged steel to resist distortion in heavy duty service. All parts are hot dip galvanized to prevent corrosion. When properly applied in sufficient number as indicated in [Table 27-1-5](#), clips will develop approximately 80% of the full breaking strength of the rope and may be revised if undamaged. [Figure 27-1-7](#) indicates the different estimated efficiencies of various types of wire rope connections.
- Wire rope clips should be attached properly to insure maximum holding power ([Figure 27-1-6](#)). The base of the clip should be applied to the live or long end, and the U-bolt against the dead or short end of the wire rope. Wire rope thimbles are required to insure the best loop protection.
- The clip nuts should be retightened to the specified torque after applying an initial load, as rope will stretch and shrink in diameter when loads are applied. The tightening torque values shown are based upon the threads being clean, dry and free of lubrication.

1.3.14 REFERENCES AND SOURCES OF ADDITIONAL INFORMATION (1991)

Refer to the References located at the end of this chapter.

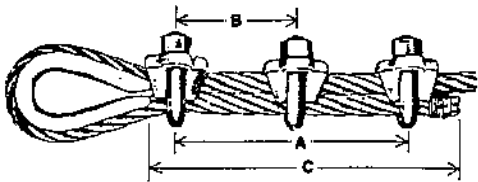


Figure 27-1-6. Clip Installation

Table 27-1-5. Clip Installation

Rope Diameter In Inches	A	B	C	Torque in Ft - Lb	Weight Per Clip Pounds
	Number of Clips (Minimum (Note 1))	Center to Center Spacing of Clips – Inches	Length of Rope Turned Back Excl. of Eye – Inches		
1/8	2	1-1/8	6	4.5	0.05
3/16	2	1-1/8	8	7.5	0.10
1/4	2	1-1/2	8	15	0.20
5/16	2	1-7/8	10	30	0.30
3/8	2	2-1/4	10	45	0.50
7/16	3	2-5/8	12	65	0.70
1/2	3	3	12	65	0.80
9/16	3	3-1/2	14	95	1.0
5/8	3	3-3/4	16	95	1.1
3/4	4	4-1/2	20	130	1.7
7/8	4	5-1/4	24	225	2.5
1	4	6	30	225	3.0
1-1/8	5	6-3/4	36	225	3.4
1-1/4	5	7-1/2	40	360	4.6

Note 1: The number of clips shown is the minimum recommended for ordinary usage.
The number of clips shown is based upon using right regular or lang lay wire rope, 6 × 37 class, fibre core or IWRC, IPS or EIPS. If greater number of clips are used than shown in the table, the amount of rope turn-back should be increased proportionately.
IMPORTANT: Failure to make a termination in accordance with instructions will cause a reduction in the efficiency rating.

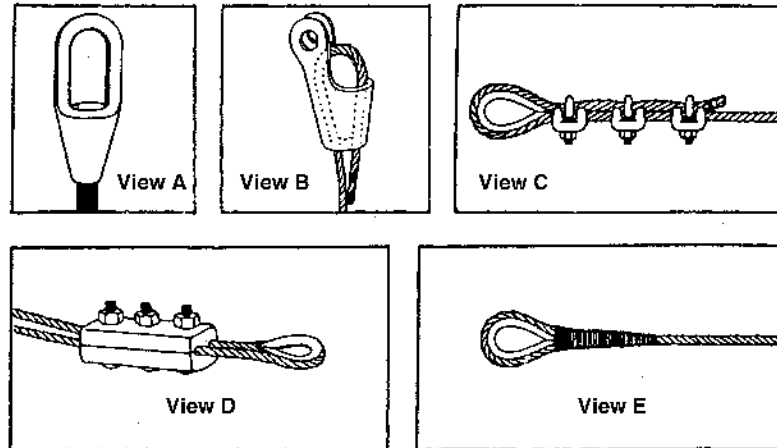
Chap
TOC

VOL
1

VOL
2

VOL
3

VOL
4



View	Type of Connection	Efficiency
	Wire Rope	100%
A	Sockets - Zinc Type - Properly Attached	100%
B	Wedge Sockets	70%
C	Clips	80%
D	Plate Clamp - Three-Bolt Type	80%
E	Spliced Eye and Thimble:	
	1/4" and smaller	90%
	5/16 - 7/16"	88%
	1/2"	86%
	5/8"	84%
	3/4"	82%
	7/8" and larger	80%

NOTE: Values as compared to safe loads on wire rope.

