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MINE HOISTING INSPECTION, MAINTENANCE AND SAFETY

BATTELLE COLUMBUS LABORATORIES
COLUMBUS, OH

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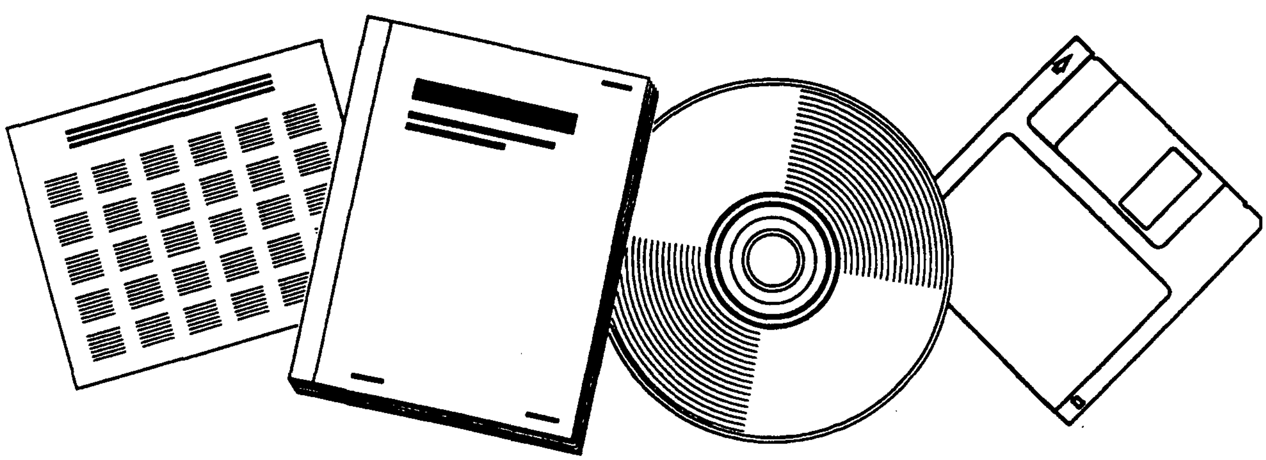

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MINE HOISTING INSPECTION, MAINTENANCE, AND SAFETY

R. A. Egen

BATTELLE
Columbus Laboratories
Long Beach Research Facility

USBM Contract Report H0346044
May 30, 1975

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16. Abstracts

The objective of this study was to develop inspection and safety guidelines for hoisting at underground mines. The objective was achieved with a report that provides the hoisting practices and criteria pertaining to the inspection and safe operation of mine hoists consolidated from all available foreign and domestic practices that are applicable to American mines. The report has been made available to mine operators, to mine inspectors, and to others who may be interested in safe hoisting practices.

The main value of the report is that it is the initial step in the development of hoisting regulations. It also identifies areas needing additional work and presents work scopes for initiating related programs.

17. Key Words and Document Analysis. 17a. Descriptors

Mining	Hoist machinery
Hoisting	Hoist controls
Inspection	Sheaves and rollers
Maintenance	Drum and wheel faces
Safety	Guides and shafts
	Friction hoists
	Federal regulations

17b. Identifiers/Open-Ended Terms

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USBM H0346044

2

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ERRATA SHEET

for Manual

"Mine Hoisting Inspection, Maintenance, and Safety"
dated May 30, 1975

Page 2-2, 6th paragraph, last line -

Change first word "of" to "at"

Page 2-16, last paragraph, fifth line -

Insert "can be as much as twice that at the drum, and, in general" after the word "deceleration"

Page 3-4, Item (3) (a), last line -

Change first word "rive" to "drive"

Page 3-7, second paragraph under COMMENT, first line -

Change "+ or x" to "⊕ or ⊗"

Page 3-15, sixth paragraph, third line -

Change "dams" to "cams"

Page 4-4, Figure 4.1 -

Change callout to read "Head Sheave or First Fixed Sheave Off Drum" instead of "of First Fixed"

Page 4-13 -

The second and third paragraphs under "Antisynchronous" should align with the sentence near the bottom of the page which reads "The following combinations are most effective:"

Page 4-19, second line under COMMENT -

Change "multiple friction hoists to "multiple-rope friction hoists"

Page 5-19, second line under INSPECTION/MAINTENANCE -

Change "terminated" to "reterminated"

4

Page 5-29, last paragraph, fifth line, under BROKEN WIRES -

Change "overhead" to "over head"

Page 5-30, Item (2), ninth line -

Change "2" to "12"

Page 5-38, Item (2) fourth line -

Change "reliance" to "Reliance"

Page 5-40, next to last paragraph, first line -

Part of word obliterated should read "compressed";

Second line - word "trip" should read "trap"

Page 9-9, second paragraph, first line -

Change "will" to "well"

Page A-1, last paragraph, second line -

Change "none" to "no"

It is suggested that these changes be made in the bound copy of your Manual in case the Errata Sheet becomes lost.

Acknowledgment

This book could not have been prepared without the help of a great many people in the mining industry—operators, suppliers, and regulatory-agency personnel, domestic and foreign—who took time from busy schedules to answer many questions; to discuss inspection and maintenance procedures; to act as guides during the inspection of many hoist installations; to dig through files and send off technical papers, forms, etc.; to permit the use of proprietary materials; and to review and comment on the handbook draft.

The author is grateful and thanks you all.

This book was written under contract USBM H0346044. The contract was administered under the technical direction of the Pittsburgh Mining and Safety Research Center with Mr. Michael Mahaffey acting as the Technical Project Officer. Additional guidance was provided by Messrs. Donald Hutchinson and Amin Alameddin of the Industrial Safety Group of MESA's Denver Technical Support Center.

Notice

The use of equipment trade names or the mention of a specific manufacturer's product is for illustrative purposes only and does not constitute an endorsement.

Foreword

The objectives of the research program that spawned this handbook were

(a) To review available foreign and domestic mine-hoisting practices and criteria relative to inspection and safe operation

(b) To determine which are applicable to a general inspection criterion for domestic mines

(c) To identify where additional research is required

(d) To develop a handbook around those practices that are currently applicable.

The program itself was conceived as the initial step toward the ultimate goal of providing a handbook, for use by both the underground mine operator and inspector, that will provide all of the inspection criteria and safety procedures to be followed with hoisting systems used in domestic underground mining.

Several general considerations were involved in deciding what to include in the handbook and how to present it. From a technological standpoint, hoisting practice and criteria cover three areas which overlap somewhat:

(a) Design, fabrication, and installation

(b) Use (hoisting procedures)

(c) Inspection and maintenance.

To cover all aspects was clearly out of the question within the time frame of the initial effort; also, the result would be an enormous book. After much deliberation, it was decided to concentrate almost entirely on the inspection and maintenance aspect. The primary reasoning was that all hoisting systems in use have already been designed, constructed, and installed, and no matter how well or badly this aspect was handled the systems must be safely lived with; so discuss how to live safely with them. Thus, only where design information might be useful in a maintenance/replacement sense is it included.

Likewise, much practice and many criteria related to use (hoisting procedures) were omitted. These aspects are, by and large, subject only to administrative control; inspecting for proper use is a hit-or-miss proposition since supervisors and inspectors can't be everywhere all the time. Regardless of how much emphasis is placed upon sensible behavior or how many times it is repeated, men will from time to time be killed or injured out of their own carelessness. Regrettable as it is, no book seems capable of solving this problem.

The ultimate goal of providing a book for both inspectors and operators requires contending with the fact that the people involved in each group range from beginners through the spectrum of experience to experts. Again, to cover all needs would result in an enormous book, probably half or better of which would include a glossary of terms and elementary material describing all the components of drum and friction hoists and portal elevators. Again, after considerable deliberation, it was decided to try for a middle road through the field of experience of those who would probably use the book and, thus, speak to those who have a working knowledge of mine-hoisting systems. It was felt that primer-like material should be a book of its own if the need were great enough.

The ultimate goal also requires contending with the fact that operators and regulatory personnel view hoisting from different perspectives. In the belief that the ultimate responsibility for providing safe, reliable mine hoists rests with the operators, this handbook was written in the form of an instruction manual from the operators' viewpoint. The material is predominantly based upon domestic practice developed and followed by operators, and the material selected from foreign practice is also in use by operators. With this approach, it is felt that operators can benefit from knowing what their colleagues are doing. Furthermore, it is believed that providing a picture of what good inspection and maintenance practices entail will enable regulatory personnel to determine whether or not such practices are being followed.

Finally, since regulations play an important role in hoisting, it was believed that if a Federal regulation applied to a topic being discussed, there would be value to presenting or citing the regulation along with the discussion. However, since the decision was made to place the emphasis on what is believed to represent good practice, it was recognized that there would be some conflicts between what was discussed and the regulations.

Having thus decided what to write about and how to write it, this book was written and a draft version circulated to some dozen and a half operators and inspectors for review and comment. Many excellent suggestions were received and incorporated into the final text. The conflict between what was written and an applicable regulation or what is considered normal practice was strongly questioned in several instances. The conflicts stand in this final version. In the author's opinion, not all domestic practice is good. Likewise, not all of the regulations are consistent with good practice. If the points of controversy herein lead to debate and eventual resolution, they will have been useful.

In addition, it seems that there is a need for a book of primer-like elementary material on hoisting. Finally, as a result of the comments received, the author feels compelled to emphasize to the reader that mine-hoisting installations in the United States encompass a wide variety of equipment and conditions, that hoisting problems often have several acceptable solutions, and that different practices can lead to the same ends. No one book, devoted even only to inspection and maintenance, could include all acceptable solutions and practice and still be practically useful. Thus, this book of examples of good practice collected from a wide variety of sources can only serve as a guide; if it is taken for gospel for all installations, more harm than good could result. The latter is meant to be and should only be interpreted as a plea for the exercise of sound, objective judgment.

Table of Contents*

*This Table of Contents lists only the major sections. Each chapter begins with its own detailed table of contents.

9

Chapter 8. Guides and Shafts

Chapter 9. Special Hoists

Appendix A. Friction Hoists—Groove-Tread Radius and Rope-Length Maintenance

Appendix B. Friction Hoists—Rope-Stretch Removal Criteria

Appendix C. Conveyance Safety Brake Testing

Appendix D. Federal Regulations

Appendix E. Bibliography

List of Numbered Figures and Tables*

Figures

Chapter 2. Hoist Machinery

Page

Chapter 4. Sheaves and Rollers; Drum and Wheel Faces

Chapter 5. Hoist Rope

Chapter 7. Conveyances and Counterweights

Appendix B. Friction Hoists—Rope-Stretch Removal Criterion

Appendix C. Conveyance Safety Brake Testing

*Unnumbered marginal sketches appear in several places to illustrate the text; there are also several unnumbered table and graph outlines used for illustrative purposes.

Tables

Chapter 4. Sheaves and Rollers; Drum and Wheel Faces

Chapter 5. Hoist Rope

Appendix D. Federal Regulations

INTRODUCTION

The purpose of this book is to provide an indication of what good hoisting practice is and how it might be achieved. To this end the book contains discussions of equipment and inspection and maintenance procedures developed and used by mining people in striving for safe, reliable hoisting equipment. Most of this information comes from domestic practice; the rest is foreign, notably from Canada. Most things discussed have long proved their general worth, and others promise to; a few are beginnings. However, nothing is conjectural or theoretical; the practices described herein are in use somewhere in the mining world.

The stress is on equipment in use; it is not a design-guidelines manual. Nevertheless, there are some sections dealing with design material since it may be of value in a maintenance/replacement sense.

Mine hoisting installations encompass such a wide variety of equipment and conditions that it is impractical to specifically cover them all. This book mainly treats conventional systems using conventional components with some discussion of the more common unconventional (special) systems in use. There is no recognized definition for a "conventional" mine-hoisting system. Herein the term means those systems most commonly used in daily operations for transporting men, materials, and product—electrically driven drum and friction hoists, with guided conveyances running in vertical or inclined shafts. Beyond this, what "conventional" means is probably best illustrated by the topics discussed.

Many aspects of inspecting and maintaining mine hoists are, of course, governed by state and Federal regulations, among which there are many differences. The Federal hoisting regulations are included verbatim with cross-reference tables in Appendix D and are referred to throughout, usually at the beginning of a topic if a regulation applied to it. State laws are not covered; but since they must also be observed, a "pocket page" is included into which a copy of the applicable state law can be inserted for ready reference.

At the end, Appendix E contains an abstracted and annotated bibliography of mining-industry literature pertaining to hoisting technology.

In the final analysis, since mine-hoisting installations in the United States encompass such a wide variety of equipment and conditions, this book can only serve as a guide. Hoisting problems often have several acceptable solutions; different practices can lead to the same end; and equipment and practice continue to be improved upon. Thus, where equipment and practices differ significantly from what is discussed herein, some changes may be desirable in some cases, but perhaps not in others.

Chapter 1
Management Aspects

Chapter 1
Management Aspects

1.1 DEVELOPMENTS IN HOISTING TECHNOLOGY

COMMENT — Throughout this handbook many techniques and equipment are discussed that may be unfamiliar or unused but that, nevertheless, have been developed to the extent of being very useful domestically.

The following items briefly discuss some additional techniques or equipment developments that are beginning to appear in hoisting practice (or already have in some countries) and are worth consideration, or at least noting:

(1) Auxiliary power units capable of supplying all power needed to operate a hoist in an emergency, not just that needed for brake hydraulic or pneumatic systems and communication or signal systems.

(2) "Unconventional" hoist brake systems that include disk brakes; springs for application (pressure release), sometimes using weights for emergency backup; pneumatic or hydraulic pressure application and release with weights for backup; pneumatic controls alone or working with hydraulic controls; hydraulic system pressures on the order of 1000 to 2000 psi rather than "conventional" operating pressures on the order of 100 to 200 psi.

These departures from conventional practice provide advantages such as smaller power supplies and fluid volumes, lighter or smaller—although not weaker—components, faster brake actuation, increased control sensitivity, and—in the case of disk brakes—less brake fade with heavy use because of better heat dissipation.

(3) Nondestructive inspection techniques for inspecting critical structural components; e.g., ultrasonics, magnafluxing, penetrating dyes.

(4) Portable, cage-mountable accelerometers that measure forces in the horizontal as well as the vertical direction and transmit the data to the surface via the hoist rope. These devices are commonly used in some countries when adjusting hoist brakes, aligning shaft guides, and determining an acceptable maximum hoisting speed for a given installation.

(5) Electronic control elements that include solid-state devices, printed circuits, and modular plug-in assemblies. These devices offer reduced maintenance, greater reliability, and smaller size, relative to the older style large, highly mechanical switches and relays.

(6) Approval of design specifications prior to ordering, constructing, or modifying equipment. This controversial regulatory technique, used sensibly, could promote hoisting safety by pointing out things forgotten or ignored.

15

1.1 DEVELOPMENTS IN HOISTING TECHNOLOGY (Continued)

(7) Commissioning of new or newly installed hoists. Perhaps even touchier than the procedure discussed in (6) is the idea of requiring official permission to use a hoist. The intent of commissionary procedures is to put a hoist through its paces, checking and testing all safety features and equipment behavior in general, to assure that the system performs as desired before it is put to work. Many operators do this as a matter of course because it is good practice; however, some do not, and every now and then things get badly out of hand and both lives and equipment are needlessly risked. Commissioning is common in the domestic elevator industry, including elevators used in coal mines in some states.

(8) Reduction of the background noise level at the hoistman's station by enclosing the control station, or enclosing or walling off such major noise sources as MG units, ventilation fans, compressors, and hydraulic supply systems. The intent is to eliminate noise that may interfere with the hoistman's awareness and understanding of signals and voice communications. However, many potentially very serious accidents have been limited or stopped short by a hoistman's awareness of unusual sounds; in this regard it is probably better to muffle or enclose the sources of unwanted noise (compressors, etc.) than to totally isolate the hoistman in a soundproofed cab.

1.2 INSPECTION AND MAINTENANCE PROGRAM

1.2.1 PROCEDURES

REGULATION* — A mandatory regulation requires, in part, that "a systematic procedure of inspecting, testing, and maintenance of shaft and hoisting equipment shall be developed and followed" (57.19-120 M).

COMMENT — A systematic procedure involves defining tasks to be done, formulating a schedule by which they are to be done, and devising checklists, etc. to verify that the work was done, by whom, and how. It is a process that generates paper and, consequently, objections. However, the value is rarely disputed; paper is usually the only management tool that assures that tasks are done as and when desired and that the people who do the work will, by virtue of the required signature, assume at least some responsibility for how well it is done.

Regardless of the procedures developed, the success or failure of a good plan depends to a large measure on the qualifications of and the authority given to those who are responsible for carrying it out, and on whether or not there is some means for an independent check on the work. In this regard, since hoist maintenance usually involves several departments of a mine, some operators have given the final authority and responsibility for checking or supervising inspection and maintenance work to someone who is in the safety department, for example, or to someone who reports directly to the mine superintendent. Sometimes this individual also does some of the more important tasks himself, such as inspecting ropes or Lilly controllers.

Although the governing regulation applies only to metal and nonmetal mining, it would appear to have equal value for coal mining as well.

*Statements under this heading that do not quote the regulations are meant to express the intent of the applicable regulation or regulations. Metal and nonmetal mine and coal mine regulations pertaining to the same topic are often written differently, although the intent is the same. The numbers in parentheses identify the pertinent metal and nonmetal mining regulations (the 57.'s) and coal mining regulations (the 75.'s). An M after a metal and nonmetal mining regulation means the regulation is mandatory; otherwise, the regulation is advisory. Coal mining regulations cited are all mandatory in effect. Note that the mandatory/advisory nature and, indeed, the regulations themselves are periodically revised.

17

1.2.2 RECORDS

REGULATIONS — Regulations recommend that "complete records should be kept of installation, lubrication, inspection, tests and maintenance of shafts and hoisting equipment" (57.19–121); records of tests of emergency escape hoists are also recommended (57.11–56); and records of daily examinations of coal mine hoisting equipment are required (75.1400–4) as are records of safety catch tests (75.1400–2).

RECOMMENDATIONS — Three general kinds of records are recommended:

(a) A hoist or hoistman's log
(b) An inspection/maintenance log, and
(c) A rope log.

These records should be kept for each hoisting installation. The hoist log should be available at the hoist at all times, and the inspection/maintenance and rope logs should be nearby or readily available at all times.

HOIST LOG

The hoist or hoistman's log should provide a chronological record of the daily operation of the hoist and include at least the following information:

(1) Date and shift
(2) Equipment tests or checks made, and results (trial runs, tests of overtravel limits, brakes, signals, etc.)
(3) Questionable or incorrect signals
(4) Any unusual hoisting operations, conditions, situations, or problems encountered; the action taken, and/or to whom the problems, etc. were reported
(5) Special notices to or among hoistmen that may involve the safety of people: for example, special work to be performed or under way in the shaft, inspection and maintenance tasks to be performed or under way
(6) An entry (preferably the first item) indicating that the shift hoistman has read all the entries of the previous hoistman and all special instructions
(7) All entries should be signed by the hoistman (or whoever makes them) together with the time of the entry.

In addition, the hoist log could serve more or less as an index to the other two logs by noting the occurrence of regular inspection and maintenance tasks along with a *very* brief description of what was done.

INSPECTION/MAINTENANCE LOG

The inspection/maintenance log should be *the* record of all inspection and maintenance tasks performed, problems encountered and solutions found or being tried, etc., involving the entire hoisting installation except for the ropes. This log is the appropriate place for the many details that would otherwise clog the hoist log or be forgotten.

A detailed description of the hoist installation should be a part of this log or form a supplement to it. This description should include at least a list of all the basic design features and equipment used; for example, horsepower, drum diameter and width, rated maximum rope load, head sheave diameter, depth of shaft, inclination(s) of shaft. Furthermore, this description should include a list of all control and safety devices used, how they are actuated, what they do when actuated, where the devices are located within the system, how they relate to one another, the sequences in which they work, etc. Most of this information is found on electrical schematics, if up to date, but schematics are not always easily understood by everyone who may have to work with the equipment. Often, a list with short descriptions or a diagram that illustrates the sequence in which the components act and react is equally useful.

ROPE LOG

The rope log should be *the* record of all

(a) Inspections
(b) Measurements
(c) Strength tests and results
(d) Rope cuts
(e) Reterminations
(f) Installation and removals, etc.,

made for all ropes associated with a hoist. It is advisable, furthermore, to organize these data separately for each rope.

This log or a supplement should also describe the factors used in the rope selection processes, especially the safety factor applied and the information and computations used to support the choice of rope on the basis of safety factors.

Furthermore, the rope log or a supplement should contain a complete description of each rope that includes:

(a) Manufacturer's name
(b) Manufacturer's rope number
(c) Date of manufacture

19

1.2.2 RECORDS (Continued)

(d) Type of construction including number of wires per strand and arrangements (e.g., 6 x 29 Warrington RT-Reg., meaning 6 strands of 29 wires each in a Warrington pattern, all layed up in a right-hand, regular lay pattern)
(e) Diameter of rope
(f) Weight per foot
(g) Grade of steel
(h) Ultimate strength (psi) of the steel
(i) Type of core
(j) Type of interior lubricant
(k) Catalogue breaking strength
(l) Actual breaking strength, when available
(m) Length installed.

COMMENTS — Records in general have value beyond serving as a guide to and reminder of work to be done. They provide a history which forms a basis for judging whether or not the work done is effective in producing safer and more reliable (or cost effective) hoists. Furthermore, they can provide continuity when personnel change and are useful for training new personnel. Finally (and not least), such records and data are the material out of which technical progress is born.

Many operators and agencies round the world take great pains to organize the "inspection/maintenance log" so that it can be used easily and so that changing conditions can be observed and compared easily. For example, two logs rather than one are common: one for mechanical equipment and one for electrical equipment. Furthermore, such logs are often subdivided into sections treating specific topics: for example, shafts and guides; control safety devices. The same sort of careful organization can also be found among "rope logs". Typically, such logs take the form of bound books or looseleaf binders.

Careful organization and separation of information cannot be overemphasized; where all this information is recorded haphazardly or in an overcrowded book, trying to trace the occurrence of a problem and subsequent actions can be like looking for the proverbial needle in a haystack.

20

1.2.3 TASKS AND FREQUENCIES

REGULATION — The inspection and maintenance tasks called for by Federal regulations are summarized in Table D.2 of Appendix D along with a reference to the regulations involved.

INSPECTION/TESTING/MAINTENANCE — The following schedule for basic inspection, testing, and maintenance is suggested:

CONTINUOUSLY

Housekeeping.

DAILY

Before regular use: Make one full trial run through shaft, and

Test:

- Overspeed and overtravel control and safety devices
- Signal and communication systems
- Brakes and friction clutches for slip
- Brake-clutch interlocks
- Conveyance position indicators for accuracy
- Semi- or fully automatic controls for conveyance positioning accuracy, especially friction-hoist position synchronizers.

Visually inspect:

- Reservoir oil levels of brake hydraulic systems
- Limit and pressure switches controlling pumps for brake systems
- Conveyance structure, suspension, and running gear
- Conveyance rope terminations and the rope nearby
- Conveyance safety brakes or safety catches
- Automatic rope lubricators
- Hoist rope (as it goes on or off drum)
- Friction-hoist position synchronizers.

Running the shaft is also advisable after the hoist has sat idle for a shift or several hours, and after any equipment or shaft repairs.

WEEKLY

Test:

- All control and safety devices, interlocks, indicators, warning devices, etc.
- Conveyance safety breaks for *actuation* capability.

1.2.3 TASKS AND FREQUENCIES (Continued)

Inspect:

- Headframes, shafts, and guides
- Sheaves and rollers
- Electrical gear and controls
- All hoist machinery
- Ropes for broken wires and distortions over their full lengths
- Conveyances (thoroughly).

Combine daily and weekly items and apply them once a week to all conventional hoists on "standby".

MONTHLY

Inspect:

- Hoist ropes thoroughly for wear, broken wires, and corrosion, making customary measurements.

Combine daily and weekly items and apply them once a month to all emergency escape hoists.

EVERY 3 MONTHS

Test conveyance safety brakes for *performance* capability.

EVERY 6 MONTHS

Inspect major, basic, electrical machinery and control equipment.

YEARLY

Thoroughly examine all components of entire hoisting installation. Specific attention should be given to massive mechanical components such as gears, shafts, couplings, frames, bails, and drums; and to control and safety devices or other such items that may have to be taken apart for a thorough examination.

COMMENT — The suggested schedule for inspection and maintenance tasks reflects common practice that provides well-maintained hoisting systems.

The schedule covers only some of the major items. It is not practical to suggest a schedule for every inspection and maintenance task necessary: too much depends upon the design and age of the hoist, its operating environment, and how often it is used. For example, there are several important aspects to rope inspection and maintenance for which the schedule of tasks depends upon the condition of the ropes; these aspects are discussed in detail in

Chapters 4, 5, and 6 and associated appendices. Similarly, lubrication has not been included because some items need attention continually, others less often, and some only occasionally. 22

It should also be remembered that good maintenance is also a matter of quality of work; and trade-offs between quality and frequency are possible in some areas. Thus, except for the items listed as "daily", there can be no argument with a plan that schedules some of the items listed under "weekly" on a 10-day or 2-week basis so long as the hoists involved are equally safe and well maintained.

Chapter 2
Hoist Machinery

Page

24

Chapter 2. Hoist Machinery

2.1 GENERAL COMMENTS

INSPECTION/MAINTENANCE — The hoist room has been called the showplace of a mine. Those that are showplaces almost always house a well-maintained hoist. *There is no substitute for good housekeeping*. A wipe rag is a simple and very effective inspection and maintenance tool. In using it more or less continuously (except on moving machinery), most potential problems will be found well before they become real problems. Paint can help control corrosion, but if overdone, it can hide cracks in critical areas.

Typically, and understandably, a hoist is given more attention the greater the need for it and the more it is used. However, this can be a trap with a hoist that "isn't used very much", is "on standby", or "only used in an emergency". Seldom used hoists also need periodic attention, and in some respects they need more than one used continuously. For example, motors and switchgear may need heat lamps to keep them dry in the absence of the self-generated heat that comes with use. Journal bearings may lose their oil film and may develop flat spots or seize if they aren't run periodically. Operating- and safety-control electrical contacts may foul with dirt. Hoist rope and safety catches will probably corrode more than usual from lack of attention.

The older the hoist, the more prone it is to structural failures through fatigue. Fatigue failures are not initiated by loads that exceed the yield or failure point of the material, but by the accumulated effects of many load cycles at stress values well below the yield point. Since the accumulation takes time, older hoists are more suspect; but fatigue failures can also occur in fairly new components. Look for cracks—they are the telltales.

Maintenance tasks are generally aided by the following practices:

(1) Use of lubrication manifolds: several grease or oil fittings mounted together in one easily accessible place which carry the lubricant to the point of need through small tubing. This eases the lubrication in general and tends to assure that all fittings are greased.

(2) Storage of commonly used tools, particularly special tools, in or close to the hoist room.

(3) Storage of a small supply of commonly used bolts, lubricants (in approved containers), etc., in or close to the hoist room.

(4) Storage or mounting of lubrication charts, electrical schematics, and maintenance manuals in the hoist room.

Grease and oils must be kept clean in storage, handling, and application. A very common cause of mechanical problems is dirt carried to critical surfaces in the lubricant.

Periodically check the security of all machinery mounts (e.g., bolts, nuts, grouting).

25

2.2 ELECTRIC DRIVES

INSPECTION/MAINTENANCE — Dirt and moisture are the major troublemakers.

Keep all components, their enclosures, and surrounding areas clean and dry. Dirt can foul mechanisms, cause shorts, reduce needed heat transfer from surfaces, and block air-cooling passages. Moisture can cause shorts and general corrosion, particularly of contractor surfaces.

A compressed-air hose is an effective tool as long as the dirt isn't blown where it isn't wanted. Oil, water, and dirt traps may have to be installed in air lines. (Use of compressed air should be in accord with nationally recognized safety standards.) Also, don't blow rotating machinery while it is running.

A wipe rag is also effective, but cotton waste should not be used to clean contacts, commutators, brushes, etc.

Solvents may be used, but consult equipment manufacturer's instructions first.

Fan-driven hot-air heaters, coil heaters, heat lamps, radiant heaters, etc., can control moisture.

Keep the filters on ventilated enclosures or ventilating systems clean. If such protection is not provided, simple enclosures with a blower and filter (and heaters, if needed) might be considered for M.G. sets and related gear. Such enclosures could be a less expensive maintenance approach in the long run. They can also be effective in reducing the noise level of the operator's station.

Look for and fix loose electrical connections and deteriorated insulation. For rotating machines, manufacturers generally recommend that insulation resistance be measured at least twice a year.

Check for undue vibrations in rotating machines. Vibration may indicate out-of-balance rotors or broken or loose components somewhere in the drive train.

The following items need specific attention:

BRUSHES

- Free up and clean stuck brushes
- Replace worn brushes before limit of spring travel is reached
- Keep brush spring at recommended pressures
- Wipe free copper off brushes.

26

COMMUTATORS (D.C. MACHINES)

- Keep clean. Do not use oil or other "special" commutator compounds.
- Soon after initial use, the surface of a good commutator should assume a polished, chocolate brown color. As long as it looks this way, leave it alone except for wiping or blowing carbon and copper dust off the surface and out of the slots. Otherwise, consult manufacturer's instructions for maintenance; commutators are very important and easily abused.

SLIP RINGS (A.C. MACHINES)

- Maintenace should be more or less the same as for commutators.

BEARINGS

- Check and maintain oil reservoir levels; periodically drain, clean, and refill. Check for overheating.

COMMENT — The above suggestions cover major but limited aspects of inspecting and maintaining electric drives and associated equipment. Some tasks, such as insulation-resistance measurement and contact and commutator maintenance, require special procedures and tools if they are to be done correctly. Such procedures and tools are described in detail in the instruction books delivered with hoists. If these books are not available, manufacturers can supply suitable instructions if there is doubt about using instructions accompanying similar equipment.

Problems with electric drives primarily affect the availability or reliability of the hoist; rarely are they the prime cause of a hoisting accident. Hoists are also often located in extremely wet and dirty locations and keeping electrics (or anything) clean and dry is a tough job at best. In these cases, the only guide to whether or not more needs to be done is whether the availability and reliability of the hoist meets production and overall mine-safety requirements.

2.3 CLUTCHES

2.3.1 GENERAL (ALL CLUTCHES)

INSPECTION/MAINTENANCE — Look for and repair cracks in highly stressed areas of:

- Spiders (at outer and inner ends of arms at pivots, and at abrupt or large changes in cross section)
- Floating collars, hubs moving on splines
- Splines, keyways
- Actuating levers at pivots, pin connections, and threaded areas.

Spiders, collars, hubs, splined shafts, etc., are good candidates for periodic (say yearly) non-destructive inspection (see 2.6).*

Look for and fix excessive wear or looseness in all pivots, pin connections, teeth, engines, control valves, etc.

Keep mechanisms clean, and lubricated where needed; particularly splines, floating collars, teeth.

Seldom used clutches should be inspected and maintained as if they were in common use.

Unused clutches should be removed and the drum fixed solidly to the shaft, or made inoperable by permanently fastening them to the drum and disconnecting or blocking the actuating mechanism.

2.3.2 BRAKE/CLUTCH INTERLOCK

REGULATION — For each clutched drum, the brake must be fully applied before the clutch can be disengaged, and the clutch must be fully engaged before the brake can be released. [57.19-5 M and 75-1403 (a)].

HAZARD — The lack or failure of a brake/clutch interlock can lead to damage to the clutch or loss of control over the drum and associated conveyance.

*Here and elsewhere these numbers reference sections of the handbook that discuss the topic in more detail or another but related aspect of the topic.

DESCRIPTION

MECHANICAL INTERLOCKS

Two types of mechanical interlocks predominate:

(1) A gate in the control console or the floor of the operating cab or platform when one lever controls both a brake and a clutch

(2) Interference blocks or cams on control rods, bell cranks or levers when a brake and a clutch are controlled by separate levers.

ELECTRICAL INTERLOCKS

Electrical interlocks typically use limit switches, mounted at the brake and the clutch engines or on their actuating mechanisms, to detect the in and out positions of the clutch and the fully applied and release positions of the brake. The switches are wired into the emergency brake control system so that the required interlocking action occurs.

MECHANICAL/ELECTRICAL

Mechanical/electrical interlocks include various combinations of the above.

INSPECTION/TEST — Disengage the clutch while observing the motion of the brake and the clutch. The brake should be *fully* applied before the clutch begins to disengage.

Re-engage the clutch while observing the motion of the mechanisms. The clutch should be *fully* engaged before the brake begins to release.

INSPECTION/MAINTENANCE — Look for and fix looseness, wear, or misalignment in position sensors and interlock mechanisms; remove extraneous, loose objects (junk) that could fall into, against, or under the mechanisms and the switches and foul their action. Keep limit-switch levers clean and lubricated to prevent freeze-up or sluggishness.

COMMENT — Some mechanical interlocks may allow the brakes to release before the clutch is fully engaged. For example, this can occur if the interlocks work on the levers controlling the brake and clutch engines, and if the brake engine operates faster than the clutch engine. One solution is a limit switch which actuates only when the clutch is fully engaged, and which is wired into the Lilly controller (or equivalent) so that the brakes cannot be released until the switch actuates.

29

2.3.3 FRICTION CLUTCHES

HAZARD — Slip can lead to loss of drum control; old band-type clutches are prone to fatigue failures.

INSPECTION/TESTING — Make a chalk mark from the drum to the clutch at some point. Try to drive a clutched drum with its brake fully applied; if this can't be done, then run a few regular trips. If the clutch slips or the chalk mark separates, indicating creep, adjustments are probably required.

It is not uncommon to make adjustments only after slip is observed during operation. If the above simple test were made daily, for example, then the need to adjust (or order parts) could be noted and scheduled before operations have to be interrupted.

INSPECTION/MAINTENANCE — Periodically clean the surface of shoes or linings and friction discs or rings.

Crazed and glazed disc or ring surfaces reduce clutch effectiveness and may require excessive tightening (and hence, stressing) of components. Periodic grinding or other resurfacing will help and may be necessary.

BAND FRICTION CLUTCHES

A band friction clutch is inherently more prone to mechanical failure than a disc-type because the driving force is transmitted between the spider and friction path by three components connected in series rather than many operating in parallel. These components are the fixed (anchor) and movable (actuator) arms and the steel band carrying the friction blocks. A failure involving any one of these components will completely disengage the clutch. Furthermore, because these clutches are old, fatigue failures are quite possible.

Figure 2.1 identifies the essential features and the critical areas of a Lane Band Friction Clutch, the most common band type still in use.

At least once a year the critical areas of these and similar clutches should be thoroughly cleaned and inspected for signs of cracks, particularly at bolt and pivot holes and threads. The retainer plate must be removed to properly examine the fixed and movable arms.

If possible, the rope should be wound on drums with these and similar clutches so that the fixed arm carries the greatest load. In Figure 2.1 this is equivalent to overwinding from the left or underwinding from the right.

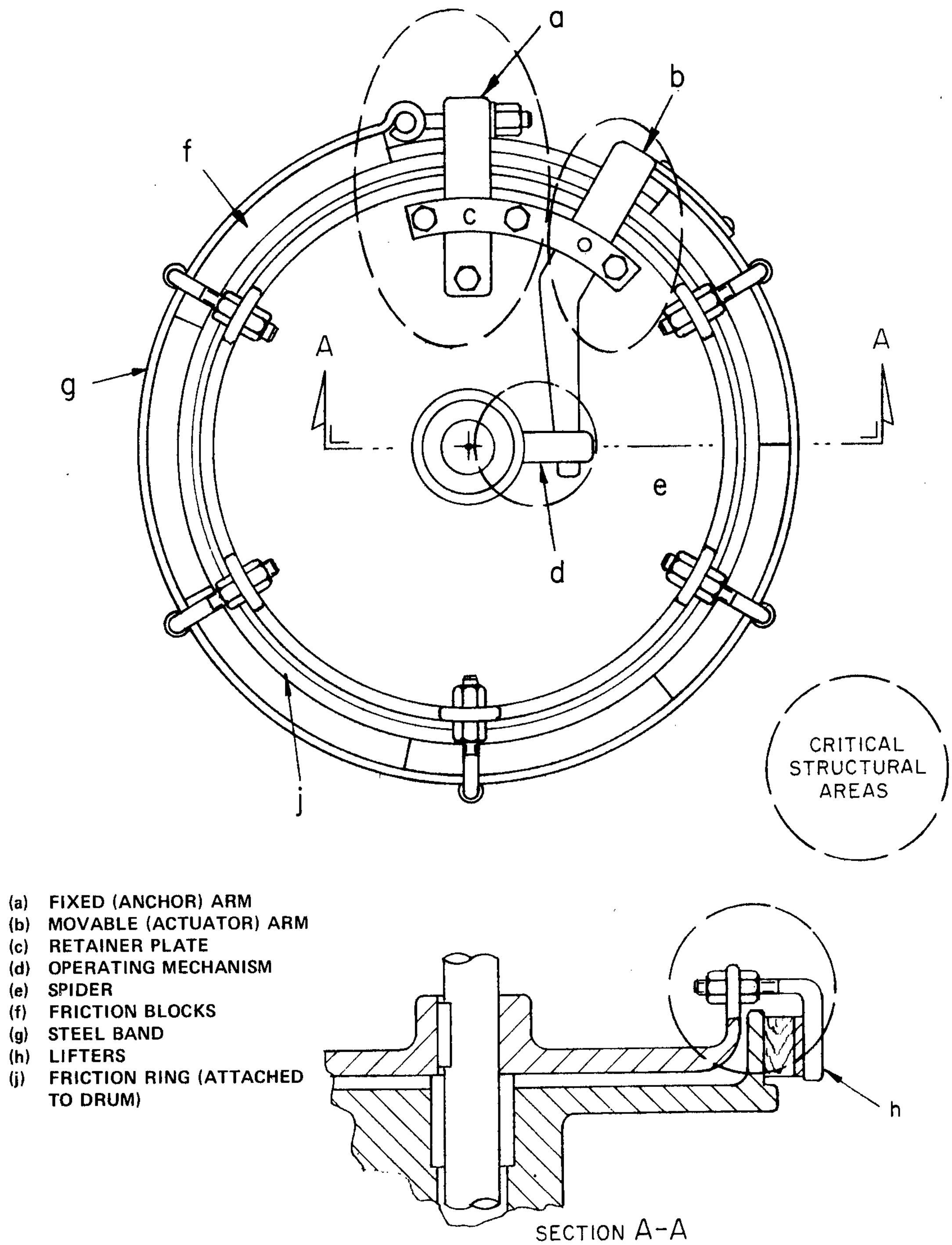


Figure 2.1. Lane Band Friction Clutch

2.3.4 TOOTHED CLUTCHES

COMMENT — When engaging toothed clutches, the closer the alignment, the less the wear and tear on teeth and other components. An effective guide to proper alignment is a series of blocks of alternating colors painted around the edges of the drum flanges.

NOTE: Do not attempt to engage a toothed clutch for any reason while the drum shaft is rotating. It is almost certain that engagement will not occur, but that major damage and, perhaps, injury will.

2.4 BRAKES

2.4.1 GENERAL (ALL BRAKES)

HAZARD — Serious accidents can result from failures of brake control mechanisms, or loss of brake capacity.

INSPECTION/MAINTENANCE — Look for and fix wear or looseness in all pivots, pin connections, engines, valves, cables, quadrant pawls (hand brakes), etc.

Look for and fix loose bolts, clevis pins, cotter pins, retaining clips, etc.

Look for cracks indicating potential structural failure in all rods, levers, bell cranks, etc., at and near pivot connections, pin connections, and threads. Threaded connections will probably have to be loosened for inspection, since the critical areas are usually at the root of the thread at or just inside the clevis, turnbuckle, etc.

Look for and remove extraneous, loose objects that could foul mechanisms.

Look for and fix loose brake shoes.

Keep mechanisms clean and lubricated where needed.

Modifications to brake systems (e.g., eliminating or "disconnecting" the brake priming capability or equipment) should be very carefully considered in advance and, if the probable effects are not clear, the manufacturer or a designer should be consulted. The danger is either a reduced or increased (see 2.4.6) brake torque capacity in an operational or emergency brake application, resulting in either a too slow or too fast stop.

COMMENT — Working from elevated catwalks permanently installed at each end of a drum can make brake (and clutch) maintenance tasks easier and safer. Catwalks parallel to the drum on the head sheave side are of similar value to drum and rope inspection and maintenance efforts.

2.4.2 BRAKE STRUCTURE CRITICAL AREAS

HAZARD — A structural failure of brake components can result in the loss of brake capacity.

INSPECTION/MAINTENANCE — Clean the critical areas noted in Figure 2.2 and carefully look for and repair cracks. Pay particular attention to pins and pinhole wear.

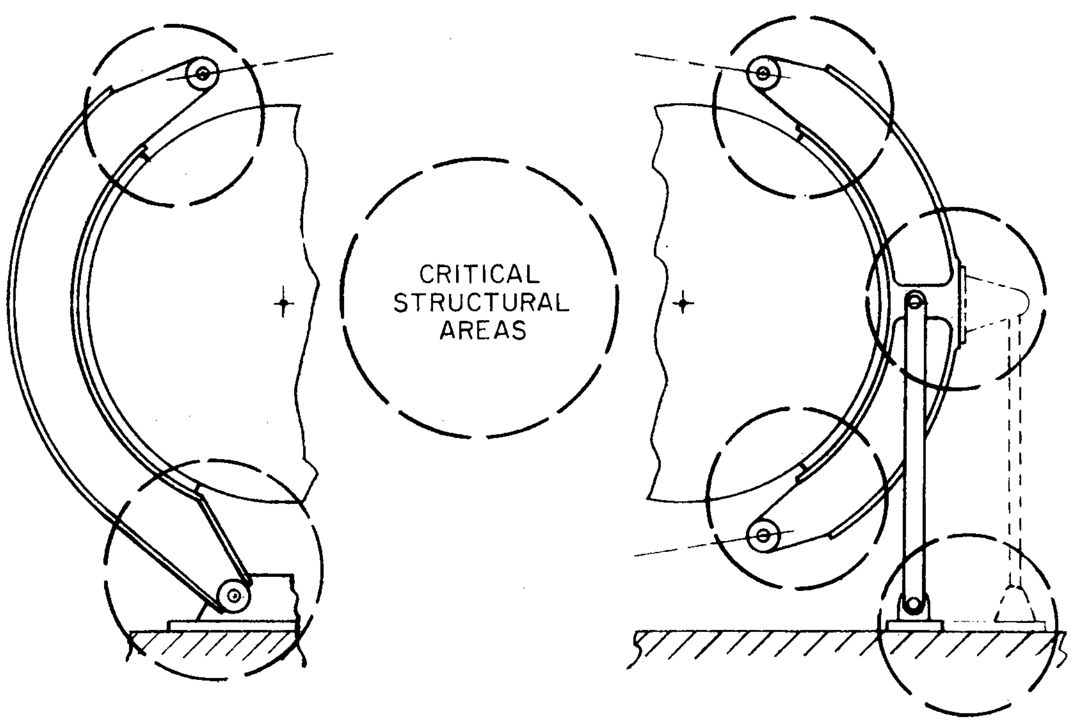


Figure 2.2. Critical Areas of Brake Structure

The critical areas on band brakes are similar to those for band friction clutches (see 2.3.3): the band, the fixed-end anchor components, the movable-end attachments, and the lifters.

