

# **SAND, GRAVEL, AND CRUSHED STONE ON-THE-JOB TRAINING MODULES**

## **Module 12 - “Inspecting and Replacing Wire Ropes”**

**UNITED STATES DEPARTMENT OF LABOR  
ELAINE L. CHAO  
SECRETARY**

**MINE SAFETY AND HEALTH ADMINISTRATION  
DAVE D. LAURISKI  
ASSISTANT SECRETARY**

**Originally Published AUGUST 2000**

**INSTRUCTION GUIDE SERIES**

**MSHA IG 40**

**MODULE NUMBER 12  
OF  
INSTRUCTION GUIDE NUMBER 40**

**ON-THE-JOB TRAINING  
FOR THE  
SAND, GRAVEL, AND CRUSHED STONE INDUSTRY**

---

**INSPECTING AND REPLACING WIRE ROPES**



This module describes basic job steps, potential hazards and accidents, and recommended safe job procedures for inspecting and replacing wire ropes. The term “wire rope” is used in this module, rather than “cable,” to avoid any possible confusion with electrical cables. This module is not intended to cover wire ropes that are used for hoisting persons.

In the sand, gravel, and crushed stone industry, wire ropes are used primarily on draglines, power shovels, and drilling equipment. Wire ropes, and wire rope slings, are used on cranes

and hoists of various types.

Wire ropes deteriorate, and will break if left in service long enough. Causes of rope deterioration may include wear, peening (hammer action), corrosion, bending, flexing, kinking, crushing, overloading, and heat damage.

Companies must provide for wire rope inspection and timely replacement. The purpose of the inspection program should be to obtain all possible service from wire ropes, while maintaining an adequate degree of safety. Wire rope replacement is costly, but if a wire rope breaks in service, there are risks of serious injury, equipment damage, and lengthy production delays.

Wire rope breakage can pose hazards to equipment operators, and persons working nearby. Persons can be injured by falling equipment and material, or by the whipping (backlash) action of the broken rope.

Wire rope failures can be fatal, although disabling injuries are more common. Two examples of fatal accidents follow:

A dragline operator at a sand and gravel operation was killed when the pendant rope of the dragline broke, and backlashed through the cab window.

A cement plant worker was killed when the boom hoist rope of a mobile crane broke, dropping the crane boom on him.

Much of the hazard of wire rope breakage can be eliminated by following a few simple safety rules:

1. Always assume a wire rope could break at anytime.
2. Do not work or pass under the buckets or booms of shovels, draglines, or cranes in operation.
3. Stay clear of suspended loads.
4. Do not ride on, or in dippers, clamshells, hoisted loads, hoisting hooks, buckets, or similar hoisting items, unless special provisions for hoisting personnel, in accordance with safety rules and regulations, are followed.

Even if the above precautions are observed, safety also depends on proper wire rope maintenance and inspection procedures, and the timely removal from service of worn or damaged wire rope.

Federal mining regulations contain few requirements relating directly to inspection and replacement of wire ropes that are not used to hoist persons. Some general federal requirements, however, do apply to such wire rope. Self propelled equipment, which is to be

used during a shift, must be inspected by the equipment operator before being placed in operation. Equipment defects affecting safety must be corrected before the equipment is used. Unsafe machinery and equipment must be removed from service immediately.

Additional information and guidance on wire rope inspection and replacement can be obtained from:

1. American National Standard for Wire Rope for Mines, ANSI M11.1, and other ANSI Standards relating to specific types of equipment.
2. Occupational Safety and Health Administration (OSHA) Standards for General Industry (29CFR 1910) and Construction Industry (29CFR 1926) .
3. State regulations.
4. Wire rope, and equipment, manufacturer's specifications.
5. Safety rules of various associations, and various companies.

Each company should have a wire rope inspection program which establishes inspection personnel, procedures, and frequency; and provides for reporting and record keeping. An effective inspection program should establish two general types of inspections:

1. Frequent inspections - visual wire rope inspections conducted by equipment operators before, during, and after equipment use, in conjunction with routine inspection of other equipment components.
2. Periodic inspections - careful and detailed wire rope inspections, including diameter measurements, conducted by a person who has extensive knowledge, training, and experience in the inspection of wire ropes and related equipment. The procedures used, and the inspection frequency for each wire rope will vary depending on operating conditions, anticipated rope life, and critical nature of service.