Figure 27-1-7. Efficiency of Wire Rope Connections

SECTION 1.4 BAR CODES AND THEIR APPLICATION FOR ROADWAY WORK EQUIPMENT¹ — 1992 —

1.4.1 INTRODUCTION (1992)

- a. Equipment maintenance and management in today's world is rapidly gaining a level of sophistication never before experienced in the industry. Sophisticated management is necessary to cope with the increasing complexity of day-to-day operations; as a result, good managers of equipment cannot afford to operate without various forms of computerization.
- b. One of the most important waves of technology sweeping American industry is the use of bar codes for Systematic Data Collection. It is driven by the need for accurate and timely data gathering from the manufacturing, inspection, maintenance, transportation, material acquisition and inventory cycles of a business operation. There is a natural fit in equipment management where machine identification, part numbers and related information are basic and well suited to this technology.
- c. BN Codes have gained acceptance as one of the most accurate and practical media to implement automatic collection of printed data. Bar codes are achieving this wide-spread popularity because they can be incorporated in the primary source marking of products from production to consumption.

1.4.2 BENEFITS OF BAR CODES (1992)

- a. Bar codes streamline identification. The black and white bars seen on most all grocery items in a supermarket represent a unique identification for that specific product. Bar codes have received overwhelming acceptance because they offer the simplest and most accurate, cost-effective approach for identifying objects by using reading machines (Scanners).
- b. Some of the more frequent errors involved with a manual data entry system are as follows:
 - Incorrect parts numbers.
 - Transposing of alpha or numeric characters.
 - Incorrect order units, i.e. each, feet, gallons, etc.
 - Insufficient or incorrect ordering description.
 - Missing or incorrect shipping instructions or addresses.
 - Illegible handwriting.
- c. Some of the main advantages of bar codes are as follows:
 - (1) Accuracy of data input.
 - (a) One of the primary advantages of bar codes over other technologies is its low susceptibility to errors involved with data input.
 - (b) The estimated error rate for generating errors due to interpreting handwritten alpha or numeric data is one error per 1,000 characters generated. This error rate is greatly influenced by the penmanship of the individual generating the document. The estimated error rate for keyed data

¹ References, Vol. 92, 1991, p. 303 and Vol. 93, 1992, p. 143.



entry is one error per 10,000 key strokes; whereas, the rate for Bar Code scanning is one error per 3,000,000 characters scanned.



- (2) Speed of entering data into the computer system. Scanning a bar code is much faster than manually recording information or keying data into a terminal.
- (3) Timeliness of information for more effective management of resources and repair parts inventories. Bar codes information can be immediately transferred to a host computer, and real-time data collection enables timely information to be accessed almost instantly.
- (4) Labor savings realized through elimination of manual systems. Improved efficiency can be realized by substituting bar code systems in place of manual systems, resulting in increased productivity and reduced labor costs.



1.4.3 EQUIPMENT (1992)

One of the compact type portable units currently used for material acquisition is portable data terminal with 32K RAM including an integral printer. The scanner is a contact type, high density, laser wand with 6 Mil. aperture.



1.4.3.1 Scanners

Reading devices (or scanners) fall into two categories, contact and non-contact readers. Contact readers are normally handheld units, while non-contact readers can either be handheld or stationary units.