COMMENT — In rough service environments, muck often covers the anchor points of jaw and parallel-post brakes or the components at and near the ends of the bands on band brakes. These situations usually need more frequent attention.

34

2.4.3 BRAKE WEAR AND ADJUSTMENTS

HAZARD — Wear of brake shoes or linings can lead to loss of brake capacity.

INSPECTION/TEST — Try to drive a drum with its brake fully applied. If the drum creeps or slips, adjustments are required. (This test may not be possible with hoists using one lever to control drive and brake.)

Manually trip each brake-wear limit switch and check that the intended action occurs.

INSPECTION/MAINTENANCE — Periodically clean the brake linings and the brake path (friction surface). Sheet-metal guards between the ends of the shoes of jaw and parallel-post brakes can keep most, if not all, rope lubricant off the brake path.

Crazed or glazed brake-path surfaces reduce brake effectiveness. Periodic grinding or other resurfacing will help. Most brake rings and discs are designed to allow periodic resurfacing without impairing their strength or heat capacity.

Worn wooden brake-shoe blocks should always be replaced with new ones of the originally recommended or supplied wood or an equivalent. Different kinds of wood exhibit different coefficients of friction on steel and iron, and use of the wrong wood could lead to reduced braking torque.

Brake adjustments should be made with care. Take time with parallel-motion brakes to assure that the top and bottom of the shoes move equal amounts. Make sure that full brake application can occur before engines bottom out or levers reach the ends of their quadrants. Brake systems on many hoists are complex; adjustments involve more than nuts and bolts, and consulting the instruction manuals before all else fails usually saves time and may save lives.

COMMENT — Good practice calls for some indicator of when to adjust or reline the brakes while there is still ample capacity available. Limit switches are often used to automatically give warning or eventually, if not immediately, shut down the hoist. These switches are commonly called "brake-wear limit" switches, although the term "slack brake" switch is sometimes encountered.

For weight-applied brakes, these switches are commonly actuated by the weights. For pressure-applied brakes, these switches may be at the service engines or at the levers, as well as at backup weights.

Disc brakes will have switches (probably very small ones called microswitches) actuated by the brake-pad carriers or by an arm attached to the carriers. (They may also have other switches that warn of dragging brake pads.)

Visual indicators are common also—markers on weights that line up with pointers, painted marks or metal tabs on handbrake quadrants.

35

2.4.3 BRAKE WEAR AND ADJUSTMENTS (Continued)

It should be noted that "brake wear" can include wear of the rigging as well as the linings. Thus, what needs adjusting depends upon where the indicator is located in the brake system and upon the design of the brake system itself. For example, indicators at the weights cover brake linings and some rigging, while those on quadrants can cover lining and all rigging wear.

On clutched hoists that don't have thruster brakes on the motor shaft, consideration should be given to wiring brake-wear limit switches into the control system so that, when operating singly, these switches cannot shut off the motor if they are activated. Otherwise, if the brake mechanism on the drum in use were to fail and also cause the wear switch to be activated, shutting off the motor, the hoistman would have no positive control over the drum.

2.4.4 HAND-WHEEL-OPERATED BRAKES

HAZARD — It is doubtful that a man can apply a hand-wheel-operated brake fast enough to prevent an accident in all emergency situations. Furthermore, the designs of many hand-wheel-operated brakes in similar applications are such that it is impossible for one man to tighten them enough to stop the machine even reasonable soon.

RECOMMENDATION — If hand-wheel-operated brakes are the sole form of emergency braking for the hoist, it is recommended that they be replaced if they cannot be modified with a weight-operated backup arrangement that automatically trips on overwind and overspeed and that can be actuated with an emergency-stop button or switch.

2.4.5 HYDRAULIC/PNEUMATIC SYSTEMS

INSPECTION/MAINTENANCE

GENERAL

Internal dirt is a major problem for any hydraulic or pneumatic system, and valves usually suffer most.

Frequently:
- Check and clean filters
- Check and maintain level of oil in reservoirs
- Drain oil, clean sumps, refill with new oil
- Check and clean water traps in air systems
- Check and maintain lubricators in air systems.

The frequency of these tasks depends upon use and environment.

Keep systems and surroundings clean, repair leaks as soon as possible, and use drip pans or cans until leaks can be repaired.

ACCUMULATORS

Daily, check accumulator-mounted pump-control switches for potential mechanical and electrical problems, e.g., loose switch arms, connections.

Air-over-oil accumulators should have a sight-glass tube or other indicator of oil level.

PUMPS/SUPPLIES

If primary and backup oil pumps (or air supplies) exist, alternating their use promotes reliability.

COMMENT — Except for the potential hazard noted below, problems with hydraulic or pneumatic brake-control systems should primarily affect only the availability or reliability of the hoist; rarely are they the prime cause of a hoisting accident. High reliability and good maintenance normally go hand in hand.

Good practice includes using a pressure gauge visible to the hoistman, with the acceptable or design operating range of pressure marked on the face.

Sometimes, pressure-sensitive switches are used to turn on the backup system, but they also could be used to give an alarm or shut down the hoist. The latter two uses would give notice of a potential problem before there is a complete loss of pressure and an automatic application of the brakes.

POTENTIAL HAZARD: Loss of Pressure and Loss of Brakes

Power-assisted brakes have been traditionally designed so that a loss of power or pressure will not prevent or will automatically lead to an application of the brakes. These designs are fail-safe only if brake application is completely independent of this power or pressure.

In this regard, pilot-operated emergency valves may be a hazard. The motion of the main spool of these valves is controlled by a smaller valve (the pilot valve) which is usually operated electromechanically. If the motion of the main spool is controlled solely by fluid pressure, this spool may not shift to the brake-on position and dump the engines if there is a partial or complete loss of pressure. A safer approach is to spring load the main spool so that it will shift with a loss of pressure.

Operators are urged to carefully review their hydraulic and pneumatic brake-control systems for any possibilities for loss of brakes with loss of pressure if emergency valves are pilot operated. Where there is doubt, modify the valve to one that is spring driven to the dump position; usually, this is a simple modification.

39

2.4.6 CONTROLLED BRAKING IN EMERGENCY STOPS

REGULATION — "Maximum acceleration and deceleration should not exceed 6 feet per second per second" (57.19–62).

HAZARD — A too-rapid emergency stop can injure men and damage equipment.

DISCUSSION — Each drum brake on a clutched hoist is designed to at least hold a fully loaded skip or cage in the bottom of the shaft when its drum is unclutched. Some hoists are designed to permit single drum operation, and each brake can also stop a fully loaded conveyance descending near the bottom of the shaft. Furthermore, brakes are commonly designed with excess capacity "just in case".

There are other hoisting configurations, both single and balanced, for which the required brake capacity is much less than for the single-drum examples cited above; but in an emergency stop the same brakes may come on with the same capacity regardless of the need. Clearly, some form of control of excess capacity is required; there are many miners who walk with a limp that can vouch for this. Furthermore, there are hoists that will be damaged by an emergency stop from full speed because of excess brake capacity.

Drum brakes may not be the only source of excess braking capacity. Some states require a second brake on a clutched drum operating singly, and this requirement is often met with a motor-shaft thruster brake (electrically released, spring applied); depending upon the control wiring, this brake may apply in an emergency stop, too. Thruster brakes are also found on single and nonclutched double-drum hoists. Furthermore, many hoists are equipped with regenerative or dynamic braking capabilities; if these "brakes" are or can be applied in an emergency, a still greater excess may exist.

The solution is not to eliminate the excess capacity; it exists because of some need. The solution is to control the rate of braking so that only what is needed is used in any situation.

Those countries and equipment builders who have addressed the problem of controlling emergency braking rates are unanimous in their opinion that, on man hoists at least, any deceleration limits must consider the dynamic behavior of the conveyance. The hoist rope acts like a spring; a natural consequence is that the deceleration that develops at a conveyance for a given drum deceleration varies in a complex way with where the conveyance is in the shaft and the direction it is moving, with whether the conveyance is operating singly or in balance, and with the maximum brake torque applied and the time taken to apply it. Or, turning it around, the deceleration needed at the drum to produce the same deceleration at the conveyance varies in a complex way with the same variables. Thus, for man and equipment safety, control of emergency braking rates has typically found expression in general limits for the maximum deceleration at the conveyance which may be exceeded, if necessary, at the ends of travel. For the general limit, South Africa finds 6 to 12 ft/sec^2 generally acceptable for emergency stops from full speed; Ontario is working with 16 ft/sec^2. Ontario's experience with this limit indicates that the corresponding deceleration at the drum may range from 8 to 12 ft/sec^2; it all depends upon the nature of the particular hoisting system. It should be noted that it is not considered necessary to achieve the same conveyance deceleration for all emergency stops, but rather to strive for conveyance

40

decelerations somewhere below, but no more than, the limit (except, as noted, toward the ends of travel if necessary).

Two basic approaches to braking control have evolved; sometimes both are used.

One uses a governor system that measures the speed of the hoist and uses the signal to control the brakes so that a more-or-less constant deceleration is produced at the drum. This can produce different decelerations at the conveyance, depending upon the configuration; but the maximum at the cage does not exceed an acceptable value.

The other approach uses a programmed brake controller that provides specific brake capacities for specific configurations hoisted. This approach has given rise to the terms "level of braking" or "braking level". In use, "level" usually refers to the maximum brake torque applied but sometimes to the time taken to apply it as well. How this is applied to one domestic metal-mine, clutched, double-drum, vertical-shaft system is illustrative. Level 1 provides the maximum possible brake torque with no delay when lowering unbalanced. Level 2 provides about 50 percent of the maximum torque on each brake in about 10 seconds from 10 percent prime for a balanced configuration midshaft, i.e., away from ends of travel. Level 3 provides a still lower braking effort when the configuration being hoisted would naturally slow and stop if the motor were shut off. This third level is really two levels: the maximum torque, the application time, and the prime effort differ for balanced and unbalanced configurations.

The degree of complexity of the above example is not required in all cases. One observer of Canadian experience indicates that for vertical shafts up to about 1500 feet deep, one level of brake effort is usually sufficient if the rate of application can be adjusted or controlled. Between 1500 feet and about 3200 feet, one level with a governor, or two levels (one for clutched and one for unclutched configurations) will usually suffice—again, if the rate of application can be adjusted. Over 3200 feet, 3 levels with controlled rates of application, or one or two levels and a governor, will likely be needed. In some cases, control of the rate of application has been provided easily by adding a dash pot (damper) to the brake-actuating mechanism of a Lilly controller.

COMMENT — The intent of the regulation quoted at the beginning of this topic is not clear. Any regulation governing the "maximum acceleration and deceleration" should specifically take emergency stops into consideration since these stops can induce the highest decelerations likely to be encountered anywhere in a hoisting system (except, of course, as a consequence of some catastrophic failure). Furthermore, as the discussion points out, it is necessary to state specifically where in the system the limit applies.

The idea of regulating acceleration and deceleration is fairly new domestically. From the discussion, it should be apparent that the regulation cited is inadequate and should be revised; and that it should not be applied to emergency stops in its present form.

Implementing any such regulation will require much field work before general guidelines can be published. While this work is in progress, operators are urged to review their braking systems to determine what their emergency braking problems are, if any, and how they might be solved.

2.5 DRUMS/FRICTION DRIVE WHEELS

INSPECTION/MAINTENANCE Look for and fix loose or broken bolts in segmented drums and wheels.

Look for and fix loose or broken bolts that fasten rope-groove sleeves (e.g., Lebus sleeves) to drums, friction blocks to drive wheels, and anything to drum flanges (projecting bolts have broken ropes).

Look for and repair structural cracks. Inspect drums and wheels from the inside as well as from the outside.

Look for and repair cracks at welds made for earlier repairs or modifications.

Keep drum bearings on clutched drums cleaned and lubricated, and rebush (or otherwise repair) before the drum starts to wobble or hop around.

Splash guards on drums are a good housekeeping measure as well as protection for the hoistman. Some operators envelop the entire drum (except for a rope slot) although this may hinder rope inspection even with access doors. Guards that partially lip over the flanges seem to control rope lubricant better than those that don't. Except for friction hoists, no guards may be a sign of poor rope-lubrication practices.

42

2.6 DRUM AND WHEEL SHAFTS AND GEARS

HAZARD — Fatigue failures of drive shafts and gears can have disastrous results. Old hoists are particularly prone to fatigue failures.

INSPECTION/TESTING — Look for cracks, principally at key ways, splines, changes in shaft cross sections, and roots of gear teeth.

Nondestructive inspection devices and techniques (e.g., ultrasonics, dye penetrant, magnafluxing) should be considered; they are more discerning and can often save time.

INSPECTION/MAINTENANCE — Look for and fix looseness and wear in fittings, fasteners, couplings, supports, and mounts.

Look for and repair loose or broken bolts in segmented components (e.g., bull gears, couplings).

Keep bearings lubricated; periodically drain, clean, and refill reservoirs.

Repair or replace worn bearings; they can lead to wear and damage to other components of the power train.

COMMENT — Sudden high loads are a major contributor to fatigue of gears and shafts and rapid stops are a prime source of such loads. Rapid stops cannot always be avoided; but something is wrong with either the equipment or the hoistman if, at the end of each trip, the stop causes the rope to slap wildly and the drive train and motors to oscillate.

Nondestructive inspection techniques are valuable because they may reduce or eliminate a need for disassembly and excessive cleaning. Fatigue cracks in shafts may be difficult to detect visually without disassembly because they often occur where the shaft is covered by a gear, a bearing, or a drum. Inspecting gear teeth visually for cracks at the root usually requires thorough cleaning.

Nondestructive techniques are best used by people specializing in such services. However, care is always necessary: shafts are commonly ultrasonically inspected from one end only, and in a few cases on record signals from well-developed circumferential fatigue cracks were misread as simply indicating the other end of the drum shaft—the shafts soon and unexpectedly failed.

Chapter 3
Hoist Controls

Chapter 3.
Hoist Controls

44

3.1 OPERATING CONTROLS

3.1.1 MANUAL CONTROLS

3.1.1.1 GENERAL

HAZARD — Failure of control mechanisms can result in loss of hoist control.

INSPECTION/MAINTENANCE — Look for and fix wear or looseness in all levers, pivots, pin connections, keys, keyways, cables, chains, switches, cams, pawls, knobs, handles, etc.

Look for and fix or replace loose and missing bolts, nuts, cotter pins, retaining clips, etc.

Keep mechanisms clean, and lubricated where needed.

3.1.1.2 BACKOUT SWITCHES AND CIRCUITRY

HAZARD — Loss of end-of-travel protection can occur if backout circuitry is incomplete or improperly installed.

DISCUSSION — Backout switches and circuits permit hoists to be operated after having been automatically shut down by an overtravel protection device (see 3.2.2). Such operation is achieved by overriding the automatic end-of-travel protection circuits. To guard against the hazards inherent in operating with an overriden end-of-travel safety, safety considerations dictate the following characteristics for backout systems:

(1) (a) In the backout mode, the hoist motor should be drivable only in "reverse", and

(b) The brakes should not be releasable until the motor torque has built up enough to assure that *only* "reverse" motion will occur.

(2) (a) Backout switches should be momentary-contact, self-returning (spring-loaded) switches. Objections to a self-returning switch stem from the need to hold it "on" while the conveyances are backed out; these objections can be overcome as follows:

(i) If one hand is needed to run the hoist, install the backout switch (button, lever, handle) within easy reach of the hoistman;

3.1.1.2 BACKOUT SWITCHES AND CIRCUITRY (Continued)

(ii) If two hands are needed to run the hoist, use a foot-operated switch. Protect this switch with a guard that permits a foot to be slipped under it but prevents loose objects from falling on and actuating the switch.

(b) Circuits should be arranged so that the hoist will be shut down if the backout switch is turned "on" during normal hoisting.

(3) In any case, a buzzer, bell, horn, or flashing light should be provided to indicate that the backout switch is on in case the hoistman forgets to reset it, to take his foot off it, or to pull the match stick (wedge) out from under it.

COMMENT — Items 1. (a) and (b) above will prevent a further overwind by making it impossible for the hoistman or out-of-balance loads to drive the hoist further into an overwind. (These things have happened). If this protection is available, the value of a self-returning switch has been questioned. It has been argued that "reverse" operation only, at creep speeds only will call attention to the fact that the backout switch is on, particularly if the warning signals (Item 3 above) are working. This is a good argument, but there are a lot of ifs; and the cost differential between self-returning and non-self-returning switches is not significant enough to warrant the risks of the ifs.

46

3.1.1.3 MOTION OF MANUALLY OPERATED DRIVE/BRAKE LEVERS

HAZARD — Different arrangements among hoist controls may result in running a hoist in the wrong direction and/or starting it instead of stopping it in an emergency situation.

DISCUSSION — In the most common arrangement of in-line double-drum hoists, the right-hand drum, looking toward the head sheave, is overwound and the motion of the manually operated control levers corresponds to the motion of the overwound rope. To lower the conveyance on the overwound rope the hoistman pushes the motor control lever away from him, and to hoist (raise) the conveyance he pulls the lever toward him. Brakes are released by pushing their control levers (if separate) away and applied by pulling them back.

This concept is also commonly applied to double-roped single drums, split or not, as well as to double-drum hoists layed out in tandem (one behind the other), no matter where the control cab or platform is placed.

The concept is regarded as "standard" by a great many hoistmen who recognize the value of it if no one else does. They are accustomed to it and those who move about, particularly those who work on shaft sinking projects, have commented that they have been confused on occasions by "non-standard" control arrangements. The concept is included in a long-standing South African regulation; and Ontario, for one, is moving in this direction. The impetus comes from accidents that have occurred because, in a moment of panic, the hoistman has automatically responded in accord with his experience, but the controls have been arranged differently.

RECOMMENDATION — To "standardize" the motion of control levers relative to the motion of the ropes, the following arrangements are suggested:

(1) Manually operated drive- and brake-control levers should push away from the operator to release the brakes and to unwind the overwound ropes. These levers should pull toward the operator to apply the brakes and to wind the overwound ropes.

(2) And to the extent feasible —

(a) Single-drum hoists with one rope should be overwound.

(b) Double-drum hoists with in-line drums should be overwound on the drum on the right, when looking toward the head sheaves.

(c) Single-drum hoists with two ropes should be wound as if they were in-line double-drum hoists.

(d) Double-drum hoists with drums not in-line should be overwound on the drum farthest from the head sheaves.

47

3.1.1.3 MOTION OF MANUALLY OPERATED DRIVE/BRAKE LEVERS (Continued)

(3) (a) Ground-mounted friction hoists should have the manually operated control levers referenced to the motion of the ropes at the top of the rive wheel, as if the ropes were overwound.

(b) Tower-mounted friction hoists should have the manually operated control levers referenced to the motion of the ropes on the side of the drive wheel farthest from the operator or to his right.

COMMENT — For existing hoists, arranging controls to follow the overwound rope should be relatively easy, and it may be as simple as interchanging a few wires. To overwind a single-drum hoist with band brakes arranged for underwinding, the brake mechanism should be reversed (i.e., anchor and actuating lever ends swapped) since band brakes can exert a greater torque if the loads act against the anchor end of the band. This modification is not, admittedly, relatively easy.

Changing a cylindrical drum from under- to overwound (and vice versa) may require making a new rope spout (the hole in the drum or the flange through which the rope passes) at the other flange, and relocating rope risers, filler strips, and kick plates. Grooves do not have to be changed although some minor modification may be needed at the spout.

Drums with conical sections cannot be changed from under- to overwound or vice versa.

48

3.1.2 SEMI- AND FULLY AUTOMATIC CONTROLS

HAZARD — Failure of components can result in loss of hoist control; the loss of synchronization of control with conveyance position can easily cause accidents.

INSPECTION/TESTING — Unless regular operations provide a more-or-less continuous check on the accuracy of automatic controls in spotting conveyances, periodically spot each conveyance at the top and bottom stations using the automatic controls. Visually confirm whether or not the conveyances stop where expected. Readjust controls if needed. Intermediate automatic stops may also need periodic checking and adjustments.

Automatic conveyance-position synchronizers on friction hoists should be tested for accuracy daily. (These devices compensate for the creep of the ropes on the drive wheel.)

The above tests should be made after:

(a) Installing new hoist ropes

(b) Cutting off and reterminating drum-hoist ropes at either end

(c) Retensioning or shortening hoist ropes on friction hoists

(d) Replacing any conveyance that is directly involved in the operation of the automatic control system, e.g., one that actuates shaft switches

(e) Repairing or modifying automatic controls.

If a semi- or fully automatic control system has not been used for a day or so, run the shaft a few times using the automatic system before beginning regular hoisting. Note that a test run made with manual controls cannot fully check an automatic control system even though some components may be common to both.

INSPECTION/MAINTENANCE

GENERAL

Look for and fix wear or looseness in control drive mechanisms—shafts, couplings, gears, sprockets, chains, bearings, etc. Loose chains should be shortened or tensioned with spring-loaded idlers. Chains kept loose because "they will climb off the sprockets" indicate misaligned sprockets.

Look for and fix looseness in cams, switches, levers, wiring, etc.

Keep mechanisms clean and lubricated where needed.

Look for and repair fraying and chafing (or other) damage to cage-control trailing cables. Find and eliminate or control the sources of this damage as much as possible.

3.1.2 SEMI- AND FULLY AUTOMATIC CONTROLS (Continued)

FRICTION HOISTS

Inspect the automatic conveyance-position synchronizer system daily for potential electrical and mechanical problems.

DRUM HOISTS—ROPE CHANGES OR END CUTTING

The following procedure eliminates the need for gross internal resynchronizing adjustments to automatic controls following rope changes or end cuts.

(a) Block or chair the conveyance at the collar (or wherever work is to be done) without slacking the hoist rope;

(b) Disconnect the mechanical drive of the automatic control system;

(c) Slack off the rope;

(d) Carry out the rope-related tasks (cutting or replacing);

(e) Reconnect rope to conveyance and take up slack;

(f) Reconnect the mechanical drive to the control system; and

(g) Finally, unblock or unchair the conveyance.

This procedure is most effective if the control system's mechanical drive permits close-interval indexing at one or more connections. Chain drives naturally permit close indexing, as do couplings with many bolt holes or serrated faces. Nonkeyed, set-screwed-fastened gears or sprockets permit fine alignment; but they are prone to slippage and must be inspected often.

COMMENT — There is a variety of semi- and fully automatic operational control systems and each type requires specific inspection and maintenance beyond the general procedure discussed above. These procedures are described in detail in the instruction manuals that manufacturers provide.

The use of push-button control of hoists from cages and stations can be expected to increase. These systems are complex and the station and cage gear need extra attention in severe shaft environments. Moisture and dirt will probably continue to be a major source of problems with these systems. However, extra care of shaft linings and with the design and maintenance of station gates may be required so that materials don't fall down the shaft and destroy trailing cables or hoist-rope antennae.

50

3.1.3 CONVEYANCE POSITION INDICATORS

REGULATION — "An accurate and reliable indicator of the position of the case, skip, bucket, or cars in the shaft shall be provided" (57.19-9 M and 75.1401), ". . . placed in clear view of the hoisting engineer" (75.1401-3).

HAZARD — Loss of a true indication of the position of the conveyances or failure of an indicator can easily result in an accident.

DESCRIPTION — Three types of conveyance-position indicators are common:

- Circular-dial indicators with pointers, pedestal-mounted somewhere between hoistman and drums, or mounted in the control console. Either the circular disc or the pointer can move. (Some circular-dial indicators are made more accurate with the use of two pointers, one moving a certain amount as the other makes a complete revolution of the face—like the hands of a clock.)

- Cylindrical drum indicators with pointers, mounted in the console; both drum and pointer move.

- Linear indicators with movable pointers, mounted on frames above the drums.

INSPECTION/TESTING/MAINTENANCE — Though used for manual operations, these mechanical devices have a counterpart in semi- and fully automatic control systems. They require much the same kind of accuracy checks, mechanical inspection, and maintenance procedures (see 3.1.2), and their accuracy should be checked daily.

Both pointers on two-pointer dial indicators, sometimes called multi-revolution indicators, must be checked for positioning accuracy—especially the slower moving one, because a small motion of this pointer corresponds to a large motion of the conveyance.

COMMENT — Although the regulation does not specify it, good practice requires an indicator for each conveyance in a balanced system, whether drum clutches are involved or not. Furthermore, safety considerations require drum-driven drives on clutched systems; shaft-driven drives should be located as close to the drum as possible on hoists without clutches if a drum drive is not feasible.

As an aid to hoist-rope inspection, indicators can be marked + or x when the rope-crossover regions are accessible to the ropeman from his customary inspection station.

Marks on drum flanges can be a valuable aid to accurate spotting of conveyances; they are acceptable provided they are used in conjunction with some dial or linear indicator.

51

3.1.3 CONVEYANCE POSITION INDICATORS (Continued)

Station markers on indicators need to be adjustable; indicators have to be periodically "recalibrated" because of hoist-rope stretch and may need fine tuning after rope changes and end cuts. Movable marker tabs, chalked marks, or marks penciled on console indicators are easier to reset than painted or inked marks.

Position indicators and overtravel and overspeed protection devices often share a common drive to some extent. If the commonly-shared portion fails, both the indicators and the protection devices cease functioning. Such failures are not unknown nor are spectacular overwinds, as a result. In such shared-drive situations, it seems that there is value in providing, instead, totally separate drives, or in installing interlocks that shut down the hoist if it is running and both the indicators and the overspeed/overtravel devices are not.

In any case, an indicator malfunction is reason enough to cease hoisting until it is repaired.

52

3.2 SAFETY CONTROLS

3.2.1 DISCUSSION

There is no clear division between operating and safety controls. Depending upon one's point of view, some of the devices mentioned in this section might belong in previous sections; and vice versa. This section focuses attention on devices which have generally proved necessary or of great value to running a hoist safely, although they may not be needed from an operating or equipment reliability standpoint.

Typically, these devices warn the hoistman and/or shut down the hoist when operating controls fail, when some critical piece of equipment fails, when something unusual has happened or is about to happen, or when someone has forgotten to do something—any of which can cause an accident or make one worse.

Most of these devices represent the last line of defense against major accidents, and their proper use and maintenance should claim the highest priority.

Chapter 1 briefly discusses how the organization and management of an inspection and maintenance program strongly influences how well the hoisting system is actually maintained. If nothing else, the use and maintenance of safety controls and devices should be carefully managed. Management is urged to designate specific persons to maintain and adjust all safety devices. These persons should know everything there is to know about how they work, how they are set up, and to what extent any adjustment affects the motion of the conveyances involved. For example, if feeler (thickness) gauges are used to check or adjust the end-of-travel cams on Lilly controllers, it is vital that the person doing this knows how far a conveyance travels when the Lilly cam dial moves, say, 0.003 inch.

Management is also urged to consider strong and decisive disciplinary action for people who make adjustments or modifications to safety (and operating) control devices and circuits, but who are not designated to do so.

These suggestions and the list of safety devices and their interrelations, suggested in Chapter 1, are made with the hope of eventually sorting out some very common accidents into two groups: those which can be feasibly prevented with some form of safety device or circuit, and those which cannot. Safety devices and circuits exist, in part, because people goof. It has been said with considerable justification that nothing can be made completely foolproof because each new foolproof device sooner or later just uncovers a new kind of fool. A common case in point is jumpering (i.e., short-circuiting) safety devices and circuits; this can be countered feasibly by managerial action only. On the other hand, overwinds continue to occur on hoists equipped with Lilly's, etc. This kind of accident needs analysis, case by case if necessary, to determine if it occurred because the Lilly or other controller was not set up or maintained correctly; or if some peculiar circumstance occurred for which the controller could not provide protection, and something else really needed to be modified or adjusted.

53

3.2.2 OVERTRAVEL CONTROLS

REGULATION — Overtravel protection is required on all hoists used to transport men (57.19–7 M and 75.1400).

HAZARD — A malfunction or lack of overtravel-protection devices can lead to a conveyance being hoisted into the head sheave, friction drive wheel, or headframe; or lowered against the shaft bottom, against a bulkhead, or into a sump. Hoisting into the head sheave, drive wheel, or headframe may just be the first of many problems if the hoist rope or a termination parts.

DESCRIPTION — Overtravel protection is typically provided with limit switches that shut down the hoist when actuated. The limit switches can be

- Built into Lilly, Simplex*, or similar controllers, and actuated by cams
- Attached to the dial of circular position indicators
- Attached to the beam of linear position indicators, and actuated by the moving pointer
- Mounted on or near the guides in the headframe and in the shaft, and actuated by the conveyances; these switches may be installed to provide primary overtravel protection, or to back up a primary-control device, or both.

NOTE: Multipurpose hoists may have primary overtravel protection for two conditions: One for material hoisting and one for man hoisting (plus equipment that permits changing from one to the other).

Tapered shaft guides can also be used to provide overtravel protection (see **COMMENT**).

INSPECTION/TESTING — Daily, test each travel-limiting device by slowly driving the hoist into the limit. The hoist should shut down (motor off and brakes applied) if system is operating properly. Secondary (backup) devices cannot be tested this way if the primary device works properly. To test backup devices, trip (actuate) them manually with the hoist running slowly. Again, hoist should shut down if the switches and circuits are sound.

Do this immediately after ropes are changed or shortened, or cuts have been made at either end.

INSPECTION/MAINTENANCE Look for and repair wear and looseness in

- All drive (see 3.1.2 and final Comment on 3.1.3) and internal components of Lilly, Simplex, or other controllers

*Lilly and Simplex are trade names for specific safety controllers manufactured by the Logan Actuator Company, of Chicago, Illinois. Lilly controllers are very widely used. However, there are other safety controllers available and in use, made by other companies. Home-made systems are also in use.

54

- Limit-switch actuator arms, rollers, wiring
- Devices on conveyances that trip limit switches
- All mechanisms used to shut off power to the motor and, particularly, to apply the brakes.

Keep controllers and limit switches clean, and lubricated where needed—especially backup limit switches installed in shafts. Proximity (magnetic) switches are generally more reliable and need less maintenance than lever- or whisker-actuated switches, but wear of shaft guides, for example, may permit the conveyance to shift far enough away to prevent actuation.

Remember that overtravel-protection devices driven by the hoist drums or friction-hoist drive wheels need readjustment as the rope stretches, and need checking and readjustment after ropes have been changed or cut off from either end (see 3.1.2).

COMMENT — The regulation requiring overtravel protection is not specific about how to do it, but there are many examples in the field that serve as a guide. Overtravel protection should be provided for both ends of travel for all conveyances, permanently attached or not. Furthermore, on multipurpose hoists, overtravel protection should include specific provisions for man hoisting. For example, such protection is not automatically guaranteed by limits at or beyond the dump if the top man-station is below the dump. The danger is dumping men into the dump from skip/cage combinations, or damaging the cage and occupants if the trailing or leading skips go through the dump. Since much depends upon the design of the headframe, dumps, cages, and skips, each hoisting system requires individual evaluation.

If a second set of overtravel limits is needed to specifically cover man hoisting, there are many ways to provide it easily with limit switches or with auxiliary equipment made for Models C and D Lilly controllers. Circuits can be arranged so that the man-mode overtravel limits are set up or switched in by the hoistman or by the men getting on the conveyance. In any case, there is always the danger that this man-mode protection will not be used because somone forgets to switch it in. To counter this to some extent, indicator lights can be used at the hoist to call attention to which mode of overtravel-limit protection is in force.

The placement of overtravel limits can make a difference. There are three possibilities for sequencing: the upper and lower travel limits can be set up to trip at the same time, or either one can be set up to trip first. For example, if the greater danger is lowering a conveyance too far, the limits could be set up so that the upper conveyance (or counterweight) reaches a travel limit before the lower one does. In this case, the lower travel limits would serve as a backup.

If overtravel-protection devices are drum driven, it may be necessary to consider the effects of a difference in rope stretch for a loaded versus a light conveyance. In hoisting, for the same number of drum revolutions, an empty conveyance will be higher in the shaft than a loaded conveyance. In lowering, a loaded conveyance will be lower in the shaft than an

55

3.2.2 OVERTRAVEL CONTROLS (Continued)

empty one. With overtravel limits set for loaded conveyances, there is the danger of hoisting a light conveyance too high in the headframe. Or, in lowering, a loaded conveyance could strike bottom before the overtravel limit is tripped. Whether or not rope stretch has to be considered depends upon clearances at both ends of travel, and, of course, the length of rope involved. Note that shaft-mounted limit switches are not affected by differences in rope stretch.

The most important factor affecting the placement of overtravel limits is the distance a conveyance travels in stopping after the limit is tripped. The limits must be set up to provide sufficient clearance; otherwise the conveyance will hit something. This may seem obvious, but it is not always observed in practice. If the design of the system permits, overtravel limits can be moved farther away from the ends. Otherwise, the speed at which the conveyance hits the limits must be low enough to permit the conveyance to stop in the space available. Conveyance speed near ends of travel is treated as a special case of overspeed control in Section 3.2.3.

TAPERED SHAFT GUIDES

Tapered guides are used mainly with friction hoists. The guides are constructed so that the space between them narrows and, hence, the conveyance is squeezed. (A guide that widens and tends to spread the sides of a shoe is not recommended.) As the upper conveyance wedges into the tapering guides, the hoist-rope tension increases until the ropes slip on the drive wheel; or, as the lower conveyance wedges, its ropes lose tension until, again, the ropes slip on the wheel. Rope and connector loads are minimized when the lower conveyance wedges first; thus, this is the better setup.

Tapered guides can also be applied to drum-hoist installations; but unless the conveyances are equipped with reliable safety catches (see 7.2), they should be applied only to the lower end of travel.

Tapered guides require strong support but otherwise little maintenance compared with limit switches, etc. (see 8.1).

56

3.2.3 OVERSPEED CONTROLS

REGULATION — Overspeed protection is required on all hoists used to transport men (57.19-7 M and 17.1400).

HAZARD — A malfunction or a lack of overspeed protection can lead to destruction of hoist drives and drums and many subsequent difficulties: the conveyance may approach the ends of travel too fast to permit a safe stop; injury and conveyance damage may result where guide alignment and high speed are not compatible.

DESCRIPTION — Overspeed protection is typically provided by ball-governor-actuated switches built into Lilly and Simplex controllers, with the speed limit determined by cams; or by centrifugal switches, with a fixed speed limit, mounted on or driven from the hoist motor or drum shaft.

Lilly controllers are equipped with a set of contacts that can be wired to a bell, buzzer, or light to provide a warning that the speed limit has been exceeded. If speed is not very soon reduced, the controls shut down the hoist. These controllers are also equipped with a bell tripped by a cam (adjustable) to warn of the approach to the ends-of-travel region.

(The above are by far the most common devices used domestically. Some hoists may have foreign-built overspeed devices similar in concept to a Lilly, or electrical in nature.)

NOTE: Multipurpose hoists may have overspeed protection for two conditions: One for materiel hoisting, and one for man hoisting (plus equipment that permits changing from one to the other at will).

INSPECTION/TESTING — The best test of any safety device is to actuate it as intended, and compare the results to the intended function. Thus, the best test of an overspeed-protection device would be to overspeed the hoist until the limit is reached and observe the results—i.e., the hoist should automatically shut down. This test should be done for maximum speed conditions and for ends-of-travel conditions if this protection is included.

While this test may be the best, there are qualifications to be considered. First, some hoists cannot be driven easily at speeds greater than the maximum (e.g., those with D.C. drives). But most important, overspeed controls initiate an emergency stop, and an emergency stop from speed will damage some hoists because of the way the brakes are currently set up (see 2.4.6).

Thus, the following tests are suggested:

(1) Drive the hoist into overspeed until the controller limit is reached, the alarm is sounded (if so equipped), and the device trips and shuts down the hoist. Note the speed at which the trip occurs as a check against the speed-limit setting. Do this midshaft for maximum speed and in the end-of-travel regions.

(2) (a) Or, with the hoist stationary and the brakes not in emergency, manually trip the overspeed-control device to check its ability to sound its alarm (if so equipped) and to initiate an emergency stop;

57

3.2.3 OVERSPEED CONTROLS (Continued)

(b) And, follow manufacturer's instructions for checking the speed-limit setting. This may require driving the controller with a separate source in conjunction with a hand-held tachometer.

Note the two aspects involved: A check on the speed-limit setting and a check on what the device does after the limit is reached.

INSPECTION/MAINTENANCE — Look for and repair wear and looseness in

- All drive (see 3.1.2 and final Comment on 3.1.3) and internal components of Lilly, Simplex, or other controllers
- Electrical components and wiring
- All mechanisms used to shut off power to the motor, and, particularly, to apply the brakes.

Keep devices clean, and lubricated where needed.

Periodically, say yearly, tear down, overhaul, reassemble, and test overspeed-control devices and associated brake-actuating mechanisms.

COMMENT — The regulation requiring overspeed protection is unspecific regarding how to do it. Again, good practice serves as a guide. Overspeed protection should be provided for both man- and materiel-hoisting on multipurpose hoists. If maximum speeds are different for man and materiel hoisting, protection should include specific provisions for man hoisting; and indicator lights at the hoist should be used to show which speed limit is in effect. Also, each conveyance in a clutched system should be provided with overspeed protection.

Furthermore, special overspeed protection should be provided near both ends of travel, where clearance will not permit a safe stop if the ends-of-travel limits are tripped at maximum speed (see 3.2.2). End-of-travel overspeed protection is typically provided by cams fastened to the dials of Lilly and Simplex controllers, and set to correspond with the ends-of-travel region for the conveyances. These cams are known as deceleration, retarding, slow-down, or overspeed cams. On Lilly controllers these cams are separate from those which trip the overtravel limits. On Simplex controllers one cam controls both overtravel and end-of-travel overspeed protection. The cams control the motion of one of a set of normally closed contacts. The movement of the other contract is controlled by the ball governor. (The Model C Lilly controller can be equipped with two ball governors for greater speed sensitivity over wider ranges.) As the cam follower rides up on the cam, the difference between "permissible" and actual speed decreases; and if the actual speed does not decrease, the contacts soon open and the hoist is shut down. Since the cams can be positioned and profiled as desired (they are delivered as blanks and are often home-made), end-of-travel overspeed control can be tailored for each installation. Furthermore, extra deceleration cams can be applied to many controllers to cover an area in a shaft where, for example, special work or poor shaft conditions require slower-than-usual speeds.

If a second level of general overspeed protection is needed specifically for man hoisting, it can be readily achieved with auxiliary equipment made for Models C and D Lilly controllers. If a centrifugal switch is used, another can be added*. If a Simplex controller is used, a centrifugal switch can also be added. The last two cases, of course, also require changeover switches and circuitry.

If end-of-travel overspeed protection is needed, it is easily provided by cams on Lilly and Simplex controllers as stated earlier. This protection is not easily provided if a centrifugal switch provides maximum speed protection. Another centrifugal switch could be used, switched into the circuit by a cam on a conveyance or a position indicator; but it would require the hoist to be slowed before this switch trips, otherwise the hoist would stop immediately. In essence, such a circuit is nothing more than an early end-of-travel limit. On the other hand, installation of a Simplex or Lilly controller in such cases might be the best approach in the long run.

It should be noted that overspeed devices must be backed up by other overspeed devices. Speed-reduction cams on Lilly controllers are sometimes profiled and positioned so that the hoist is shut down when the cam follower reaches the end of the cam, even though Lilly controllers have separate overtravel limit switches and cams. However, this setup does not necessarily make the regular overtravel limits a backup to the end-of-travel overspeed limits; if the latter fail, there is nothing to prevent a conveyance reaching the overtravel limit at a speed too great for a safe stop. In these cases, positioning the lower-end deceleration cams to back up the upper-end deceleration cams (or vice versa) would be a safer arrangement.

Always remember that overspeed and overtravel control devices are but parts of a larger control system. In setting up one, the other must also be considered. This larger system also includes the hoist brakes, since both overspeed and overtravel devices initiate an emergency stop. Thus, how the brakes perform in an emergency stop under the various load, speed, and conveyance-position configurations that may occur (see 2.4.6) must also always be considered when setting up overspeed and overtravel controls.

In the context of emergency braking performance, the overspeed alarm that can easily be wired to a Lilly and the approach-to-end-of-travel bell that is a part of Lilly controllers have added value. If an emergency stop is particularly rough, avoiding it when possible is good for both men and machinery. Even if emergency stops are "acceptable", they still induce loads that should be avoided if possible. Both alarms mentioned provide a means for avoiding an emergency stop in many cases by alerting the hoistman to the impending stop if he doesn't soon reduce speed.

It should be noted that the approach-to-end-of-travel bell is not directly associated with an overspeed shutdown mechanism as are the overspeed alarm contacts. It is only a bell tripped by its own cams. If, for example, there are no slowdown dams, then the bell warns the hoistman that if he doesn't slow the hoist, it will soon run into the end-of-travel limits and, as stated in 3.2.2, this doesn't necessarily assure a safe stop. Thus, no matter how the Lillys are equipped otherwise, the use and continued workability of overspeed alarms and approach-to-end-of-travel bells can contribute to safety in general and the use of these devices is strongly recommended.

*Centrifugal switches are commercially available, cover a wide variety of speed ranges, and are adjustable within each range.

3.2.4 SLACK-ROPE DETECTORS

HAZARD — The malfunction or lack of slack-rope warning or shutdown devices can lead to hoist-rope damage at best; and to serious accidents with conveyances at worst.