In addition to inspecting wire rope itself, wire rope inspections should also include rope terminations (end attachments) at both ends of the particular rope, and items contacted by the rope, including sheaves, drums, and rollers.

### Wire Rope Basics

The following summary provides equipment operators with basic information useful for frequent inspections of wire rope. Persons responsible for making periodic, detailed inspections should have a much more comprehensive knowledge of wire rope.

## Wire Rope Use

Some common uses of wire rope include:

1. Hoist and boom suspension (pendant) ropes on power shovels, draglines, clamshells, and mobile cranes.
2. Crowd, retract, and dipper trip ropes on power shovels.
3. Boom hoist ropes on draglines, clamshells, and mobile cranes.
4. Drag (rehaul) ropes on draglines.
5. Holding, closing, and tag ropes on clamshells.
6. Pull down, hoist, bull, and sandline ropes on drills.
7. Hoist ropes on overhead hoists, and overhead traveling cranes.
8. Slings.

## Wire Rope Construction and Terminology

Most wire rope is constructed of many small diameter wires. This construction provides the flexibility necessary for wire rope to bend frequently in use, such as over sheaves.

Occasionally, large strands, or ropes constructed of a few wires of large diameter, will be used for applications where very little bending occurs, such as boom suspension (pendant) ropes on shovels, or draglines.

Most wire ropes consist of three parts:

1. A core, which forms the center of the rope. Cores may be either fiber cores (FC), or steel cores. Steel cores may be either “independent wire rope cores” (IWRC) - a miniature wire rope which serves as a core for larger rope, or “strand cores” (SC) - a strand, similar to other strands of the rope, which runs down the center of the rope.
2. Wires, which are twisted into strands. The individual wires that appear on the outside of the rope, and bear against sheaves and drums, are called crown wires, or simply “outer wires.”

3. Strands, which are twisted around the core to form the rope.

Wire rope is designated by the number of strands, the number of wires per strand, and the rope diameter. For example, a wire that has 6 strands of 19 wires each is referred to as having a 6x19 “construction.” Wire ropes of similar construction are sometimes grouped into a general “classification.” The 6x19 classification usually includes 6x21 and 6x25 construction ropes, as well as 6x19 construction ropes.

Rope diameter is measured by rotating a caliper around the circumference of a wire rope until the caliper is positioned to give the maximum possible reading. The length of rope needed for one strand to make a complete turn around the core is a “lay.”

### Safety Factor/Design Factor

The rated breaking strength of a new rope, divided by the maximum normal load to be placed on the rope, is the “safety factor,” or “design factor”.

$$\text{Safety Factor} = \frac{\text{Breaking Strength}}{\text{Max Normal Load}}$$

A rope with a 100,000 pound breaking strength, carrying a maximum normal load of 10,000 pounds, has a safety factor of  $100,000/10,000=10$ .

The minimum safety factors for various wire rope applications are specified in the ANSI standards. In most cases, “load” is determined by the weight of the structure, and the material supported. In some cases, however, such as for drag ropes on draglines, the load is based on the maximum stall force of the power source.

### Lubrication

Proper lubrication extends the service life of wire ropes. Proper lubrication:

1. Reduces wear
2. Protects against corrosion
3. Reduces friction between individual wires and strands, allowing wires and strands to move and to adjust to load and bending forces. This ease of movement increases the flexibility of the rope, allowing more even distribution of the load over all the wires, which reduces the probability of wire breakage.

New ropes need ample lubrication to ease the break-in period. The rope manufacturer should

be consulted to be sure that proper types of lubricant and application methods are used. Generally, the more severe the rope operation - higher speeds, heavier loads, greater number of bends, and more corrosive conditions - the more frequently the rope should be lubricated. Light, frequent lubrication is generally better than heavy, occasional lubrication.

The following safe job procedures will help to minimize incidents which could cause injuries, and adversely affect production.

**REQUIRED OR RECOMMENDED PERSONAL PROTECTIVE EQUIPMENT:**

HARD HAT, SAFETY SHOES, SAFETY GLASSES, GLOVES,  
SAFETY HARNESS AND LINE.