1.4.3.1.1 Contact Readers

- a. Contact readers must either touch or come in close proximity to the bar code symbol. The most common type of contact reader is a pen wand or light pen. They serve as an excellent substitute for the traditional clipboard, paper and pencil, or keyboard data-entry and collection methods. Primary benefits from using contact readers include a reduction in the number of clerical errors in recorded data, a reduction in labor and paperwork to process the data, faster and more accurate inventory taking, material acquisition or payroll document completion. Careful attention must be given to match the wand resolution to the bar code density. A high-density resolution wand used to read a low-density symbol might see an ink spot as a bar, or an ink void as a space. Conversely, a low-resolution wand may not be able to recognize the narrow bar of a high-density bar code.
- b. The angle at which the wand is positioned to the surface of the symbol (45–90 degrees), as well as the speed at which the wand is moved across the symbol (3–6 inches per second), are both key parameters affecting high first-pass read rate.

1.4.3.1.2 Non-contact Readers

Non-contact readers include handheld and stationary scanners. The main characteristic of these scanners is that they don't have to come in contact with the bar code symbol and can read bar codes up to several feet depending on the symbol size and scanner type. One of the disadvantages of using non-contact scanners is the possibility of reading the wrong bar code when several bar codes are located in close proximity, as would be the case with work equipment repair parts books.

1.4.4 BAR CODE FORMAT (1992)

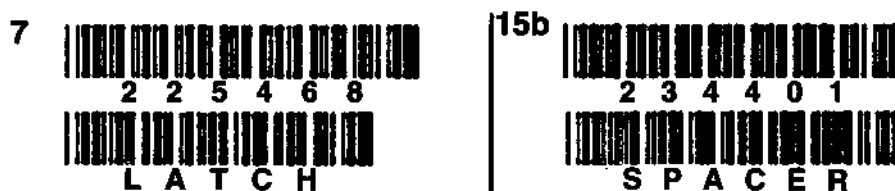
- a. The bar code format that has been standardized by many railroads and the current material acquisition process is Code 39 (3 of 9). Code 39's flexibility to encode alpha and numeric characters has contributed to its widespread use, with some of the prominent advantages being:

- Incorporates alpha and/or numeric characters.
 - Codes can be variable in length.
 - Allows bi-directional scanning.
 - Density is approximately 3-9.5 characters per inch.
 - Applications include LOGMARS (Department of Defense), GSA, AIAG (automotive) and wide acceptance throughout general industry.
 - The quiet zone is 10 times the width of the narrow bar.
- b. The 3 of 9 bar code is a variable length, bi-directional, discrete, self-checking alpha-numeric bar code. Its data character set contains 43 characters:
- 0-9, A-Z, -, ., \$, /, +, % and space.
- c. Three of the nine elements are wide and six are narrow. A common character (*) is used exclusively for both a start and stop character and must be included in every bar code symbol to provide the bar code to be bi-directionally scanned.
- d. Typical samples of a low medium and hi-density code of 3 of 9 bar code is shown in [Figure 27-1-8](#).

Low Density:



Medium Density:



High Density:



Figure 27-1-8. Sample Bar Codes

1.4.5 APPLICATIONS (1992)

- a. There are currently three primary applications which are being pursued for bar code use with Roadway Work Equipment:

Chap
TOC

VOL
1

VOL
2

VOL
3

VOL
4



- (1) Repair parts, material acquisition,
- (2) Repair parts, material inventory control system,
- (3) Collection of payroll data information for shop and field maintenance personnel.

- b. Great efforts are currently being made to incorporate bar codes into the material acquisition process for work equipment field and shop maintenance personnel to ease the data entry process. It is obvious this type of process greatly reduces the potential for data entry errors.

1.4.6 MANUFACTURERS REQUIREMENTS FOR PARTS BOOKS (1992)

In order to achieve a level of uniformity throughout the railroad industry in the work equipment departments, it is required the following guidelines be adhered to:

- a. The bar code comply with the Code 39 (3 of 9) format guidelines.
- b. The parts books will contain bar codes, and human readable information for the manufacturers part number as well as the noun description for that particular part number.
- c. The maximum readable characters for part numbers and noun description will be 16 characters. This does not include the start/stop (*) characters.
- d. The “quite zone” preceding and following the start/stop character must be a minimum of 1/4 inch.
- e. The bar codes should be 1/4 inch in height to again minimize space requirements, and in no instances should the bar codes be less than 1/4 inch high.
- f. The bar code symbols shall use the hi-density format, 7-9 characters per inch, to make the best utilization of available space. This will also be required to minimize the expansion in overall size of existing non-bar coded parts books.
- g. Common readily available standard hardware type items such as wrought iron washers, hex bolts and nuts, machine screws, cotter keys, hydraulic hoses, fittings, non-special adapters, etc., should not be coded. This will assist in conserving valuable space in the parts books. The parts books will contain human readable part numbers, as well as the corresponding detailed non-truncated noun description for all items of the parts books. This can be accomplished through use of a bill of material layout or similar format. It should be noted that non-bar coded items could still be ordered by manually entering the part number and non description via the handheld computer.
- h. The human readable and bar coded part number and noun description for each item in the parts book should be laid out to be operator friendly; with each item being easily recognizable and set apart or divided from each other to minimize confusion and the possibility of the operator inadvertently ordering incorrect repair parts.
- i. The high density bar codes must have a high “first read rate,” meaning the percentage of correct readings that will be obtained in one pass of the scanner over the bar code symbol.
- j. It is recommended the laser printer used to generate bar codes have the capability of producing print with a minimum of 300 dots per inch, and periodic monitoring of the toner adjustment has found to provide consistency in “First Read Rate” ability.
- k. The manufacturers part number should be compressed so there are no spaces or dashes and numeric character strings. See [Table 27-1-6](#) for examples.

Table 27-1-6. Example Part Number Formats

Traditional Part #	Revised Part Number Format
A-7288-Y-01	A728Y01
0-1406079-0-02	01406079002

1. Providing these guidelines are followed, the sophisticated and time saving bar code parts ordering data collection system can be used to a great advantage.

SECTION 1.5 EQUIPMENT OPERATORS TRAINING AND CERTIFICATION — 2009 —

1.5.1 INTRODUCTION (2009)

The training of operators for railway maintenance and construction equipment is carried out for the purpose of improving the safety profile, the efficiency, and the productivity of track maintenance equipment. The capital investment required to own and operate this equipment, coupled with the requirement to achieve production and maintenance goals within decreasing availability of track time windows demands competent operators with the training and skills to maximize the efficiency of these assets.

1.5.2 OPERATOR TRAINING METHODS - BACKGROUND (2009)

- a. **OJT** or "on-job training" has traditionally been the fundamental method used by railways as labor skills were supplemented by equipment. This method typically consists of either no, or only rudimentary, instruction to the new operator. In the short term, this method can be effective for less complex pieces of equipment.
- b. **Informal training** has become a minimum necessity as track maintenance equipment has increased in complexity and the time available for program rework and equipment maintenance has minimized. Differing levels of expertise can be gained by the operator using Operator-Instructors and/or manufacturer representatives as trainers. While more complete than "on-job training", this method suffers from not providing comprehensive instruction in a variety of operating conditions.
- c. **Advanced training** is a hybrid and generally couples informal field training with equipment videos and classroom training. However, the training is not concurrent and it is generally not application-specific. It is a combination of "hands on" practice to develop correct technique, followed at a later time by lectures and provided related reference materials for the operator.
- d. **Certified training** programs begin with established goals, have comprehensive and concurrent practical and theoretical sessions, and test the newly-trained operator to dually determine learned skills and effectiveness of the program. These programs are typically multi-day, and can be taught by railroad trainers, representatives of a manufacturer, or a third party training specialist. These can be held either on railroad property or at dedicated training facilities. Formal documentation shall be provided.
- e. **Recurrent training** takes the training program and expands it to occur periodically, in order to reinforce correct operating and maintenance techniques. Various forms of this exist on different properties, utilizing



a variety of training formats, information sources, and training aids. (Promising technologies and computer-based training are on the leading edge of these efforts.) This is the only method which addresses the problem area of an increasing pace of change to operating and maintenance procedures that utilize the latest training methods.