Drum hoists alone are prone to these hazards. Problems causing slack ropes on friction hoists tend to be self-limiting since the loss of tension accompanying slack ropes leads to rope slip on the drive wheel, and further slack does not develop; however, rope slip on the wheel leads to other problems (see 3.2.5).

DESCRIPTION — A slack-rope indicator provides a warning (bell, light, horn) or shuts down the hoist. It is typically actuated by a limit switch.

The limit switch is tripped by a wire or bar strung beneath each hoist rope, usually where the rope exits the hoist room, or closer to the drum; and/or by the motion of the conveyance safety-catch mechanism if this mechanism responds to a loss of rope tension (see 7.2.2).

INSPECTION/TESTING — Pull the wire or depress the bar and confirm that the intended warning is given and/or a slowly moving hoist is shut down.

Conveyance-mounted devices can be tested by manually actuating the detector (see 7.2.2).

INSPECTION/MAINTENANCE — Keep switches and mechanical gear clean, lubricated as needed, and mechanically and electrically sound.

COMMENT — The experience of many hoist operators indicates that slack detectors are more reliable if placed at or near the drums rather than where the rope exits the hoist room (rope slot). The latter location is thought to provide protection against slack developing on either side of the slot. However, the detecting wire or rod is often set low to keep it away from the normally bouncing rope, and in a slack condition the rope rests on the edge of the slot and bridges over the wire or bar, or doesn't depress it far enough to actuate the switch.

Although detectors closer to the drum can detect slack inside the hoist room—a not uncommon occurrence—they will probably not detect slack between the hoist room and the head sheave. Generally, it is not as easy to cover the latter region, particularly if intermediate support and fleeting sheaves are used. What is done here is left to the operator's discretion.

In general, a far greater danger is posed by slack rope piling up in the shaft (usually on top of a conveyance), particularly if two conveyances are involved, and especially if a conveyance is equipped with an unreliable safety catch or none at all. In most situations, slack rope piling up in the shaft, if not everywhere in the system, will cause a loss of rope tension at a conveyance. Thus, slack detection at the conveyance seems best in general and is possible using available equipment (see 7.2.2).

Slack-rope detectors may be useful even for slope systems where the rope normally becomes slack during regular operations; e.g., where the rope is disconnected from the conveyance or trip, where the slope is shallow, or where conveyances run out onto level areas at either end. Detectors installed close to the drums can at least prevent pile-up in the hoist room when the rope becomes slack under abnormal conditions.

61

3.2.5 ROPE-SLIP DETECTORS

HAZARD — The malfunction or lack of rope-slip detectors or protectors can lead to serious heat and wear damage to the hoist ropes and the drive wheel and, if not caught in time, to destruction of the ropes and the wheel.

Friction hoists alone are prone to this hazard.

DESCRIPTION — Rope-slip protection is provided by a number of devices, all of which sound an alarm or shut down the hoist if the rope speed is not equal to the drive-wheel speed. For example, a tachometer may be driven by a wheel running against a hoist rope or a deflection sheave; the output signal is processed and compared with the drive-wheel speed; and a difference automatically shuts down the hoist.

INSPECTION/TESTING — Disconnect the tachometer drive, or otherwise interrupt the circuit while the hoist is moving slowly. The hoist should shut down and/or an alarm be given.

3.2.6 DEAD-MAN CONTROLS

DESCRIPTION — A dead-man control uses a spring-loaded switch, either foot operated or attached to a control lever and hand operated—neither requiring much pressure to depress. The switch is wired into the control system so that the hoist is shut down if it is not held "on". Such systems are operational only when hoisting with manual controls.

COMMENT —Dead-man controls are domestically common in coal-mine hoisting, although no regulation calls for them.

Their purpose, of course, is to automatically shut down the hoist if the hoistman becomes incapacitated for any reason, the assumption being that, under such circumstance, he would let go of or take his foot off the switch.

The need for dead-man controls is debatable. On the one hand, properly adjusted and well-maintained overspeed and overtravel controls would assure an eventual safe stop should the hoistman become incapacitated. Furthermore, portal elevators and automatically controlled cage hoists are unattended and rely on the automatic overspeed and end-of-travel controls and other safety devices. On the other hand, it is argued with some justification that overspeed and overtravel controls may not always be operating properly; and even if they are, dead-man controls provide at least a feeling of added security. Any argument that dead-man controls on hoists provide essentially the same measure of protection as they do on locomotives seems invalid; locomotives are not generally equipped with overspeed and overtravel protection systems. Likewise, arguments in support of dead-man controls because other safety features are not properly provided make a better case for fixing this lack since overspeed and overtravel safety devices can provide far more comprehensive coverage of human incapacity and machinery problems. On the whole, it seems that the use of dead-man controls would better remain optional.

3.2.7 MISCELLANEOUS INTERLOCKS

DESCRIPTION/EXAMPLES — In addition to the safety controls already mentioned, there are many others using limit switches and/or circuits to provide a warning or shut down the hoist in a situation considered abnormal or undersirable. Examples of these situations are:

- Open shaft-station gates
- Loading or dumping bins protruding into shaft
- Overfilled dump and loading pockets
- Overloaded skips
- High water levels in shaft sumps
- Shaft rock falls (detected with wires that break)
- High bearing temperatures
- Dragging brake shoes
- Excessive wear of friction blocks on friction hoists
- Collar doors open during bucket dumping.

INSPECTION/TESTING — If regular operations do not provide a more-or-less continual check, manually actuate all such interlocks and note whether the intended action occurs.

INSPECTION/MAINTENANCE — Keep all mechanisms clean and lubricated where needed.

Check for burned-out warning lights, frayed wires, loose connections, and loose objects that could foul mechanisms.

COMMENT — A wide variety of such interlocks is in use. Many protect against equipment failures, while others are installed to protect against human error. This is an important but grey area: the more such interlocks, the more operating problems or accidents hopefully prevented, but the more involved the inspection and maintenance tasks. The way to determine whether such interlocks are needed is to evaluate the risks involved. Good practice reflects the tendency to minimize risks.

64

3.2.8 CONTROL CAB/CONSOLE INDICATORS

DESCRIPTION — Control cab or console indicators typically consist of gauges, lights, bells, and horns associated with operating and safety controls, or with devices that monitor equipment, shaft, or operating conditions.

HAZARD — Malfunctioning indicators can lead to accidents.

INSPECTION/TESTING/MAINTENANCE — If regular operations do not provide a more-or-less continual check of these devices, inspect, test, and maintain them according to their needs to assure that they remain functional.

COMMENT — Two widely used control indicators are hoist motor ammeters and rope or drum speed meters; their use is urged for all hoists used to transport men. These meters can indicate abnormal conditions before an actual problem develops or gets worse. Ammeters are particularly sensitive to both lower- and higher-than-usual loads on the hoist motors, and these conditions imply a variety of abnormal situations (e.g., a stuck or disconnected conveyance, or a broken rope). To be of value, ammeters and speed meters must be of sufficient sensitivity and size so that minor changes can be detected and seen; thus, the bigger is usually the better.

The value of brake-system hydraulic or pneumatic pressure gauges visible to the hoistman has already been stated (see 2.4.5).

Indicator lights are common; good practice calls for sensible grouping, clear labeling, and fail-safe use as much as possible. Indicator lights relative to one condition or function should be grouped together; and the more important the function, the closer or more visible the group should be to the hoistman. Labeling avoids confusion and speeds training. Fail-safe use of lights requires that a light be on when conditions are safe or acceptable; thus, no light showing means either an unacceptable condition or a burned-out bulb. If indicators are within reach of the hoistman, bulbs can easily be checked by using the type of lamp that permits bulb testing by pushing the bulb cover. If indicators are mounted well away from the hoistman, two bulbs wired in parallel will indicate whether "no light showing" means an unacceptable condition or a burned-out bulb (unless, of course, both bulbs burn out). Different colors can be effective because a change is more apparent than if all lamps are the same color—green or blue for OK, and red for not-OK is fairly standard.

Closed-circuit television systems are sometimes used to provide the hoistman with a view of such often-problematic areas as dumping and loading pockets. Operators are urged to at least consider using these TV systems in problematic areas; one good picture may be worth more than a dozen limit switches; at least it provides a good backup to them.

Metal and nonmetallic mining regulations require posting a sign, "Men Working in Shaft", at the hoist and at all hoist controls, and informing the hoistman of the situation when such work is under way (57.19-107/108 M). This regulation should apply to coal-mine hoisting as well. Prelettered signs or chalkboards are commonly used to implement this regulation in the hoist room. There is value to extending either approach to any occasional and potential-

3.2.8 CONTROL CAB/CONSOLE INDICATORS (Continued)

ly dangerous hoisting operations; e.g., when handling underslung loads or heavy equipment that require slower-than-usual operating speeds. Special notices for special jobs are common in industry, and the usual procedure followed, as well as the safest, is that the man responsible for the job is also responsible for posting and removing the notices.

Chapter 4
Sheaves and Rollers; Drum and Wheel Faces

Chapter 4.
Sheaves and Rollers; Drum and Wheel Faces

67

4.1 HEAD, TURNING, AND DEFLECTION SHEAVES: DRUM HOISTS

4.1.1 INTRODUCTION

Sheaves and rollers are one of the major sources of damage to hoisting ropes.

Distinctions among sheaves are often made on the basis of the angle of rope departure (the amount of turn) and its effect on selecting sheave size. There are also other ways to distinguish among sheaves, and a perhaps simpler way that includes all others is the following: (1) Increasing-load sheaves—sheaves on which the rope-induced load tends to increase with an increase in the rope tension; and (2) decreasing-load sheaves—those on which the rope-induced load tends to decrease with an increase in the rope tension.

The first group includes head sheaves and, in general, turning and deflection sheaves. The second group includes idler sheaves (fixed or fleeting) and slope rollers.

The first type can be a source of fatigue, wear, and distortion damage to the rope; and the second, mainly wear. The first type requires particular concern for groove shape and, in general, as large a tread diameter as feasible. Typically, space restrictions limit the diameter of turning and deflection sheaves (e.g., knuckle and curve sheaves on slopes) but the general rule is that fewer and larger sheaves are better than many small ones. The second type requires a greater concern for freedom of action—rotation, fleeting—than for groove shape and tread diameter.

Sheaves and rollers are treated in this chapter according to the distinction presented above. Much of what is presented is design information. However, this information is useful in a replacement maintenance sense if improvements in rope life can be obtained. The major emphasis is not on extending rope life, but on man safety; ropes with short service lives, due mainly to system-design deficiencies, have a greater potential for undetected imminent failure than ropes with long service lives.

68

4.1.2 DIAMETER

REGULATION — Recommended and minimum diameters for head sheaves (and drums) for each rope construction are given in terms of multiples of rope diameter (57.19-39, also Table 36, ANSI M11.1—1960).

HAZARD — All else being equal, the smaller the tread diameter, the shorter the rope life because of fatigue (broken wires).

DESCRIPTION — The tread diameter—that measured to the bottom of the rope groove—is the diameter of interest. Sheaves are often listed in catalogues or discussed with reference to the diameter over the flanges; this can be misleading. Sheave and drum diameters are commonly expressed as a multiple of the rope diameter (the ratio of sheave or drum diameter to rope diameter), and use of the flange instead of the tread diameter can make a significant difference, especially for smaller sheaves.

For head sheaves and drums, good practice calls for a diameter ratio of about 80 as a minimum for stranded ropes and about 100 for semi- or full-locked coil constructions.

Turning or deflection (knuckle, curve) sheaves can rarely be this large but, as a rule, use the largest, lightest wheel possible.

MAINTENANCE — Although sheave diameters are often limited by the design of the installation, there may be opportunities to replace an older sheave, when worn out, with a larger one. It may even be economically worthwhile in the long run to make modifications that permit a larger sheave to be used.

COMMENT — The recommended and minimum diameter ratios suggested for head sheaves and drums in the Federal mining regulations (57.19-39) and domestic standards (ANSI M11.1—1960) are smaller than the values presented above. Much experience shows that as the diameter ratio reaches about 80, fatigue damage approaches a minimum. There is some indication that fatigue is minimized, insofar as bending over sheaves is concerned, at a diameter ratio of about 120. Ratios of 80 or more are often found in the United States and are usually used on new hoists. Ratios in the range 100 to 120 are common in many other countries, particularly on friction hoists.

In general, there is no way to quantify how much additional life results from a ratio of 80 versus a ratio of 60, for example. Too many other factors also affect rope life. It all depends upon the particular hoist installation.

The larger the sheave diameter the greater the inertia and, hence, the greater the potential for slip between rope and sheave in starting and stopping. In normal practice slip rarely occurs, except maybe during an emergency stop, or when a permanent hoist is used during shaft sinking and a light bucket is quickly braked. However, the potential for slip should always be noted when considering a larger sheave; the lighter the rim the better, consistent with adequate strength.

If cost considerations cannot support as large a drum diameter as might be desirable, there is still value in striving for large sheaves, even if their diameters significantly exceed that of the drums. Rope fatigue life can be expressed in terms of bending cycles—on and off a sheave (or drum) is one cycle. In one complete hoisting cycle—through the shaft in both directions—parts of the rope go on and off the drum once, and on and off the sheave twice. Thus, head sheaves can contribute as much as 2/3 of the bending-fatigue damage, and increasing their size alone may be of significant value.

70

4.1.3 ALIGNMENT

4.1.3.1 FLEET ANGLE AND HEAD SHEAVES

REGULATION — "Fleet angles should not exceed 1-1/2 degrees" (57.19-37); a minimum of 1/2 degree is also suggested (ANSI M11.1—1960).

HAZARD — The larger the fleet angle the greater the probability of poor drum winding, and the greater the wear of the rope from rubbing against adjacent drum wraps and the flanges of the head sheave—both poor winding and rubbing reduce rope and sheave life.

DESCRIPTION

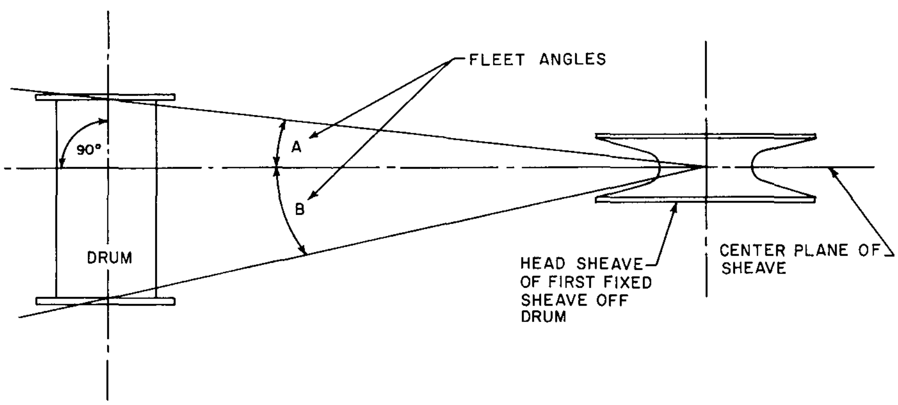


Figure 4.1 Definition of Fleet Angle

INSPECTION/MAINTENANCE — Periodically check the alignment of the head sheave (or first fixed sheave) with the drum. Proper alignment requires that the sheave and drum shafts be parallel *and* that the sheave be placed along its axis so that the fleet angles A and B are maintained as designed.

Sometimes misalignment can be detected and proper alignment checked by watching the fleeting motion of the rope while looking toward the head sheave from the drum, or toward the drum from behind the head sheave. Some operators use a transit for both checking and realigning head sheaves.

COMMENT — Fleet angle is fixed by the design of the installation and can rarely be reduced if too large, except by using a deflection sheave to lengthen the amount of rope between the head sheave and the drum. In such cases the deflection sheave must be free to fleet (move axially) with little side load on the rope.

To further minimize rope wear on drums wound single layer, or partially onto the second layer, some operators align the head sheaves so that the center plane of the sheave tends to split the live wraps, rather than the entire drum width, for example. This is fine tuning, but it is reportedly worth the effort, particularly in high-speed hoisting.

4.1.3.2 TURNING AND DEFLECTION SHEAVES

HAZARD — Poor alignment causes rope and sheave-flange wear which can lead to failure of both.

INSPECTION/MAINTENANCE — Maintain or provide proper alignment.

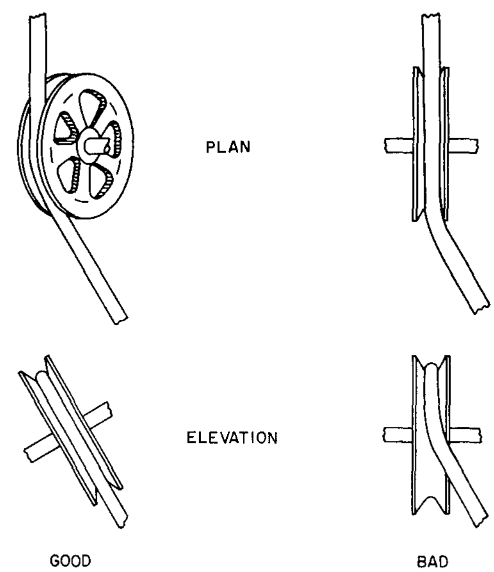


Figure 4.2. Example of Good and Bad Deflection-Sheave Alignment

Poor alignment shows as one flange shinier or more worn than the other.

Providing proper sheave alignment requires no fancy equipment; a good eye, a handful of shims or blocks, and maybe a torch or drill to make new mounting holes are usually enough.

COMMENT — Providing good alignment of turning and deflecting sheaves is one of the more commonly neglected tasks.

Again, increased rope life is not the major concern; badly worn sheave flanges can fail at any time, and the resulting impact could snap the rope, since it is usually badly worn also.

72

4.1.4 GROOVE SHAPE

REGULATION — A general regulation calls for the proper use and maintenance of grooves (57.19-40).

HAZARD — Undersized, oversized, or improperly shaped sheave grooves wear and distort the rope; distortion—pinching or flattening—causes fatigue and abrasion, and, eventually, broken wires.

DESCRIPTION — Figure 4.3 illustrates the recommended groove shape in a cast (and machined) sheave rim. The recommended groove diameters and diameter tolerances are given in Table 4.1.

Table 4.1 Recommended Groove Diameter and Tolerances

Nominal Rope Diameter, inches	Groove Diameter, inch, Nominal Rope Diameter Plus	Groove Diameter Tolerances,* inch	
		Oversize	Undersize
1/2 - 3/4	1/32	+ 1/32	- 1/64
13/16 - 1-1/8	3/64	+ 3/64	- 3/128
1-3/16 -1-1/2	1/16	+ 1/16	- 1/32
1-9/16 - 2-1/4	3/32	+ 3/32	- 3/64
2-1/4 -3	1/8	+ 1/8	- 1/16
Over 3	5/32	+ 5/32	- 5/64

*Example: for a nominally 1-1/4-in.-diam rope, the recommended groove diameter is 1-5/16 in., + 1/16, - 1/32.

Sheaves are also fabricated, and the rim may resemble the section shown in Figure 4.4. The groove shape and diameters for cast rims apply also to fabricated sheaves. When new, the throat or included angle of a fabricated sheave may not be easy to see; but it exists and becomes more apparent with successive regrooving. The edges of the groove must be rounded to prevent rope wear and wire damage.

73

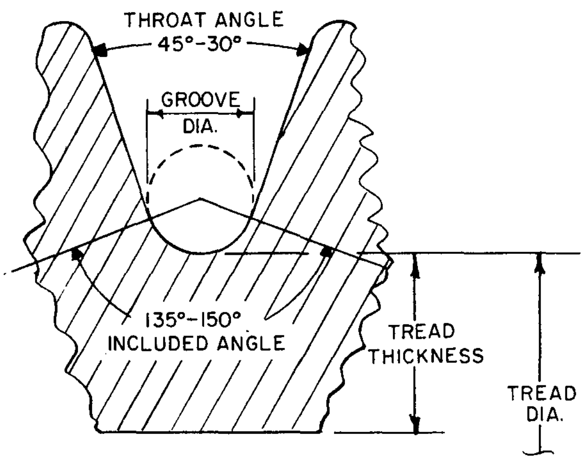


Figure 4.3. Recommended Groove Shape—Cast Rim

See Table 4.1 for recommended groove diameter and tolerances.

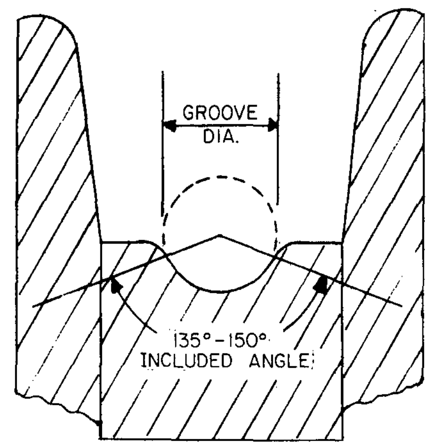


Figure 4.4 Example of a Fabricated Sheave Rim

(Not to scale)

As a sheave groove wears, the rope seats farther into the rim; since the rope wears also, this produces a smaller groove diameter and a smaller effective throat angle. The groove bottom may also corrugate in a pattern like that of the wires in the rope (see 4.1.5), and this corrugation further wears the rope. A new rope run in a worn sheave groove can be rapidly degraded from pinching, corrugations, and sharp groove edges.

INSPECTION/TESTING/MAINTENANCE — Periodically check sheave groove diameters with groove gauges.

Groove gauges come in sets like feeler (thickness) gauges and are usually available from wire-rope suppliers. They are normally made to the recommended minimum diameters of Table 4.1, although this may not be directly stated. Since some older gauge sets may have gauges for both minimum and maximum diameters, and since it is important to know which is which, the following example may be useful. Suppose a gauge is marked "1-1/8 Dia. + 3/128". According to Table 4.1, the groove diameter for a rope nominally 1-1/8 inch in diameter is 1-1/8 + 3/64. Furthermore, the maximum recommended diameter for this rope size is 1-1/8 inch + 3/64 + 3/64, or 1-1/8 + 3/32. The minimum, likewise, is 1-1/8 + 3/64 - 3/128, or 1-1/8 + 3/128. Thus, in this example, the gauge is a minimum-diameter gauge.

4.1.4 GROOVE SHAPE (Continued)

To use the gauges to check for an undersized groove:

(1) Determine the nominal rope diameter being used.

(2) Find the gauge marked with this nominal rope diameter and determine that it is for the minimum recommended diameter.

(3) Place the gauge in the groove, at right angles to the flanges and the tread bottom.

(4) If the groove is undersized, there will be a gap between the bottom of the groove and the gauge, and the gap will be the greatest in the center, as shown in Figure 4.5a.

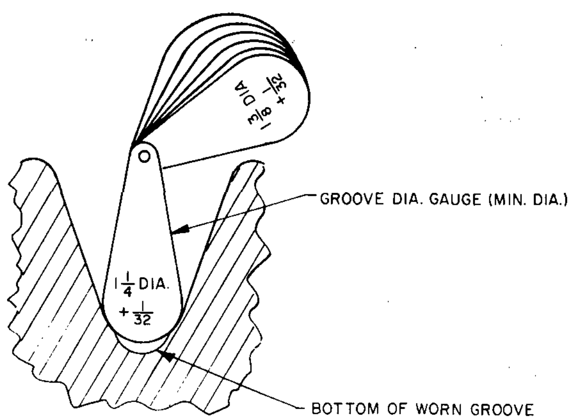


Figure 4.5a. An Undersized Groove Indicated by a Groove-Diameter Gauge

(5) If the groove has not yet worn to the minimum diameter, the gauge will not fit snugly and it will be possible to rock it back and forth somewhat; in this case there will also be a gap between the gauge and the groove, but the farther from the bottom center of the gauge, the greater the gap, as illustrated in Figure 4.5b.

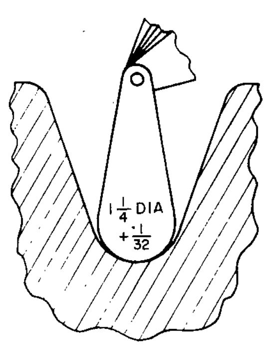


Figure 4.5b. An Oversized Groove Indicated by a Groove-Diameter Gauge

Maintain groove diameter within the recommended tolerances. Always regroove a worn groove to tolerance before installing a new rope.

> Sheaves can often be regrooved in place with grinding or turning attachments mounted at the sheave. If the hoist rope is to be used to drive the sheave while regrooving, use the old rope.
>
> Note that when regrooving, throat sides will usually have to be dressed up as well. Make a simple template for the minimum throat angle (30°) to guide this work if necessary. If the throat angle becomes too small, the rope will chafe (and wear) on the flange, particularly if large fleet angles exist, or, with modest fleet angles, if the sheave diameter is very large.

Grind away corrugations developing in the groove as they appear: be careful not to change the shape or diameter of the groove beyond the recommended tolerances.

Keep the edges of wearing grooves and the edges of grooves in fabricated sheaves smooth or rounded.

4.1.5 LINERS

DESCRIPTION/LOCATION — Liners are replaceable tread segments. They are usually of harder material than the rest of the sheave; their purpose is to minimize sheave wear.

Metallic liners are bolted in place, usually with radial bolts in the centerplane of the sheave.

INSPECTION/TESTING/MAINTENANCE — Maintain groove diameters and throat angles as discussed in Section 4.1.4. Hard liners will, of course, reduce the frequency of this maintenance.

Keep liner-retaining bolts tight no matter how they are installed. Especially watch for and repair radial rim bolts that show signs of rotating after being cut by the rope (or by regrooving). Good design can prevent this turning, but watch anyhow; rotating bolts can severely damage a rope.

COMMENT — There is controversy over hard versus soft sheave tread or liner materials. While hard materials undoubtedly cut down on sheave wear, they must take their toll in rope wear and peening—the softer material yields to the harder. Soft metals wear and corrugate; and corrugations, in turn, can damage the rope. However, elastomeric liners—polyurethane, for example,—appear to promise much. Though soft, they yield elastically rather than permanently. Thus, there are no hard-edged corrugations to damage the rope and, in turn, be worn away by the rope. Furthermore, although the elastomeric material will slowly wear, the abraded particles are also soft and cannot damage the rope. Elastomeric liners are used extensively in aerial tramways and substantially reduce sheave wear and maintenance while also reducing rope wear and peening. Polyurethane is used successfully on friction-hoist drive wheels; while its friction characteristics are the primary reason for use here, reduced rope wear is nevertheless a side benefit. Domestic use of elastomeric liners on conventional head sheaves is minor and recent; while it is too early to judge the effects on rope life, rope wear appears less, and sheave maintenance has definitely been reduced. (Elastomeric liners are probably best wedged in and retained by an undercut taper machined into the rim.)

4.1.6 STRUCTURAL

HAZARD — Structural failures of sheaves can result from improper maintenance.

INSPECTION/MAINTENANCE — Look for and repair broken and loose bolts meant to hold liners in place, segmented sheaves together, and bearings to supports.

Look for and repair cracks in castings and weldments.

Check sheaves for balance after structural modifications and repairs, and tack on compensating weights if needed. Unbalanced sheaves can be self-destructive.

Keep bearings lubricated as required.

Replace sheaves with excessively worn flanges or thin rims; thin rims have collapsed with disastrous results. Consult the manufacturer about the recommended minimum rim thickness if not known.

78

4.2 DRUM FACES

4.2.1 GROOVE PATTERNS AND SPOOLING AIDS*

Drums are another major source of damage to hoisting ropes.

The major factors which affect rope life are drum diameter, number of rope layers, grooving (or lack thereof), and the uniformity of winding. These factors are not ordered according to influence; their influence can vary from one installation to another. In general, the larger the drum diameter, the fewer the number of layers; and the smoother the winding, the longer the rope life. Proper grooving also extends rope life.

The drum diameter and the number of rope layers are fixed by design and are rarely alterable. (Reuse of a hoist elsewhere in a shallower shaft would permit a reduction of the number of rope layers.) Drum diameters should be as large as possible; the suggested minimum diameter ratios of 80 for stranded ropes and 100 for locked-coil constructions apply to drums as well as to increasing-load sheaves.

Grooving and evenness of winding may, however, be modified to advantage on hoists with cylindrical drums. Plates with grooves can be attached to an ungrooved drum and even to a grooved drum.

Four types of grooving are in use:

HELICAL

A spiral groove like a screw thread

PARALLEL

A series of circular grooves, each completely parallel to the flanges; grooves are (or should be) shallow so that the rope is not damaged where it crosses the ridge between grooves.

LE BUS GROOVING**

(Sometimes called counterbalanced grooving.) A combination of helical and parallel grooving: grooves are mostly parallel to flanges, but halfway around the drum the groove moves over a distance equal to 1/2 the pitch (distance between rope centerlines), and then travels parallel to the flange for another 180 degrees, where it again moves over another 1/2 pitch; and so forth across the drum face.

*This topic applies to cylindrical drums only. Drums with conical sections are, by nature, always helically grooved and wound single-layer—the best combination for winding with a minimum of rope wear and damage.

**Developed and patented by LeBus International Engineers, Inc., Longview, Texas.

79

ANTISYNCHRONOUS

A variation of the LeBus grooving pattern; the 1/2 pitch moves occur at about 0 and 60 degrees rather than at 0 and 180 degrees. The stated purpose is to avoid even rhythmic impulses to the rope which can induce wild oscillations between the drum and the head sheave (or the first fixed sheave).

The term "parallel" is commonly misapplied to LeBus and antisynchronous groove patterns; there are meaningful differences.

Grooving alone does not assure even winding. The following spooling aids are also of value:

FILLER

A metallic bar which fills the space between the first wrap and the flange and prevents the last wrap of the second layer from wedging between the flange and first layer. The bar is as thick as the nominal rope diameter and tapered horizontally to conform to the winding pitch; it should be as long as needed to fill the gap. (The wide end abuts the start of the first wrap.)

STARTER

A bar like the above used on ungrooved drums; the length and taper are selected to determine the winding pitch.

RISER

A bar placed against the flange at the end of the first layer to raise the rope to the second layer and support it until it crosses over and starts back on the second layer. The rope is raised to the second layer on a vertically tapered section that is about 20 rope diameters long. The bar is also tapered horizontally to conform to the winding pitch.

FALSE FLANGE

A full-ring plate or a series of plate segments attached to the inside of a flange. In effect these plates or segments narrow the width of the drum face, but their purpose is to boost the rope into the first crossover on a new layer or to assist in a change of layer when a riser cannot be used. Segments are sometimes called kick plates or control bars.

The following combinations are most effective:

SINGLE-LAYER WINDING

- Helical grooving is best.
- If used, a plain-faced or parallel-grooved drum should have a starter strip.

4.2.1 GROOVE PATTERNS AND SPOOLING AIDS (Continued)

TWO-LAYER WINDING

- Helical grooving with a riser, or
- LeBus or antisynchronous grooving with a riser. The horizontal shapes of these strips will have to conform to the groove pattern; they will not be uniformly tapered.
- Parallel grooving is not as good as the above but, if in use, a riser should be installed. But the riser will have to be relocated as the rope wears, unless the ridges between grooves are ground away to guide the rope in crossing over at the same place regardless of wear.

THREE-LAYER WINDING

- LeBus or antisynchronous grooving with riser and filler strips are best.
- If helical grooving is used, riser and filler strips are needed. The riser strip should be designed and installed so that the top end of the vertically tapered section (the riser portion) lines up with the start of the first wrap at the other flanges; this may require a false flange as shown in Figure 4.6. Kick plates may be needed on the other flange to assist the change from the second to the third layer; these plates should be chamfered and smooth on all edges!

MORE-THAN-THREE-LAYER WINDING (if necessary)

- LeBus and antisynchronous grooving with riser and filler strips.
- Parallel grooving, particularly with ridges ground away to control crossovers, and riser and filler strips; usable, but not as good.
- Helical grooving is not recommended; but if used, kick plates can be of use in smoothing the transition from the third to the fourth layer.

If all is well, the following patterns can be observed:

HELICAL GROOVES

- Smooth first layer.
- Two slightly raised crossovers per wrap on the second layer.
- Essentially even helical pattern on the third layer with a raised area per wrap above the second-layer crossovers, but somewhat uneven at the change-of-layer areas at the flanges.

PARALLEL GROOVES

- One raised crossover per wrap on the first layer.

- One raised crossover per wrap on the second layer, usually above the first-layer crossover.
- Third layer the same, but the raised areas are more pronounced.
- Fairly smooth at the flanges. (Raised areas are not as pronounced if groove separators have been ground away to provide specific crossover points.)

LE BUS AND ANTISYNCHRONOUS GROOVES

- Two crossovers per wrap on the first layer.
- The same on successive layers but with raised areas at the crossovers on these wraps.
- Fairly smooth at the flanges.

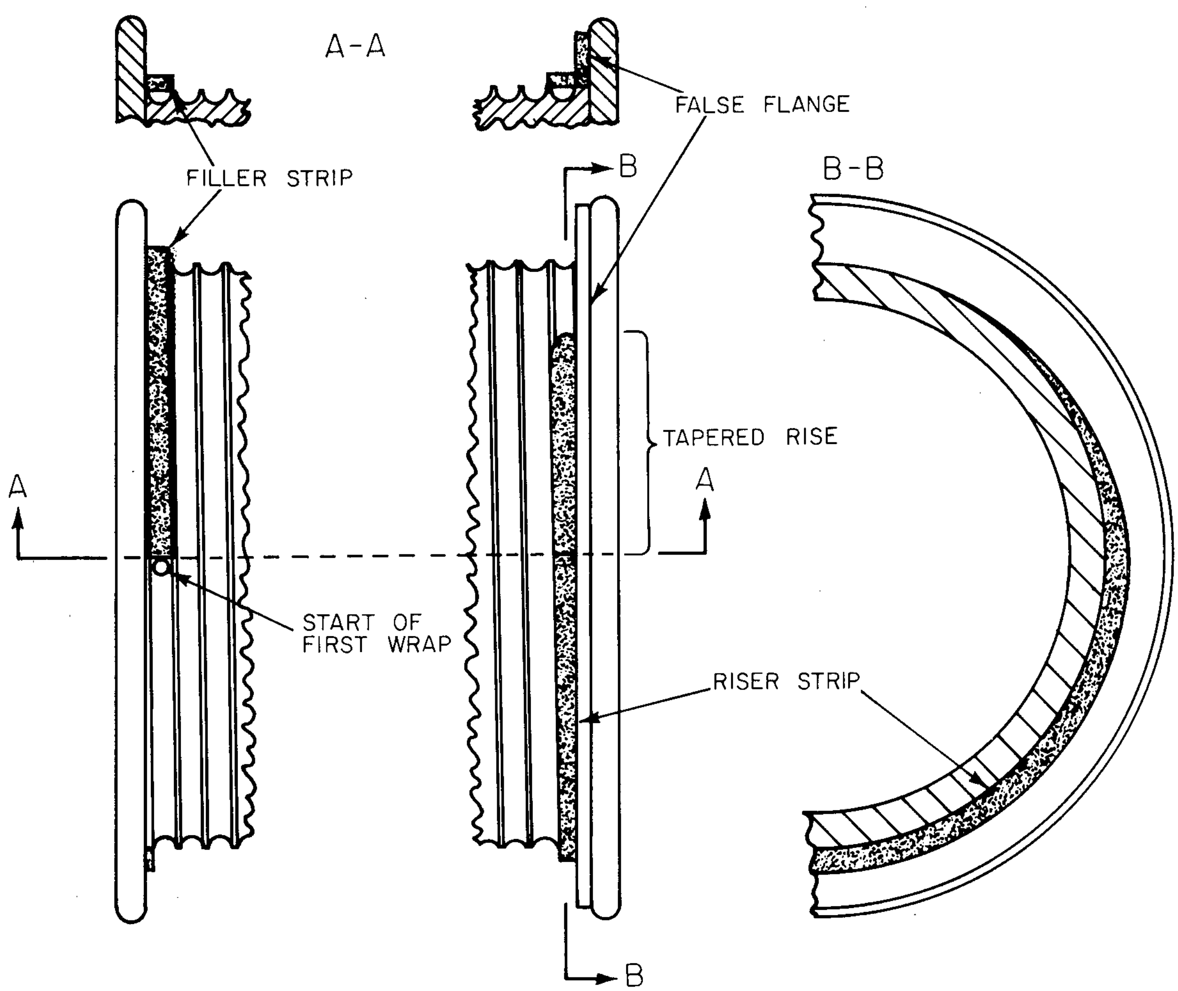


Figure 4.6. Use of a False Flange With a Riser Strip

4.2.2 GROOVE SHAPE

HAZARD — Undersized, oversized, or improperly shaped or spaced grooves wear and distort the rope.

DESCRIPTION — Groove diameters, groove tolerances, and throat angles should conform to the values recommended for sheaves (see 4.1.4).

Groove pitch (groove center-to-center spacing) is also important. Minimum recommended values are given in Table 4.2.

TABLE 4.2 RECOMMENDED GROOVE-PITCH DIMENSIONS

Nominal Rope Diameter, inches	Pitch, inches	Tolerance, inch
1/2	17/32	1/32
9/16	19/32	1/32
5/8	21/32	1/32
3/4	25/32	1/32
7/8	59/64	3/64
1	1-3/64	3/64
1-1/8	1-11/64	3/64
1-1/4	1-5/16	1/16
1-3/8	1-7/16	1/16
1-1/2	1-9/16	1/16
1-5/8	1-23/32	3/32
1-3/4	1-27/32	3/32
1-7/8	1-31/32	3/32
2	2-3/32	3/32
2-1/8	2-7/32	3/32
2-1/4	2-11/32	3/32

The recommended values are primarily useful as a guide for drum design. They are included here for use in inspecting and confirming that ropes and grooves are correctly matched.

INSPECTION/TESTING/MAINTENANCE — Check and maintain groove shape and diameter as for sheaves (see 4.1.4).

Corrugations in grooves should be smoothed with a grinding wheel whenever found. Removing the high spots is usually enough; in grinding the entire corrugation away, be careful not to modify the shape and diameter of the grooves.

83

4.2.3 FLANGE HEIGHT

REGULATION — "Flanges or drums should extend radially a minimum of two rope diameters and not less then 4 inches beyond the last wrap" (57.19–11).

HAZARD — A hoist rope could fall off a drum in the case of a misspool coupled with insufficient flange height. The fall would produce a shock load that could break the rope or the conveyance-end termination, or at least badly bend and damage the rope.

INSPECTION — Measure the distance between the outer edge of the flange and the top of the outermost rope wrap with the conveyance at its uppermost station. This distance should be at least 4 inches.

COMMENT — Although primarily a design criterion, the regulation should also guide the reuse of a hoist in an application that requires more rope layers than originally considered during design. In general, the greater the number of rope layers, the greater the probability for uneven spooling (and hence, a misspooling). In a misspool, the rope could pile up at and near the flange and over the top if there is insufficient flange height. This potential is increased where fleet angles are small.

4.2.4 STRUCTURAL

HAZARD — Structural failures in and about drum faces can damage ropes as well as initiate more comprehensive damage.

INSPECTION/TESTING/MAINTENANCE — Look for and repair loose or broken bolts meant to hold groove plates to drum faces and anything to the flanges.

Look for and repair cracks in flanges.

Look for and repair loose riser, filler, and starter strips and flange plates.

Keep drum faces free of accumulated dirt and rope lubricant to ease structural (and rope) inspection.

4.3 FRICTION-HOIST DRIVE WHEELS

HAZARD — Unequal groove diameters on drive wheels can quickly lead to rope damage; structural problems can lead to accidents.

DESCRIPTION — Hoist ropes are supported on the drive wheels by nonmetallic tread blocks, lately of polyurethane, but other elastomerics or wood may be encountered on older installations. Tread blocks are held in place by keeper blocks bolted through the wheel faces, or wedged in place and held by some form of undercut edge or taper.

New tread blocks are thick enough to permit regrooving. Some blocks provide automatic wear monitoring; imbedded wires give an alarm or stop the hoist when broken by wear.

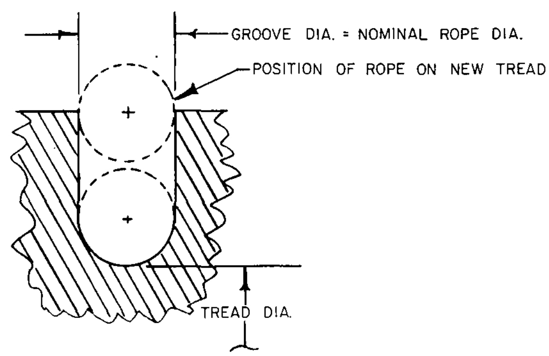


Figure 4.7. Recommended Groove Shape—Friction-Hoist Drive Wheels

INSPECTION/TESTING/MAINTENANCE — Keep wheel surfaces, and especially tread surfaces, clean and dry; otherwise the coefficient of friction may be reduced and the rope may slip.

Look for and repair looseness in tread blocks, retainers, and associated fasteners.

Look for and repair cracks in flanges and block-retaining structures. Nondestructive inspection techniques may be of value (see 2.6).

Maintain groove-tread diameter (or radius) in accord with the procedures described in Appendix A.

COMMENT — Minor variations among rope length and groove-tread diameters (less than 0.010 inch) on multiple friction hoists can cause constructional upsets in both stranded and locked-coil ropes. The upsets usually take the form of waviness (long, corkscrew-like distortions) in the rope; the outer wires of locked-coil ropes can loosen significantly. These upsets usually appear in the rope just below the drive wheel or deflection sheave when the associated conveyance is at the uppermost station. Constructional upsets can significantly weaken a rope and are to be avoided.

The groove-tread diameter and rope-length maintenance procedures described in Appendix A are the only procedures currently proved capable of solving this problem. Developed in Canada, these procedures are becoming standard practice throughout the world.

4.4 IDLER SHEAVES AND ROLLERS

HAZARD — Rope is easily damaged by poor use and maintenance of idler sheaves and rollers.

DESCRIPTION — Idler sheaves are typically used to support the hoist rope between the hoist and the head frame; they should be fleeting if the fleet angle is determined by the head sheave. Idler sheaves can also be used in this region specifically to damp or eliminate wild oscillations in the hoist rope. The hoist rope is like a guitar string, and the impulses from drum crossovers can induce vibration, particularly if the hoisting speed and crossover spacing is such that the impulses occur near or at the natural frequency of the rope. So used, the sheave(s) should be located at some odd fractional position (not at multiples of 1/4 the distance) to break up the oscillations. They alone may not eliminate oscillations; sometimes the only way is to reduce (or increase) the speed of hoisting. The oscillations induce fatigue damage; but since the rope is moving through the region of oscillations, fatigue damage is spread through the rope and, hence, it is not as severe as it would be for oscillations occurring between the head sheave and the conveyance. However, if the oscillations are very severe, the rope may jump off the head sheave.