**I. INSPECTION OF WIRE ROPES**

<b>SEQUENCE OF BASIC JOB STEPS</b>	<b>POTENTIAL ACCIDENTS OR HAZARDS</b>	<b>RECOMMENDED SAFE JOB PROCEDURES</b>
<p>10. Plan and schedule inspection. Schedule complete inspections for idle shifts, or scheduled maintenance periods, if possible. Obtain an accurate caliper, if diameter measurements are to be taken.</p>	<p>1. A) Not inspecting frequently enough - unnecessary down-time of expensive equipment.</p>	<p>1. A) Schedule complete, detailed inspections on a regular basis. Interval between inspections is determined by operating conditions, anticipated wire rope life, critical nature of service, state regulations, company policy, and manufacturers recommendations. All wire ropes should be visually inspected, to the extent possible, before, during, and after use.</p>
<p>2. Clean rope, if necessary.</p>	<p>2. A) Falling</p>	<p>2. A) Work from safe location. Do not climb booms of equipment in operation, unless adequate steps, handholds, and railings are provided. Wear safety harness and line if there is a danger of falling.</p>



**SEQUENCE OF  
BASIC JOB STEPS**

**POTENTIAL ACCIDENTS  
OR HAZARDS**

**RECOMMENDED SAFE JOB  
PROCEDURES**

- |  |   |  |
|--|---|--|
|  | B) Failure to detect broken wires, or other indications of rope deterioration.      | 2. B) Wipe excess lubricant from section of rope to be examined.   |
|  | C) Cut, or puncture, from broken wire snagging hand or glove.                       | C) Do not use bare or gloved hand alone on moving rope. Rag can be held around rope, while rope is run at a slow speed (50 feet per minute or less).                               |
|  | D) Caught between rope and sheave, drum, or roller.                                 | D) Do not wipe moving rope near where rope goes onto sheave, drum, or roller. Face direction rope is moving, so that rag will be pulled away from you if it snags on broken wires. |
| 3. Visually inspect wire rope before, during, and after use, and watch equipment in operation. | 3. A) Unnecessary downtime of expensive equipment.                                  | 3. A) Carefully examine all wire ropes for obvious damage, such as kinking, bird caging, broken strands, or broken wires.  |
|  | B) Improper reeving can cause ropes to wear faster, and hamper equipment operation. | B) Check for proper reeving in accordance with manufacturer's recommendations.   |

**SEQUENCE OF  
BASIC JOB STEPS**

**POTENTIAL ACCIDENTS  
OR HAZARDS**

**RECOMMENDED SAFE JOB  
PROCEDURES**

	<p>C) Rope or sheave damage. Excessive vibration and stresses. Struck by falling or whipping rope; or falling load, if rope breaks.</p> <p>D) Caught in moving equipment.</p>	<p>C) Avoid excessive pull-down pressure on drills. Be sure there are no hook-ups between bucket, boom, and hoist ropes. Operate equipment smoothly. Do not jerk or drop loads attached to wire ropes. Impact loading can break even a new rope. Check that backlash guards, where provided, are in place and secure.</p> <p>D) Remove dirt from equipment, such as rope guards and dragline fairleads, as needed. Equipment must be shut down and locked out.</p>
<p>4. Position equipment and yourself for complete inspection.</p>	<p>4. A) Failure to get close enough to wire rope and other components to detect defects.</p> <p>B) Fall to lower levels.</p>	<p>A) Lower booms and masts where possible, and/or place boom against a pile of material or a bank.</p> <p>B) Do not climb booms of equipment in operation unless adequate steps, handholds, and railings are provided. Use safety harness and line where there is a danger of falling.</p>

SEQUENCE OF BASIC JOB STEPS	POTENTIAL ACCIDENTS OR HAZARDS	RECOMMENDED SAFE JOB PROCEDURES
5. Conduct complete visual/manual inspection of wire ropes.	<p>5. A) Wire rope failure due to inadequate inspection.</p> <p>B) Cuts, or punctures, from protruding wires.</p> <p>C) Caught between rope and sheaves, drums, or rollers.</p> <p>D) Rope failure due to excessive wear.</p> <p>E) Rope failure due to corrosion.</p>	<p>5. A) Have the wire rope run past your inspection point at a slow speed (50 feet per minute, or less). Check entire rope. Usually, entire length cannot be inspected from one location. If a potential problem is detected, signal equipment operator to stop rope, and examine rope more closely.</p> <p>B) A rag, or cotton waste, can be held around the rope.</p> <p>C) Face direction rope is moving. Do not wipe rope near where it enters sheaves, drums, or rollers.</p> <p>D) Look for excessive wear on crown (outer) wires. If surface of strands looks almost smooth, and valley between crown wires appears almost as a fine line, wear could be approaching 50 percent, or ½ of crown wire diameter.</p> <p>E) Look for corrosion which causes pitting of wires. Look for small flecks of rust in the lubricant, or pitting or scale in strand valleys, which may indicate internal corrosion.</p>