1.5.3 CANDIDATE SELECTION AND CLASS SIZE CRITERIA (2009)



a. The selection of potential equipment operators should consider the work history and past experience of the individual. Items such as past injury exposure, safe working habits, and personal attitude are indicative of potential success of the employee in the training program.



b. Past equipment experience is an obvious desirable objective attribute. Should the individual be able to demonstrate maintenance responsibilities and operating capabilities with similar equipment, the probability of acquiring additional skills from training programs is high. In cases of specialized equipment where there may not be any similar experience for the new operator, aptitude testing can provide significant guidance as long as relevant criteria are utilized.



c. A subjective attribute which is typically a determinant of success is a desire to improve on behalf of the employee. A positive attitude and "wanting to learn" are perhaps the most important indicators of a potential training success. While modern roadway maintenance equipment is more user-friendly, it also has more features and requires more knowledge to operate safely and effectively.



d. For the group to be trained, the trainee-to-trainer ratio should not exceed twelve to one for a classroom session. For practical training with equipment at a work site, half of that ratio should be the maximum. While that ratio may seem high for certain types of equipment, the trainer should interface individually with each student for specific instruction, allowing the others to observe and learn through the repetitive process.

1.5.4 OPERATOR TRAINING PROGRAM REQUIREMENTS (2009)

a. Training programs have cost and benefit elements associated with them, and must be budgeted accordingly.

b. Each training program must have established goals. Safety and minimization of injury occurrences are always paramount in these goals, as are reduction of damages to railway assets and property. The instructional goals must be application-specific, critical skill-based, and relevant to both the work conditions encountered and the level of operating and maintenance capability of the trainee.

c. Following these goals, the development of a custom training manual should be undertaken. As opposed to a copy of an available operating manual, it should be designed for specific tasks in line with the established goals, and be brief and easily understandable to the student. The training manual must cover both the theoretical aspect of the program during the training, and act as a resource for the trained operator following completion of the program.

d. Practical, or "hands on", training within a variety of operating situations is imperative. This eliminates the "trial and error" technique which can generate poor operating and maintenance learned skills. Further, instructor corrections during practical training reduce the operator learning curve, and discourage the development of poor equipment maintenance practices. "Hand ons" training should also include automation training, specifically the proper set-up of computer-assisted track maintenance machines. In practical training it is important that as few distractions as possible are allowed, and that similar equipment, or an appropriate simulator, be used during the training.

e. Determination of what was learned in the training is important for both the employee and the trainer. The only way to measure this objectively is to pre-test the employee for skills or knowledge, and to follow the training program with a comprehensive examination to determine knowledge gained. In most cases a practical demonstration of learned skills in accord with the program goals should suffice. However, with

more complicated machinery it may also be appropriate to test learned knowledge with a combination of written testing and a practical demonstration of proficiency.

- f. On the trainer's behalf, the result of the testing should give clues as to which parts of the program or curriculum is weak or strong, such that appropriate adjustments can be made prior to the next group of trainees. Another very important part of the feedback loop for the trainer is a formal course evaluation by the students with regard to content. Finally, equipment supervisory employees should be utilized to provide feedback to determine if learned skills are being practiced by the operator in the work environment. The latter can be done informally, but is an important source of feedback information for the design of future programs.
- g. Certification of the trained operator includes all of those requirements involved with documentation of the training program. Initial certification is an important step in the training process, and subsequent levels of certification should be established such that an operator can progress through a series of training programs. A training time limit should be established to determine when specific retraining is necessary, and that schedule distributed among affected operators.
- h. It is desirable that labor agreements reflect program needs of selecting capable employees and placing trained personnel according to the individual's ability.
- i. These guidelines should be set to adhere to existing policies and standards as applicable to the individual railroad.

1.5.5 RETRAINING AND RECERTIFICATION (2009)

With track maintenance equipment changing at an ever-increasing rate and with continuing reductions in maintenance fleet size, a recurrent training and recertification process for experienced operators can be as important as original training and certification for new operators. Reinforcement of correct operating and maintenance techniques is critical in order to be effective and productive in maintaining the roadway. Periodic practical reviews of competency designed to maximize production time and minimize repair expenses, and to eliminate injuries and lost time due to accidents, should be encouraged by the establishment of criteria associated with successive levels of recertification.