Idlers should be light and their diameter ratios no less than 30, and preferably 45 minimum.

Idler sheaves are good candidates for elastomeric liners.

Rollers are typically used to support hoist ropes on slopes. Rollers should be spaced close enough to prevent the hoist rope from dragging on track, on any structural members, or on the ground. To minimize rope vibrations on long slopes or with high-speed operation, rollers should be placed at irregular intervals.

Roller diameter ratios should be no less than 9. Rollers must be wide enough to accommodate horizontal rope oscillations and changes in the horizontal alignment of the slope (slight curves) so that the rope does not excessively scrub against the roller flanges. Cylindrical surfaces are acceptable, but concave surfaces may guide the rope better. Good practice calls for elastomeric liners or coatings for rollers; such surfaces significantly reduce rope wear.

An increase in the pitch of the slope will increase the rope-induced load on the rollers as the rope tension increases. As stated in the beginning of this chapter, this case ideally calls for a few sheaves with diameters as large as possible, rather than many with small diameters. The same applies to a decrease in the pitch of the slope that requires deflector sheaves on the hanging wall. Space limitations may not allow a few large-diameter sheaves to be used, but do what is possible in order to use as few rollers with as large diameters as possible.

Rollers mounted on frames, which in turn bolt or screw to cross ties or other supports, may speed replacement operations. Sealed bearings are also valuable maintenance-time savers.

INSPECTION/TESTING/MAINTENANCE — Check and maintain good alignment on fixed and fleeting idler sheaves (see 4.1.3).

Idler sheaves need proper groove diameters and shapes like the more heavily loaded sheaves. Thus, maintain grooves as if they were head sheaves (see 4.1.4); however, note that wear should be less.

Keep sheave bearings clean and well lubricated, especially bearings on fleeting sheaves.

Keep slope rollers clean and lubricated as needed so that they always rotate easily. This is difficult to do in many environments, but it is just these environments that most degrade ropes.

Replace rollers, especially steel-surfaced rollers, that are significantly grooved. Excessive grooving usually occurs because rollers aren't free to rotate.

Chapter 5
Hoist Ropes

Chapter 5
Hoist Ropes

89

5.1 INTRODUCTION

The previous chapter deals with the major interfaces between the rope and rotating hoist components, and Chapter 7 deals with the final major component interface with the hoist rope, the conveyance. This chapter focuses on hoist-rope terminations and fittings, and on the rope itself.

This chapter is neither the last word nor an in-depth treatment of hoist rope; it does not, nor could it, provide answers for everyone; it deals with topics generally useful to all. Thousands of pages have been written about hoist ropes, and one salient feature emerges that is rarely given due regard: the great many variables that contribute to the behavior of hoist ropes. Beyond the variations in rope construction details and techniques, these variables include the design details of all the hoisting-system components which interface with the rope, how the hoist is run, the environment, and the rope-maintenance procedures. No systematic study of the effects of all these variables appears to have been made; nor does it seem possible to exactly evaluate all the factors bearing on rope performance in service. Perhaps this is why people sometimes derive contradictory conclusions relative to hoist-rope performance. However, such conclusions may be contradictory only when taken as generally applicable; the results may be entirely valid for the hoisting system from which they were derived. But the other side of the pendulum's swing is equally confounding, namely, using the uniqueness of each hoisting system as an excuse for not giving serious attention to what someone else has found useful. Rope performance in service could benefit from a critical eye as well as an open mind toward what the literature and lore of hoist ropes offers.

5.2 TERMINATIONS—DRUM HOISTS

5.2.1 TERMINATIONS AT CONVEYANCES/COUNTERWEIGHTS

REGULATIONS—One regulation prohibits open hooks (57.19-75 M); others set forth mandatory requirements regarding procedures for use of poured sockets, thimble-and-clip, and "other" terminations [57.19-24 (a-d) M].

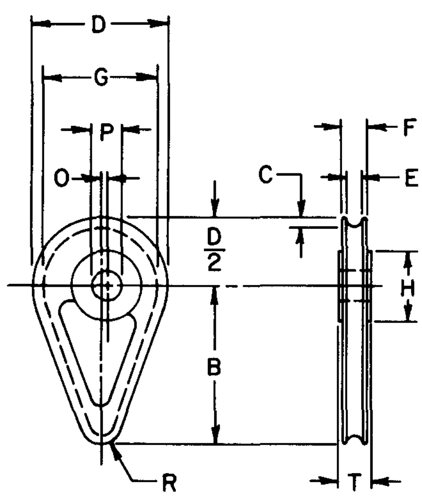
HAZARD—Terminations and rope may fail mechanically or corrosively.

DESCRIPTION—Three basic types of conveyance-end (or counterweight-end) rope terminations are available and in use:

(a) Thimbles and clips
(b) Wedge types
(c) Sockets.

THIMBLES AND CLIPS

Figure 5.1 shows the ANSI M11.1-1960 recommendations for the design details for mine hoist thimbles.



P = 2.0 X DIA*
G = 8.0 X DIA
D = 9.5 X DIA
B = 11.0 X DIA
O = 0.5 X DIA
R = 1.25 X DIA
E = 1.06 X DIA
F = 1.75 X DIA
C = 0.75 X DIA
T = 2.0 X DIA
H = 4.5 X DIA

*DIA REFERS TO NOMINAL DIAMETER OF WIRE ROPE WITH WHICH THE THIMBLE WILL BE USED.

Figure 5.1 Design Recommendations for Mine-Hoist Thimbles (Dimensions vary among manufacturers)

Thimbles are either cast or fabricated. The groove contour should be circular; the width or diameter of this circle, dimension E in Figure 5.1, is consistent with the groove-diameter recommendations for increasing-load sheaves (see 4.1.4). Note that the centerline of the pinhole should be in line with the centerline of the live side of the rope.

Crosby clips* and similar type clips, Figure 5.2(a), are the most commonly used; Fist Grip clips*, Figure 5.2(b), and clamps, Figure 5.2(c), are also used. Forged clips and clamps galvanized or chrome-plated are best.

Thimbles with a built-in clamp are also sometimes used.

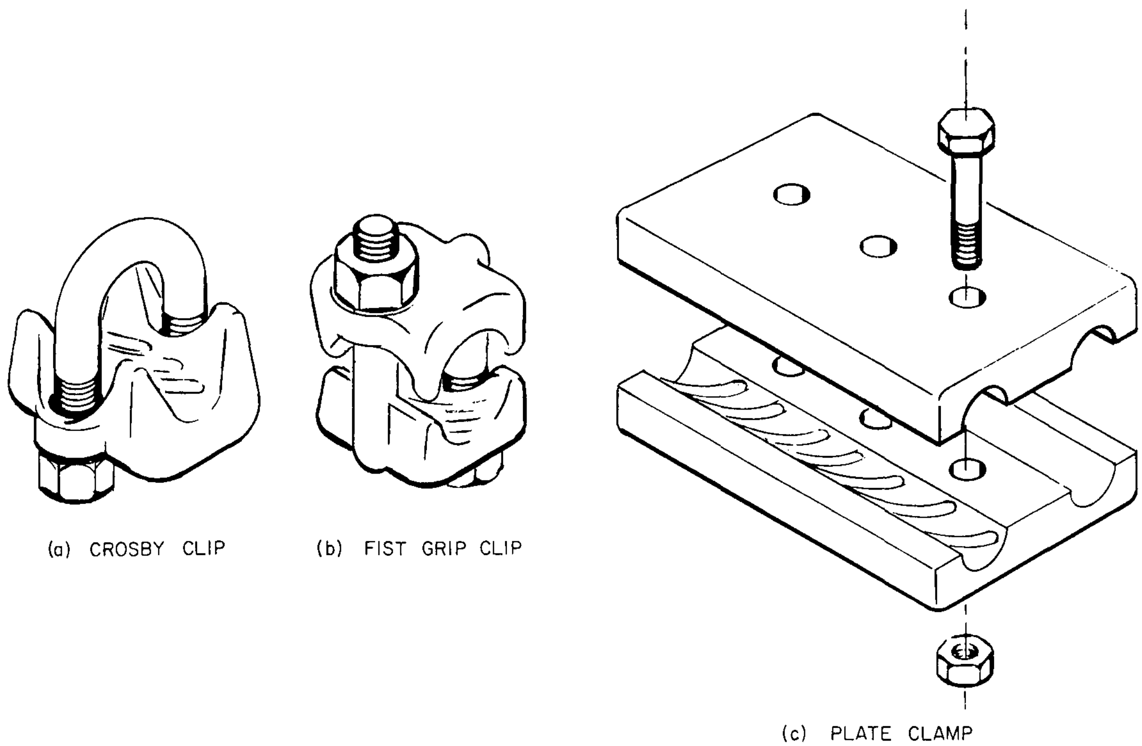


Figure 5.2. Clips and Clamps Commonly Used with Thimble Terminations

*Crosby and Fist Grip clips are manufactured by Crosby-Laughlin, Fort Wayne, Indiana.

5.2.1 TERMINATIONS AT CONVEYANCES/COUNTERWEIGHTS (Continued)

WEDGE TYPES

The Short Coupled Thimble and the Reliance wedge-type cappel* shown in Figure 5.3 are the most common wedge-type terminations in domestic use.

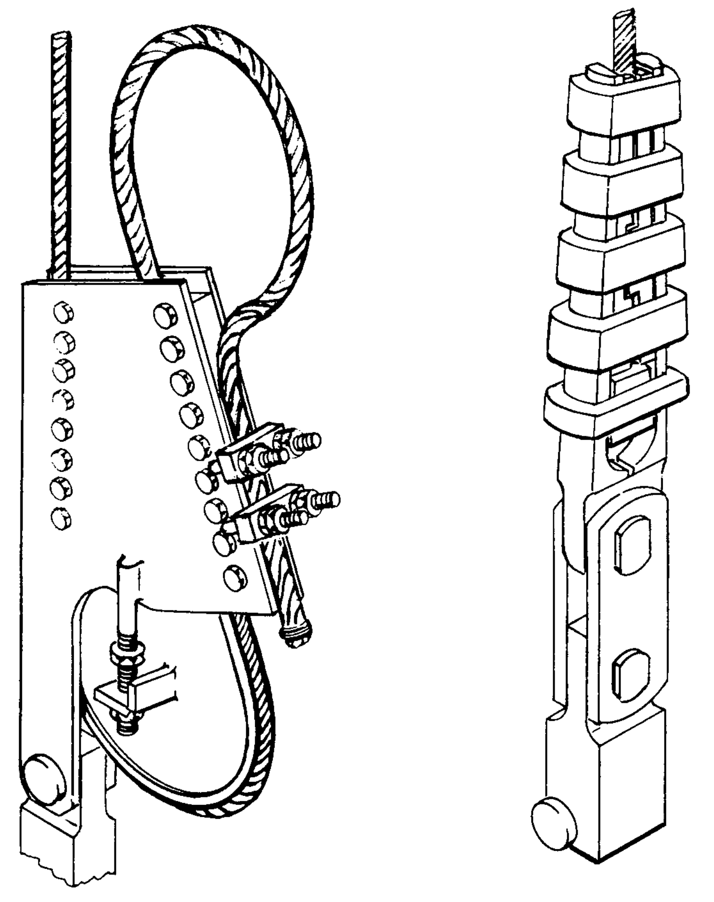


Figure 5.3. Commonly Used Wedge-Type Terminations

*Short-Coupled Thimbles are patented and manufactured by Lake Shore, Inc., Iron Mountain, Michigan; Lake Shore is the U.S. distributor for the Reliance Rope Attachment Co. Ltd., Cardiff, U.K.

SOCKETS

Figure 5.4 illustrates the two types of sockets in use. The open type is preferred since the pin connection is less prone to wear. Drop-forged sockets are strongest, and galvanized finishes delay corrosion.

Mining literature is notably lacking in specifications or recommendations for design of sockets despite long use and much emphasis.

Figure 5.4. Sockets

Federal Specification RR-S-550B or the most recent modification is recommended for governing design of mine-hoist rope sockets. There are but minor variations in socket dimensions among manufacturers and some designs already conform to RR-S-550B.

INSTALLATION

GENERAL

The total weight of the hoist rope and end termination may be enough to bend the rope if the termination falls over or drops. Mechanical hold-up devices may not be practical in vertical shaft installations, but they are on slope conveyances where an auxiliary cable or chain is simple to install and sometimes used to prevent the termination from dropping down and bending the rope when the rope goes slack.

THIMBLES AND CLIPS

Table 5.1 presents the manufacturers recommendations regarding attachment of Crosby and Fist Grip clips; these guides may be applied to all such clips.

5.2.1 TERMINATIONS AT CONVEYANCES/COUNTERWEIGHTS (Continued)

Table 5.1. Manufacturer's Recommendations for Using Crosby and Fist-Grip Clips with Thimble Terminations

A termination made in accordance with the instructions, and using the number of clips shown, has an approximate 80 percent efficiency rating. This rating is based upon the catalog breaking strength of wire rope.

The number of clips shown is based upon using right regular or Lang lay wire rope, 6 x 19 class or 6 x 37 class, fibre core or IWRC, IPS or XIPS. If Seale construction or similar large outer wire type construction in the 6 x 19 class is to be used for sizes 1 inch and larger, add one additional clip.

The number of clips shown also applies to right regular lay wire rope, 8 x 19 class, fibre core, IPS, sizes 1 1/2 inch and smaller; and right regular lay wire rope, 18 x 7 class, fibre core, IPS or XIPS, sizes 1 3/4 and smaller.

For other classes of wire rope not mentioned above, it may be necessary to add additional clips to the number shown.

If a greater number of clips are used than shown in the table, the amount of rope turnback should be increased proportionately.

Clip * Size Inches	Minimum No. of Clips	Amount of Rope to Turn Back in Inches	Torque in Ft. Lbs.
1/8	2	3 1/4	
3/16	2	3 3/4	
1/4	2	4 3/4	15
5/16	2	5 1/4	30
3/8	2	6 1/2	45
7/16	2	7	65
1/2	3	11 1/2	65
9/16	3	12	95
5/8	3	12	95
3/4	4	18	130
7/8	4	19	225
1	5	26	225
1 1/8	6	34	225
1 1/4	6	37	360
1 3/8	7	44	360
1 1/2	7	48	360
1 5/8	7	51	430
1 3/4	7	53	590
2	8	71	750
2 1/4	8	73	750
2 1/2	9	84	750
2 3/4	10	100	750
3	10	106	1200

*Same as nominal rope diameter.

To attach clips:

(1) Temporarily wire the thimble to the rope in the position determined by the recommended length to be turned back; this length should not include any rope on the thimble. Note that the off-center pinhole in the thimble should be on the live side of the rope.

(2) Bend the rope around the thimble and temporarily wire the live and dead portions together, keeping the rope portions and the thimble in the same plane.

(3) Place the first clip at the dead end but away from it a distance about equal to the width of the saddle; tighten the nuts evenly to the recommended torque. Note that the saddles of all clips must be against the live part of the rope.

(4) Place and partially tighten the clip nearest the thimble.

(5) Space the remaining clips on the rope evenly; partially tighten the nuts, working away from the thimble and keeping the live and dead portions of the rope straight and together.

(6) Load the rope and thimble enough to straighten the rope and seat it equally around the thimble. Fully tighten all the nuts evenly to the recommended torque beginning at the thimble and working away from it. Oiling the threads will help.

(7) Load the termination with the conveyance and check clip tightness. Run a trip and check clip tightness again. Recheck tightness after first hour's use.

As the fittings and rope are worked, the clips will have to be retightened until the rope dimensions stabilize, and daily checks are advisable initially.

If a torque wrench is not available, assume the man tightening the clips will weigh about 180 pounds (or whatever) and divide this number into the torque value to determine the length of the wrench needed. Slip a pipe over the wrench handle if extra leverage is needed, pin the pipe to the wrench so it doesn't slip off.

PLATE CLAMPS

The recommended number of plate clamps is given in Table 5.2.

Table 5.2. Recommended Number of Plate Clamps for Thimble Terminations

Nominal Rope Diameter, inches	Number of Clamps*
⅞–1¼	4
1⅜–1⅝	5
1¾–2¼	6

*Includes any clamp built into thimble.

If clamp grooves are corrugated to match rope lay, these corrugations should be on one side of the clamp only. Place clamps as close together as possible consistent with matching the corrugations to the rope. And, except for the two clamps nearest the thimble, corrugations should be on the dead side of the rope only.

Clamps should be installed in the same sequence as clips. Tighten clamp nuts evenly and as tight as possible short of more than mildly distorting the rope.

5.2.1 TERMINATIONS AT CONVEYANCES/COUNTERWEIGHTS (Continued)

WEDGE-TYPE CAPPELS

With reference to Figure 5.5:

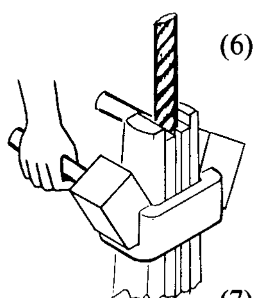
(1) Carefully attach the safety block to the end of the rope; use *zinc*. (The safety block is, in essence, a socket and the procedures for attaching it are the same as for a socket.) Never omit this block.

(2) Slip the hoops over the safety block, starting with smallest and working up in size; shove them a few feet up on the rope.

(3) Carefully clean all lubricants from the rope grooves of the wedge pieces and from the outside of the rope over the length of the wedges, starting about one inch from the safety block. Be sparing and careful with solvents on the rope; otherwise they may later seep out, bringing internal lubricants and effectively relubricating the rope and wedge grooves. Remove burrs and smooth the edges of the wedges at both ends of the rope groove.

(4) Place the interlocking wedges on the rope about ½ inch away from the safety block with thick ends toward this block.

(5) Grease the mating surfaces of the wedge pieces and the frame and slide the frame into position so that the small ends of the wedge piece are about even with the end of the frame but not beyond.



(6) One by one, slip the hoops onto the frame and drive them home. After the first is seated as far as possible, stand the cappel on end, and drive the hoop (and others) with a sledge, using blocks set against the hoops to provide a striking surface. As the hoops begin to wedge tightly, it may be necessary to go from one to another to seat them all firmly. (Some manufacturers sell special jacks for tightening the hoops.)

(7) Suspend the empty conveyance on the termination and check hoop tightness. The gap between the safety block and the wedge pieces is a good indicator of slip. (If slip occurs, the block is supposed to drive the wedge pieces tighter into the frame; hence the necessity of careful attachment of the block.)

(8) Run a few empty trips and check hoop tightness and gap. Repeat with a full load. Recheck after an hour's use and frequently thereafter during first few days.

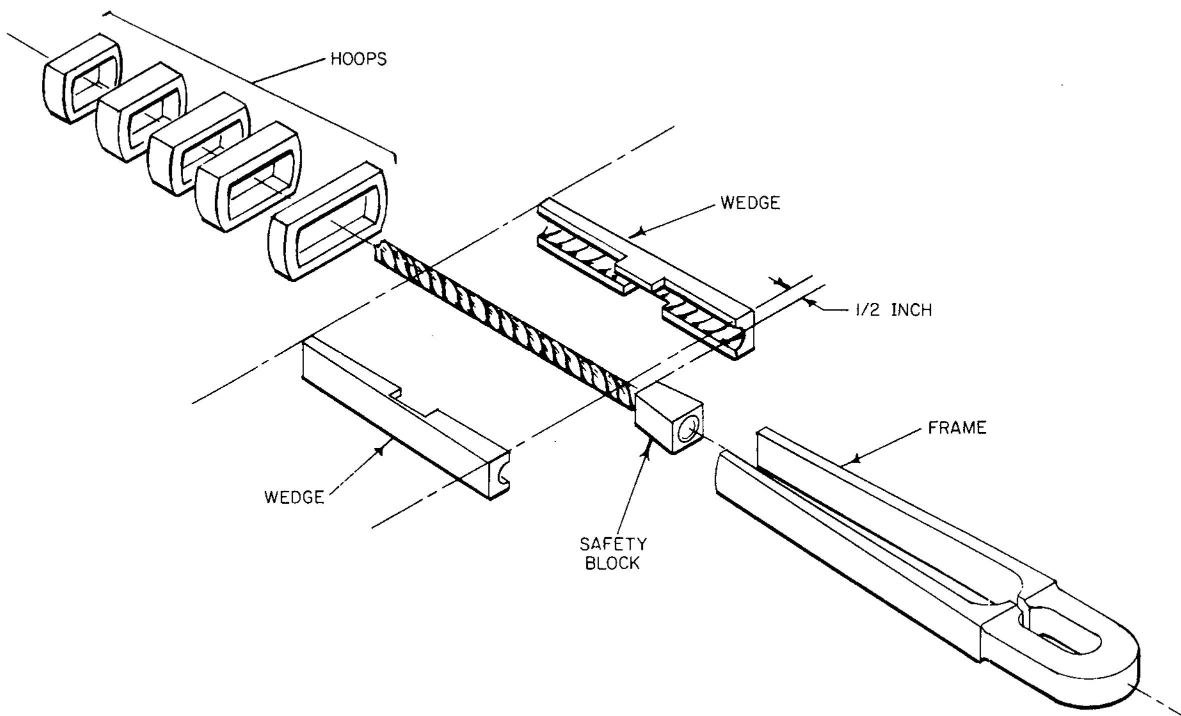


Figure 5.5. Assembly of Reliance Wedge-Type Cappel Termination

5.2.1 TERMINATIONS AT CONVEYANCES/COUNTERWEIGHTS (Continued)

SHORT-COUPLED THIMBLES

With reference to Figure 5.6:

(1) Clean all dirt and grease from the wedge block and from the thimble where it mates with the wedge block. Clean and lightly grease the inside surface of the slide block and the mating surface of the thimble. The attachment will probably have to be disassembled to do this. The thimble release (backout) nuts can be used to start the thimble out if needed.

(2) Clean dirt and lubricants off that part of the rope that will separate the thimble and wedge block. Be sparing and careful with solvents. The first time this is done the location of this area will have to be more-or-less guessed at; hence, clean a generous area. After the reeving is complete measure and record how much rope extends from the exit point, around the loop, and through the safety clamps; it may save time next time. The manufacturer suggests that the loop not project beyond the outside edge of the slide block (next to hoist rope); otherwise, it could rub the hoist rope. The line of bolts through the carrying frame, holding the slideblock in place, provide a more easily used reference for the loop size; this reference is noted in Figure 5.6.

(3) Install or back out the thimble, keeping the thimble against the slide lock, so that there is a big enough gap between thimble and wedge block to pass the rope. Tightening the thimble in this position with both backout and preload nuts may ease the next step.

(4) Reeve the rope through the device and tightly clamp the end under the safety clamps. Some juggling may be necessary to get the loop correct. Make sure the safety clamps seat only against the rope and not the frame as well; otherwise the rope could slip out.

(5) Turn the thimble backout nuts up as far as they will go and then tighten the preload nuts until the thimble seats securely. Check to be sure that the rope is fully in the groove in both the wedge block and thimble and that the thimble is against the slide block. Tighten as much as practical, noting that the threads will strip well before the rope is damaged.

(6) Attach termination to conveyance. This device will tip over without tension on the rope. Avoid tipping—the rope could be damaged.

(7) Suspend the empty conveyance on the termination and check tightness of preload nuts and safety clamps; note any change in loop size.

(8) Run a few empty trips and recheck preload nuts, safety clamps, and loop size. Repeat with a full load. Recheck after an hour's use and frequently thereafter during the first few days.

99

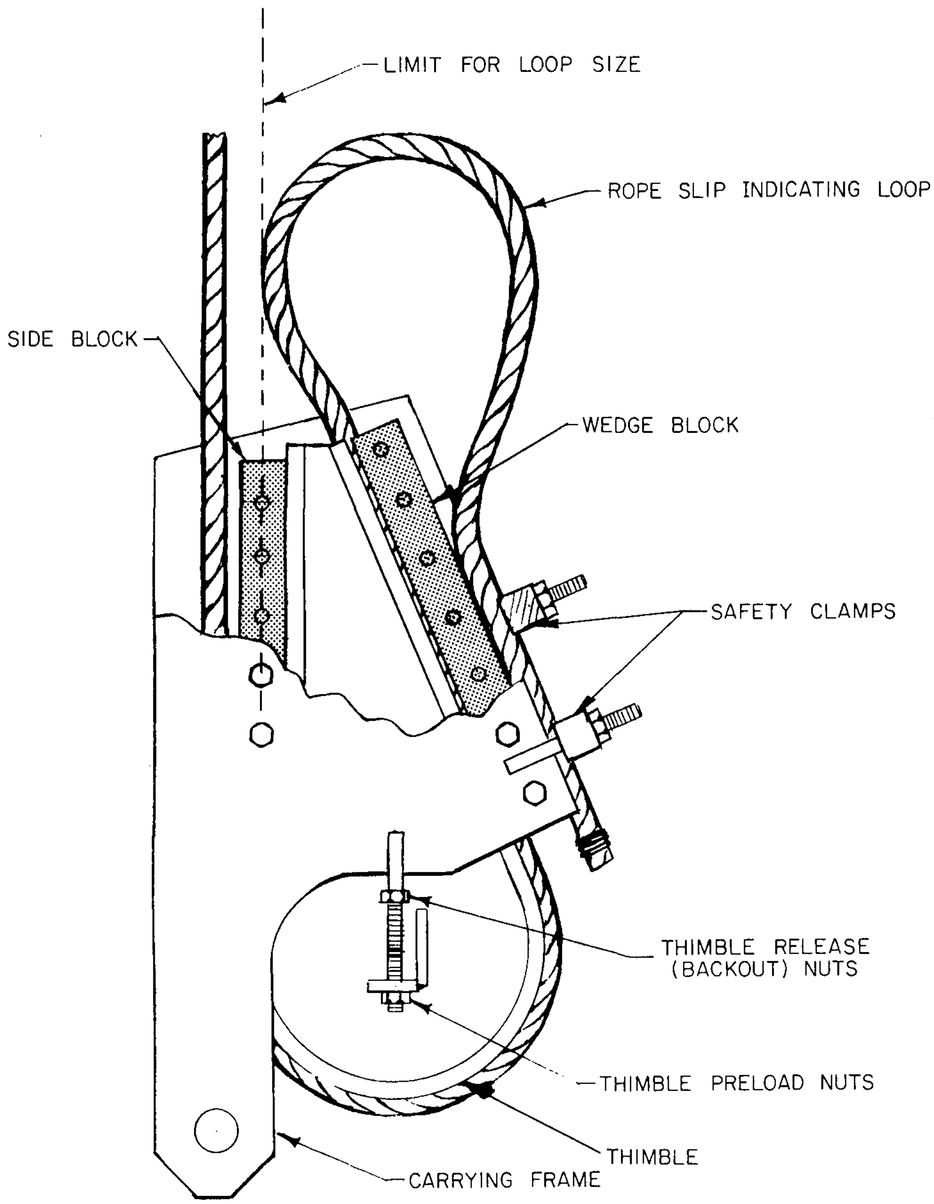


Figure 5.6. Assembly of SHORT-COUPLED THIMBLE Termination

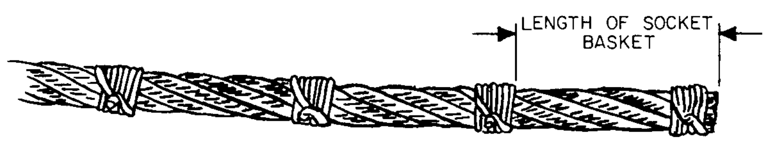
5.2.1 TERMINATIONS AT CONVEYANCES/COUNTERWEIGHTS (Continued)

The rope in this termination can be easily renewed by loosening the preload nuts, loosening the thimble with the backout nuts, removing the bitter end from the safety clamps, and pulling new rope through the device. It is advisable first to thoroughly clean off all dirt and lubricant from the rope that will pass through the device, otherwise the wedge block and thimble will be lubricated. If come-alongs are used to jack the rope through, avoid nicking or gouging the rope.

It is important to keep the backout and preload nuts and their studs well lubricated and corrosion free. If there is concern about the preload nuts loosening, or if they are found loose, use two nuts and lock them together.

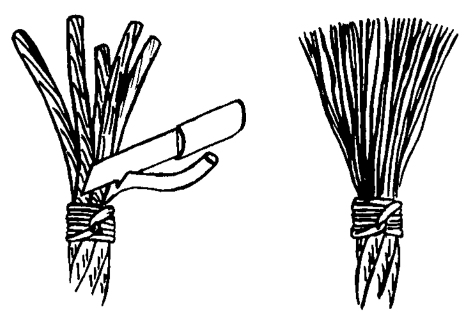
SOCKETS

Follow the procedure outlined in Figure 5.7. The most important aspects are cleanliness of broomed-out wires, preheating of the socket, correct temperature of the zinc at pour, and natural cooling of the poured socket.



(1) Seize the rope at a point away from the cut end a distance equal to the length of the socket basket. Apply two more seizings fairly close behind this one. These seizings should be tight; it is very important to prevent the rope from unlaying in this area.

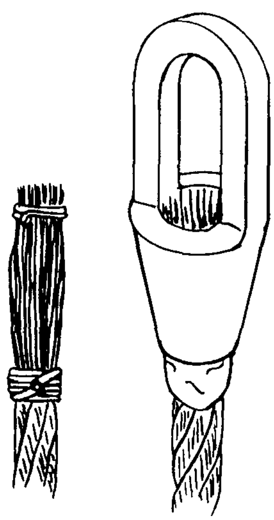
(2) Open up the rope down to the first seizing and cut off fiber or synthetic core materials as close to the first seizing as possible, untwist all wires to form a broom-like appearance. Wires should be fairly straight although they need not be completely straightened.



(3) Clean the broomed wires as follows:
   (a) First dip the broomed wires into a solvent up to the first seizing. Shake off excess solvent and dry;
   (b) Second, dip the broomed wires ¾ the length of the broom into clean, commercial muriatic acid until the metal is a clean, dull grey color (usually 30 to 60 seconds). After removing the rope from the acid, hold it cut-end down while shaking off excess acid or until it drips free. Throughout this operation avoid getting acid anywhere else on the rope;

Figure 5.7. Assembly of Socket Terminations

(c) Third, dip broom into boiling water containing a small amount of soda to neutralize any acid remaining on the wires. If the acid is not neutralized it will corrode the wires and the socket may fail. From here on it is important to keep the cleaned wires clean.



(4) Temporarily serve the broom together, slip the socket over the wires, remove the temporary serving, and align the socket flush with the top of the wires and centered on the rope axis. Seal the bottom of the basket with clay, putty, or asbestos.

It is usually suggested that the socket be preheated to about 200° F prior to this step, but with care the socket can be preheated with a torch after it has been placed on the rope aligned, and sealed. Preheating before pouring helps the zinc to fully distribute within the socket and among the wires and prevents it from cooling too rapidly. (Water boils at a temperature between 200 and 212° F between about 10,000 ft and sea level. Practically, then, the socket is hot enough when water or spittle boils off when flicked on it.)

(5) Pour molten zinc into the basket until it is full; one continuous pour is best. Use only zinc of a "high grade" or better quality per A.S.T.M. Specification B6 (latest version). The temperature of the zinc at pour should range between 850 and 1000° F and the dross should be skimmed prior to filling the ladle for the pour.

The temperature of the zinc can be easily measured with temperature-indicating crayons (heat-sensitive, colored materials in pencil form that melt at specific temperatures). Obtain crayons for the minimum and maximum temperatures indicated. Dip the ladle into the melt, take it out, and rub both crayons across the bottom of the ladle. When the mark from the lower-temperature crayon melts but not the upper, the zinc is ready to pour.

(6) Let poured socket air-cool.

(7) Remove the socket seal, all seizings, and lubricate the rope well at and near the socket to replace any lubricant that may have been removed by cleaning and heat.

Figure 5.7. Assembly of Socket Terminations (Continued)

102

5.2.1 TERMINATIONS AT CONVEYANCES/COUNTERWEIGHTS (Continued)

SWIVELS

Do not use free swivels, separately or built into hoist rope terminations (see 5.5.6). The rope may unlay and fail; at best it will be weakened.

INSPECTION/MAINTENANCE—Visually inspect terminations daily for signs of rope slip. On thimble-and-clip types a two- or three-wrap serving on the live rope opposite the dead end will provide a reference for gauging slip. Loops and safety-block gaps serve as indicators on wedge types. For sockets, use a serving or a painted band on the rope where it enters the socket. Note that a small amount of slip is typical with a newly poured socket as it adjusts to loads.

Daily, check pins, etc., connecting terminations to conveyance to be sure they are still locked in place and in no danger of working out.

Check tightness of clips, clamps, wedge hoops, wedge-tightening nuts, etc., weekly and retighten if necessary.

Routinely (say, weekly) clean off terminations and inspect rope for broken wires or other changes in rope structure, particularly where the rope enters a socket. Examine terminations for structural damage and wear; especially look for cracks at and around connections to conveyance. An annual nondestructive examination (e.g., ultrasonic, magnetic particle inspection) of thimbles, reused sockets, and wedge-type terminations, particularly cappel hoops, is strongly recommended.

Control corrosion of termination as much as possible. Routine cleaning helps; so does coating structural parts with grease as long as it is periodically cleaned off to be sure it's effective.

Keep ropes *well* lubricated at terminations except at wedge-rope interfaces. Problems arise under clips and clamps; around thimbles, particularly at the bottom; at the bottom of thimble-like wedges; and within cappels and sockets. Penetrating lubricants are recommended (see 5.5.4); they are probably best applied with a brush and should be applied often enough to keep the rope well lubricated.

Specifically, reterminate the rope at conveyances

(1) Any time the rope at or within the termination exhibits the symptoms of loss of strength that are normally used to remove the rope itself (see 5.5.1), and

(2) At least every 6 months, unless this or a more frequent retermination schedule is automatically provided by conveyance-end rope cuts made to distribute rope wear (see 5.5.3).

Cut the rope above the termination or the highest clip or clamp or, if safety cables or chains are in use, above the device connecting them to the hoist rope (see 5.5.3). Don't reuse clips, clamps, bolts, or worn connector pins. (Cast plate clamps can be reused so long as they are in good condition.)

After retermination take the cut-off portion of the hoist rope apart and carefully examine it inside and out. Especially look for internal corrosion and dryness of core. Rope corrosion at termination may be (but, not necessarily will be) worse than at other places. Regardless of what is written, said, or believed about rope lubricants and practices, a careful examination of this cut-off piece of rope will provide some indication of whether or not lubrication is effective.

COMMENT—Hoist-rope terminations are commonly ranked according to their efficiency, that is, the force required to pull them apart or otherwise fail them expressed as a percentage of the rope-breaking strength.

One problem with such rankings is that some relate to the catalogue breaking strength of the rope, some to the actual breaking strength, while others don't indicate either. The actual breaking strength is typically higher, by as much as 20 percent, than the catalogue strength. Another problem with ranking terminations according to efficiency is that all such ratings apply to new conditions, and the rope at terminations may (again, but not necessarily will) deteriorate faster than elsewhere; thus, after a while the rating becomes sort of academic—hence, the practical value of routine retermination.

In any case, a rating of less than 100 percent does not necessarily mean that a termination is less "safe". Here is a more meaningful consideration. Compute a termination's safety factor by dividing the termination rating times the catalogue breaking strength of the hoist rope by the sum of the weight of the conveyance plus its maximum load. Compare this termination safety factor to the safety factor for the hoist rope when new; if it is equal to or greater than the rope safety factor the termination is as "safe" as the rope. Remember that the rope safety factor includes the weight of all the hoist rope that can be in the shaft as well as the weight of the conveyance and its load; forget about acceleration and bending stresses.

Of equal, if not greater, practical value are such considerations as ease of installation (and hence retermination), ease of inspection and maintenance, and inherent propensity to degrade the rope, and the space required. In these matters, thimble types appear to have the edge over cappel and socket types, except, perhaps, for space requirements.

104

5.2.2 ATTACHMENTS FOR SAFETY CHAINS/CABLES

REGULATION—A very general regulation governs selection, installation and maintenance in accord with manufacturer's specification (57.19-26 M).

HAZARD—These attachments can damage the hoist rope and accelerate rope corrosion.

DESCRIPTION—The best hoist-rope attachments for safety chains and cables appear to be those that more-or-less fully enclose the rope over a length of about ½ foot or more, and have attached bails or eyes for connecting the safety chains or cables to them. Perhaps even better are those which have rope grooves with patterns corresponding to and engaging the strands of the rope. Two representative types are the Bethlehem Steel two-piece "Lay-lock" clamp and the Reliance wedge-type glands.

Do not use clips, small clamps, or any device that can produce a very local rope deformation.

Do not use the conveyance termination or its fittings in any way.

INSTALLATION—Clean lubricant from the mating surfaces of the fittings and the rope.

Deburr and round the edges where rope enters and exits the fitting. Install the fitting and tighten as much as possible without distorting the rope. Reliance and similar wedge glands must be installed upside down, so that a downward load on the bails further tightens the wedges against the rope.

INSPECTION/MAINTENANCE—Inspect weekly for signs of rope damage, e.g., broken wires, distortion, corrosion.

Keep bolts and nuts tight on clamp-type attachments.

Check for slip of attachment: A one- or two-wrap serve around the rope at the upper end of any attachment can be a simple indicator of slip.

Keep attachments and rope at and near them clean and lubricated as much as possible except for wedge-rope mating surfaces.

Monthly, remove attachment and inspect rope underneath for signs of corrosion.

(Retermination of rope at conveyance end [see 5.2.1] and conveyance-end rope cuts [see 5.5.3] will require retermination of safety chain and cable.)

105

COMMENT—The need to keep the rope well lubricated to prevent corrosion inside and out may be counter-productive by providing a lubricant between the rope and the attachment; the attachment may slip if the safety chains or cables are called upon to support the conveyance.

Furthermore, like end terminations, these fittings collect moisture and promote rope corrosion. They can also promote fatigue damage if they damp out horizontal oscillations of the rope in a short distance.

There is no requirement to proof test the ability of these attachments to support the weight of the conveyance, let alone the shock loads likely to occur if the rope failed below them; also, none seem to be tested.

Other aspects of safety chain and cables are discussed in Section 7.2.9. All things considered, the use of safety chains and cables appears to be of questionable value as things stand.

106

5.2.3 TERMINATIONS AT DRUM

REGULATION—General regulations describe procedures for attaching the hoist rope to the drum [57.19-23 and 75.1403-3(c)].

HAZARD—Drum terminations can damage rope.

DESCRIPTION—Terminations at the drum consist of either plate clamps for attaching the rope to the drum or spokes, or clips or clamps for attaching the rope to itself, after the rope encircles spokes or the drum shaft. Clamps are sometimes built into the drum structure; for example, one of the two pieces may be machined into a spoke.

Normally, drum terminations do not carry loads as high as those carried by conveyance terminations. The dead wraps are a major factor, acting like the 3 to 5 rope wraps on a capstan which permit heavy loads to be lifted with relatively small tensions applied to the free end. Thus, three of four clips or clamps are usually enough. However, extra clamps may be required if ropes are doubled down the shaft to tension the rope for winding (see 5.4.2) because the drum terminations may have to carry as much as ½ the weight of the rope and conveyance.

If all the rope is stored in layers and wraps on the drum, clip or clamp terminations will do. However, if some of the rope is stored coiled within the drum, special care at drum terminations is required. Otherwise, after one or more conveyance-end cuts, a section of the rope weakened by a drum termination will be pulled onto the drum and be brought into use as part of the running rope. In this case, several plate clamps are probably best, particularly those that have corrugated grooves or corrugated groove inserts that match the wire and lay pattern of the rope.

The shape and quality of the drum spout is an important part of the drum termination. All spout surfaces should be smooth and deburred, particularly where the rope enters and leaves. Spouts that induce sharp-radius bends in the rope are to be avoided, especially if rope is stored within the drum. Although spouts are built into the drum, they can usually be reshaped without an excessive amount of effort.

INSPECTION/MAINTENANCE—Look for and fix loose or broken drum terminations.

Keep fittings painted to control corrosion and weakening, and keep them clean to ease inspection.

Keep drum spout surfaces smooth. Remove corrugations and burrs before installing a new rope.

(Drum-end rope cuts [see 5.5.3] will periodically renew drum termination.)

5.3 TERMINATIONS—FRICTION HOISTS

HAZARD—Deterioration of rope may occur at and within termination; termination may fail.

DESCRIPTION—Any of the previously described (see 5.2.1) terminations can be used, but cappel types predominate since they require little lateral space. Terminations are usually connected to conveyance through a series of links and pins that provide articulation to ease the fatigue damage due to rope oscillations. Connectors should permit relatively fine adjustments to rope length at one conveyance at least; if used, rope-tension equalizers (whipple trees, compression cylinders, or springs) should be installed at one conveyance only.

INSTALLATION—Follow the same procedures as for drum hoists (see 5.2.1).

INSPECTION/MAINTENANCE—Inspection/maintenance is basically the same as for drum hoists (5.2.1) except that ropes cannot usually be periodically terminated. Thus, inspection for possible rope deterioration and maintenance to prevent it is highly important.

Keep ropes at and near the terminations well lubricated (except at wedge-rope interfaces) to control corrosion; special friction-hoist lubricants (see 5.5.4) or light, penetrating, anticorrosive, water-displacing lubricants (see 5.5.4) can be used and should be applied liberally and often. Make sure non-special lubricants do not get onto the drive wheel, or are not tracked onto it if deflection sheaves are used.

5.4 STORAGE, HANDLING, AND INSTALLATION

5.4.1 STORAGE

HAZARD—Improper storage and handling results in corrosion and other physical damage to rope.

INSPECTION/MAINTENANCE—Protect stored rope from excess moisture, heat, and dirt; cover if necessary, but allow air to circulate so that moisture does not condense under the cover.

Look for dry or cracking lubricant and, if found, relubricate; better too much lubricant than not enough (see 5.5.4 and 5.5.5).

Protect the rope from mechanical damage; don't store other things on top of the rope and be careful in moving reels with fork lifts, slings, etc.