**SEQUENCE OF  
BASIC JOB STEPS**

**POTENTIAL ACCIDENTS  
OR HAZARDS**

**RECOMMENDED SAFE JOB  
PROCEDURES**

	F) Rope failure due to distortion of rope structure.	F) Look for distortion of rope structure, such as kinking, crushing, or heat damage.
6. Evaluate condition of rope.	6. A) Failure of wire rope.	6. A) Exercise judgement based on condition of rope, and operating conditions, critical nature of service, and manufacturer's recommendation.
7. Report and record results of the inspection.	7. A) Possible use of equipment already determined to be defective.	7. A) Report results of inspection to appropriate officials. Record results for later reference. Tag equipment, if appropriate.

**NOTE:** Although the following retirement criteria apply only to wire rope used for personnel hoisting, they should be considered as indicators for potential failure in all situations. Ropes that meet or exceed these retirement criteria should be considered for retirement if the damage or deterioration cannot be removed by cutoff:

1. The number of broken wires within a rope lay length, excluding filler wires, exceeds either:
  - a) Five percent of the total number of wires.
  - b) Fifteen percent of total number of wires within any strand.
2. On a regular lay rope, more than one broken wire in valley between strands in one rope lay length.
- C) A loss of more than one-third of the original diameter of the outer wires.

- D) Rope deterioration from corrosion.
- E) Distortion of rope structure.
- F) Heat damage from any source.
- G) Diameter reduction from wear that exceeds six percent of the baseline diameter measurement.
- H) Loss of more than ten percent of rope strength as determined by nondestructive testing.

## II. INSPECT WIRE ROPE TERMINATIONS

<b>SEQUENCE OF BASIC JOB STEPS</b>	<b>POTENTIAL ACCIDENTS OR HAZARDS</b>	<b>RECOMMENDED SAFE JOB PROCEDURES</b>
1. Plan, and schedule, inspection of rope terminations.	1. A) Equipment down-time, and possible injury due to failure of rope termination.	1. A) All terminations must be inspected before use of equipment. Schedule complete, detailed inspections on a regular basis. Terminations, and sections of ropes near terminations, may require more frequent inspections than the main body of rope.
2. Check for proper lubrication.	2. A) Inadequate lubrication causing failure at termination due to corrosion and/or wear.	2. A) Check for proper lubrication. If lubrication was cleaned off rope for inspection, reapply when done.
3. Inspect socket terminations.	3. A) Failure of socket, or failure of rope at socket.	3. A) Check socket for cracks, deformation, and excessive wear. Check that socket is lined up square with the rope. Check for broken wires where rope enters socket.

<b>SEQUENCE OF BASIC JOB STEPS</b>	<b>POTENTIAL ACCIDENTS OR HAZARDS</b>	<b>RECOMMENDED SAFE JOB PROCEDURES</b>
4. A) Inspect wedge socket terminations.	4. A) Rope failure at wedge, or rope slipping through wedge socket.	4. A) Be sure wedge is seated properly. Check for evidence of slippage. Be sure at least one rope lay on dead end of rope extends beyond wedge. Check for broken wires on live end of rope. Check visible portion of wedge socket for cracks, deformation, and wear.
5. Inspect U-clip terminations.	5. A) Rope failure at termination.  B) Rope slipping through termination.   C) Failure of U-clips, or thimbles.	5. A) Check for broken wires throughout termination.  B) Check for evidence of slippage, such as scrubbed places on the rope, or U-clips slid together. Check for proper number, spacing, torque, and orientation of U-clips.  C) Check U-clips and thimbles for cracks, deformation, and excessive wear.
6. Check other types of terminations (mechanical splices, swagged sockets, etc.).	6. A) Failure of rope at termination, or failure of termination.	6. A) Check for broken wires, and corrosion, at termination. Check for proper installation. Check for cracks, deformation, and excessive wear.