The documentation of recertification and recurrent training is a valuable tool for gauging the value of each training session on the capabilities of operators. Mandatory certification and recertification is a tool that is making the industry safer, more reliable and accountable.



Part 2

Roadway Machines¹

— 2009 —

TABLE OF CONTENTS

Section/Article	Description	Page
2.1 Specifications for Track Motor Cars		27-2-4
2.1.1	General Description (1993)	27-2-4
2.1.2	Operational Requirements (1993)	27-2-4
2.1.3	Engine (1991)	27-2-5
2.1.4	Frame, Wheels, Axles and Bearings (1991)	27-2-6
2.1.5	Suspension (1991)	27-2-7
2.1.6	Fuel Tank (1991)	27-2-7
2.1.7	Hydraulic System (1991)	27-2-8
2.1.8	Pneumatic System (1991)	27-2-9
2.1.9	Brake Systems (1991)	27-2-10
2.1.10	Travel Speed and Performance (1991)	27-2-10
2.1.11	Cab (1991)	27-2-11
2.1.12	Standard Equipment (1991)	27-2-13
2.1.13	Miscellaneous (1991)	27-2-14
2.1.14	Paint (1991)	27-2-15
2.1.15	Stenciling (1991)	27-2-15
2.1.16	Optional Equipment (1991)	27-2-16
2.1.17	General (1991)	27-2-16
2.1.18	Reliability (2004)	27-2-17
2.1.19	Maintenance of Way - Work Equipment Bulletin (2004)	27-2-20
2.2 Specifications for Railway Push Cars		27-2-23
2.2.1	General Description (1991)	27-2-23
2.2.2	Operational Requirements (1991)	27-2-23
2.2.3	Frame, Wheels, Axles, and Bearings (1991)	27-2-24
2.2.4	Suspension (1991)	27-2-25
2.2.5	Standard Equipment (1991)	27-2-25
2.2.6	Miscellaneous (1991)	27-2-25
2.2.7	Paint (1991)	27-2-25
2.2.8	Stenciling (1991)	27-2-26

¹ References, Vol. 31, 1930, pp. 1254, 1820; Vol. 2, 1931, pp. 541, 751; Vol. 33, 1932, pp. 162, 713; Vol. 34, 1933, pp. 356, 804; Vol. 39, 1938, pp. 606, 878; Vol. 41, 1940, pp. 266, 849; Vol. 47, 1946, pp. 180, 607; Vol. 48, 1947, pp. 339, 868; Vol. 51, 1950, pp. 244, 825; Vol. 54, 1953, pp. 638, 644, 1373; Vol. 56, 1955, pp. 513, 1099; Vol. 59, 1958, pp. 630, 1235; Vol. 63, 1962, pp. 356, 738; Vol. 92, 1991, p. 102, Vol. 97, p. 220. Revised 1996.

TABLE OF CONTENTS (CONT)