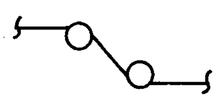
Used rope stored for possible future use should be thoroughly cleaned, relubricated, carefully reeled, and treated in storage as if it were new.

5.4.2 INSTALLATION

HAZARD—Poor installation procedures can cause immediate or subsequent rope damage.

PROCEDURES—Before reeving new rope, check sheave-groove and drum-face conditions and rework as needed (see 4.1.4 and 4.2).

Before unreeling, place the storage reel on an axle so that it resembles an underwound drum and provide some form of brake to control reel speed. Unreel from the bottom; any other approach can easily yield kinks, and kinks must be avoided. At the first sign of a kink developing, stop and take out the twist.



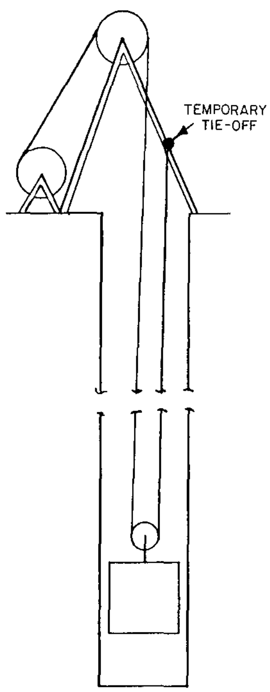
Reverse Bends

Reeve in the most direct route possible from spool to hoist. Keep the number of temporary, intermediate sheaves to a minimum and the diameter as large as feasible; if small sheaves or blocks have to be used, keep rope tensions low during reeving. Reverse bends are acceptable during reeving if needed.

Keep rope out of the dirt and away from rough surfaces or hard edges as much as possible; use planks or other lagging as needed to prevent damage to rope.

Plain-faced drums should be overwound from the left flange (looking toward the headsheave) and underwound from the right flange with right-lay rope; reverse the procedure for left-lay rope. Wraps should fit snugly but not so closely that the strands interlock. The oncoming rope may have to be tapped into place on the first layer: use a soft-faced hammer that won't damage the rope (e.g., plastic, wooden, copper, or lead); otherwise hammer against a wooden block placed against the rope. (Grooved drums take care of themselves, regardless of rope lay.)

Wind the rope onto the drum under as much tension as possible. If small deflection blocks or sheaves are needed for reeving or if circumstance or equipment do not permit much tension during installation, one of the following methods can be used to tension the drum wraps before beginning regular hoisting:



Doubling Down

(1) Run the empty conveyance to bottom of shaft, load it to maximum load or as close to it as feasible (no men) and then rewind.

(2) Double the rope down the shaft using a loaded conveyance and as large a conveyance-mounted sheave as feasible.

(3) Run both ropes and conveyances to bottom of shaft, disconnect ropes from conveyances, and temporarily connect ropes together. If possible, use a full muck bucket with a big sheave on it to tension the ropes further. Unwind all the rope off one drum, while winding on the other. Then wind up on the empty drum until the other drum is fully unwound. Then rewind this drum (unwinding the other) until the temporary connector is again at the bottom. Disconnect ropes from one another, reconnect to conveyances, and wind each to the top of the shaft. Take care that the ropes are not damaged where they pass between compartments.

Use whichever method will give the most tension in the most rope. The first method tensions to the full load of the conveyance and the rope in the shaft; the second to ½ the weight of the conveyance and the rope in the shaft; the third to the weight of the rope in the shaft (more if the bucket and sheave is used) but only on the bottom layers—more in the other layers after the conveyances are reattached. The second and third methods allow all the rope on the drum to be tensioned to some degree. If all the rope is to be wound off the drum, make sure that the drum-end terminations can carry the imposed load.

Rope length must be initially long enough to allow for all periodic cuts at the conveyance and the drum (see 5.2.1 and 5.5.3) and still reach the bottom of the shaft with a minimum of three dead wraps [57.19-22 and 75.1403-3(c)].

Inspect new ropes for damage or distortion before regular hoisting begins (see COMMENT).

110

5.4.2 INSTALLATION (Continued)

The following practices are potentially very dangerous and should *not be done:*
(a) Splicing a hoist rope
(b) Swapping ends (end-for-ending)
(c) Reusing a discarded conveyance rope for a counterweight rope
(d) Reusing a discarded hoist rope in an emergency (see COMMENT).

COMMENT—Winding the hoist rope as tightly as possible before regular use is very important at installation as well as after drum-end rope cuts. In use the rope will tend to loosen at the dead wraps, including those which are dead initially, but come off later as cuts are made. In loosening, lower wraps tend to work up through upper layers, upper layers work down in between lower layers, and the resulting mess is rough on the rope. It is good rope practice to retension whenever loose wraps are noted.

The details of reeving and unreeving during rope changes vary among operators and often must vary because of the particulars of the installation. Many operators use a power-driven-and-braked steel reel onto which the rope is initially wound from the storage reel and from which the rope is reeved into the hoist. This powered reel allows good control over the rope during reeving and unreeving (for drum-end cuts, for example) and permits controlled back tension during winding onto the drum. Furthermore, a well-designed steel reel will support more rope tension than the typical wooden storage reel.

Good practice calls for inspecting a new rope for broken or damaged areas and constructional upsets (see 5.5.1.2) before hoisting begins. Inspecting the rope as it comes off the storage reel may save time, since now and then a new rope is defective or has been damaged in transit or storage.

It is difficult to logically justify reusing a discarded hoist rope for any other hoisting application, especially for the same class of service (i.e., same magnitudes for loads and speeds). In general, the breaking strength of the discarded rope at its weakest point is not known, and sometimes the location of the weakest point is not known. In addition, in the final stage of rope-strength deterioration, usually heralded by the appearance of broken wires in significant numbers (see Appendix B), strength deterioration proceeds at an accelerated rate. Furthermore, the criteria used to judge removal are often vague. Thus, what qualitative or quantitative base can be used to determine when to remove a reused rope the second time?

All or part of a discarded hoist rope is sometimes used in a lower class of service, e.g., a service slope or a haulage slope between levels. Qualitatively, this use is more nearly justifiable; but, on what quantitative base is the rope removed from its new service? Nondestructive rope inspection, discussed in Section 5.5.2.3, could provide a quantitative base on which discarded hoist rope might justifiably be reused in a lower class of service. But unless such data are available for every foot of the rope, reuse entails great risks.

It is sometimes argued that a discarded hoist rope may have to be reused in an emergency. If an emergency is a situation in which men's lives are in the balance, and a discarded hoist rope is all there is to be used, even though it might tip the balance in the wrong direction, so be it. But a discarded rope stored to cover contingencies (e.g., ordering mistakes, delivery problems) is not good practice; new rope layed by for such purposes is best and probably more cost effective in the long run.

112

5.4.3 BREAK-IN

PROCEDURES—With new ropes, tensioned and ready for use, run full-shaft trips for about 20 minutes under each of the following conditions:

(a) At half speed, with empty conveyance
(b) Then, at full speed, with empty conveyance
(c) Then, at half speed, with half load
(d) Then, at full speed, with half load
(e) Then, at half speed, with full load

These procedures apply to drum and friction hoists.

COMMENT—Ropes not broken in before regular use tend to have shorter service lives. With use, the wires in a stranded rope readjust their relative positions and dent one another where they touch, the strands seat into the core, and the rope stretches. If this happens gradually, wear and stresses are minimized. If it happens immediately, wear and high stress occur as the rope is bent around sheaves and drums. Break-in permits the rope to gradually adjust its structure to high loads and rapid bends (high speed). The more gradual the break-in, the more service the rope is likely to give. No data are known that specifically indicate how much break-in is enough; the suggested procedures are based on practice associated with high tonnages hoisted per set of ropes.

5.5 INSPECTION AND MAINTENANCE

5.5.1 REMOVAL CRITERIA

5.5.1.1 REGULATIONS

REGULATIONS—Removal criteria regulations are paraphrased below [57.19-21 M and 57.19-128 M (a-d)]:

MINIMUM SAFETY FACTORS

Table 5.3. Recommended Hoist-Rope Safety Factors

Length of Rope in Shaft, feet	Minimum Factor of Safety, new rope	Minimum Factor of Safety, for removal	Effective Strength Loss*
up to 500	8	6.4	20%
501–1000	7	5.8	17
1001–2000	6	5.0	16-2/3
2001–3000	5	4.3	14
3001 or more	4	3.6	10

*Not part of regulation; presented for information only.

NUMBER OF BROKEN WIRES

Six anywhere within one lay length.

WIRE WEAR

Thirty-five or more percent loss of original crown-wire diameter.

CORROSION OR DISTORTION

Marked amounts.

OTHER

Combinations of the above which may be unsafe.

(*NOTE:* The broken wire and wear criteria were originally developed for 6 x 19 construction [not class] ropes of plow steel.)

COMMENT—Except for the broken wire, wear, and distortion (see 5.5.1.2) criteria, the above removal recommendations have little practical value for general practice. The minimum safety factors for removal require knowledge of the breaking strength of the rope at its weakest point or, what is equivalent, some way to relate the observed corrosion, wear,

114

5.5.1.1 REGULATIONS (Continued)

broken wires, and distortion to loss of strength. Marked corrosion and distortion mean different things to different people; moreover, what is going on inside the rope is generally unknown and, more often than not, is of greater significance than what can be seen outside.

Since selecting a new rope might be considered a maintenance item, the following should be noted. The procedure for using the safety factors is to divide the catalogue breaking strength of the rope being considered by the total suspended static (dead) weight of the conveyance, its load, and the rope. The use of only the total static load is often criticized for neglecting the dynamic rope stresses—acceleration, bending at sheaves and drums, general impact loads due to uneven guides, etc. Dynamic loads should not be added even though it is commonly recommended—they were included in formulating the recommended values for the safety factors; these values were specifically made higher than they would have been for static loads alone so that the computations could be simplified. A good case can be made for some change in the current safety-factor approach; but until such changes can be thoroughly and systematically formulated the current approach should be followed as intended without arbitrary changes that cannot be rationally substantiated.

The previous regulations are but a part of a series of recommendations for rope selection and removal proposed for use in 1915 until better information was developed.* The series essentially consisted of two somewhat different sets of recommendations. Current Federal and state hoisting regulations consist of parts of one or the other set but rarely all of either; ANSI M11-1-1960, likewise, contains only a part of one set. Those fortunate enough to find a copy of the footnoted reference could benefit from reading the hoisting-related sections: both sets of recommendations are fully presented, and most importantly, the reasoning behind the recommendations is clearly presented.

5.5.1.2 PRACTICE

DESCRIPTION—In practice, removal criteria other than or in addition to those recommended by the regulations are commonly used and the following have general value:

- Three broken wires in the same strand within one lay length.
- A prediction of from 10 to 15 percent loss of strength (based upon measurements of rope diameter, wear pattern dimensions, and the number of broken wires), estimated with a series of charts and graphs published in the *Roebling Wire Rope Handbook*.** These retirement guides are applicable to most 6 x 19 class, round-strand, regular and Lang lay constructions, in the absence of significant corrosion.
- A prediction of 10 percent or greater loss of rope strength based on the results of electromagnetic nondestructive testing with an alternating-current device manufactured and/or operated by Rotesco, Ltd., Toronto.

*Ingalls, W. R., Douglas, J., Finlay, J. R., Channing, J. Parke and Hammond, John Hays, "Rules and Regulations for Metal Mines", U.S. Department of the Interior, Bureau of Mines, Bulletin 75, 1915.

**Published by The Colorado Fuel and Iron Corporation, Roebling Wire Rope, Trenton, New Jersey. Roebling is out of business and material is no longer available from the publisher.

- A change in the shape of the graph of rope-elongation-versus-time data for friction hoist ropes. The procedures for this criterion are included in Appendix B.
- A kink (a pulled-out twist loop), a dogleg (a simple, permanent bend), a birdcage (strands separated and ballooned out), loose or high strand(s), a badly out-of-round section, a crushed section with abraded or broken wires, loose wires with no visible breaks, a protruding core, an unusually small diameter locally, or an unusually short or long lay length locally—all too far from the end of a rope to be removed with an end cut. It should be noted that these items are all radical changes—constructional upsets—in the structure of the rope. (The regulatory criterion of marked amounts of distortion usually is taken to mean any of these kinds of structural changes.)

COMMENT—The *Roebling Wire Rope Handbook* data for estimating remaining strength are widely used and much respected guides. These data are reportedly based upon actual breaking-strength test data and their accuracy is often cited as being good to 5 percent. The demise of Roebling has prevented direct verification, although some operators claim to have made breaking-strength tests on discarded ropes that support these data.

There are a wide variety of hoist-rope removal criteria in use other than the five general ones mentioned above. They have been developed out of experience, sometimes supported by breaking-strength tests of discarded ropes, but often not. Typical of these are number of broken wires per lay, or per strand per lay, or a combination thereof; diameter reduction; tonnage hoisted; and service-life time. None can be faulted from a safety standpoint so long as hoist ropes are removed before they fail. But in general, each hoist system is a unique machine and its rope will degrade in a unique way. Thus, there is danger in applying a home-grown removal criteria, however good, to a different installation; for this reason, none have been presented for general use.

There are some industrial standards that present rope-removal criteria in terms of allowable reductions in rope diameter for various ranges of nominal rope diameters, in addition to criteria similar in many cases to those discussed above and in Section 5.5.1.1. Experience may support such rope-diameter-reduction criteria in the industries where used, but there is no known accumulation of experience that indicates these criteria are generally or specifically applicable to mine hoisting ropes, and their use is not recommended unless they can be qualitatively and/or quantitatively supported technically. As stated, some mine operators do use a diameter-reduction criterion; but, in the cases investigated, these criteria are outgrowths of experience with the Roebling criteria and correlations with measurements of diameter reduction; they are, in effect, procedural simplifications which have been found effective for the particular hoisting installations involved. If the typical number of broken wires or the amount of corrosion experienced were to be different with these cases, the chances are good that the allowed diameter reduction would be different also.

From an engineering viewpoint, many hoist ropes are removed well before they need be. For example, a discarded hoist rope that, at its weakest point, break-tests at or above the catalogue breaking strength obviously still has some useful life; and this is not a rare situation. Such practice is justified by not wanting to take chances—and rightfully so. However, it points up the lack of generally recommended removal criteria that are adequate from all viewpoints—safety, engineering, and economic.

116

5.5.2 INSPECTION

5.5.2.1 LOCATIONS OF ROPE-STRENGTH DEGRADATION

DESCRIPTION—Strength degradation varies in severity along a rope. The following regions can be sites of especially severe deterioration and they should always be given attention during inspection:

GENERAL

- At, under, and near end terminations
- At, under, and near any other permanent or temporary attachments to the rope
- At a hole in a floor, bulkhead, or other shaft closure when the conveyances are at the most-often-used stations and especially when parked
- In the vicinity of water leaking into shaft, particularly where this water may drip onto or splash off shaft timbers and onto the rope when the conveyances are at the most-often-used stations and especially when parked.

DRUM HOISTS IN PARTICULAR

- At head, deflector, and turning sheaves when the conveyance is at dump, loading, top, bottom, and parking stations; and during acceleration from and braking to these stations. This includes turning sheaves atop counterweights (or a conveyance of any kind) that are suspended with a multiple-part reeve.
- The section going onto and off the drum during acceleration from and braking to the above stations
- The dead wraps, including those that become live during the rope's service life
- At and near the drum spout
- At drum crossovers.
- At drum change-of-layer regions
- Near the conveyance end, in general, especially for ropes commonly disconnected from conveyances.

FRICTION HOISTS IN PARTICULAR

- Just below the drive wheel, and, perhaps, also just below deflection or head sheaves when the associated conveyance is at its highest normal station.

5.5.2.2 MANUAL/VISUAL INSPECTION TECHNIQUES

PROCEDURES

BROKEN WIRES

Broken wires are easily missed. Adequate cleaning and careful inspection are a must.

(1) Encircle rope with a rag or cotton waste and run hoist slowly. If broken wire ends protrude and catch the rag, either the rag or bits of it will show the location of broken wires. It is best to face in the direction the rope is moving when holding the rag so that it is pulled away from the holder if it snags on broken wires. A bare or gloved hand rather than a rag or waste can be dangerous. A rope speed of about 50 feet/min. is usually suggested.

Soaking the cotton waste or a rag with solvent can be of value except for friction hoist ropes. First, the rag is less likely to burn away; second, the solvent will carry some lubricant into the rope.

This time-honored approach will work only if broken wires protrude somewhat; valley breaks, particularly on preformed ropes, may go undetected.

(2) Look at an area several feet distant while sighting more-or-less along the rope as it moves slowly by; broken wires, from valley breaks in particular, may protrude just enough above the surface to be seen. Feeling for surface irregularities at the same time with a bare hand can be of value, but if the rag method has not been previously used, the rope should be run slowly to avoid possible injury.

The cleaner the rope the better the chances of finding broken wires with either method. The heavier the lubricant, the more difficult it is to detect broken wires other than those on the crown, particularly if the lubricant fills the valleys and the rope looks like a smooth black rod with some shiny areas on the surface. Rope segments that do not pass overhead or other heavily loaded sheaves are likely to be totally covered with drying or dried-out lubricant. These segments will probably have to be cleaned, at least to the condition of a black rod with shiny surface areas if broken wires are to be detected.

DIAMETER AND LAY LENGTH

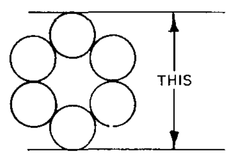
Diameter and lay-length measurements are most easily made at the same time and at the same locations along the rope.

Since the geometry of a rope will change rapidly during the break-in periods, measurements should not be made at installation. The first set of measurements should be made after the constructional adjustment period but

118

5.5.2.2 MANUAL/VISUAL INSPECTION TECHNIQUES (Continued)

before significant wear begins. This first set of data is important since it serves as the basis for comparing all additional data. Furthermore, all subsequent measurements should be made under the same conditions to the extent possible. For example, don't measure with a full conveyance one time and an empty one the next. On slope systems where it is normal to detach the conveyances from the rope, measurements should always be made with the same conveyances attached and loading the rope.



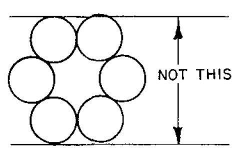


Diagram Measured

(1) Measure rope diameters with calipers. Diameters should be measured across the crowns and not the "flats", and across all three crown diameters. The average diameter is all that needs to be recorded unless the three differ appreciably, indicating a developing flattening or distortion that needs watching.

Check for localized diameter reductions or enlargements all along the rope while looking for broken wires. Localized diameter differences can often be felt; with the rag method they can be heard sometimes as a change in the noise the rope makes while running through the rag.

NOTE: The regulatory removal criteria dealing with crown-wire diameter wear has little practical value; the diameter of the wire cannot be directly measured easily nor accurately enough in most cases and, realistically, not at all if peening is present. The so-called "Q-method" of measuring the wear pattern, which is part of the strength-estimating procedure presented in the *Roebling Wire Rope Handbook,* is, in essence, an indirect measure of crown-wire diameter that is translated with charts into remaining wire area. The Q-measurement is easy to make.

(2) Measure lay length with a tape graduated in 64ths of an inch. Place the end of the tape at the center and highest part of a strand and call this strand Strand #1. Count off the strands and read once, twice, or three times the lay length from the tape at the center and highest part of Strand #7, #13, or #19 for 6x ropes; or of Strand #13, #25, or #37 for 18x and 19x ropes. The strand numbers refer to Strand #1 after it makes 1, 2, and 3 complete revolutions of the rope; that is, at the end of 1, 2, and 3 lay lengths. (18x and 19x ropes have 2 outer strands.) For accuracy, it is better to measure over 2 or 3 lay lengths and divide by the number of lay lengths to obtain an average value.

Special lay-length measuring devices have been constructed that are more accurate than a tape and eliminate miscounting the strands. The essential features of such devices are a length of angle iron that straddles the rope; a fixed, centered reference point inside the angle at one end which fits into the rope valley; near the other end of the angle is a slidable point which fits into the valley at the other end of the lay. The sliding point includes a reference mark which lines up with a graduated scale attached to the outside of the angle. Settable blocks on either side of the sliding point limit the motion of the sliding point; these are set a short distance to either side of the nominal lay length. The device is placed over the rope with the fixed reference point in a valley and the sliding point moved until it too settles into a valley; the lay length is then read directly off the scale.

Diameter and lay length should be measured at regular intervals along the rope. In addition, diameter should be measured at and near the worst crossovers on each layer and at any apparent irregularity. Regular intervals along the rope are typically determined by shaft stations, or every so many drum revolutions. Usually the same spotting procedure is used each time measurements are made, even though rope cuts bring previously unmeasured areas to the measuring station. Sometimes "odd" shaft stations are used for spotting the rope for measurements, with the "even" stations used the next time. Whatever the procedure used, it is suggested that measurements be made at least at 10 locations along the length of the rope.

The assumption justifying measurements at regular intervals, regardless of rope cuts, is that the diameter and lay length will vary gradually along the rope and, thus, all is well even though the measurements are not always made at the same place along the rope. This is not necessarily true, however, because localized difference can be completely missed; and a localized diameter and lay length change, larger, or smaller, can be a symptom of serious internal degradation. Thus, measurements at regular discreet points should always be supplemented by at least feeling or looking for local diameter variations over the entire length and measuring diameter and lay length at these locations when found. Localized diameter reductions and lay length changes may indicate one or more of the following:

(a) Core damage or failure
(b) Serious internal corrosion
(c) Serious internal crushing or wear.

CORROSION

(1) Look for scale or pitting on the outer surfaces of wires. Note that wear and peening may erase these indicators.

(2) Look for pitting or scale in the strand valleys where these indicators are not easily erased by wear and peening; corrosion here may be the only sign of corrosion inside the rope.

(3) Look for corrosion at and under attachments (e.g., glands) and at and near end terminations.

Unless corrosion is visible on the surface it can easily go undetected. Signs of corrosion can easily be hidden beneath the rope lubricant, particularly if the

5.5.2.2 MANUAL/VISUAL INSPECTION TECHNIQUES (Continued)

lubricant piles up, soft or caked, in the valleys. Dig out the lubricant, perhaps wipe off the area with a solvent-soaked rag, and then look.

In some places it has been the practice to slack a rope and carefully unlay it with a marlin-spike-like tool to inspect for interior corrosion. However, it is too easy to damage the rope structurally in the process and this approach should not be used.

STRUCTURAL DAMAGE

Structural damage is fairly easy to spot. The types that call for *immediate* rope removal, if they cannot be removed by end cut, include kinks, doglegs, birdcages, loose or high strands, and protruding core (see 5.5.1.2).

Ropes are sometimes run if doglegs (bends, not kinks) are "not too bad", but this is risky business in general.

Kinks are also sometimes purposely taken out and the rope kept in service. However, a true kink severely twists the wires, and taking it out will not undo the damage. The place where it "was" can always be felt if not seen. Running with an unkinked kink is even riskier than running with a dogleg.

Waviness developing in a rope must be very closely watched. Loose wires with no visible breaks, loose strands, and birdcages may develop out of waviness. Waviness on friction-hoist ropes usually means unequal wheel-grooved diameters or rope lengths; and when these contributors are corrected (see 4.3 and Appendix A), the waviness may dissipate over a larger area or just stop growing. If it dissipates, or stops growing and isn't bad, the ropes may run for a long time with no further problems—however, these structural variations must be closely watched. Waviness on drum-hoist ropes is likely to grow into something else, and the causes cannot usually be corrected. However, if waviness appears in dead wraps, retensioning may eliminate further problems.

5.5.2.3 NONDESTRUCTIVE TESTING (NDT) TECHNIQUES

DESCRIPTION—Two types of electromagnetic nondestructive testing (NDT) devices are sufficiently developed and readily available to be of significant value. One type uses direct current (D.C.) to energize the rope—electrically or with permanent magnets—and is primarily sensitive to broken wires. The other type uses alternating current (A.C.) and is primarily sensitive to loss of metallic area through wear, peening, and corrosion.

These devices have two units. The rope passes through one unit. This detecting unit consists of energizing and detecting coils and typically can be opened and closed around the rope. It is portable enough to be set up almost anywhere.

The other unit contains the controls and a strip-chart recorder for the output data. The motion of the strip chart is synchronized with the motion of the rope, usually using a tachometer generator or a selsyn driver mounted on the detecting unit and driven by a wheel that runs against the rope. D.C. units usually have only one output trace, whereas A.C. types have two. The output data for A.C. devices can be translated into estimates of rope strength or strength loss using calibration curves which should accompany all such instruments.

During inspection with these devices, ropes are usually run at speeds of 200 to 300 feet per minute; such speeds significantly reduce the time required for inspection relative to that required for a thorough inspection using conventional manual/visual procedures.

PROCEDURES

A.C. DEVICES

(1) Obtain an NDT record for new ropes after the initial constructional stretch has occurred—typically after several weeks' use. This data is very important; it is the basis for comparing subsequent NDT data and, for all practical purposes, it indicates the condition of the rope when new.

(2) Periodically obtain other NDT data as the rope is used. In addition to the record, convert the data to estimates of the rope strength or strength loss in weakening areas.

    How often these subsequent tests need to be made must be determined for each installation. The object is to obtain enough data to establish the degradation-versus-time pattern with some confidence. Initially at least NDT inspection is suggested every 4 months over the life of a rope. With experience and confidence NDT inspection could be less frequent but should be done at least every 6 months.

(3) After each NDT test, visually examine the rope wherever the NDT record indicates a developing weakness or an inexplicable pecularity, and record the observations.

122

5.5.2.3 NONDESTRUCTIVE TESTING (NDT) TECHNIQUES (Continued)

(4) Remove the rope if the results of A.C. NDT testing indicates a strength loss of 10 percent or more at any point, whether or not anything is visible at those points.

(5) Remove the rope if the rope safety factor computed with the rope strength estimated from the NDT data reaches or goes below the recommended minimum safety factors for removal listed in Table 5.3.

NOTE: A.C. (or even D.C.) NDT tests do not replace regular visual/manual inspection. As stated, A.C. devices are not primarily sensitive to broken wires (although broken wires are commonly found where the device indicates a weakness). Thus the results of NDT tests have to be tempered by the existence of broken wires and the broken-wire removal criteria should also be observed.

COMMENT—There are many electromagnetic NDT rope-inspection instruments made and used in the mining world. All require operators experienced in use and in data interpretation. There are some large, foreign mine operators who own and operate NDT equipment (some of whom, in fact, have been instrumental in the development of such instruments). In most cases, however, such devices are most often used by companies specializing in such services or by regulatory agencies. Domestic operators who routinely use NDT inspection utilize the aforementioned Canadian organization (see 5.5.1.2). For this reason, for one, the previous procedures and those in Chapter 6 for NDT inspection are based upon the use of this organization's A.C. instrument. For another, there is no other organization, foreign or domestic, yet offering a comparable NDT service available to domestic operators.

NDT instruments provide information that cannot be obtained in any other way, particularly about conditions in the interior of the rope. Though interpretation is complicated, it is not magic; the basics are fairly easy to understand and, if for nothing more than to gain confidence in the operator, he should be asked for a short course on the basic principles of operation and data interpretation.

No NDT device has been "perfected", and development continues throughout the world. Nevertheless it is a mistake to assume that they have no value or should not be used because they are not yet perfected. For example, within some 5 years after A.C. NDT inspection was required in Ontario in the early 60's, operators were using hoist ropes twice as long as before, on the *average*. Improved rope maintenance certainly had some effect, but this was prompted in part by a more certain knowledge of what was going on inside the rope provided by NDT inspection. The extended life can also be attributed to a more certain knowledge of the actual strength of the rope as it degrades in use. In this regard, the development and use of the aforementioned Rotesco A.C. device is supported by data from tensile tests to failure of many samples from hundreds of used hoist ropes.

In any event, beware of anyone who offers an NDT instrument that can detect broken wires as easily and as accurately as loss of metallic section through wear and corrosion; if such devices exist, they are not yet available domestically. A reliable organization knows and will state the limitations of their instruments, as well as provide evidence to support their claims.

The best practice with NDT devices also involves tensile tests to failure of samples of new and retired ropes, especially break tests of the weakest points on retired ropes. The actual breaking-strength data provide a data base with which to compare the strengths estimated from NDT data; such comparisons provide a continuing basis for instrument improvement and a means by which confidence in the technique is obtained.

Small "pocket" (miniature) nondestructive inspection devices are under development in several countries. They are pocket-sized only insofar as they are much smaller and far more portable than the typical A.C. or D.C. device. They will not be as accurate as the larger devices, but they will be cheaper, easier to use, and capable of at least calling attention to potential problem areas in the rope.

124

5.5.3 ROPE CUTS—DRUM HOISTS ONLY

REGULATIONS—General requirements and procedures cover rope cuts at conveyance and drum ends (57.19-124/-125).

HAZARD—A rope used without end cuts eventually suffers unequal distribution of wear and corrosion and, hence, shortened life.

DESCRIPTION—Rope cuts at the conveyance are valuable because they:

(1) Remove weakened rope near and within the termination

(2) Bring fresh rope to the sheaves for those critical configurations where the conveyance is at, accelerating from, and decelerating into the stations, especially the most frequently used stations

(3) Bring fresh rope to the critical region where the rope leaves the drum when the conveyance is at, accelerating from, and decelerating into stations.

Rope cuts at the drum end are valuable because they:

(1) Remove rope from the drum spout and drum terminations where it may be weakened

(2) Bring fresh rope to the crossover regions

(3) Bring fresh rope to the change-of-layer region

(4) Bring fresh rope into the dead wrap region when spare rope is stored within the drum.

PROCEDURES

GENERAL

Any change in the position of the rope within the hoisting system requires compensating adjustments to conveyance-position indicators, and semi- and fully automatic hoist-control equipment. Section 3.1.2 lists general procedures for making rope cuts or rope changes that will prevent indicators and automatic control equipment from being grossly out of adjustment after ropes are changed or cut off. The procedures below relate mainly to Step (d) of these general procedures, that is, to work done on the rope.

In making cuts, be careful of built-up torque (twist); do not permit rope to spin free (see 5.5.6). Pull carefully on any rope; come-alongs or other grips may easily gouge or nick the outer wires or distort the rope.

CONVEYANCE-END CUTS

(1) With the conveyance blocked or chaired at the collar, the control system and indicator drives disconnected (see 3.1.2), and provisions made to control twist, slack the rope enough to uncouple the termination.

(2) Cut off the rope above the highest termination fitting or above the safety chain or cable attachments and remake the attachment.

For thimbles and clips or clamps and for close-coupled-thimble-type terminations, a torch cut is acceptable but don't do the cutting over the open shaft. Whether cut by torch, saw, or bolt cutter, the rope should be served or secured with one or two hose clamps on the live side before the cut is made.

For poured sockets and cappel-type terminations, a saw or a bolt-cutter cut is best since the cut end is then easy to broom out and metallographic changes due to heat are minimized. The rope should be served (seized) on the live side before the cut is made.

The regulation recommends that the rope be cut off 6 feet above the highest connection. This figure–6 feet–was originally recommended for poured-socket terminations to permit removal and inspection of some of the rope close to the termination because this part of the rope was believed to be always subject to the most rapid degradation. As stated in Section 7.2.9, this is not always the case. However, another reason for the length was to provide a sample sufficiently long to permit a thorough examination of the condition of the rope, inside and out. It has been suggested that the 6-foot portion be tensile tested to failure to indicate the actual breaking strength of the rope at this point, as is required in some countries. However, a 6-foot length is too short for such a test, 8 to 10 feet being more appropriate.

(3) Before reattaching the newly made termination, take care of twist (see 5.5.6).

(4) Reattach the termination to the conveyance, take out the slack, reconnect drives to indicators and controllers, and then unblock conveyance.

(5) Run several empty trips to adjust rope to its new position in the system; check termination tightness after first and last trips. This is a good time to check the positioning accuracy of indicators and controllers and readjust them if needed.

126

5.5.3 ROPE CUTS—DRUM HOISTS ONLY (Continued)

DRUM-END CUTS

(1) Unwind the rope under tension as far as possible: either run the conveyance to the bottom of the shaft or double the rope down the shaft.

(2) Clamp the rope at collar or as close to the drum as feasible to retain rope tension and torque (spin) between the clamp and the conveyance. This "clamp" will be heavily loaded and capable of damaging the rope if not carefully used or long enough; reliance or similar wedge glands tied off to head frame or set across beams of the collar are recommended for this operation. (Such beams should be sound and periodically inspected for degradation.)

(3) Pull the remaining rope off the drum, keeping it tensioned as much as feasible until all the rope is off the drum. Be careful of stored-up torque that can make the rope very cranky near and at the dead wraps.

(4) Detach the rope from the drum terminations. Make cut, and reterminate. The cut can be made off the drum or the rope can be pulled through spout, reterminated, and then cut off. The new end of the rope should be served or clamped to keep it from unlaying.

The amount of rope cut off (or pulled onto) the drum should be enough to put fresh rope into the crossover and change-of-layer areas. A length equal to 1¼ wraps is usually recommended for multilayer winding; this length will completely renew the rope at the flanges and, hence at the change-of-layer and crossover areas. Drums wound single layer need only about ¾ of a wrap cut off. In any event, avoid even multiples of ½ wrap: that is, ½, 1, and 1½ wraps.

NOTE: Step (4) does not apply to a drum on which the extra rope is stored inside. For this case, after Step (3) loosen drum terminations, pull fresh rope through spout, and then reterminate. Again, be careful with built-up torque.

(5) After retermination is completed, rewind rope under as much tension as possible. For all practical purposes, from here on consider the situation identical to installing a new rope and winding for the first time. However, keeping the rope under tension and winding it tightly is even more important now that build-up torque is likely to be present.

(6) After the rope is rewound onto the drum, and the collar clamp(s) removed, run several empty and full trips at reduced speed to permit the torque and lay lengths to redistribute throughout the rope.

FREQUENCY OF CUTS

How often cuts should be made to distribute *general* rope wear depends upon how fast the rope wears. Since rope wear depends upon usage, the nature of the hoisting system and other rope-maintenance practices such as lubrication, no generally applicable schedule can be recommended. (Note, however, that conveyance-end retermination at least every 6 months has been suggested for renewing the rope *at* the termination [see Section 5.2.1].) In practice, some operators schedule on the basis of the number of hoisting hours, others by tonnage or number of trips, still others by the calendar. Good rope-maintenance practice calls for some schedule for end cuts, and operators are urged to formulate one that is best suited to prolonging rope life whenever drums permit extra rope storage.

5.5.4 LUBRICATION—DRUM-HOIST ROPES

REGULATION—The governing regulation recommends that the rope always be well lubricated from end to end according to manufacturer's suggested instructions (57.19-123).

HAZARD—Insufficient lubrication can lead to increased internal wear and corrosive failure.

LUBRICANT—Low-viscosity, mineral-based, paraffinic (e.g., petrolatum-based) oils are recommended; they should contain additives to prevent corrosion (e.g., acid or base neutralizers, such as dinonyl naphthlene sulfonate) and/or to displace water from metallic surfaces (e.g., dimethyl polysiloxene). Automotive motor oils (e.g., SAE 10 or 20) may work just as well. Applied well, these lubricants will not be washed off by falling shaft water.

Lubricants that dry and leave behind gummy residues that build up in and fill up the rope valleys are not recommended; this includes asphalt-based lubricants. Lubricants with high viscosities—those that have to be heated to be applied, for example—are not recommended either.

PROCEDURES—Keep ropes well lubricated at all times over their whole length.

Good practice calls for automatic oilers, continuously applying lubricant while the hoist is running. Installation of such oilers at the head sheave (or turning or deflection sheave) seems most satisfactory as well as practical. Drip oilers driven by the sheave are the most common; spray oilers, typically motor driven, are often recommended for their ability to provide better initial penetration. The latter are not used much—perhaps more reliable designs are needed. Automatic oilers need a regulating valve so that the total flow can be varied as needed; in general, the more continuous and/or high speed the hoisting, the more oil flow needed.

Good practice also calls for special attention to those areas of the rope not covered by an automatic oiler: between the head sheave and the conveyance with the conveyance up, and between the head sheave and the drum spout with the conveyance down. Special attention is also needed at, around, and under conveyance-end terminations, drum-end terminations, and safety chain or cable attachments; and for any rope stored inside the drum. These areas will probably need liberal, manual lubrication, preferably brushed or sprayed and often enough to keep them well lubricated.

Keep ropes free of accumulated old lubricant: clean off periodically with compressed air (use a water trip in the line) or with brushes if necessary. If steam is used be sure it is superheated, otherwise too much moisture will be carried into the rope. A set of motor-driven brushes in a common frame could be easily constructed, easy to use, and perhaps, more effective in cleaning out the valleys in stranded ropes.

Clean and relubricate ropes as soon as possible after they have been accidentally covered with shaft water, sand, concrete, muck, etc. For many slope-hoist ropes this sort of an environment is normal. The more attention given to such ropes, the longer they will last and, more importantly, the better the chances will be of finding an impending failure.

Match lubricant viscosity with seasonal temperature variations. Thin lubricants with a solvent, or change to a lower viscosity (lighter) oil when cold weather prevails: accidents have occurred when deposits of solid lubricants or mixtures of ice and lubricants on exposed head sheaves have built up enough to permit the rope to climb off. Likewise, in very hot environments or in summer, the viscosity may have to be increased so that the lubricant does not run and drip off as fast as it is applied.

Splash guards, perhaps extending well above the drums, will be necessary with use of light lubricants. If the guards do not extend below the drums, the pit could be kept clean by suspending a plastic sheet underneath the drums, with a hole in the sheet at the lowest point and a bucket under it. The collected oil can be reused after it has been strained and mixed with new oil.

COMMENT—Technical papers, reports, discussions, etc. about mine-hoist rope lubricants could fill a book. Missing from most of this is data supporting the arguments—that is, comparisons of what is said with what the rope looks like and how well the lubricant works.

The earlier recommendation for low-viscosity oils is a conclusion based upon field observations and discussion with operators, and a few qualitative and quantitative data in the literature—all involving the effects of lubricants on the rope from either visual observation or test data. The trend of the observations is that low-viscosity lubricants give longer rope life and definitely make visual and manual inspection easier and more accurate.

Several more pages could be added to the existing literature by arguing here for light versus heavy lubricants. But rather than argue the point operators are urged to confirm it for themselves. Every mine hoist operator has at his disposal the perfect experimental laboratory for determining what lubricant will do the best job for him: his hoist installation, particularly if it has two ropes, as most do. Try a different lubricant on each rope when new, watch carefully, and look carefully at the inside as well as the outside of cut-offs. The lubricant providing the least internal wear and best corrosion protection, all else being equal, is the best lubricant. Be fair about the experiment: ingrained habits ("we've always used Z brand"), purchasing agreements, etc., can easily bias the results if they are not successful in preventing the experiment in the first place.

130

5.5.5 LUBRICATION—FRICTION-HOIST ROPES

REGULATION—The regulation given in 5.5.4 (applying to lubrication of drum and hoist ropes) also applies to lubrication of friction-hoist ropes.

HAZARD—Insufficient lubrication leads to increased internal wear and corrosive failure.

LUBRICANT—Special dressings (lubricant) should be used at least for those areas of the rope that pass over drive and deflector wheels. If regular oil or grease lubricants are used on these areas, the ropes will slip on the drive wheel.

Light oil-type lubricants (see 5.5.4) could be used on areas that do not pass over wheels and, hence, will not be tracked onto drive wheel. Such lubricants could also be used at terminations.

PROCEDURES—For rope areas that run over drive and deflection (or head) sheaves:

Keep rope surface cleaned of internal rope lubricants that seep out. Dry clean by dusting with an absorbent powder—dry cement is sometimes used. Although the powder/lubricant mixture will track onto the drive wheel, it should soon dry and flake off by itself. Never clean this area of the ropes with a solvent: it will only bring more internal lubricant to the surface.

Keep rope surfaces well treated with the special lubricants. The more corrosive the environment, the more frequent the application; daily application may be required in the most corrosive environments (e.g., potash mines).

Do not apply special lubricant to all ropes at the same time. The lubricant will reduce the coefficient of friction somewhat and slip may occur; however, after a few hours' operation the lubricant dries enough to restore the coefficient of friction to normal. Hence, apply the lubricant to one rope at a time; lubricating one rope a day, another the next, and so forth, may be the best approach in very corrosive environments.

For ropes that do not run over drive and deflection wheels:

The lubricants and procedures for drum hoists could be applied to these areas.

Remember that while friction-hoist ropes are often shortened because of rope stretch, as a rule they cannot be cut off and shifted to distribute wear or to remove excessive corrosion at terminations; thus extra care is required.

NOTE: Rope length and drive-wheel groove diameters need special attention and maintenance to prevent or control constructional upsets in the ropes. For these procedures see Section 4.3 and Appendix A.

131

5.5.6 TORQUE (SPIN) RELEASE

HAZARD—Rope failure or severe weakening can result if too much spin is released; men can be injured in handling ropes if spin is ignored.

DISCUSSION—Hoist ropes of stranded, non-torque-balanced constructions (e.g., the typical 6 x 19 class constructions) especially will undergo a redistribution of lay lengths throughout the rope with use: lay lengths will shorten toward the conveyance end and lengthen toward the drum end. Furthermore, some very peculiar things can occur toward the drum spout in the dead wraps. If such a rope is freed from all attachments, the short-lay regions will tend to unlay and the long-lay regions will tend to lay up—all because of elastic strain energy accompanying the lay length changes. This stored-up strain energy is often referred to as torque, spin, or twist buildup, and a rope with stored up torque as "wild" or "cranky".

This stored-up torque can cause problems. With slack at the conveyance when chairing, for example, the rope may kink; when making drum-end cuts or changing a rope, the rope in the dead wrap area has been known to completely twist itself apart. Furthermore, short lays near the conveyance can cause it to twist against the guides and wear them unevenly. (This wear can be minimized or eliminated with guide wheels—see 7.1.) The stored torque may be enough to corkscrew the rope below a head sheave.

While mine hoist operators and rope experts the world over appear to be unanimous in their opinion that release of twist is eventually detrimental, there is no agreement on how much twist should be relieved or where in the shaft to relieve it.

RECOMMENDATION—If spin release is needed to reduce or eliminate a problem, remove only what is necessary. When there is so much torque built up that it cannot easily be released without danger to men, some operators will let the rope spin dead (but controlled so that it won't flail about) at the collar or midshaft, and then put back in as many turns as two men can manage.

It is further suggested that spin be relieved to any substantial degree no more than twice for any rope.