<b>SEQUENCE OF BASIC JOB STEPS</b>	<b>POTENTIAL ACCIDENTS OR HAZARDS</b>	<b>RECOMMENDED SAFE JOB PROCEDURES</b>
7. Evaluate condition of termination, and condition of rope at termination.	7. A) Failure of termination, or of rope at termination.	7. A) Exercise judgement based on condition of rope and termination, operating conditions, critical nature of service, and manufacturer's recommendation.
8. Report and record results of inspection.	8. A) Possible use of equipment found to be defective.	8. A) Report results of inspection to appropriate officials. Record results for later reference. Tag equipment, if appropriate.

**NOTE:** Although the following end attachment retermination, and end attachment replacement standards apply only to wire rope used for personnel hoisting, they should be considered as indicators for potential failure in all situations:

1. End attachment retermination: damaged, or deteriorated, wire rope should be removed by cut off, and rope retermination where there is:
  - a) More than one broken wire at an attachment.
  - b) Improper installation of an attachment.
  - c) Slippage of an attachment.
  - d) Evidence of deterioration from corrosion at an attachment.
2. End attachment replacement: wire rope attachments should be replaced when cracked, deformed, or excessively worn.



### III. INSPECT SHEAVES, DRUMS, AND ROLLERS

<b>SEQUENCE OF BASIC JOB STEPS</b>	<b>POTENTIAL ACCIDENTS OR HAZARDS</b>	<b>RECOMMENDED SAFE JOB PROCEDURES</b>
1. Plan, and schedule, inspections of sheaves, drums, and rollers.	1. A) Equipment down-time, and possible injury due to failure of sheaves, drums, or rollers, and damage to wire rope due to worn or damaged sheaves, drums, or rollers.	1. A) All sheaves, drums, and rollers must be inspected before use of equipment. Schedule complete detailed inspections on a regular basis.
2. Inspect sheaves, drums, and rollers in operation.	2. A) Sheave, drum, or roller failure.  B) Excessive rope wear or damage.	2. A) Watch for any wobbling, or out of round motion. Be sure that bearings are properly lubricated, and not excessively worn. Be sure that mounting bolts are tight.  B) Notice if rope is being squeezed into sheave or drum grooves, or is scrubbing on side of the groove. Be sure that rope is spooling smoothly on drums - not cross-winding, or leaving gaps.
3. Check sheave guards.	3. A) Broken, or badly damaged rope, if rope jumps off sheave.	3. A) Check that rope guards are in place over sheaves which are subject to rope jumping off, such as point sheaves. Guards should usually be located about ½ inch above sheave.

<b>SEQUENCE OF BASIC JOB STEPS</b>	<b>POTENTIAL ACCIDENTS OR HAZARDS</b>	<b>RECOMMENDED SAFE JOB PROCEDURES</b>
4. Check sheave grooves, drum grooves, and roller surface.	4. A) Rope wires being cut by sharp edges.	4. A) Check for sharp edges in sheave grooves, drum grooves, and on roller surfaces. Check for print of rope worn in these surfaces.
5. Check drum end terminations.	5. A) Rope pulling out of drum. Drum end termination failure, due to excessive stress, if rope is completely spooled out and stopped by termination.	5. A) Wire rope should be attached securely by clips after making one full turn around drum spoke, or shaft, or by properly assembled anchor bolts, clamps, wedges, or other design feature of drum.

#### IV. REPLACING WIRE ROPE, AND TERMINATIONS

<b>SEQUENCE OF BASIC JOB STEPS</b>	<b>POTENTIAL ACCIDENTS OR HAZARDS</b>	<b>RECOMMENDED SAFE JOB PROCEDURES</b>
1. Obtain new rope.	1. A) Installing improper rope.	1. A) New rope should be the same size, grade, and construction, or as otherwise recommended by manufacturer due to operating conditions.
2. Remove old rope.		2. A) Secure load (bucket, etc.). Slack rope slightly. Detach old rope from load, and attach it to empty reel. Transfer old rope to reel. Depending on situation, use small ropes, and additional drums, reels, winches, or mobile cranes to safely control handling and transfer of old rope.
3. Attach new rope to drum.	3. A) Damage to new rope.	3. A) Avoid kinking rope.
4. Transfer new rope from reel to drum.	4. A) Damage to new rope.	4. A) Avoid reverse bending.