Section/Article	Description	Page
2.2.9	Optional Equipment (1991)	27-2-26
2.2.10	General (1991)	27-2-26
2.3	Specifications for On-track Roadway Machines	27-2-27
2.3.1	General (2000)	27-2-27
2.3.2	Material (2000)	27-2-28
2.3.3	Brakes (2000)	27-2-28
2.3.4	Wheels, Axles and Bearings: Frame and Suspension (2000)	27-2-29
2.3.5	Insulation (2000).	27-2-30
2.3.6	Engine and Power Train (2000)	27-2-30
2.3.7	Fuel Tank (2000)	27-2-31
2.3.8	Exhaust System (2000).	27-2-31
2.3.9	Hydraulic System (2000)	27-2-31
2.3.10	Electrical System (2000).	27-2-35
2.3.11	Pneumatic System (2000)	27-2-36
2.3.12	Body or Cab Top (2000)	27-2-37
2.3.13	Travel Speed (2000)	27-2-37
2.3.14	Controls (2000)	27-2-38
2.3.15	Clearance and Safety (2000)	27-2-38
2.3.16	Initial Preparation and Servicing (2000).	27-2-38
2.3.17	Paint (2000).	27-2-39
2.3.18	Shipping (2000).	27-2-40
2.3.19	Parts and Instruction Books (2000).	27-2-40
2.3.20	Repair Parts and Service (2000)	27-2-40
2.3.21	Additional Specifications (2000)	27-2-41
2.3.22	Noise Exposure (2000)	27-2-42
2.3.23	Delivery (2000)	27-2-42
2.3.24	Non-Compliance (2000)	27-2-42
2.4	Axle, Wheel and Hub Specifications	27-2-43
2.5	Hydraulic Systems	27-2-43
2.5.1	Introduction (1980).	27-2-43
2.5.2	General (1980)	27-2-44
2.6	Electrical Systems	27-2-46
2.6.1	Introduction (1980).	27-2-46
2.6.2	General (1980)	27-2-46
2.6.3	Electrical Apparatus Cabinets (1980)	27-2-46
2.6.4	Motor Control Apparatus Overload Relays (1980)	27-2-47
2.7	Specifications for Rail Guide Wheel Equipment	27-2-47
2.7.1	General (1996)	27-2-47
2.7.2	Material (1996)	27-2-48
2.7.3	Brakes (1996)	27-2-48
2.7.4	Wheels, Axles and Bearings (1996)	27-2-49
2.7.5	Insulation (1996).	27-2-49
2.7.6	Hydraulic System (1996)	27-2-50
2.7.7	Electrical System (1996).	27-2-52



TABLE OF CONTENTS (CONT)

Section/Article	Description	Page
 2.7.8	Pneumatic System (1996)	27-2-53
 2.7.9	Controls (1996)	27-2-54
 2.7.10	Clearance and Safety (1996)	27-2-54
 2.7.11	Initial Preparation and Servicing (1996)	27-2-54
 2.7.12	Paint (1996)	27-2-54
2.7.13	Shipping (1996)	27-2-55
2.7.14	Parts and Instruction Books (1996)	27-2-55
2.7.15	Repair Parts and Service (1996)	27-2-56
2.7.16	Additional Options (To be completed by vendor or manufacturer.) (1996)	27-2-56
2.7.17	Delivery (1996)	27-2-56
2.7.18	Mounting of Rail Guide Wheel Equipment to Vehicle (1996)	27-2-56
2.7.19	Setup and Alignment (1996)	27-2-57
2.7.20	Non-Compliance (1996)	27-2-57
2.8	Lockout/Tagout (LOTO) During Maintenance of Roadway Machines	27-2-58
2.8.1	General (2002)	27-2-58
2.8.2	Definitions (2002)	27-2-58
2.8.3	Requirements (2002)	27-2-59
2.8.4	Procedures (2002)	27-2-59
2.9	Railway Track Equipment Operator Sightlines and Visibility Guideline for New On Track Machinery	27-2-60
2.9.1	Definitions (2009)	27-2-60
2.9.2	Railway Track Equipment Operator Sightlines and Visibility for "Travel" Mode (2009)	27-2-61
2.10	Access Systems for Maintenance of Way Machines	27-2-62
2.10.1	Purpose (2009)	27-2-62
2.10.2	Scope (2009)	27-2-62
2.10.3	General (2009)	27-2-62

LIST OF FIGURES

Figure	Description	Page
27-2-1	AREMA Wheel and Flange for 14 Inches, 16 Inches and 20 Inches Wheels on Motor Cars, Trailers and Push Cars.	27-2-7
27-2-2	Maintenance of Way - Work Equipment Bulletin	27-2-20
27-2-3	Axle, Wheel and Hub Specifications for Work Equipment	27-2-43
27-2-4	Direction of Travel Sightlines and Visibility, Top View	27-2-61
27-2-5	Direction of Travel Sightlines and Visibility	27-2-62
27-2-6	Ladders	27-2-63
27-2-7	Steps	27-2-63
27-2-8	Handrails and Handholds	27-2-64
27-2-9	Platforms, Walkways and Guardrails	27-2-64
27-2-10	Stairways	27-2-65