After any spin release, run a few empty full-shaft trips before resuming normal hoisting to redistribute the spin remaining in the rope.

132

5.5.7 MISCELLANEOUS

5.5.7.1 GALVANIZED ROPES

COMMENT—Galvanized ropes can be very effective in many corrosive environments and are commonly used in many countries. There is little domestic use of galvanized ropes, and the typical reason given is that galvanized ropes are not as strong. This is not necessarily true. Ropes made from wires hot-dipped after drawing will show about 10 percent less strength; but ropes made from wire electrogalvanized after drawing, or from wire drawn after galvanizing, will have about the same strength as their bright counterparts.

Nevertheless, a galvanized rope 10 percent weaker than bright rope may still be suitable. New ropes commonly have a safety factor greater than the minimum recommended value. Thus, for example, if a bright rope has a safety factor of 6.3, whereas the minimum required is only 6.0, a galvanized rope 10 percent less strong would yield a safety factor of 6.3 x 0.9, or 5.7, which is unsuitable. However, if the bright rope has a safety factor of 6.7, the 10 percent-less-strong galvanized rope would have a safety factor of 6.0, which would be suitable.

Tensile tests of new ropes could be of use here. Ropes are typically stronger than the catalogue breaking strength; and a galvanized version, although about 10 percent less strong, may still test higher than the catalogue strength and, hence, be suitable.

It is also argued that the zinc soon wears off on sheaves and drums. On the outside of the rope where it touches sheaves, drums, and other parts of the rope, yes; but not necessarily so elsewhere, and particularly on the interior where corrosion usually proceeds unseen and is often at its worst.

5.5.7.2 WEATHER PROTECTION

COMMENT—Regardless of lubrication practice, if conveyances are parked in the same place all the time, the ropes may corrode more at the head sheaves than at other places if the sheaves are exposed to the elements. Changing the parking position can help; so can a simple sheet-metal roof, or smaller covers installed several inches above each sheave.

5.5.8 AFTER DISCARD

COMMENT—Discarded hoist ropes are the most valuable source of information for any development of more meaningful and useful removal criteria.

Currently, discarded hoist ropes are best used in a comprehensive inspection program that involves tensile tests to failure of many samples from the rope, NDT records made at or just before or after removal, and careful examination of the tensile test and other samples inside and out. The goal is to correlate what can be observed and measured while the ropes are in use with the actual strength of the rope, thus providing a directly meaningful base for judging when to remove ropes. As yet, there are no domestic facilities for pursuing such an effort for the mining community as a whole.

The next best use of a discarded rope would be to tensile test to failure one or two samples from the weakest section, to compare the actual strengths with the removal criteria used, and to examine the interior of the rope in the weakest area as well as in several of the typically critical areas. The goal is to obtain a better feeling of what is occurring, how well the criteria relates to strength, and, perhaps, to a decision to use the ropes longer (or even not as long) or to modify lubrication, etc. practices. Less comprehensive than the first, this approach is one that any operator could currently pursue.

If nothing more, discarded ropes should be opened up and inspected in the areas that determined removal as well as at several of the major critical areas; e.g., at terminations, sheaves, areas of smaller than usual diameter, etc. The object, again, is to get a better feeling for what is happening to the rope, particularly with regard to effects of lubrication practices.

Chapter 6
Guide and Tail Ropes

Chapter 6
Guide and Tail Ropes

135

6.1 GUIDE (AND RUBBING) ROPES

REGULATION — Guide ropes must be of locked-coil construction (57.19–54 M).

HAZARD — Failures of guide or rubbing ropes can lead to conveyances colliding with each other or with the sides of the shaft.

DESCRIPTION — Wire ropes are sometimes used for conveyance guides in vertical shafts. They are usually installed one at each corner of the conveyance, but may all be at one side. Rope guides do not have the lateral stability of fixed steel or wood guides, and the conveyances can swing horizontally somewhat. Rubbing ropes are sometimes placed between "compartments" on two-conveyance systems to prevent the conveyances from colliding when passing.

Locked-coil constructions—half- or full-locked coil or strands—are called strand instead of rope because they are laid up like the strand in ordinary rope. The value of these constructions in this application stems from their smooth surface, which more evenly distributes wear among the wires. Round-wire track strand could also be used. Furthermore, 1 x 7 rope is often used in other countries. This rope resembles a regular 6 x rope, except that the "strands" are solid, large-diameter wires, six on the outside and one in the center.

SELECTION — A safety factor of no less than 5 is suggested for guide and rubbing ropes. This should be computed on the basis of catalogue breaking strength and total static load—weight of rope in shaft plus weight of tensioning weights and gear.

Guide ropes less than 1 inch in diameter are of doubtful value. Usually, they are about 1-1/2 inches or more in diameter. Rubbing ropes should never be smaller in diameter than guide ropes and preferably should be larger.

Guide and rubbing ropes must be tensioned, and the tension is normally provided by stacked weights suspended from the lower end. An average tension of about 7 pounds per foot of rope is common. However, the tension in each rope should be different to prevent them from swaying in unison, and individual tensions ranging from 10 percent above to 10 percent below the average tension are suggested.

Galvanized guide and rubbing ropes are recommended for wet, corrosive shafts unless there will be adverse reactions with the zinc. Although the zinc will be worn off the surface, it will remain on the interior, providing protection where corrosion is always a problem.

6.1 GUIDE (AND RUBBING) ROPES

INSTALLATION — Wedge-type rope-handling glands are most often used for end terminations. The rope should pass through the gland as straight as possible and extend 3 to 5 feet beyond. Ends should be sealed if possible. Two 2-bolt clamps, grooved to fit the rope, should be installed one above the other against the wedges. These clamps should be installed at 90 degrees to each other, forming a cross. An extra 2-bolt clamp is sometimes installed several inches away from these clamps as an indicator of rope slip.

Install guide and rubbing ropes with much care. As these ropes are stiff, permanent bends are induced easily and will wear rapidly; sheaves used during installation should probably have diameter ratios on the order of 50 or more. At the shaft bottom, tensioning gear should be allowed to move vertically, but should not be permitted to rotate; otherwise, the rope may unlay. Tensioning gear is often attached at the collar and lowered with the rope; prevent spinning as much as possible while the rope and gear are lowered.

Use sleeves or some other kind of chafing protection where guide and rubbing ropes pass through bulkheads.

INSPECTION/MAINTENANCE — Keep ropes well lubricated to control corrosion as well as to reduce friction between these and the conveyance guide shoes and rubbing surfaces. Pay particular attention to the end terminations, especially those at the bottom.

Keep water and muck in sumps away from tensioning gear and ropes. A sump water-level indicator that warns the hoistman of an excessively high water level is useful.

Guide and rubbing ropes dirtied by shaft spills or sand-pipe breaks, for example, should be cleaned off and relubricated.

Periodically rotate these ropes about 1/4 of a turn to distribute wear around the circumference.

Look for broken wires at end terminations. Although these are standing ropes, they oscillate, and wire-fatigue breaks can occur at the entrance to end terminations. If possible, guide and rubbing ropes should be initially longer than necessary. This will permit them to be shortened should fatigue breaks at terminations be a particular problem.

Look for broken wires in active portions and if possible cut them off and file the ends smooth without scarring other wires. Protruding broken wires may catch in a conveyance guide shoe and cause serious rope damage.

INSPECTION/REMOVAL — Removal of a rope is recommended when:

(1) The strength reaches 75 percent of the original, or

(2) Severe surface corrosion exists, or

(3) Constructional distortions appear.

Nondestructive inspection can be used to determine remaining strength, and the following schedule for A.C. electromagnetic inspection (NDT) is suggested:

(1) Every 12 months, or

(2) Every 8 months after a loss of 5 percent or more strength is indicated at any point, or

(3) Every 4 months after a loss of 10 percent or more strength is indicated at any point.

Carefully examine visually each rope at any point where the inspection device indicates an irregularity or a loss of strength.

138

6.2 TAIL (BALANCE) ROPES

HAZARD — Failures of tail ropes can lead to loss of conveyance control.

DESCRIPTION — Domestically, at least, tail ropes are used only on friction hoists. They hang below the conveyances and compensate for differences in the weight of the hoist ropes in each compartment. Each end is attached to the bottom of a conveyance (or a counterweight), and the rope runs to the bottom of the shaft and makes a U-turn between compartments. Several ropes are usually used; but no matter how many there are, their combined weight per foot must equal the combined weight per foot of the hoist ropes. In this manner the hoist always "sees" the same rope weight on each side no matter where the conveyances are located; thus, the alternate name, "balance" ropes.

SELECTION — Flexible, nonrotating constructions are most common, and galvanized ropes are recommended for wet, corrosive environments, except where there will be adverse effects on the zinc (e.g., potash mines).

The safety factors applicable to hoist ropes are suggested for tail ropes unless otherwise advised. The safety factor should be computed using the catalogue breaking strength of the rope and the total static load of the rope itself*.

INSTALLATION — Wedge-type terminations are most often used on tail ropes (see 5.2.1).

Some form of control of tail ropes and their loops is necessary at the shaft bottom; without it the ropes may foul and tangle each other or a rope may twist about itself, forming a closed loop or a knot which may ride up the shaft. Such tangles and loops can severely damage the ropes. Wide boards separating tail ropes and timbers through loops are common control devices; large-diameter sheaves are sometimes used. The bottom of the loop will naturally move up and down, particularly during acceleration and deceleration of conveyances; thus, timbers through the loops must be far enough above the bottom of the loops to permit this motion without fouling the rope. Similarly, loop control sheaves have to be mounted in guides and weighted, like tensioning sheaves, to accommodate this motion.

An automatic loop monitor has value. A device much like a slack rope detector could be used—a small cable strung through and above the bottom of the loop and attached to a limit switch. If the bottom of the loop rises too high, or if a tangle hits the cable, an alarm would be sounded in the hoistroom. For fully automatic modes of operation this monitor could be wired to shut down the hoist.

*Recent work by Battelle and others shows that significant loss of breaking strength can occur in stranded nonrotating ropes with free swivel terminations. The work is not yet complete nor have the ramifications for selection and application of ropes all been sorted out yet. Clearly, some reduction in catalogue or actual breaking strengths will have to be applied during selection processes for some applications. The effects of free swivels on, say, 18 x 7 or 19 x7 constructions used as tail (or hoisting) ropes has yet to be clarified. Therefore, it is suggested that operators be aware of this situation and periodically ask rope suppliers for applicable results of the work in progress.

INSPECTION/MAINTENANCE — Keep tail ropes and terminations clean and well lubricated. Internal corrosion is the most common form of degradation. Corrosion is most likely at the bottom loop when the conveyances are at the most commonly used stations.

Look for polished areas on the surfaces, particularly if no sheaves are used at the bottom. They indicate that the ropes are striking something (or one another), inducing not only surface wear but also wire nicking between strands. Do what is possible to eliminate such chafing: relieve some twist, install some boards, etc.

Keep automatic loop monitors clean and operable.

INSPECTION/REMOVAL — Removal of a rope is recommended when

(1) The strength reaches 85 percent of the original, or

(2) Severe corrosion is evident,

(3) The number of broken wires per lay exceeds six

(4) Constructional distortion appears (e.g., kinks, knots, birdcages, etc.).

Nondestructive inspection can be used to determine remaining strength, and the following schedule for A.C. electromagnetic inspection (NDT) is suggested:

(1) At the end of 12 months' service, then

(2) Every 8 months, or

(3) Every 4 months after a loss of 5 percent or more strength is indicated at any point.

Carefully inspect visually any point on the rope where the inspection device indicates an irregularity or a loss of strength.

Chapter 7
Conveyances and Counterweights

141

Chapter 7
Conveyances and Counterweights

7.1 CONVEYANCES*—STRUCTURAL

REGULATION — There are regulations that relate to structural design (57.19–45 M and 75.1403–3(d)) and to design or application of connections to rope or other conveyances (57.19–75 M and 75.1403–7).

HAZARD — Failures of structure, guide shoes and wheels, or connecting links can lead to disastrous accidents.

INSPECTION/TESTING/MAINTENANCE —

GENERAL

Good practice calls for keeping extra conveyances. Not only can they be used in an emergency, but a regular maintenance/reconditioning program can be applied as conveyances are periodically rotated out of service.

Good practice also calls for routine cleaning to remove any accumulation of dirt. An air hose is an effective tool. Blowing (or washing) out the inside of trailing cages to remove muck and rocks before a shift change may prevent injuries.

FRAME/BODY

Look for and repair cracks in frames and major body members. Nondestructive inspection techniques can be a valuable aid (see 2.6).

Look for and repair loose and broken sheeting, flooring, gates, and gate latches.

Look for and repair loose or missing bolts, rivets, etc.

Look for and remove tools and materials that catch in cracks or openings and protrude outside. They can catch on guides, sets, linings, and crossties.

Look for and repair wear, looseness, and damage to dump gates, gate-operating mechanisms, and all hinges and pivots. Keep hinges and pivots clean and lubricated.

*Conveyance means all carriers of men as well as of product and materials—skips, cages, platforms, buckets, mantrips, gunboats, etc.

Look for and repair broken, damaged, or loose bonnets; maintain components of inspection platforms in good repair.

Maintain removable inspection platforms and skip seats in good repair, particularly components used to fasten these items to cages and skips.

RUNNING GEAR

Look for and repair loose or worn wheels. Gently prying with a wrecking bar is a simple way to check for both loose fastenings and worn bearings.

Keep bearings clean and lubricated. (Factory-lubricated and sealed bearings are much less prone to dirt problems and are easier to maintain.)

Look for and repair loose and worn guide shoes. Replace worn shoes before wear affects shoe fasteners. Worn shoes that tear loose can cause significant damage.

Pay particular attention to shoes running on wire rope guides—check them daily. Leading and trailing edges should be maintained rounded or chamfered and free of burrs, and the shoes well lubricated.

CONNECTORS

Clean and carefully inspect bails, links, chains, wire ropes, and all fittings connecting conveyances to hoist-rope terminations and to other conveyances. Especially look for cracks at holes for connector pins. Repair cracking and wear of bails; replace worn or cracked links, chains, and ropes. Connecting and safety ropes between conveyances are prone to the same ailments as hoist ropes; the greatest danger will probably be from corrosion, especially on the inside of the rope and under fittings. Don't repair cracked or worn pins—replace them.

NOTE: Critical connecting elements (e.g., bails) as well as major frame components are prime candidates for nondestructive inspection (see 2.6).

COMMENT — The structural integrity of major frame and connector elements is an absolute necessity since they carry the large loads that can be induced by hoist brakes or conveyance safety catches and brakes (see 7.2.3, .4, and .5) during an emergency stop. Some countries require annual dissassembly and inspection, often by nondestructive techniques, of these and other major hoist components.

Rubber-tired guide wheels can drastically reduce wear and maintenance of shaft guides. To be most effective they should bear on the guides at all times; this requires metal or elastomeric springs in the mounts to lessen shocks from uneven or misaligned guides. If these wheels are used and guides continue to wear significantly, something is probably wrong with the installation or the design of these wheels and their mounts. Generally, higher hoisting speeds call for larger diameter wheels to minimize wheel bearing failure. Furthermore, these wheels should be set up off-center to counteract hoist-rope spin (see 5.5.6) which, without wheels, tends to wear the guides on one side. This setup minimizes shoe contact (hence, wear) if misalignments cause the wheels to bounce.

166

7.2 CONVEYANCES—SAFETY DEVICES

7.2.1 COMMUNICATIONS SYSTEMS

REGULATION — "A method shall be provided to signal the hoist operator from cages or other conveyances at any point in the shaft" (57.19-92 M).

HAZARD — Conveyances can encounter many situations that may prove fatal to the men aboard. These men are usually the first to become aware of these situations, and a communications system that permits them to notify the hoistman or shut down the hoist can provide a measure of safety otherwise unavailable.

DESCRIPTION — Systems permitting communication between conveyances and hoistman include the traditional pull-cord-operated signals, using a pull cord suspended throughout the shaft, and the more recent electrical or electronic devices on conveyances that permit voice, bell, buzzer, or horn communication with the hoistman and, perhaps, between conveyance and shaft stations.

Electrical devices can also be arranged to permit hoist shutdown. The electric signals can be transmitted via a trailing cable or inductively along the hoist rope. Hoist-rope inductive transmission systems use an antenna (coil or straight wire) atop the conveyance and a pickup antenna usually near the head sheave; power is provided by a conveyance-mounted battery. Transmitting devices can be permanently installed; or they can be of the portable, plug-in type that can be used for cage-top shaft inspection as well as during regular hoisting.

INSPECTION/TESTING — If regular operations do not provide a more-or-less continuous check, specifically operate all communication systems daily.

INSPECTION/MAINTENACE — Maintain pull cords in good condition.

Keep the electrical equipment out of harm's way; protect with shields if needed.

Look for and repair chafing or fraying of all trailing cables, and for damage to or interference with antennae. Eliminate sources of this damage as much as possible.

Periodically check and/or replace the batteries. (How often depends upon use and battery capacity.)

COMMENT — Electrical conveyance-mounted systems would appear to fulfill the signaling-system need better than pull-cord-operated systems in many cases. Full shaft bell cords are not feasible in deep vertical shafts, although they have been roof-suspended with success in long slopes. In any case, however well they may serve for shaft inspection, in regular hoisting it seems that a hand could be severely injured or easily lost in an attempt to use these cords, if they could even be reached.

With regard to shaft inspection activities, some means of communication between the men atop the conveyance and the hoistman is highly desirable. If an electronic system is not used and if a full shaft bell cord is not feasible, at least install bell cords near each end of travel, and particularly beyond the usual top and bottom stations. Men atop cages have been slowly hoisted into the headframe timbers because there was no way to signal the hoistman.

At the bottom, the electrical communicating devices are no different than devices that permit complete control of the hoist from the cage (see 3.1.2); in practice, however, these devices usually provide for no direct control other than perhaps initiating an emergency stop.

There are several reliable commercially available electronic systems fitting the general descriptions given earlier. In addition, attempts have been made to provide a direct electrical link using conductors built into the hoist rope; this approach is problematic because the conductors usually go to ground or part long before the rope needs to be replaced.

There appear to be no basic technological limitations to adding electrical conveyance-mounted communications devices to any vertical-shaft hoisting system. Inclined shaft systems pose problems. Trailing cables do not seem practical, but hoist rope-antenna links may be practical if the rope is always tensioned and if the rope-support rollers and sheaves do not provide a complete electrical ground.

7.2.2 SLACK-ROPE DETECTORS

HAZARD — The major causes of slack in hoist ropes are conveyances stuck in tight guides, impeded by broken guides or dislodged shaft timbers, caught in loading or dumping chutes, derailed for any reason, lowered against bulkheads, etc. Disastrous accidents have occurred when the slack has spilled into an adjacent compartment and fouled an ascending conveyance; and when a stuck conveyance has become unstuck, the slack runs out, and the rope snaps.

DESCRIPTION — Slack-rope detectors on conveyances typically use limit switches that detect the motion of conveyance safety-catch operating mechanisms. Signals are transmitted to the hoistroom via a cage-communication system to give warning or shut down the hoist.

INSPECTION/TESTING — Manually actuate the detector and confirm that intended action occurs.

INSPECTION/MAINTENANCE — Keep detector devices clean, lubricated where needed, and protected from debris.

COMMENT —The devices described above need a communications link to the hoistroom and, thus, can only be used in conjunction with some type of cage-control or cage-communications system (see 7.2.1). A slack-rope detector is offered as an option with some of these systems.

It should be noted that the safety-catch mechanism is the basic detector of slack rope for the devices described above. In the absence of safety catches, or with catches that are actuated by other than loss of rope tension, detection requires ingenuity and may not always be possible or practical.

7.2.3 SAFETY BRAKES—INTRODUCTION

REGULATION — "Cages, platforms, or other devices which are used to transport persons in shafts and slopes shall be equipped with safety catches or other no less effective devices approved by the Secretary that act quickly and effectively in an emergency, ..." (75.1400).

COMMENT — Few hoisting-system components are as notorious as conveyance safety catches. In large measure, this notoriety is undeserved and arises more from a lack of interest in dealing with their problems than from any lack of technological alternatives.

A thorough review of the safety-catch problem shows the following:

(1) There is ample evidence to support the contention that, as a general type of safety device, conveyance safety catches can provide protection otherwise unavailable. This is stated with full recognition of the historical debates about the unreliability of safety catches as a class, and with an understanding of why this is so.

(2) "Catch" implies a quick stop and its use is regrettable. So is the word "quickly" in the regulation. As for an emergency stop induced by the hoist brakes (see 2.4.6), there are practical reasons why a safety catch should not stop a conveyance as quickly as possible. In this sense, "safety brake" would be a far better term.

There are two aspects that must be dealt with in designing a safety brake: (a) actuation and (b) performance during and after a stop. Actuation addresses the principles and methods used to bring the brake into action. Historically, safety catches have been designed to actuate automatically in the event of a loss of tension in the hoist rope; this loss covers a broken rope as well as a descending conveyance that sticks. However, there are situations in which actuation by overspeed or manual command from the conveyance is highly desirable; both are technologically possible and have been done.

Performance during a stop involves the deceleration induced. There is a mechanically necessary lower limit determined by the weight of the conveyance and load, usually 1 g for vertical shafts—necessary because otherwise the conveyance may not stop. There is also, a humanly (physically) acceptable upper limit, typically between 2 and 3 g's for vertical shafts. Performance after stop involves both the capacity of the brake to hold the conveyance in place (preferably indefinitely), and the method for releasing the brakes.

A 1–3 g stop is much rougher on men than the 1/2 g stop being sought in emergency hoist-brake stops in vertical shafts. However, there are more options available for controlling an intact hoist system than there are for controlling a free-falling conveyance. Furthermore, the hopefully infrequent need for safety-catch stops and the relatively harsh environments in which these catches typically operate call for a reliable braking capability under any circumstances with a minimum of mechanical complexity. Although a reasonably comfortable stop is ideal, 1–3 g's is survivable and can be achieved with a fairly high degree of certainty.

140

7.2.3 SAFETY BRAKES—INTRODUCTION (Continued)

(3) The design of a conveyance safety brake is a systems design problem. It involves, foremost, the design of the brake mechanisms on the conveyance and the design of the shaft guides and supports. In turn, the general design of the conveyance and the shaft can be affected. If a designer forgets he is designing a brake that depends on the guides, or if the "safety catch" is an afterthought, the result is usually worthless.

Furthermore, it is necessary to face the fact that, as for many components of a hoist system, each conveyance safety brake is likely to be custom made to some degree. This does not mean that the basic principles or the basic design may be different in each case, but it does mean that the dimensions or the general configuration of the components may commonly differ from one installation to the next.

This custom-built nature is really a boon since it permits great flexibility. But in many retrofit situations the lack of a specifically suited and readily available safety catch is often the excuse for doing nothing, particularly if major modifications to the guide system are also necessary. Reality requires accepting the fact that a high cost for retrofit can itself be justification for doing nothing; but such decisions should be amply supported by good engineering estimates that consider what technology does offer.

(4) Current technology offers the following:

- Actuating mechanisms that respond to loss of hoist-rope tension, overspeed of conveyance, reversal in direction of conveyance motion, manual actuation
- Highly reliable dogs for wood guides that can be designed to produce whatever braking force is needed
- Proven braking elements for T-rail and tubular metallic guides.

These and other concepts, some of unknown reliability and others of known unreliability, are discussed in further detail in Sections 7.2.4 and 7.2.5.

NOTE: A conveyance safety brake should be capable of safely stopping an empty or full conveyance from any speed. More work is required to stop a full conveyance descending at speed than to stop an empty ascending conveyance or one moving slowly; a brake system that can handle the former safely can automatically handle the latter safely, but not necessarily vice versa. Sections 7.2.4 and 7.2.5 are written with concern for a comprehensive braking capability—a brake system that can handle the easy but not the hard task is no good.

149

7.2.4 SAFETY BRAKES—VERTICAL SHAFTS

REGULATION —See 7.2.3.

HAZARD — A disaster is the likely result of a failure of safety brakes to operate effectively when needed.

DESCRIPTION — Two conveyance brake elements have been proved reliable and capable of providing a reasonably smooth stop. One is the single-tooth dog for use with wood guides, shown in Figure 7.1. The other is the Type B, wedge-clamp device used on elevators, shown in Figure 7.2. Both devices have been proved reliable in extensive testing during development and or use.

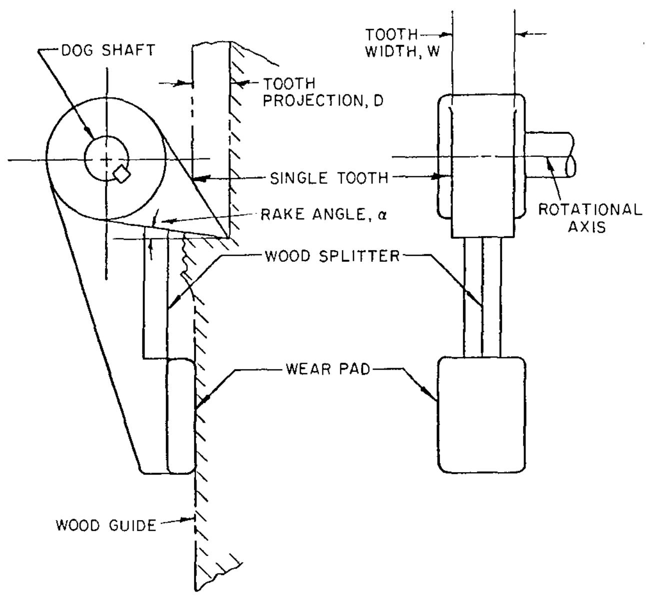


Figure 7.1. Single-Tooth Dog for Wood Guides, Showing Major Elements and Design Parameters

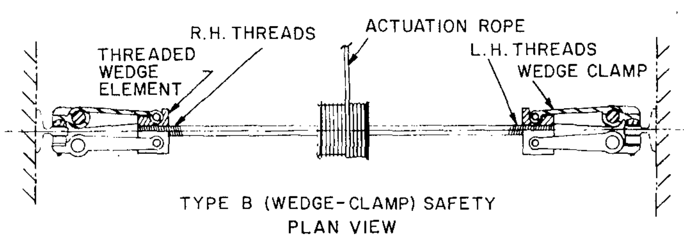


Figure 7.2. Type B Elevator Safety Brake System

The single-tooth dog produces a constant force essentially independent of the speed of the conveyance. The design automatically compensates for some degree of guide wear. Tooth width, tooth projection (i.e., penetration), and rake angle all are design parameters; the greater the tooth penetration and the smaller the rake angle, the greater the braking force. Guidewear compensation occurs because although penetration is less with wear, the rake angle is also less since the wear pad must travel farther before contacting the guide. (This or any dog should be used in pairs, each working on the side of the guide.)

7.2.4 SAFETY BRAKES—VERTICAL SHAFTS (Continued)

The elevator device produces a force that increases as the conveyance slows; in use, the cage normally stops well before the maximum available force has been developed. This brake is applied by a wire rope—the governor rope—that extends throughout the shaft. The elevator device is not known to have been applied to a conventional mine hoist. A governor rope may be problematic, undesirable, and even impossible. But there are other ways to actuate this brake, and its principles seem to remain unapplied domestically to mine hoisting for lack of engineering attention.

Dogs for wood other than that shown in Figure 7.1 are not recommended unless they have been or can be demonstrated to be safe. Many of the multi-toothed wedge and cam dogs which are currently in use have been proved by special testing to be highly unreliable. They either foul with wood spoil and slide or induce unnecessarily high forces in their own mechanisms and in the guides—enough force, in some cases, to destroy themselves and the guides as well.

Except for elevator devices, there is no definitive data available by which to judge the performance capability of any dog, cam, or wedge operating on T-rail or other steel guides, on wire-rope guides, or with auxiliary ropes. However, judging by the performance of many cams and wedges on wood, it seems probable that most multi-toothed cams and wedges in use with steel guides will slide or develop destructively high forces. *These are subjective judgments; objective judgements require test data.*

All the above brake elements require actuation mechanisms. The mechanism shown in Figure 7.3 is one design that implements the most commonly used approach: actuation by springs which are normally held compressed by the tension in the hoist rope. In general, compared to difficulties encountered with dogs, cams, and wedges, actuation mechanisms present few problems. However, the following aspects of the design of these devices should be noted:

(1) Springs used in compression are more reliable than those used in torsion or tension.

(2) The force required to compress these springs (i.e., to set the mechanism or retract the dog) should vary between 30 and 70 percent of the weight of the empty conveyance. As a rough guide, 35 to 45 percent for hoisting speed of about 1200 feet per minute and higher; 45 to 55 percent between about 800 and 1200 feet per minute; and 55 to 65 percent up to about 800 feet per minute.

(3) Slotted links (see Figure 7.3) or any other so-called antitrailing-rope devices are not necessary with the spring-compression values indicated above, and may cause the dogs to set inadvertently. The trailing-rope hypothesis—that a rope break well above the conveyance will lead to sufficient tension in the rope to prevent safety-catch actuation if the trailing rope snags on the guides and sets or drags against them—is not supported by fact.

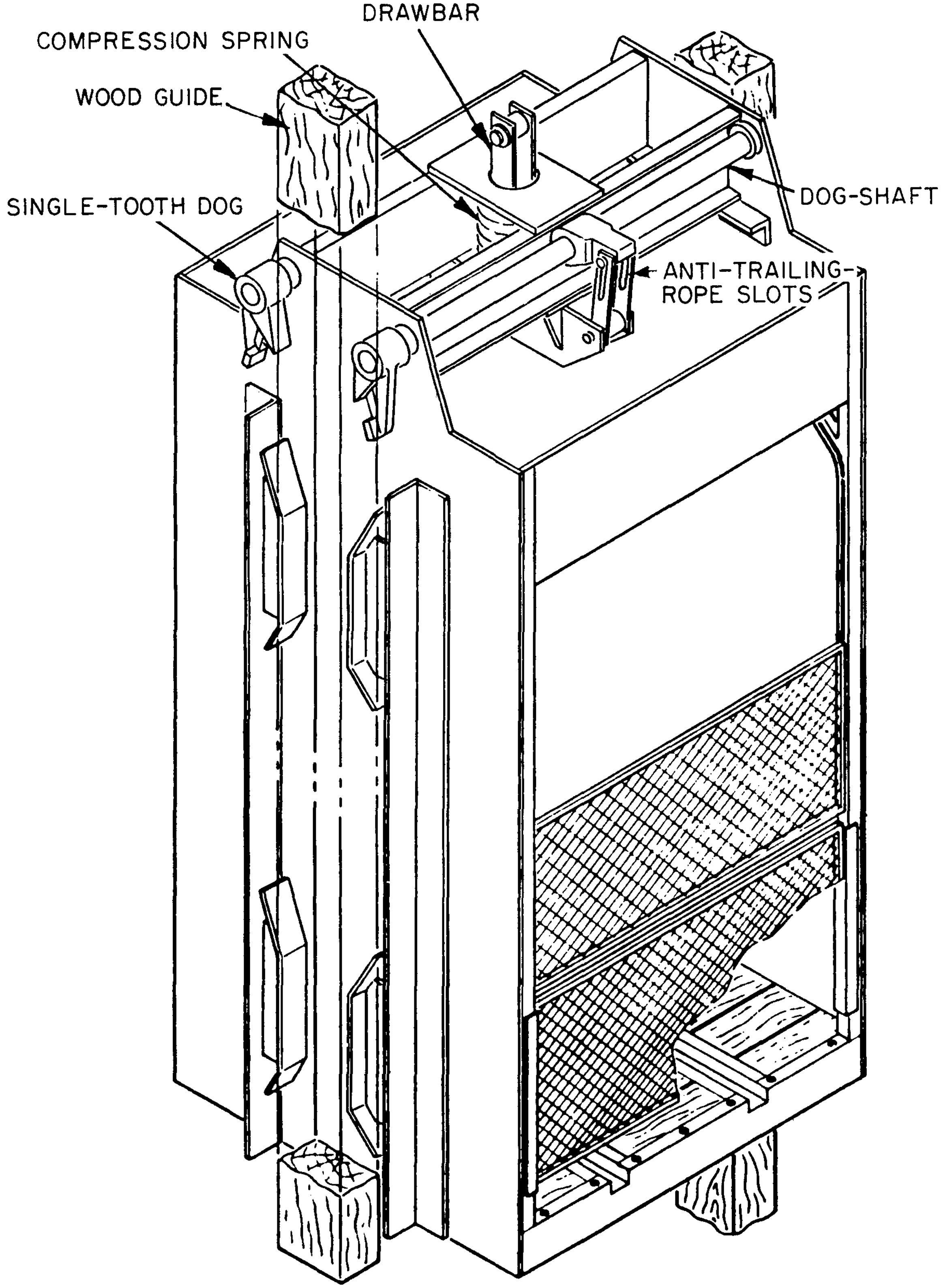


Figure 7.3. Example of a Conveyance Safety Catch Actuating Mechanism

7.2.4 SAFETY BRAKES—VERTICAL SHAFTS (Continued)

INSPECTION/TESTING

ACTUATION TEST

PURPOSE

To determine whether or not the brake-actuation sensors and mechanisms are working properly.

PROCEDURES

(1) For actuation in the event of slack rope:

- (a) Chair or block the conveyance.
- (b) Slack the hoist rope.
- (c) Confirm the ability of the mechanisms to bring the braking elements (shoes, dogs, etc.) into contact with the guides.
- (d) If the system does not actuate, look for the causes, and repair immediately.

(2) For manual actuation:

- (a) Chair or block the conveyance.
- (b) Push the button, pull the lever, or otherwise actuate the device.
- (c) Confirm the ability of the mechanisms to bring the braking elements (shoes, dogs, etc.) into contact with the guides.
- (d) If the system does not actuate, look for the causes, and repair immediately.

(3) For actuation in the event of direction reversal:

- (a) With the conveyance stationary, set the mechanism for actuation with down-shaft motion.
- (b) Start to hoist slowly, then begin to lower slowly.
- (c) Confirm the ability of the mechanisms to bring the braking elements (shoes, dogs, etc.) into contact with the guides.
- (d) If the system does not actuate, look for the causes, and repair immediately.

(4) For actuation in the event of car separation:

- (a) Block the conveyances.

(b) Manually disconnect the brake lines or whatever pulls apart to actuate the brakes in the event of trip separation.

(c) Confirm the ability of the mechanisms to bring the braking elements (shoes, dogs, etc.) into contact with the guides.

(d) If the system does not actuate, look for the causes, and repair immediately.

(5) For actuation in the event of conveyance overspeed:

This mode of actuation is neither easily nor realistically testable with a conveyance stationary or slowly moving. A conveyance-mounted governor-like device is involved (e.g., a centrifugal switch in an electric brake system). If this device can be easily tripped manually, follow the procedure for manual actuation, Item (2) above. If not, then actuation will have to be tested along with performance (see below). However, it is necessary to assure that the speed at which the conveyance governor trips is properly set and has not changed. This may require removal of the governor for bench testing; nevertheless, it should be done at least twice a year if not testable otherwise.

NOTE: The speed at which a conveyance-mounted safety-brake governor trips should always be somewhat greater than the speed at which the hoist overspeed controller trips.

Test every mode of actuation built into the safety-brake system.

NOTE: An actuation test can tell nothing about whether or not the brakes can stop a moving conveyance.

PERFORMANCE TEST

PURPOSE

To determine whether or not the brake system can stop a loaded, descending conveyance.

PROCEDURE

Conduct a Free Fall Test—step-by-step instructions for testing and evaluation are given in Appendix C, "Conveyance Safety Brake Testing".

CAUTION: A Free Fall test is rigorous. It should never be conducted with equipment whose potential for performance is unknown or questionable. In these cases begin with a Drop Test and work up to a full Free Fall test in accord with the instructions given in Appendix C.

154

7.2.4 SAFETY BRAKES—VERTICAL SHAFTS (Continued)

INSPECTION/MAINTENANCE — Keep all mechanisms clean, and lubricated where needed.

Coating all parts with heavy grease can help control corrosion, but periodically the grease should be completely removed, the mechanisms carefully inspected, then repacked.

Cutting edges on dogs for wood must be maintained sharp. Use a file if necessary but with care—the shape of the cutting portions cannot be radically changed without also changing the performance characteristics. Paint or heavy grease can help control corrosion and should not affect the braking performance since it will be wiped off quickly when the dogs are brought into use.

Keep actuating mechanisms, particularly those atop a conveyance, protected from debris and tools that may fall down the shaft. Accidents have occurred when such items have fouled the actuating mechanism. A metal shield is valuable, but must be openable or removable to permit inspection and maintenance.

Periodically—say yearly—disassemble, clean, inspect, repair or replace parts if needed, and rebuild mechanisms. Pay particular attention to springs and other powering devices; check springs for loss of compressive force and replace if loss is greater than 10 percent.

COMMENT — Safety brakes that can be actuated manually at the conveyance can provide a measure of protection otherwise unavailable. Manual actuation should be used only on unbalanced hoist systems in shafts with one hoisting compartment unless manual actuation of the safety brakes also shuts down the hoist. Otherwise, slack rope may cause additional problems, principally with other conveyances.

7.2.5 SAFETY BRAKES—INCLINED SHAFTS

REGULATION — See 7.2.3.

HAZARD — A disaster is the likely result of a failure of safety brakes to operate effectively when needed.

DESCRIPTION — Although few are used domestically, conveyance safety-brake systems available for inclined shafts show a greater variety of design than those for vertical shafts.

There is no definitive performance data available for any of these systems. The major concern is the deceleration induced during a stop—it is relatively easy to throw a man facing downslope off his seat into the seat or bulkhead in front of him, into the car roof, against the hanging wall or overhead timbers, or off the car and down the shaft. Note, again, the systems nature of the problem—the design of a safety brake for inclined-shaft conveyance *must* take into consideration the design of the conveyance and the direction the men face.

Of the brake systems in use or available, the following appear to be potentially safe and reliable:

(a) Cars equipped with magnetic track brakes (electric actuation);

(b) Systems that grip the sides of rails or tubular guides; actuated hydraulically, pneumatically, electrically (magnetic) or with compression springs;

(c) Systems using the dogs shown in Figure 7.1 acting on auxiliary wood guides or stringers (not crossties!) beneath, between, or alongside the rails;

(d) Systems using a capstan brake acting on an auxiliary rope strung throughout the shaft (care of the auxiliary rope is of the utmost importance).

These systems can be equipped for actuation under any of the following conditions:

Loss of hoist-rope tension, conveyance overspeed, reversal of direction or motion, separation of trips, loss of pressure or power, and manual command.

Brake-system types (a) and (b) are usually not recommended (by the manufacturers) for slopes greater than 20 degrees (1 in 5). Types (c) and (d) appear applicable to any inclination. The proven reliability in vertical shafts of dogs like that of Figure 7.1 would appear to make type (c) systems worthy of much wider application. *These are subjective judgments; confirmation requires test data.*

Of the systems in use or available, the following appear extremely hazardous and should not be used unless they can be demonstrated safe:

7.2.5 SAFETY BRAKES—INCLINED SHAFTS (Continued)

(a) Buck hooks or similar anchor-like devices

(b) Drags

(c) Underslung devices that drop down and are overridden by the conveyance to provide weight for braking.

These devices can induce high-impact loads that may destroy or derail conveyances.

INSPECTION/TESTING/MAINTENANCE — Same as for vertical shaft devices—see 7.2.4 and Appendix C.

NOTE: Acceptable limits to deceleration for safety brakes on slope conveyances have yet to be established; they will, however, undoubtedly be much less than the usual 1–3 g's applied to vertical shafts. Until some general guidelines can be established operators are urged to experiment in accord with the suggestions in Appendix C.

COMMENT — Safety brakes that can be manually actuated at the conveyance provide a measure of protection otherwise unavailable. This capability should be used only on unbalanced hoist systems in shafts with one hoisting compartment, unless manual actuation of the safety brakes also shuts down the hoist; otherwise the slack rope may cause additional problems, principally with other conveyances.

7.2.6 CARS STOPS/BLOCKS

REGULATION — Car stops or blocks are required on all cages or skips that carry mine cars (57.19-79 M).

HAZARD — If a car rolls partially or completely off a moving conveyance, major conveyance and shaft damage is likely.

DESCRIPTION — Car stops include permanently mounted devices that can be swung over the rail or raised above the rail surface, or sections of the rail that drop down, or bars across each end of the car; all should prevent a car from rolling.

NOTE: Loose chains, wedges, and blocks should not be used; they can be dislodged too easily.

INSPECTION/TESTING/MAINTENANCE — Look for and repair broken or missing car stops.

Keep devices clean and lubricated where needed so they are always operable.

COMMENT — This regulation would seem to have equal value for coal-mine hoisting.

7.2.7 DUMP-CAGE LOCKS

REGULATION — "Self-dumping cages, platforms, or other devices used for transportation of men should have a locking device to prevent tilting when men are transported thereon" [75.1403-3(e)].

HAZARD — Lack of, failure of, or failure to use dump-cage locks can lead to men or equipment being dumped into the shaft or bins.

DESCRIPTION — Dump-cage locking devices include a variety of cage-mounted mechanisms that permit the body to be locked to the main frame or bail.

INSPECTION/TESTING/MAINTENANCE — Look for and repair worn, broken, or missing locks.

Keep mechanisms clean and lubricated where necessary so they are always operable.

Apply guards if needed so locks cannot be unlatched by debris falling in the shaft.

COMMENT — Accidents with dump cages are not too common, but some have been spectacularly tragic. Usually, cage locks must be manually operated and there is the danger they won't be set when men are hoisted. This danger can be countered partially with overtravel protection specifically for man hoisting if the dump is above the top man station (see 3.2.2).

This regulation would seem to have equal value for metal and nonmetal mine hoisting.

7.2.8 CHAIRS

REGULATION — "Chairs should be used to land shaft conveyances when heavy supplies are being handled" (57.16-35).

HAZARD — Lack of, failure of, or failure to use chairs can easily lead to human injury and equipment damage.

DESCRIPTION — Chairs are chains or sliding or pivoting props that rigidly hold a conveyance in place at a station.

Chairs can be manually or power operated and are usually designed to automatically release when the cage is hoisted.

NOTE: Chairing mechanisms may be found installed in the shaft rather than on the conveyance.

INSPECTION/TESTING/MAINTENANCE — Look for and repair worn, loose, and damaged mechanisms. Pay particular attention to limit switches used with power-operated chairs for actuation or to indicate whether chairs are in or out.