<b>SEQUENCE OF BASIC JOB STEPS</b>	<b>POTENTIAL ACCIDENTS OR HAZARDS</b>	<b>RECOMMENDED SAFE JOB PROCEDURES</b>
5. Cut new rope if necessary.	5. A) Not allowing sufficient length.  B) Unlaying of strands.  C) Cutting hazards with torch, or shears, abrasive wheel, etc.	5. A) Allow sufficient length for maintaining minimum recommended number of dead wraps on drum, for cutting off and remaking terminations at both ends, and for turning rope end-for-end to minimize local wear.  B) Apply seizing, strapping, or other method to prevent unlaying of strands on both sides of cut.  C) Wear eye protection. Wear gloves. Use controlled force with power tools.
6. Make a wedge termination, if used.	6. A) Rope damage, or termination failure due to improperly made termination.  B) Mashed fingers.	6. A) Place live (long) end of rope on the eye side of socket. Form a loop through socket, and insert wedge. Pull wedge and rope into position - final tightening occurs under full load.  B) Wear gloves, and avoid pinch points.

**SEQUENCE OF  
BASIC JOB STEPS**

**POTENTIAL ACCIDENTS  
OR HAZARDS**

**RECOMMENDED SAFE JOB  
PROCEDURES**

7. Make other types of terminations, if used.

7. A) Rope damage, or termination failure due to improperly made termination.

7. A) Make other types of terminations in accordance with ANSI Standards, or manufacturer's recommendations. If U-clips are used, be sure to use proper number and spacing of clips, and proper torque values. U-clips must be retightened periodically. If zinc sockets are used, proper unlaying of wires, and proper zinc temperature are very important.

8. Record all new rope information.

8. A) No record to establish normal rope life, and base diameter for wear comparisons.

8. A) Record date, and rope diameter, length, manufacturer, construction, grade, and normal life. Take, and record, rope diameter measurements after initial rope stretch (break-in).

## GENERAL INFORMATION

This module is part of an Instruction Guide that was developed to assist the sand, gravel, and crushed stone industry in conducting effective on-the-job training (OJT) of new employees, or employees reassigned to different jobs. The use of training materials, such as this module, is an important part of an effective, systematic, OJT program.

This Instruction Guide uses a generic Job Safety Analysis (JSA) of jobs common to the industry. The JSA format facilitates uniform basic training in safe job procedures, while requiring only a minimum of time and effort on the part of the trainer. This material is generic to the industry; therefore, each company using this guide will need to tailor the material somewhat to fit their particular requirements. In some cases, the material must be general in nature, and will not include specific details of procedures or equipment that must be taught by the trainer.

Recommendations for an overall OJT program are contained in the Mine Safety and Health Administration (MSHA) guide: "Structuring Effective On-The-Job Training Programs"

## TRAINING RECOMMENDATIONS

On-the-job training is usually best done by the employee's immediate supervisor. If the supervisor relies on another employee to do certain parts of the training, the supervisor should be present to monitor the training. OJT is conducted at the actual job site, where the work will be done.

The supervisor/trainer should use the training materials (this module, or other materials) while the training is being done, to help ensure that all job steps are covered, and that no important safety precautions are omitted. Effective OJT should begin with an explanation (lecture and/or discussion) of the safe job procedure. The explanation should be followed by a hands-on demonstration of the proper job procedure. A good demonstration is, perhaps, the most important part of OJT. The demonstration is followed by supervised practice, during which the supervisor/trainer coaches (corrects and encourages) the employee, and evaluates when the employee is ready to do the job without direct supervision.

The first step - explaining the job to the employee - can be done in different ways. The supervisor/trainer and the employee can sit down and go through the training materials together. It may be advantageous to provide the employee with a copy of the training modules that are applicable to his/her job. The fact that most of the training is conducted at the job site does not preclude the use of a classroom, or a quiet office, for the first part of the training. Any general theory, or knowledge training, as well as the initial explanation of the job procedure, may be best done in an office/classroom setting; especially when noise levels, or other conditions at the job site, make communication difficult. A complete series of job steps could be presented through the use of slides developed at the mining operation.