Keep mechanisms clean and lubricated where necessary so they are always operable.

Unused chairing mechanisms should be removed or made inoperable.

COMMENT — Lack of or failure to use chairs recurringly causes severe injury and death in the mining world, particularly when heavy motors or similar equipment are being transported. For example, as soon as the motor is half on or off, the cage sinks or lifts, tipping the motor over or causing it to roll uncontrollably on or off. Chairing mechanisms should be applied to every conveyance where such incidents can occur and, of course, they should be used.

7.2.9 SAFETY CHAINS/CABLES

REGULATION — Safety chains or cables are required in coal mining [75.1403-36(b)] and suggested when possible in noncoal mining (57.19-27).

HAZARD — The basic intent of the regulation is to provide protection against failures of the hoist rope or its end fittings at the conveyance.

The real hazards are

(a) Hoist-rope damage caused by fittings that connect safety chains or cables to the hoist rope (see 5.2.2);

(b) Probable failure of safety chains and cables due to poor design, installation and maintenance; and

(c) In many cases, the fact that the basic intent cannot be met because of the manner of installation.

DESCRIPTION — These devices consist of chains or cables attached to the conveyance at one end and the hoist rope at the other end; chains or cables attached to the conveyance at both ends and passing through holes in thimbles, or through bails on the fittings attached to the hoist ropes.

COMMENT — The use of safety chains and cables undoubtedly stems from the historic problems with hoist-rope terminations: ropes can slip through clips and thimbles and wedges, ropes can fail at or just inside sockets (poured sockets can also be difficult to make up properly). Perhaps these difficulties have led to the belief that the weakest point on a hoist rope is or develops at the conveyance termination. This may be so in some installations. However, the experience of people who routinely and comprehensively inspect and test discarded hoist ropes shows that the weakest point of the rope is just as likely to develop elsewhere; for many installations, it always develops elsewhere. It all depends on the nature of the particular hoisting installation and on the way the hoist ropes are maintained.

If safety chains or cables are to protect against rope failures at terminations they must be independent of these terminations, and attached to the hoist rope above them. They should never be attached to the hoist rope with the same clips used to terminate a hoist rope. Furthermore, safety chains or cables that pass through holes in thimbles, for example, cannot protect against hoist-rope problems at the termination; they can cover only a failure of the connector pin or the parts of the thimble and the conveyance through which the pin passes.

Equally important is the load-carrying capacity of these chains and cables. They are invariably slack under normal conditions. Thus, if called into action they will experience impact loads that will be *at least twice* and, typically, *far more than twice* the weight of the conveyance and its load.

Proof tests of these chains and cables are not required and are apparently never made. This situation, the problems that their attachment to the hoist rope can cause (see 5.2.2), and the fact that conveyance safety brakes can provide more comprehensive protection raises serious questions about the entire practice. Field observations indicate that the vast majority of these devices are probably safe in name only.

162

7.3 COUNTERWEIGHTS

HAZARD — Counterweights tend to be forgotten. Usually, they move as fast and weigh more than the associated conveyance (usually the dead weight of the conveyance plus one-half the weight of the maximum load that may be carried); thus, they may do similar damage if they are overwound or if they run away.

INSPECTION/TESTING/MAINTENANCE — Maintain guards (e.g., fences) around counterweight compartments at collars and all shaft stations.

Treat counterweights as if they were conveyances as far as load-carrying frames, running gear, and rope connections are concerned (see 7.1).

Pay particular attention to the hoist rope at the counterweight sheaves if counterweights are suspended with a two-part (or more) reeve, especially if the counterweight spends idle time in the same place (see 5.5.2.1).

COMMENT — Unguided counterweights (e.g., those running in pipes) must be suspended on ropes of nonrotating constructions. Otherwise the weight will tend to unlay the rope, causing drum-spooling problems and short rope life.

Safety catches for counterweights are rare. Logic appears to call for them if the associated conveyance is so equipped and the counterweight is guided. Whether or not they should be applied can only be determined by evaluating the trade-offs between the inspection and maintenance involved and the risk of damage and injury without them.

Chapter 8
Guides and Shafts

164

Chapter 8
Guides and Shafts

8.1 GUIDES AND SUPPORTS

HAZARD—Broken guides are an immediate danger to the conveyance and its occupants. Weakened or loose guides are potentially dangerous at any time, particularly if the conveyances have safety catches or brakes (the guides must withstand the braking forces).

DESCRIPTION—Guides in common use are square or rectangular wood stringers and T-, box-, or hat-section steel stringers bolted or screwed to buntons or set timbers. Railroad-style rails are screwed or spiked to wood cross-ties, or to wood stringers set on top of cross-ties or similarly braced. (Newer systems may have rails welded or bolted to steel or concrete cross-ties or supports.) Wire ropes are also used for guides; guide ropes are discussed in Section 6.1.

INSPECTION/TESTING/MAINTENANCE—Look for and fix loose or missing bolts or lag screws attaching the guides to their supports.

Look for and repair or replace damaged or excessively worn guide sections.

Look for and replace rotted wood guides.

Maintain correct face-to-face guide spacing. Maintain as good alignment as possible. Poor alignment induces damaging impact loads in equipment and degrading vibrations in hoist ropes and terminations.

Look for and repair or replace loose or broken fish plates or other connectors between guide sections.

Maintain guide support structures. Guides can be no sturdier than their supports.

Maintain shaft linings, utility lines, conduits, and attachments.

COMMENT—The wide variety of guide sizes, shapes, and materials does not allow a general criterion for limits of wear for replacement. Furthermore, conveyance safety brakes may require their own wear limits. Appendix C, Section C.2.1, discusses the need to ensure that conveyance safety brake shoes or dogs can fully engage the guides; both guide wear and changes in guide spacing can adversely affect safety-brake performance. The limits to guide wear and spacing variations, therefore, must be determined for each installation. Once determined, go/no-go gauges or templates can be easily built for checking both wear and spacing.

165

A general criterion for guide alignment does not seem feasible, either. At bottom, concerns for alignment grow out of considerations relative to maximum hoisting speeds. In general, the higher the speed, the more precise the alignment must be. Thus, alignments need to be no more precise than necessary for the maximum speeds contemplated or in use. On the other hand, guide misalignments caused by ground shifts often have to be lived with. One approach to a general criterion that is feasible is an indirect one, where permissible maximum hoisting speeds are determined by a limit to the horizontal accelerations induced in man cages by guide misalignments (see 1.1). Such a criterion would permit choices—reduce maximum speed, or realign, or some combination of both.

Section 7.1 argues for periodic exchange of "spare" and "regular" conveyances and overhaul of the "regular" conveyances. Swing guides at the collar can be a time-saving aid to this task. Swing guides are guide sections mounted on hinges: latching devices are opened, the guides swung, the conveyance run into the open area and then pulled directly out.

TAPERED GUIDES

Section 3.2.2 discusses the use of tapered guide sections as overtravel protection devices, particularly for friction hoists, although they could be applied to some drum-hoist installations. Tapered guides stop a conveyance through friction as the conveyance wedges between them (guides taper toward the conveyance). To be effective, they must withstand large outward horizontal forces, which in turn are transmitted to the buntons, the set timbers, or whatever supports them. Thus, they and their supports must be sufficiently strong initially and throughout their useful life. Otherwise, they are relatively maintenance-free compared to more conventional overtravel-protection devices.

166

8.2 SHAFT SAFETY DEVICES

8.2.1 SAFETY GATES

REGULATION—Safety gates are required at all shaft stations, including collars constructed so that "materials will not go through or under them" (57.19-100 M and 75.1403-11).

HAZARD—Lack of landing gates or failure to keep them closed when no conveyance is present can lead to men and materiel falling down the shaft.

INSPECTION/TESTING/MAINTENANCE—Keep gates and latches in good repair.

COMMENT—Landing gates can be and have been provided with limit switches which sound an alarm or shut down the hoist if gates are opened while the hoist is in motion. Conversely, these switches can prevent the hoist from starting unless the gates are closed and latched. Such gate interlocks can be and have been provided with station or general bypass switches, operated with special keys, to permit hoist operation during timber or machinery unloading, shaft repair work, etc.

167

8.2.2 CAR STOPS/BLOCKS/DERAILS

REGULATION—Car stops, blocks, or derails are required on all tracks leading to shaft stations and collars [57.19-79 M/-101 M and 75.1403-8(e)].

HAZARD—Lack of, failure of, or failure to use car blocks can result in cars and loads (and motors) accidentally projecting into or going down the shaft.

DESCRIPTION—Car stops, blocks, and derails include permanently mounted devices that can be swung over the rail or raised above the rail surface; or track switches (turnouts). Some of these devices prevent a car from passing by them; others derail the car.

These devices can be manually or power-operated.

NOTE: Loose chains, wedges, and blocks should not be used; they can be dislodged too easily.

INSPECTION/MAINTENANCE/TESTING—Upon installation or after modifications or repairs, test the ability of the device to stop or derail a loaded, moving car if there is doubt.

Look for and repair broken or missing car stops.

Keep devices clean and lubricated where needed so they are always operable.

COMMENT—The primary purpose of car blocks on conveyances is to keep cars from moving while being hoisted. The primary purpose of car blocks or derails on tracks approaching shaft openings is to prevent all cars—moving or stationary—from accidentally entering the shaft. Devices for stopping moving cars must be stronger than those for holding stationary cars. Furthermore, derails must be set far enough from the shaft opening or portal to ensure that cars will stop rolling before they go down the shaft. These conditions may be obvious, but they are not always observed in practice.

Good design calls for tracks sloped downward away from shaft openings whenever possible, in addition to providing adequately strong stops or blocks.

Good practice also calls for car blocks or derails at the top of slopes (inclines or declines) between levels. Practice at the bottom varies, and the proper approach can only be determined by evaluating the hazard involved if a car or trip runs away. In most cases, a derail is the only approach likely to stop a car or trip from traveling too far. Many simple blocks or stops at the bottom of slopes would be carried away by a runaway car or trip; while the cars may be slowed somewhat, it is not obvious that they would be stopped or derailed. However, if man cars or trips are involved, derails or blocks at slope bottoms could be dangerous; conveyance safety brakes could provide much safer protection. Such practices should be carefully reviewed for effectiveness and safety, and changes made where necessary.

168

8.2.3 COMMUNICATION SYSTEMS

REGULATION—Several regulations require two communication systems between hoist room and all shaft stations, one of which provides voice communication (57.19-90 M, 75-1600, 75-1402, and 75-1402-1).

HAZARD—Failures of such systems would essentially prevent use of the hoist.

DESCRIPTION—Such systems include telephones, voice tubes (outdated), or horn or bell-signal systems actuated by pull cords; pull cords accessible to men riding in the conveyance. Horns, bells, or lights are also sometimes present at each station.

INSPECTION/TESTING/MAINTENANCE—Test systems daily; repair as necessary.

8.2.4 CHAIRS

COMMENT—Chairs can be found shaft-mounted as well as conveyance-mounted. In either case, the hazards and the maintenance tasks are essentially the same; see Section 7.2.8.

Chapter 9
Special Hoists

170

Chapter 9
Special Hoists

9.1 INTRODUCTION

This chapter deals with hoists used in underground mining that, by reason of some aspect of their use or design or both, stand somewhat outside the mainstream of conventional mine-hoisting systems. Nevertheless, these "special" hoists often highly resemble their "conventional" counterparts.

The purpose of this chapter is to call attention only to those items which call for special attention or different approaches to inspection and maintenance. Otherwise, the guidelines discussed in the previous chapters apply.

171

9.2 SHAFT SINKING—MUCK HOISTS

REGULATIONS—There are several specific regulations related to design of buckets and crossheads for vertical shafts [57.19-50 M (a-d)]; the use of bulkheads (57.19-110 M); operations (57.19-76/-77 M/-78); and several general regulations that apply by virtue of generalities relative to conveyances, or such phrases as "... or buckets".

DESCRIPTION—Muck hoists are generally identical to conventional drum hoists except for the conveyance and associated guide gear. These hoists may be temporarily set up for the job, but often the hoist intended for regular use is installed early and used for sinking operations.

INSPECTION/TESTING/MAINTENANCE—*NOTE:* Although muck hoisting is a "temporary" operation, it can continue for years, and relocating a hoist at a lower level, for example, really changes nothing. Procedures and attitudes based on the temporariness of the job should be discouraged as they often lead to shortcuts. For all practical purposes a muck hoist system should be inspected and maintained as if it were a permanent installation, and all the essentials of good hoisting practice should be observed.

SAFETY CONTROLS

Regulations covering safety controls apply to all hoists used to transport men; this includes muck hoists unless men are not normally transported with bucket or skip.

Do not use muck hoists for sinking operations before all control systems devices, especially safety devices, have been installed, connected, and tested to demonstrate that they are working as intended. A direct test is best—e.g., driving the hoist into the overtravel limits. Indirect tests—e.g., manually tripping overspeed controllers—should be carried out only if a direct test is impossible.

DRUM FACES

Every effort should be made to provide smooth winding of ropes. Section 4.2.1 discusses spooling aids and their use; such aids should be considered if they will promote good spooling.

Sinking ropes may have different diameters than the ropes that will be later used for production on the same hoist. If the drum is grooved for the production ropes, both the drum grooving and the sinking ropes can be protected from excessive wear as follows:

(a) Lag the drum with ¼- to ½-inch thick rubber sheet or heavy felt paper, or 1/32- to 1/16-inch thick aluminum sheet. This lagging can be held on by metal bands or by the rope itself if there are enough dead wraps.

172

(b) Rubber or aluminum sheets between rope layers. These sheets need not be held on by anything but the "dead" wraps; let them fall out as these wraps come into use.

CONVEYANCE-END ROPE TERMINATIONS

Pay special attention to tightness of terminations, their structural condition, and the condition of the rope at and near terminations. Bucket loading and dumping operations may completely unload the rope. This periodic complete loss of tension may loosen the termination. Furthermore, depending upon the design of the bucket bail or the mode of operation at the shaft bottom, the termination may tend to tip to one side or completely drop and bend the rope.

HOIST ROPE

The minimum safety factors for ropes when new and for removal, given in Table 5.3, apply to muck hoist ropes. Use the factor that applies to the maximum depth at which the ropes will work. If 18 x 7 or 19 x 7 nonspin constructions are used and permitted to spin free—that is, if swivels are used at the bucket or spin is periodically released because rope guides are wearing too much—note the following: the catalogue breaking strength may have to be reduced during the selection process.* The 6 x constructions should not be permitted to spin free, nor is spin release recommended: if either situation is anticipated use a nonspin construction.

Pay particular attention to the critical areas at the drum and sheaves when the bucket is at the bottom and at the dump.

Pay particular attention to the tightness of dead wraps and retension the rope at the first signs of loose wraps. The loss of tension mentioned above will promote looseness in dead wraps which can lead to constructional upsets—loose strands or wires.

Drum- and conveyance-end cuts should be made just as for a regular hoist.

There are no generally recognized removal criteria for 18 x and 19 x nonspin ropes in terms of number of broken wires and wire wear. However, the minimum safety factor for removal applies and A.C. NDT inspection can provide the measure of existing strength needed for estimating the safety factors. Furthermore, removal with a 10 percent or more loss of strength indicated by an A.C. device can be applied in this application. Constructional upsets such as kinks, doglegs, birdcages, etc., are also grounds for removal.

*See footnote, Section 6.2, page 6-4.

173

CROSSHEADS

Crossheads that lock to the rope are generally best; the locking mechanism is automatically opened by chair-like stops at the bottom of the guides. Non-locking crossheads have a long history of hanging up in the guides, particularly at the dump, jarring loose later, dropping uncontrolled down the shaft, and causing much havoc and injury.

Keep crosshead guides and locking mechanisms clean and well lubricated; look for and repair damage.

SPILL DOORS

Collar spill doors, normally closed, are a generally recognized safety feature. Accidents with them—e.g., dumping muck down the shaft through open spill doors, hoisting buckets through closed spill doors—have prompted a variety of basic safety control devices associated with spill doors. One approach uses indicator lights that are controlled by the door itself, not the door actuating controls; and limit switches, in the shaft or on conveyance position indicators, tied in with door-position switches so that the hoist is stopped before a bucket hits a closed door.

174

9.3 SHAFT SINKING—STAGE/PLATFORM HOISTS

REGULATIONS—A very general regulation relates to strength of ropes supporting platforms (57.19-53 M).

DESCRIPTION—Stages or platforms are suspended with one or more pairs of ropes with single- or multiple-part reeving at the platform. Portions of these ropes often double as guides for bucket crossheads. Stage hoists can range from winches through conventional drum hoists to complex arrangements using capstan hoists with elaborate back-tensioning gear that includes moving weights and braked and power-driven storage reels.

As for any hoisting situation, the drive and brake capability of the hoists should be sufficient for the planned maximum working depth and maximum load to be carried. Hoist and sheave diameters do not have to be as large as for regular hoists, however, because the ropes are not usually run as often nor over as long a distance. Nevertheless, for multilayer winding, a large drum diameter will provide better support for and less damage to ropes.

INSPECTION/MAINTENANCE

CONTROLS

If more than one hoist is used, it is necessary to ensure that they run together. Common controls (often used) should be wired so that if one hoist stops, the other(s) stop also; and if one hoist doesn't start, neither will the other(s). Furthermore, an emergency stop button should be provided and all hoists should be equipped with overspeed-shutdown devices.

ROPES

The safety factors for selection (new) and removal presented in Table 5.3 should be applied to stage ropes unless advised otherwise.

It is recognized that these factors may be especially conservative for this application since they were derived for running ropes, and, in use, stage ropes more resemble standing ropes.

In general, stage ropes will need to be maintained tensioned and well wound on drums to avoid structural damage. If winch-like drums are used—narrow, deep-flanged and wound with many layers—ropes should be initially wound as evenly as possible and with as much tension as possible. A running rope usually cannot be well spooled on such drums, but on a stage hoist, good spooling initially provided should last a while. Rewind and retension when the live rope begins to wedge into lower layers.

Keep ropes very well lubricated with penetrating lubricants. Lubricant will have to be manually applied since the ropes do not run far or often enough to use a fixed-location automatic oiler.

Inspect ropes as if they were running ropes; the job will be more difficult and probably will have to be done from a bucket unless the stage is run to the collar and back.

Inspect and maintain end terminations as if the ropes were running ropes, whether the termination is attached to the platforms or to the headframe. If there is evidence of corrosion, make an end cut and reterminate.

The rope removal criteria discussed in Section 5.5.1 can be applied to stage-hoist ropes.

STAGES/PLATFORMS

Inspect and maintain stages and platforms with as much care as for regular conveyances.

COMMENT—It is not unusual for platforms to stick in the shaft, nor is it unusual to try to jerk the platform free by slacking the hoist ropes and getting a running start with the hoist, as it were. A jerk start (with any type of hoist) is extremely risky; there is a very good chance of something failing. The stresses in any component designed on the basis of static loads—and this includes the rope selection—will be a minimum of twice their normal magnitude during a jerk start, and in most cases much more than twice that magnitude.

Jerk starts should not be permitted as a normal operational procedure, but if necessary as a last resort, advance warning should be given along with sufficient time to permit everyone to clear the area.

9.4 EMERGENCY ESCAPE HOISTS

REGULATIONS—General qualitative regulations cover application, use, inspection and testing of emergency hoisting facilities [57.11-55 M/-56 and 75.1704-1(b)].

HAZARD—Escape hoists may fail to operate as expected when needed; and components, particularly hoist ropes, may fail due to neglect.

DESCRIPTION—The regulations requiring emergency escape hoists are relatively new and the term does not yet relate to any general type of equipment. In addition to hoists specifically designed for the purpose, some conventional hoists once in regular use are now designated for emergency use only. Thus, a great variety of equipment is in use ranging from slightly modified winches to fully equipped conventional hoists.

Several departures from conventional hoisting practice are evident and can be expected to be a permanent aspect of emergency escape hoists. One is unguided conveyances. Another is portability; this ranges from truck-mounted units to tracked units that are stored clear of the shaft a short distance. A third is shaft sharing: the shaft doubles as a ventilating shaft with fans mounted topside next to the hoist; the hoist may be used to move the fan before the cage is connected and the man hoisting begins.

The regulations also call for emergency hoists to conform as much as possible to safety requirements for other man hoists. What this means in practice relative to safety devices has yet to be settled. All hoists are prone to much the same problems regardless of how often they are used or for what purpose. Thus, a good case can be made for overtravel limits at both ends, overspeed in general, and even some form of less-than-maximum speed control toward the ends of travel. A conveyance-position indicator also seems necessary. All these hoists should have manual controls, at least; many are also provided with rudimentary remote controls operable from the shaft stations.

TESTING—Regulation 57.11-56 calls for at least monthly testing. Standby machinery not run periodically is likely not to run when needed. The best test is one that runs the hoist just as if it were being used to hoist men in an emergency. This not only exercises the machinery but the procedures for using it as well.

Where emergency hoists share a shaft with a ventilating fan it is not unusual to test the hoist simply by starting it and moving the drum to check the controls and brakes. This is not enough. It is suggested that the hoist should be fully tested each month by moving the fan or ducting, hooking up the conveyance, and running it full shaft a few trips, loaded to simulate its man load.

177

INSPECTION/MAINTENANCE

GENERAL

Insofar as the equipment is the same or similar, the procedures for inspecting and maintaining conventional hoists should be applied to emergency escape hoists.

The major problems will be dirt and moisture, and time and inactivity will be on their side.

Keep hoist-machinery enclosures closed as much as possible but allow for some air circulation so that moisture does not condense on equipment.

Keep equipment dry. Heat lamps should be considered in damp regions or seasons. These lamps should definitely be considered for cold seasons to assure that oils and greases do not thicken and liquids freeze and prevent operation.

Keep machinery and control gear free of rust. Clean and paint as required.

Keep electrical gear free of dirt and moisture that can foul or prevent action. Provide enclosures if needed.

Keep machinery enclosures free of hornet's and wasp's nests, and, in snake country, block or screen all holes at ground level and upward 2 or 3 feet.

Keep machinery well lubricated where needed.

HOIST ROPES

Drum and sheave diameters do not need to be as large as those for hoists in regular use because the ropes will not be run much and wire fatigue will not be nearly as much of a problem as corrosion and mistreatment. The smaller diameters usually recommended for hoist drums and head sheaves (57.19-39) are probably suitable here. However, sheave groove shape and diameter should follow the recommendations of Section 4.1.4.

Drums will probably often resemble those of a winch more than those of a mine hoist—narrow faces and many layers of rope—and good spooling will be difficult if not impossible to maintain when the hoist is running. Lebus grooving can help and is recommended.

Ropes of nonrotating (nonspin) constructions must be used on nonguided cages. Ropes of the 18 x class are recommended; avoid wire rope cores (IWRC ropes) and locked-coil constructions.

Keep ropes will lubricated. Since these ropes will rarely be used, the relative motion of wires and strands will not be available to distribute the internal lubricant. The lubricant will also tend to dry out faster. Use light, penetrating oils; soak the ropes and keep them soaked everywhere. It is doubtful that rope lubrication can be overdone in this application. Corrosion is the major enemy.

Maintain end terminations, particularly those at the conveyance end, just as if the hoist were in regular use.

Avoid kinks, doglegs, and mishandling in general.

Wind the rope under tension and keep it under tension with the conveyance or by attaching the end termination to a dead eye in the head frame.

During the monthly test run, inspect the rope for broken wires, constructional changes, and wear. Diameter and length measurement are probably not required. These ropes are superb candidates for NDT testing, both from an accuracy and a time-saving standpoint.

COMMENT—A great many emergency escape-hoist systems come off second best; seldom used, they are seldom well cared for.

Rope maintenance often leaves a lot to be desired. Frequently, the ropes are dried out, stiff and rusty, poorly spooled, and often kinked or bent, particularly if the conveyance end is loose.

While a good case can be argued for excellent maintenance, a realistic goal is treatment equal to that for hoists in regular use.

An emergency escape hoist and a ventilating fan sharing the same shaft does not have to be problematic and, in fact, should not be. The setup can and should be designed so that the fan (or ducting) can be rapidly removed (or opened up) to permit use of the hoist in an emergency; this condition should be a design criterion. Under these conditions, a monthly operational test of the hoist would not be problematic either.

179

9.5 PORTAL ELEVATORS

REGULATIONS—General regulations covering design apply to elevators as well as conventional mine hoists [75.1403-2 and 75.1704-1(b)]; other regulations apply specifically to design of automatic elevators [75.1403-4(a-d)].

DESCRIPTION—Portal elevators are in common use in lieu of man hoists of a more conventional design. Most are very similar to friction hoists.

Except where the mine environment requires stronger cages and special enclosures or constructions for electrical gear, elevators are designed and built according to a recognized national standard governing the elevator industry as a whole: the American Standard Safety Code for Elevators, Dumbwaiters, Escalators, and Moving Walks (ANSI A17.1-1965 or the latest revision).

INSPECTION/TESTING/MAINTENANCE—Inspection, testing, and maintenance of portal elevators should conform to the recommendations of ANSI A17.1 and its companion, the American Standard Practice for the Inspection of Elevators—Inspector's Manual, ANSI A17.2-1960 including subsequent supplements or the latest complete revision. Both codes are available in compact hardbound format from the American Society of Mechanical Engineers, 345 East 47th Street, New York, N.Y. 10017.

The rope removal criteria given by these codes are in terms of a range of broken wires for several different distributions of breaks or types of machinery. The number of breaks allowed is much higher than the hoist rope criteria of Section 5.5.1.1 mainly because elevators' ropes are required to run at considerably higher safety factors. However, as the code indicates, "unfavorable factors" such as corrosion, wire wear, poor sheave grooves, etc., require a reduction of the allowed number of breaks by one-half, which brings them close to those allowed for mine-hoist ropes. However, portal elevator ropes should be viewed as being no different than regular hoist ropes, particularly since internal corrosion can go undetected from the outside and lead to rope failure.

Pay particular attention to all the ropes—hoists, balance, and governor—where they pass around any sheaves when the cage is parked, particularly if the cage automatically parks in the same place when not in use. Pay attention especially to hoist ropes at the bottom of sheaves on counterweights—water can easily collect there and ropes have failed there from corrosion. Again, NDT inspection (see 5.5.2.3) can be a valuable tool.

Also pay attention to conveyance and counterweight rope terminations. Note, however, that rope socketing practices differ: elevator sockets are applied by bending the individual strands back on themselves toward the rope center, and babbit rather than zinc is used as the bonding agent.

Elevator safeties (safety catches) should be tested at least every 3 months. They are very reliable if somewhat complex mechanisms. Their relative complexity requires good maintenance. Keep the mechanism clean, well lubricated, and free of rust.

Elevator safeties (see 7.2.4 and Figure 7.2) are actuated by the governor rope and a rope tether attached to it and running to the cage mechanisms. Again, these are wire ropes exposed to a mine shaft environment and their good condition is absolutely essential. Keep them well lubricated and inspect them carefully (the governor rope can be nondestructively inspected). With any doubt about strength, replace them immediately.

Appendix A
Friction Hoists—Groove-Tread Radius and Rope-Length Maintenance

Page

Appendix A
Friction Hoists—Groove-Tread-Radius and Rope-Length Maintenance*

A.1 INTRODUCTION

As stated in Section 4.3, minor variations among drive-wheel groove diameters and among the lengths of the hoist ropes can rather quickly lead to constructional damage to the ropes that may require immediate rope replacement. The following procedures can be used to prevent such damage or, once started, to stop this from developing further and, perhaps, eliminate the need for immediate rope replacements.

Part of these procedures involves measurements and groove-tread-machining values on the order of hundredths and thousandths of inches, which will undoubtedly raise questions about the need or value of such fine tuning. In Canada, where these procedures were developed and are used together with good rope and hoist maintenance all round, average rope-service lives of 300,000 skip loads are reported, with 500,000 skip loads having been achieved and higher values considered probable. For a conservatively estimated 10-ton payload, such service life yields uncommonly high tonnages hoisted per set of ropes.

Questions will also undoubtedly be raised regarding better or easier methods than those described for maintaining good groove-diameter equality; many have been tried but, as yet, none others work at all well. The test described is a dynamic test which automatically includes the natural deflections of the drive wheel and tread material and the changes in rope diameter that occur across the wheel; although all these deflections and changes are small, they are significant.

*Prepared from a paper by Humphrey Dean of Wire Rope Industries of Canada Ltd., Montreal, "Hoist Rope Stress Analysis and Preventive Maintenance", The Canadian Mining and Metallurgical Bulletin for October, 1970, pp 143-1155, and from discussions with the author.

183

A.2 GROOVE-TREAD RADIUS MAINTENANCE

A.2.1 PREPARATION

(1) Obtain:

(a) A can of aerosol-spray paint, preferably white or yellow

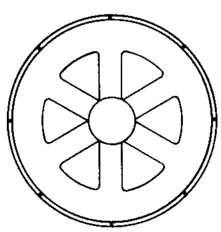
(b) A straight edge long enough to span all the hoist ropes

(c) A spirit level (an accurate carpenter's level combining both a level and straight edge is better yet)

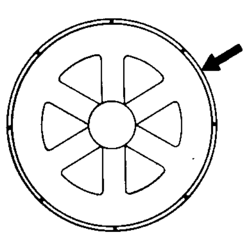
(d) Some small C-clamps or equivalents to fasten straight edge to rope

(e) A ruler marked in one hundredths of an inch.

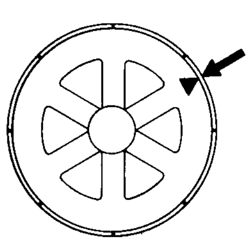
(2) The evaluation of the collar-to-collar test results (discussed next) requires a fairly accurate measure of the number of drive-wheel revolutions made during the test and during a regular trip from the lowest to the highest station. The former number may need to be determined anew every time the test is run, but the latter need not be redetermined once established. Any method for determining the number of drive-wheel revolutions can be used and the following is offered as a suggestion only:



(a) Permanently mark the edge of a flange so that its circumference is divided into 8 or 16 equal sections. Record the distance between marks and the total (actual) circumference.



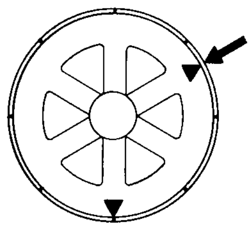
(b) Install a permanent reference marker or pointer on something stationary close to the flange.



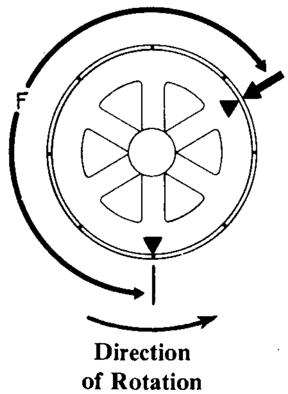
(c) Place a temporary marker (e.g., with chalk) on the flange opposite the reference mark.

184

(d) Run the hoist (for either the test or the full trip) and count the full revolutions noting the temporary marker.



(e) When the hoist stops, place another temporary marker on the flange opposite the reference marker.



(f) Measure the fractional revolution, F, in direction of rotation. For ease and accuracy count the full segments between the temporary flange markers and measure the distances on the circumference between the temporary and permanent markers. In the sketch shown it might be easier to measure the shorter portion between the temporary markers and subtract this length from the total circumference.

(With temporary and permanent flange markers, the wheel can be turned to ease measurement without losing the necessary data.)

(g) Compute the fractional revolution to the nearest one-hundredth and record the total (e.g., 18.47).

A.2.2 COLLAR-TO-COLLAR TEST

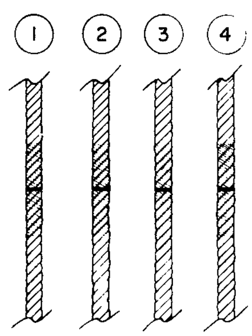
Make a collar-to-collar test as soon as feasible after the hoist has been in more-or-less continuous operation. Otherwise, flat spots can develop in the tread blocks and produce inaccurate results. If the hoist has been idle for any time, run it up and down for 20–30 minutes first; the conveyance need not be loaded.

(1) Bring one conveyance to the collar or its highest normal station; call this Conveyance A.

(2) Lower Conveyance A to mid shaft.

(3) At the collar or highest normal station associated with Conveyance A, mark each hoist rope at the same elevation as follows:

(a) Spray paint each rope over a distance of about 1 foot.



(b) Place the straight edge at about the center of the painted area and clamp it level.

(c) With a pencil or ballpoint pen make an easily visible horizontal line in/on the paint on each rope.

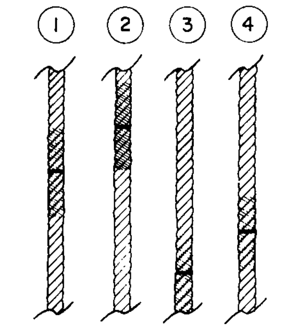
(Also, place the first temporary wheel-flange marker at this time if the method suggested in A.2.1 is used.)

(4) Raise Conveyance A slowly until the marks on the ropes pass over the drive wheel and arrive in the other compartment, more-or-less opposite to where they were first put on, then stop and hold the hoist.

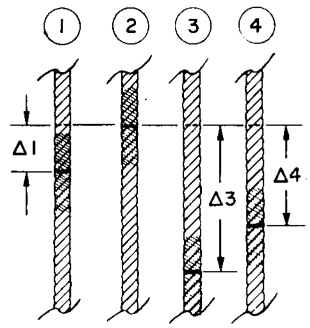
(Wheel revolutions can be counted during this step and the second temporary wheel-flange marker placed after the hoist is stopped.)

NOTE: If the rope marks travel too far and access to them is lost (e.g., go too far below the collar) *DO NOT REVERSE HOIST* to make them accessible: START ALL OVER AGAIN FROM STEP 1. Reversing the hoist to make marks accessible produces incorrect results: believe it.

(5) With the rope marks accessible opposite where they were put on, measure the differences in travel distance (elevation) for each of the marks as follows:



(a) Place the straight edge just below the highest mark, level it, clamp it, and mark each rope at that elevation. (Hopefully, these new marks will fall on the painted region.)



(b) Measure and record the differences in travel distance, Δ 1–Δ4, for each rope mark; measure these Δ's several times to permit averaging.

This concludes the collar-to-collar test.

187

A.2.3 EVALUATION

(1) Make up the following table or an equivalent, and list measured travel differences in line (a).

	ROPE	1	2	3	4
(a)	Travel distance differences (measured)—inches	0.42*	0	1.01	0.75
(b)	ΔR Groove radius difference—inches	0.0062	0	0.0154	0.0108
(c)	Average radius difference—inches	0.0080	0.0080	0.0080	0.0080
(d)	Variation from average radius difference—inches	-0.0018	-0.0080	+0.0078	+0.0028
(e)	±G Groove radius tolerance – inches	±0.0031	±0.0031	±0.0031	±0.0031
	Variation within tolerance?	Yes	No	No	Yes

*All table numbers are hypothetical but realistic.

(2) Compute differences in grooved-tread radius for line (b) as follows:

$$\Delta R = \frac{\text{(Travel distance difference)}}{6.28\left(\begin{array}{c}\text{Wheel revolutions made} \\ \text{during collar-to-collar test}\end{array}\right)}$$

To obtain equal groove-tread radii, the example shows that ropes 1, 3, and 4 must be deepened or trimmed by the amount ΔR. Making cuts on the order of ΔR will not be easy to do with the accuracy shown. However, the groove-tread radii need only be "equal" within a certain tolerance.

(3) Compute the average radius difference for line (c) by adding up the ΔR's and dividing by the number of ropes.

(4) Compute the variations from the average radius differences for line (d) by subtracting line (c) values from line (b) values. (Values can be + or –.)

(5) Compute the groove-tread radius tolerance, ±G, for line (e) as follows:

$$G = \pm \frac{T \ell}{6.28\ A\ E\ n} \quad \text{(inches)}$$

where

T = total static load on one hoist rope with conveyance at its highest normal station. This value is the sum of the empty conveyance, its maximum pay load, and the weight of all balance (tail) ropes in the shaft; all divided by the number of hoist ropes (lb).

ℓ = length of hoist rope from conveyance to drive wheel with conveyance at its highest normal station (inches).

A = total metallic cross-sectional area of hoist rope ($inches^2$).

E = modulus of elasticity for hoist rope ($lb/inches^2$).

n = number of drive wheel revolutions for normal trip from lowest to highest station.

NOTE: Values of A and E for the ropes in use can be obtained from wire-rope catalogues.

The example shows that the groove-tread radii of Ropes 1 and 4 are within the allowable tolerance. However, since turning can only be done relative to the smallest groove radius (Rope 2 in this example), the grooves for Ropes 1, 3, and 4 will still have to be deepened.

Thus, do what is possible to deepen grooves according to the ΔR values. Then, repeat the collar-to-collar test, the measurements, and the evaluation to determine how things stand. Repeat the process—cuts, tests, evaluation—until the groove-radius variations from the average are all within the allowable tolerance. (As for the collar-to-collar tests, grooves should be trimmed after the hoist has been in use to avoid flat spots on the treadblocks and, hence, unevenly trimmed grooves.)

189

A.3 ROPE-LENGTH ADJUSTMENTS

A.3.1 INTRODUCTION

Equal rope lengths are as important to good rope behavior and life as equal groove-tread diameters. The concern is for maintaining equal tensions insofar as rope-length difference can cause tension differences.

If systems have automatic hoist-rope tension equalizers (whiffle-trees, pneumatic cylinders, or springs) it is nevertheless necessary to check them periodically to assure that they are still free to move and have not reached some end of travel. Equalizers should be used at one end of the hoist ropes only.

Systems without automatic tension equalizers should have some form of linkage as part of the suspension gear that permits fine length adjustments to each rope at at least one conveyance.

The following procedures apply most directly to the latter systems although they also have some value for automatically tensioned systems.

A.3.2 ADJUSTMENT PROCEDURE

(1) Block or chair conveyance at lowest normal station, but maintain as much weight on ropes as possible.

(2) *Slowly* turn the hoist until the last hoist rope just loses tension, then stop the hoist. As tension reduces, termination pins will loosen and the termination and rope will begin to sag away from the vertical. Measure as well as possible the vertical motion that occurs from the time the first rope loses tension until the last rope loses tension.

(3) Shorten the other ropes until all ropes are of more-or-less equal length; that is, until all terminations sag about the same amount. The lengths of all hoist ropes should be maintained equal within the following rope-length tolerance:

$$R = \pm \frac{1}{10} \frac{W}{AE} L \quad \text{(inches)}$$

where

W = total load at the end of one hoist rope for an empty conveyance at the *highest* normal station; that is, the sum of the weight of the empty conveyance and the weight of the balance ropes hanging below it, divided by the number of hoist ropes (lb).

A = total metallic cross-sectional area of hoist rope (in.^{2}).

E = modulus of elasticity of hoist rope (lb/in.^{2}).

L = length of hoist rope in shaft with conveyance at *lowest* normal station.

The motion measured in Step (2) should be no greater than twice R.

In practice, R is likely to range from 0.50 inch to several inches.

NOTE: Rope-length adjustments should not be made immediately after groove-tread diameters have been trimmed; wait a week or two until the rope lengths readjust to the new grooves.

191

A.3.3 COMMENTS

Good rope maintenance in general will normally lead to all ropes being changed at one time. However, accidental damage, for example, to one or more ropes may require changing less than the full set.

When less than the full set of hoist ropes is changed, major tension variations among all ropes are highly likely. During the initial period of constructional stretch and seating of the new ropes, length adjustments should be made frequently—once a day is advisable, at least initially.

If only one rope is changed, time can be saved by initially connecting this rope so that it is several inches shorter than the others. Again, a daily check is advisable initially; perhaps a second, short adjustment will be needed before rope stretch catches up with the other ropes.

It should be noted that groove radius and rope-length maintenance go hand-in-hand. After initial adjustments a weekly collar-to-collar test is a good indicator of the stability of the system.

Having once achieved good groove-radius and rope-length equality, additional groove trimming (and perhaps rope-length adjustments) may be necessary only once or twice a year. Good rope performance can be expected from a system with good drive-wheel and tread structural stability and with control over corrosion.

However, if structural stability is not good, or corrosion not controlled, or rope torque characteristics not similar, then frequent groove maintenance will probably be necessary and, even though done correctly initially and subsequently, poor rope performance is likely from one or more ropes.

Appendix B
Friction Hoists—Rope-Stretch Removal Criterion

Page

Appendix B
Friction Hoists—Rope Stretch Removal Criterion

B.1 INTRODUCTION

The procedures discussed in the following sections are based upon the general stretch behavior of friction hoist ropes over their entire service life. This behavior is illustrated in Figure B.1*.

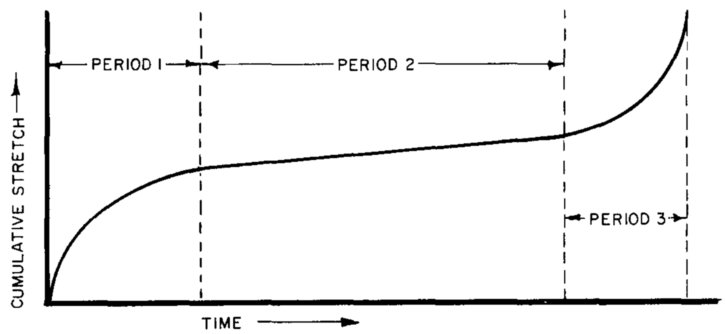


FIGURE B.1. General Stretch-Time Behavior of Friction Hoist Ropes

Period 1 is a time of rapid stretching—high initially, but tapering off later. This stretch is usually called the "constructional stretch".

Period 2 is a time of slow, more or less steady stretching as indicated by the straight-line segment. Experience indicates that this behavior is due far more to metallographic changes than to geometric or constructional changes.

Period 3 is again a time of relatively rapid stretching; but in contrast to Period 1, stretch is slow initially and increases more and more rapidly. It is also a period when broken wires begin to appear in significant numbers; as the stretch increases so does the number of broken wires. Left alone, stretch and broken wires increase faster and faster and the period ends with rope failure.

This general behavior will occur if corrosion is at least fairly well controlled, if drive-wheel groove diameters and individual rope lengths are at least fairly well maintained, and if no rope damage occurs because of an accident or through mishandling.

No general-purpose graph like Figure B.1 can be drawn with numbers because, in practice, the numbers vary significantly with rope construction, the nature of the hoist installation, the amount of work done with the rope, and the rope maintenance procedures. However, every friction-hoist operator can develop such a graph from his own data that can be of great value: it can indicate when to replace the ropes (soon after Period 3 begins); it can indicate when it's time to make

*This general behavior is also true for ropes used on drum hoists.

194

preparations for rope change (when Period 3 begins); and it can indicate the effects of maintenance-procedure changes if the stretch history of one set of ropes is compared with that of another.

If this information and the following procedures are unknown or unused, it is recommended that the procedures be followed and a graph like Figure B.1 be developed for the next set of ropes while maintaining and replacing the ropes as usual. However, for the following set, or at most by the third set, sufficient information should have been developed and enough confidence gained to make the data useful in a predictive manner.

NOTE: The method described below treats all the hoist ropes as a set, not as individual ropes. Minor variation in the stretch of each rope is not considered. However, minor variations in individual rope lengths are very important to the life of ropes, and the procedures discussed in Appendix A should be followed.

B.2 PROCEDURES

(1) Determine the nominal length of the ropes in use—the length from one conveyance to the other (or to the counterweight) over all wheels and sheaves. The design length or a length taken from installation drawings is sufficient.

(2) Use the following comments to formulate stretch-measurement procedures most suitable to each hoist installation.

Stretch is best measured by noting the change in position of one conveyance when the other is spotted at the same place each time the measurement is made. It is advisable to use the conveyances in the same way for the entire life of the set of ropes; for example, always measure with Conveyance A empty and spot with Conveyance B empty.

It may also be desirable to measure the position of Conveyance A relative to a reference mark that can be relocated if needed after ropes are shortened. For example, suppose the difference between the floor levels of Conveyance A and the collar station is initially the measure of stretch. Eventually, it may be necessary to shorten the ropes because operations require it. If, after the ropes are shortened, the floor of Conveyance A is again at or just below the collar level; all is well. However, if the conveyance floor level is somewhat above the collar, this difference will have to be recognized in subsequent stretch measurements; it may be simpler to paint or chalk a reference mark on the gates (or whatever is handy and permanent) and to measure from this mark until the next time the ropes are shortened. Ropes will probably not be shortened on a conveyance/counterweight system, but eventually the measured stretch may be so long that it is more convenient or safer to measure from a new reference.

Measure stretch to the nearest inch. Likewise, spot Conveyance B at the same place each time within an inch or two; this place should be identified with a paint mark if there is a possibility of losing or missing it otherwise.

(3) Use the following comments to determine how often to make stretch measurements.

The curve of Figure B.1 is drawn smoothly with a straight line through Period 2. In practice it is doubtful that a curve drawn through the data points will be anywhere near this smooth. The data points will be subject to errors in measuring stretch and in spotting conveyances for the measurement; what is thought to be stretch may be only a change in shaft and rope temperature; a dusty environment or a sand spill may bind the rope, only to have it unbind later after cleaning and lubrication; etc. Furthermore, such variations in the data will produce greater changes in the shape of the curve where it is steep than where it is shallow. In dealing with this approach for the first few times, and not knowing for sure when the third period begins, operators have panicked when a higher-valued data point has appeared and has seemed to indicate the beginning of the end; whereas the data point was high only for one of the reasons indicated above.

Thus, during the period of "constructional stretch", measurements taken weekly or even every few days may be necessary to establish a good feeling for what is happening.

With an indication of the beginning of the second period, the time between measurements can be increased. Perhaps once a month will be enough, or perhaps every two weeks. If a peculiar data point appears and visual inspection shows nothing, wait a few days and remeasure. Or if prior experience indicates the ropes still have months to go, forget about it.

With an indication of the beginning of the third period—that is, consistently higher data points, the appearance of broken wires in more than normal amounts, or on the basis of past experience—the time between measurements should be shortened.

As the time for replacement nears, based upon previous experience (remember, however, that this is being written for first-timers), a daily measurement may be in order. The more data points available for this critical end-of-life period, the better the rope behavior will be known.

The major point to remember is that this procedure is being used to develop another tool for use in deciding when to replace ropes and the more data the better the understanding. Furthermore, with confidence in the procedure, it is probable that ropes will be used longer if it turns out that ropes are now being removed during the second period.

It has been suggested that since all hoist ropes exhibit a general stretch-time behavior like that shown in Figure B.1, procedures essentially like those just discussed could be formulated for use with drum hoists as well. There are scattered reports that some Canadian operators are experimenting with this approach and, as expected, have noted that periodic drum and conveyance-end rope cuts lead to a significant bookkeeping problem.

196

B.3 EVALUATION

The goal is to plot a graph of rope stretch as a percent of nominal length versus work done by the ropes. For production hoists, the work done by the ropes is adequately expressed by the tonnage or by the number of skip loads hoisted. For man and materiel hoists, plotting stretch versus time, e.g., months, is sufficient.

(1) For data analysis, prepare the following table or an equivalent:

Nominal Rope Length ______________ ft						
Date	Cumulative Tonnage or Skips Hoisted	Measured Stretch, ft-in.	Increase in Stretch, ft-in.	Cumulative Stretch, ft-in.	Cumulative Stretch as % of Nominal Rope Length	Comments
(a)*	(b)	(c)	(d)	(e)	(f)	

*Letters refer to following comments:

(a) Always record the date of the stretch measurement, even if not used later.

(b) Cumulative tonnage or skips hoisted need to be recorded only for production hoists.

(c) Always record the stretch value measured and note the references used for the measurement under Comments.

(d) The increase-in-stretch value is the difference between the current and the previous measure of stretch, *except* for the first stretch measurement made after a change of references, e.g., after ropes are shortened. Always record a change of references used for measurements under Comments.

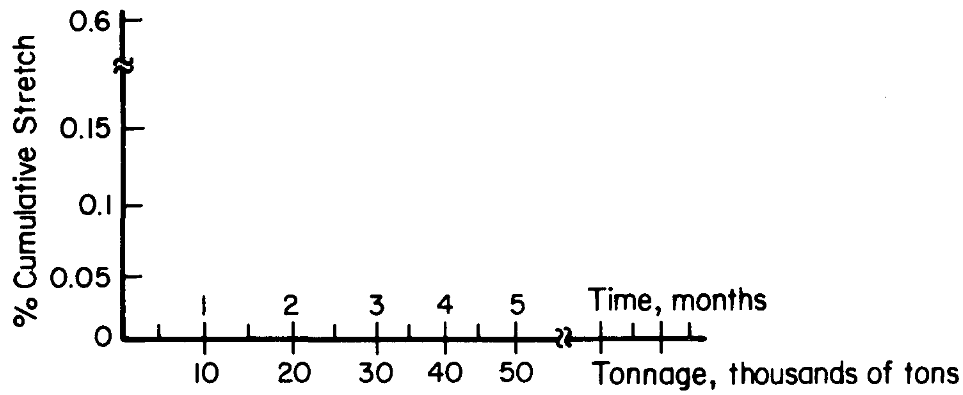
(e) The cumulative-stretch value is the running total of the increase-in-stretch values. A running total of the amount ropes are shortened should agree reasonably well with the cumulative-stretch value nearest in time.

(f) Compute cumulative stretch as a percentage of nominal rope length as follows:

$$\% \text{ Cum. Stretch} = \frac{\text{Cumulative Stretch}}{\text{Nominal Rope Length}} \times 100.$$

197

(2) For plotting, prepare the following graph or an equivalent:



For production hoists plot the values of Column (f) in the previous table against cumulative tonnage or skips hoisted. For man and materiel hoists plot the values of Column (f) against time.

The graph outlined shows both time and tonnage for illustration only; use only what is needed, not both.

B.4 COMMENT

As stated in the Introduction, an upturn in the curves of percent elongation versus time (or tonnage) well after the initial period of construction signals the approach of end-of-life for the ropes, Period 3 of Figure B.1. With experience and confidence such curves can be used to prepare for rope removal in advance of the actual change, and to decide when to remove.

When several data points definitely show that Period 3 has begun, it is time to prepare for rope changes. However, in general, it cannot be said that the ropes must be changed immediately: don't panic. Unless the hoist is very heavily used 'round the clock, there will probably be plenty of time for scheduling rope changes, perhaps days or weeks. It all depends upon the particular hoist system.

Above all, this procedure should not be the only guide to rope replacement. The methods currently in use should always take preference until confidence is gained and even then still be used as a guide. However, it should be noted that if present methods indicate it's time for a rope change and the curve is still slowly and more-or-less steadily rising (Period 2), consideration should be given to using the ropes longer.

Canadian experience has been that no ropes are known to have failed using this method, although ropes have been removed before Period 3 occurred for various reasons, e.g., construction upsets due to poor drive-wheel groove diameter and rope-length maintenance, accidental rope damage, poor corrosion control, etc.

Appendix C
Conveyance Safety Brake Testing

Appendix C
Conveyance Safety Brake Testing*

C.1 INTRODUCTION

The tests described and discussed in this Appendix—Free Fall and Drop—were originally developed for safety catches actuated by loss of hoist-rope tension and installed on vertical-shaft conveyances. In a free-fall test, actuation is purposely delayed until the conveyance attains a speed (in a free fall) more-or-less equal to the maximum permissible speed for hoisting. In a drop test, actuation occurs naturally after detaching (dropping) the conveyance from the hoist rope. Both tests are conducted with a conveyance loaded to simulate maximum load conditions. A free-fall test simulates the worst dynamic situation (high speed and load) for which a safety brake may have to stop a conveyance.

The procedures involved have been expanded below to include inclined-shaft conveyances. However, they are still written for actuation by loss of hoist-rope tension. While actuation is important, the emphasis in these procedures is on braking (stopping) ability; tests of actuation capability can be conducted separately and much more easily (see 7.2.4). Thus, if a safety brake actuates under other conditions, the procedures can be modified as needed. At bottom the procedural details used are unimportant so long as the goal is achieved. However, once established, the details should not be varied without serious consideration of the effect on the results; otherwise an apparent change in braking performance may be, in reality, the result of procedural changes and not brake capability.

This is the goal: to determine and periodically reconfirm the ability of a conveyance safety brake to stop a fully loaded conveyance which is descending at about the maximum permissible speed for hoisting. The free-fall test is a proven method for achieving this goal. It is a rigorous and potentially dangerous test and should never be conducted with a safety brake system (conveyance, brake mechanisms, guides) whose performance capability is unknown or doubtful. In these cases a drop test—a less rigorous test—should be made as the first step toward achieving this goal. In general, no matter what procedural details are evolved, all brake testing must include the following:

(1) PROTECTION AGAINST FAILURE

Some means of preventing the conveyance from falling uncontrolled to the bottom of the shaft (Even the most reliable safety-brake systems can sometimes fail.)

(2) MEASUREMENTS

Best:

(a) Distance conveyance travels from release to point of engagement of the brakes with the guides

(b) Distance conveyance travels from point of engagement of the brakes to stop

*If a safety brake develops a changing rather than a constant force during a stop, most of the evaluation procedures given in this appendix are useless, and other procedures are required.

201

C.1 INTRODUCTION (Continued)

Acceptable:

(a) Distance between point of engagement of the brakes with the guides to point of rest after stop or

(b) Distance between point of release and point of stop.

Use of these data is described along with the test procedures.

In the last analysis these procedures should be considered as guides. The deceleration limits suggested for evaluating the performance of safety brakes for inclined-shaft conveyances need to be validated and this requires experience. If these limits, or indeed any of the procedures are found wanting with experience, they will be modified.

C.2 FREE-FALL TEST—VERTICAL SHAFTS

C.2.1 PREPARATION

(1) Borrow or make:

(a) A detaching (trip) hook that allows the conveyance to be quickly disconnected from the hoist rope—One design for a trip hook is sketched in Figure C.1; any equivalent will do.

(b) A lockout device that delays actuation of the safety brake until it is removed—One design for a lockout device is sketched in Figure C.2. Since actuating mechanisms differ, so will lockout devices.

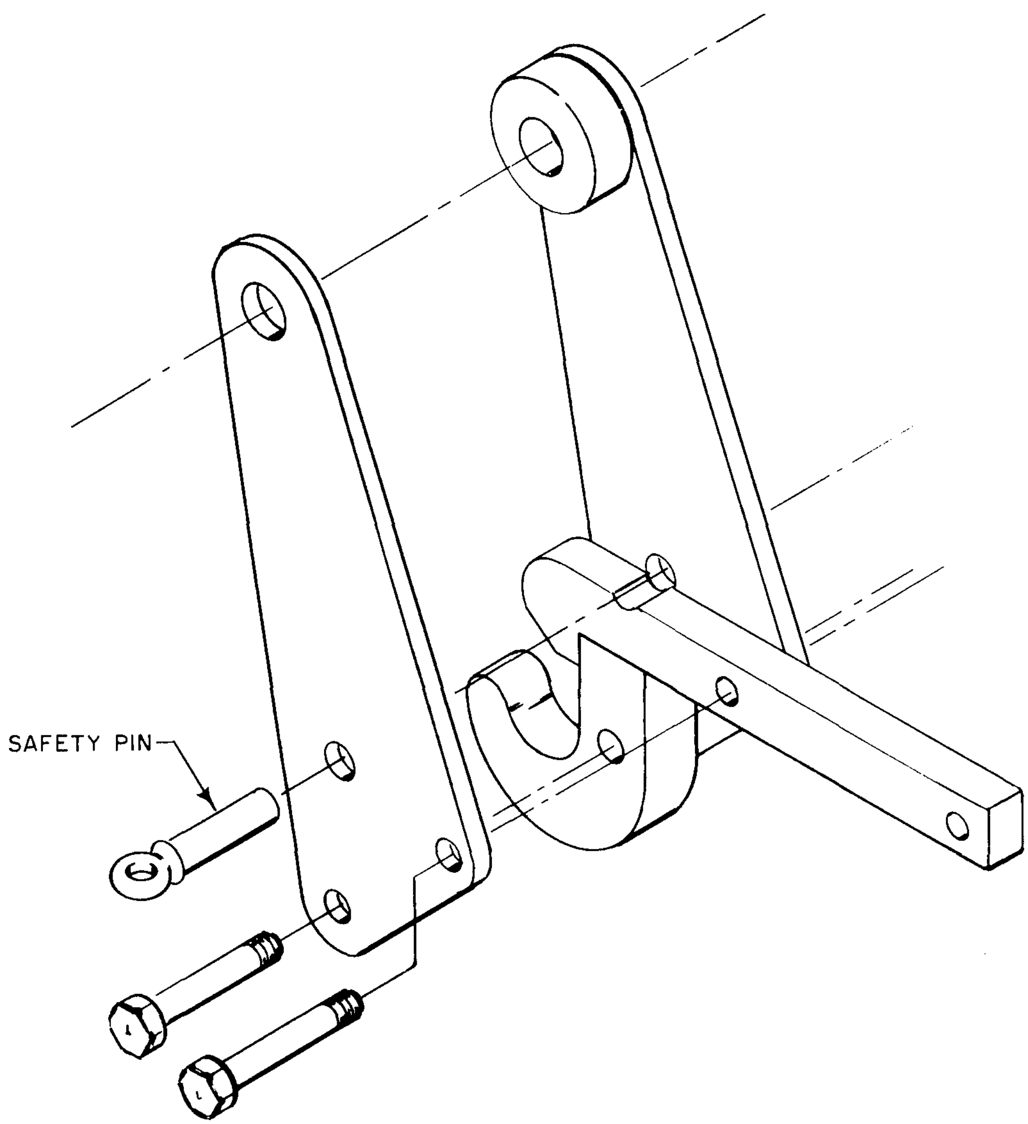


Figure C.1. Sketch for Trip Hook

C.2.1 PREPARATION (Continued)

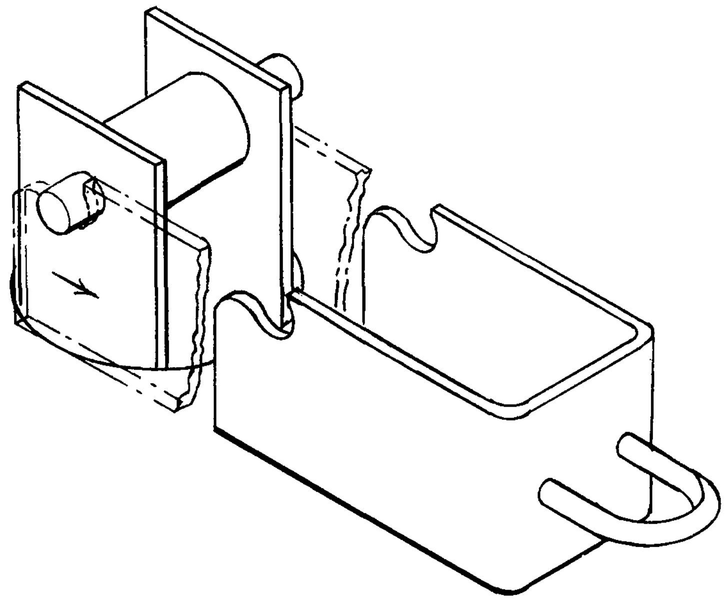


Figure C.2. Sketch for Lockout Device

(2) Prepare two stout tethers (chain, cable or rope):

(a) A tether connecting the hoist rope to the guides or guide supports so that the hoist rope will not recoil and flail about when the conveyance is disconnected.

(b) A tether connecting the lockout device to the guides or guide supports that pulls out the lockout device causing actuation of the safety brakes. Since the conveyance falls free (builds up speed) until this tether fetches up and pulls out the lockout device, the length of this tether determines the speed at which actuation occurs. The length of this tether between tie-offs* should be about

$$\text{Tether length (feet)} = \left[\frac{\text{max permissible hoisting speed (feet/min)}}{482}\right]^2$$

A tether about 10 feet long provides a speed of about 1500 ft/min. at actuation.

(3) Obtain:

(a) Sandbags, rock-filled drums, etc., for ballast to simulate the maximum permissible man loading for the conveyance.

(b) Strong steel or wood beams and straw bales or used tires to block the shaft and provide a shock-absorbing cushion.

*A tether must be longer than the computed length so it can be connected, or "tied-off", at each end. Otherwise, the conveyance speed at actuation will be less than expected.

204

(4) The weight of the empty conveyance and the force needed to compress the actuating springs must be accurately known. If these are not supplied with accuracy by the manufacturer, borrow a dynamometer (like a large spring scale) and make the following measurements:

(a) Empty conveyance weight. Block the conveyance, disconnect the hoist rope (don't let it spin free), install a chain hoist or block and tackle on a temporary beam, install the dynamometer between the conveyance drawbar and the chain hoist, lift the conveyance free of its support, and note the conveyance weight on the dynamometer.

(b) Actuator spring compression force. After the above, slowly lower the conveyance. When the drawbar first begins to move downward relative to the conveyance, and just after the conveyance touches the supports; the dynamometer will indicate the spring compression force.

Repeat these procedures several times to obtain average values.

(5) Guide Preparation:

The value of these tasks is better appreciated with knowledge of where and how the tests occur, and the possible results. Thus, it is suggested that this topic be reread after the following sections have been studied.

(a) Inspect the guides and supporting structure for soundness and rigidity in the region where the brakes will stop the conveyance. The guides must not spread during the test; replace bracing, etc., that may be missing or defective if there is doubt.

(b) The test should be conducted on guide sections representative of the worst in the shaft: oldest, most worn, wettest, and most rotted (if applicable). Find some of these sections and reinstall them in the test region so that the brake shoes or dogs will engage them during the test. This is most essential with wood guides and dogs like that of Figure 7.1; wear, water, and rot can seriously affect the performance of these dogs. Do not test on frozen wood guides; the result will be excessively high deceleration. Furthermore, if wood guides are used, it is necessary to release a conveyance from a position that assures that the dogs will not engage the guides in the grooves produced during a previous test. If such a starting position is not available, replace the guide sections.

Swing guides may pose a problem (see 8.1). It may be practical to swing them aside and install special temporary sections for safety-brake testing.

(c) Check the guide-to-guide spacing, particularly across the shaft, and the position of the guides relative to the brake shoes or dogs; shoes or dogs that cannot fully engage the guides as designed are useless. Hoist the conveyance to the expected stopping area and pry it fully to one side; if the shoes or dogs are at the edge or partially off the guide when engaged, or will be with wear of the guides or the conveyance guide-shoes or guide-wheels, take corrective action before proceeding with test.

205

C.2.2 TEST PROCEDURES

(1) Hoist the conveyance above the collar. (Tests may be done anywhere it is convenient to do so, but above the collar is usually the most convenient location.)

(2) Block the collar with beams and cushioning.

(3) (a) Set the conveyance on the beams.

(b) Install the trip hook; don't let the hoist rope spin free during this operation.

(c) Load the conveyance with ballast.

(4) Hoist the conveyance about 2-1/2 times the tether length above the cushioning. (The conveyance will free fall the length of the tether; a 1-g stop would bring the conveyance to a stop in the same length, while a 2-g stop would require half the tether length.)

(5) (a) Tether the hoist rope.

(b) Install the lockout device and tether it to the guides or guide supports at as nearly the same height as possible.

(c) Mark the guides to indicate this starting point. Reference the mark to some point on the conveyance or brakes; this reference will be needed in Step 8. A convenient reference is the center of the dog shaft, or the middle or the uppermost edge (trailing edge) of a brake shoe.

A representative sketch of the test configuration at this step is provided in Figure C.3(a).

(6) Clear the area and all stations below.

(7) Trip the trip hook.

A representative sketch of the test configuration at the point of actuation is provided by Figure C.3(b); after stop by Figure C.3(c).

(8) Mark on the guides the point of brake engagement and the stopping point. For dogs working in wood, the start and end of the groove produced will serve well enough.

(9) Measure:

(a) The distance the conveyance travelled to the point of engagement of the brakes—the free-fall distance.

(b) The distance the conveyance travelled after engagement to stop—the stopping or braking distance.

These distances are illustrated in Figure C.3(d) for dogs acting on wood guides.

(10) Inspect all mechanisms for bent or damaged components; this could occur if the brake forces are too high (see Evaluation), the mechanism is too weak, or both.

(11) Inspect the guides and supports for looseness or damage, and wood guides for splitting.

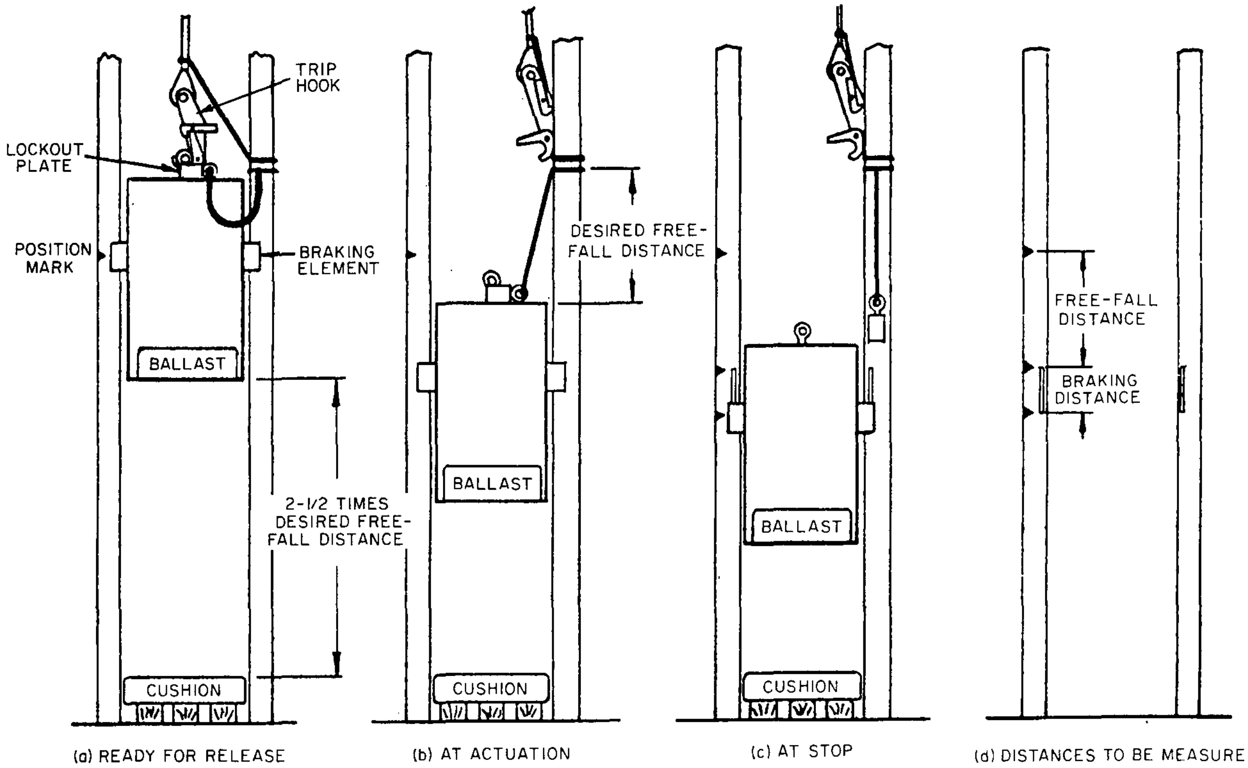


Figure C.3. Free-Fall Test; Vertical Shaft

207

C.2.3 PERFORMANCE EVALUATION

C.2.3.1 DEFINITIONS AND DATA NEEDED

Evaluation requires values for the following:

V_o = max permissible hoisting speed, ft/min

C = conveyance weight, lb

M_o = max permissible man load, lb

M = conveyance test load (M should be as close to M_o as practical)

E = max permissible equipment or material load, lb

S_1 = distance conveyance travelled from release to brake engagement (free-fall distance), ft

S_2 = distance conveyance travelled from brake engagement to stop (braking distance), ft.

C.2.3.2 EVALUATION

(1) Compute the actual speed at actuation:

$V = 482\sqrt{S_1}$ (ft/min).

The value of V should be close to V_o.

The equation used to select the length of the lockout tether is a variation of this equation. Because, among other things, the tether is tied off to one side, it is doubtful that the actual speed at actuation will be what the tether was supposed to give. It doesn't really matter as long as the two speeds are close. If V is significantly less than V_o, lengthen the tether the next time around. If V is significantly greater than V_o, and the tether is not at fault, the actuating mechanism may be taking too long to do its job and should be examined for damage or corrosion.

(2) Compute the average deceleration produced by the brake system (and the deceleration that would be experienced by each man on board if the system were actuated with a full man load):

$$\overline{A} = \left[\frac{S_1}{S_2}\right] g .$$

The value of $\overline{A}$ should be greater than 1.0 g and less than 3.0 g.

(3) Compute the average total braking force:

$$\overline{F_B} = (C + M)\left[\frac{S_1}{S_2} + 1\right] \text{ lb}$$

The value of $\overline{F}_B$ must be divided by the number of dogs or brake shoes to determine the force produced by each dog or shoe.

These values provide a check on the design of dogs or shoes as well as an indication of the effects of changes that may occur naturally, or be purposely made.

(4) Compute the average deceleration that would be induced if one man only were on board (and experienced by him):

$$\overline{A}_o = \left[\frac{\overline{F}_B}{C} \right] g \ .$$

The value of $\overline{A}_o$ should be less than 3.0 g.

(5) Compute the ratio of the average total braking force to the maximum load when material or equipment are hoisted:

$$R_E = \frac{\overline{F}_B}{C + E} \ .$$

If the value of R_E is greater than 1.0 the brakes will stop a conveyance carrying its maximum permissible material or equipment load. If the value is less than 1.0 no stop occurs; if exactly 1.0 (doubtful) it could go either way.

The stopping distance with a full material or equipment load is:

$$S_E = \frac{1}{R_E} \left[\frac{V_E \text{ ft/min}}{482} \right]^2 \ ,$$

where V_E is the hoisting speed at which actuation occurs.

NOTE: The condition of the guides in the test region will affect the values computed, and the guide conditions should be fully recorded along with the test results. For example, new dry guides may yield decelerations 20 to 100 percent higher than wet, worn ones. As stated, frozen wood guides could yield large decelerations. Similarly, smooth, oily metal guides may yield lower decelerations than rough, dry ones.

It is necessary to determine the highest and lowest decelerations that a conveyance brake may provide over the range of guide conditions existing in the shaft. If it appears that some guide-condition extreme existed during the test it is advisable to make some effort to retest under guide conditions more typical or representative of the other extreme existing within the shaft.

Once these performance extremes are established it is not necessary to confirm them all in subsequent tests as long as the range of guide conditions in the shaft does not change in a direction that could extend the performance extremes.

209

C.3 DROP TEST—VERTICAL SHAFTS

C.3.1 PREPARATION

Preparing for a drop test is identical to preparing for a free-fall test with two exceptions: neither a lockout device nor its tether are needed (see Section C.2.1).

C.3.2 TEST PROCEDURE

(1) Hoist the conveyance above the collar.

(2) Block the collar with beams and cushioning.

(3) (a) Set the conveyance on the beams.

(b) Install the trip hook; don't let the hoist rope spin free during this operation.

(c) Load the conveyance with ballast.

(4) Hoist the conveyance about 4 feet above the cushioning.

(5) (a) Tether the hoist rope.

(b) Mark the guide to indicate the starting point (see Section C.2.2).

A representative sketch of the test configuration at this step is provided in Figure C.4(a).

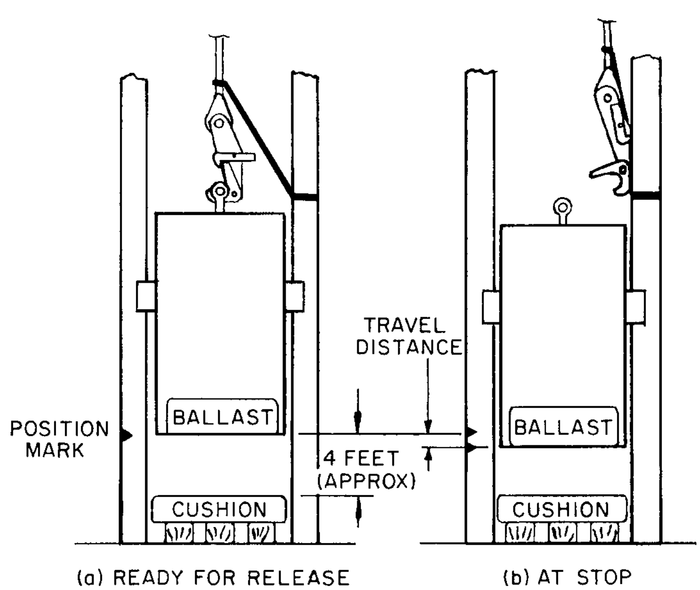


Figure C.4. Drop Test: Vertical Shaft

(6) Clear the area and all stations below.

(7) Trip the trip hook.

(8) Mark the stopping point with reference to the conveyance in the same manner as the mark of Step 5b.

(9) Measure:

(a) the distance the conveyance travelled from release to stop

(b) if possible, the distance from release to brake engagement, and the distance from engagement to stop as in the case of a free-fall test.

C.3.3 EVALUATION

If the safety brake and the guides are in good order and providing stops on the order of 2–3 g's, the total distance from release to stop is likely to be on the order of a foot and the distance from engagement to stop an inch or so.

If the braking force is too large, the stopping distance will probably be very short, perhaps less than the length of a shoe, or no more than the length of that portion of a dog that embeds itself in the guide. If the braking force is excessively large damage to brakes and guides can be expected.

If the braking force is too small, the stopping distance will be relatively long and probably easily and fairly accurately measurable. In these cases the data can be used as in the evaluation of free-fall test data to provide numbers for deceleration, braking force, etc., that can be used to modify the brakes.

For many reasons a drop test is not particularly good for quantifying performance. The stopping distance is short with good brakes because there is relatively little kinetic energy to dissipate. The distance can also vary from test to test because of natural variations in the physical properties of the brake shoes or guides or because environmental conditions vary from test to test. Being short, the distance is difficult to measure accurately because the beginning and end may not be sharply defined. Thus, significant changes in this short stopping distance are likely to be the rule from test to test even though the overall performance capability of the brake may not change.

The distance from release to engagement of the brake will probably be a large percentage of the total distance because it is mainly an expression of actuation time. Actuation time can easily vary a fraction of a second due to slight variations in test-procedure details or to differences in the lubrication or temperature of the actuating mechanism; and a fraction of a second's difference in actuation time could produce a significant change in the overall travel distance.

211

C.3.4 TESTING UNKNOWN OR DOUBTFUL BRAKES

The final goal is a free-fall test. The following general approach should be used with brakes whose performance capability is unknown or doubtful (i.e., never tested). After each step evaluate the result and either proceed to the next step or modify the brakes as needed, and repeat the step before proceeding.

(1) Drop test with an empty conveyance.

(2) Drop test with a ballasted conveyance. Compute the actual speed at actuation if possible (see Section C.2.3, Step 1).

(3) Free-fall test with an empty conveyance *but* cause actuation (with a short lockout tether) at a low conveyance speed.

(4) Repeat (3) with a ballasted conveyance.

(5) Repeat (4) for increasingly higher conveyance speeds at actuation until testing occurs at the maximum permissible speed for hoisting. Depending upon the results or concern, Steps (3) and (4) could be taken for each increase in speed at actuation.

212

C.4 FREE-FALL TEST—INCLINED SHAFTS

C.4.1 PREPARATION

Preparation is essentially the same as for free-fall tests in vertical shaft (see C.2.1). Blocking the shaft may be more difficult and consideration should be given to conducting the test near the bottom of the shaft, particularly if there is a more or less flat runout area.

The lockout tether length between tie-offs is:

$$\text{Tether length (ft)} = \left[\frac{\text{max permissible hoisting speed, ft/min}}{482}\right]^2 \frac{1}{\sin\theta},$$

where θ is the shaft-inclination angle measured from the horizontal ($\sin\theta = 1$ for a vertical shaft; for all inclined shafts $\sin\theta$ is less than 1).

C.4.2 TEST PROCEDURE

Step by step procedures are more or less identical to those for testing in a vertical shaft (see C.2.2). The same measurements are to be made.

C.4.3 PERFORMANCE EVALUATION

C.4.3.1 DATA NEEDED:

V_o = max permissible hoisting speed, ft/min

C = conveyance weight, lb

M_o = max permissible man load, lb

M = conveyance test load (M should be as close to M_o as practical)

E = max permissible equipment or material load

S_1 = distance conveyance travelled from release to brake engagement, ft

S_2 = distance conveyance travelled from brake engagement to stop, ft

θ = inclination of shaft from horizontal.

213

C.4.3.2 EVALUATION

(1) Actual speed at actuation:

$$V = 482 \sqrt{S_1 \sin \theta} \text{ (ft/min)}.$$

As in the case of a vertical shaft, it may require experimentation to find the proper length for the lockout tether to make V more or less equal to V_o.

(2) Average deceleration along slope:

$$\bar{A} = \frac{S_1}{S_2} (\sin \theta)\, g.$$

(3) Average deceleration in horizontal direction:

$$\bar{A}_H = \bar{A} \cos \theta.$$

The value of $\bar{A}_H$ should be greater than 0.15 g and less than 0.45 g.

NOTE: These suggested limits are educated guesses—made, in part, with knowledge of European haulage practice, but with more concern for not throwing men who face downslope off seats or cars. These suggested values definitely need validation.

(4) Average braking force (parallel to slope):

$$\bar{F}_B = (C + M) \left[\frac{S_1}{S_2} + 1 \right] \sin \theta \text{ (lb)}.$$

(5) Average deceleration down slope for one man aboard:

$$\bar{A}_o = \left[\frac{\bar{F}_B}{C} - \sin \theta \right] g.$$

(6) Average deceleration in horizontal direction with one man aboard:

$$\bar{A}_{Ho} = \bar{A}_o \cos \theta .$$

The value of $\bar{A}_{Ho}$ should be less than 0.45 g. Again, this suggested limit needs validation but should always be the same as the maximum value for $\bar{A}_H$ above.

(7) Ratio of average total braking force to maximum material or equipment load:

$$R_E = \frac{\bar{F}_B}{(C + E) \sin \theta} .$$

If the value of R_E is greater than 1.0 the brakes will stop the conveyance carrying its maximum permissible material load.

TRIPS/TRAINS

The above equations (and, in fact, the test procedures) assume that one conveyance with a brake is involved. In hoisting, one conveyance with a brake may be used with one or more unbraked conveyances. It is not necessary to conduct the test with all conveyances, however. The braked car alone can be used; but if it should stop abruptly enough to make the required measurements difficult or inaccurate, attach one unbraked car (or more if necessary) to obtain good distance measurements.

In these cases all the above equations can be used directly as long as only the vehicles used in the test are considered and only their weights and loads used.

The following equations can be used to evaluate the performance of the entire trip normally used (all cars, not just those tested):

(8) Average deceleration of entire trip along slope:

$$\bar{A}_T = \left[\frac{\bar{F}_B}{(C_T + M_T)} - \sin\theta \right] g ,$$

where C_T is the weight of all conveyances and M_T is the total load of the trip.

(9) Average deceleration in horizontal direction:

$$\bar{A}_{TH} = \bar{A}_T \cos\theta .$$

Again, $\bar{A}_{TH}$ should be greater than 0.15 g and less than 0.45 g.

(10) Average deceleration down slope for one man aboard:

$$\bar{A}_{To} = \left[\frac{\bar{F}_B}{C_T} - \sin\theta \right] g .$$

(11) Average deceleration in horizontal direction for one man aboard:

$$\bar{A}_{THo} = \bar{A}_{To} \cos\theta .$$

And again, A_{THo} should be less than 0.45 g.

(12) Ratio of average braking force to maximum material or equipment load:

$$R_{TE} = \frac{\bar{F}_B}{C_T + E_T} \sin\theta .$$

where E_T is the equivalent load carried.

If R_{TE} is greater than 1.0, the whole trip plus whatever load is carried will be stopped by the brakes.

215

C.4.3.2 EVALUATION (Continued)

CHANGES IN SLOPE

This entire section is written thus far as if the shaft were of constant inclination throughout. If not, conduct the test and evaluation on the steepest part of the slope. If this is not practical conduct the test and make the distance measurements where feasible and use the following equations to evaluate the performance at the steepest part.

In the following equations, θ, S_1 and S_2 apply to the place of test. θ_{max} is the inclination of the steepest part.

(13) Average deceleration along slope in steepest part·

$$\bar{A}_{min} = \left[\left[\frac{S_1}{S_2} + 1\right] \sin\theta - \sin\theta_{max}\right] g\ .$$

The subscript "min" means minimum deceleration—it will be the minimum.

(14) Horizontal component:

$$\bar{A}H_{min} = \bar{A}_{min} \cos\theta_{max}\ .$$

A_{Hmin} should be greater than 0.15 g and less than 0.45 g.

(15) Average braking force is the same, i.e:

$$\bar{F}_B + (C + M) \left[\frac{S_1}{S_2} + 1\right] \sin\theta\ .$$

(16) Average deceleration for one man aboard:

$$\bar{A}_{o_{min}} = \left[\frac{\bar{F}_B}{C} - \sin\theta_{max}\right] g\ .$$

(17) Average horizontal deceleration for one man aboard:

$$\bar{A}_{Ho_{min}} = \bar{A}_{o_{min}} \cos\theta_{max}\ .$$

$\bar{A}_{Ho_{min}}$ should be less than 0.45 g.

(18) Equipment ratio:

$$R_E = \frac{\bar{F}_B}{(C + E)\sin\theta_{max}}\ ;$$

The conveyance and load will stop if R_E is greater than 1.0.

C.5 DROP TEST—INCLINED SHAFTS

Enough has been said already about free-fall and drop tests to indicate how a drop test should be carried out in an inclined shaft, if needed.

As for vertical shafts, the value of such a test is to get a feeling for the capability of unknown or doubtful conveyance safety brakes before slowly working up to a full free-fall test as discussed in Section C.3.4.

Appendix D
Federal Regulations

Page

219

Appendix D
Federal Regulations

D.1 INTRODUCTION

This appendix provides a reference to the U.S. Federal regulations pertaining to hoisting in underground metal, nonmetal, and coal mines.

Section D.2 is a topical cross-reference to these regulations, and only the topics discussed in this handbook are included. The arrangement of topics parallels the format of Chapters 1 through 9 as noted.

Section D.3 presents the regulations themselves.

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220

D.2 TOPICAL CROSS-REFERENCE

Table D.1. Records (Chapter 1)

Item	Regulations: Metal/Nonmetal	Regulations: Coal
Installation, lubrication, inspection, tests, and maintenance of shafts and hoisting equipment	57.19-120 M 57.11-56 (Escape Hoists)	
Daily examination of hoisting equipment		75.1400-4
Safety catches (or other such devices) tests		75.1400-2

Table D.2. Inspection and Maintenace Tasks (Chapter 1)

Item	Frequency	Mode*	Regulation: Metal/Nonmetal	Regulation: Coal
HOIST MACHINERY				
General	Start of each shift	Examine	57.19-129 M	
	Daily	Examine		75.1400**
Brake mechanism	Start of each shift	Test	57.19-129 M	
HOIST CONTROLS				
Conveyance position indicator	Daily	Check accuracy		75.1401-3
	Start of each shift	Test	57.19-129 M	
Overtravel, deadman controls	Start of each shift	Test	57.19-129 M	

*The words used under "Mode" of inspection and maintenance are those used in the regulations, or a parallel. Except for the conveyance safety catch tests called out in the noncoal regulations, no test methods are described.

**The daily examination of hoisting equipment called for in 75.1400 (coal) is so general it could be interpreted to apply to everything. This requirement and all parts of 75.1400-3 apply to automatic elevators as well.

Table D.2. (Continued)

Item	Frequency	Mode	Regulation: Metal/Nonmetal	Regulation: Coal
SHEAVES, ROLLERS, DRUM AND KOEPE WHEEL FACES				
Sheaves	Daily	Inspect	57.19-134	
Head sheaves	Daily	Examine		75.1400 75.1400-3
HOIST ROPE				
Terminations	Daily	Inspect, examine	57.19-131	75.1400-3(b)
Rope:				
Wear, broken wires, corrosion, etc.	Daily	Visual examination		75.1400-3(a)
Wear, damage	At regular intervals	Measurements	57.19-126	
Rope cutoff and Retermination:				
At conveyance	As often as necessary	Examine cut-off portion	57.19-124	
At drum	As necessary		57.19-125	
CONVEYANCES				
Structure	Daily	Examine		75.1400-3(d)
Connections to other conveyances	Daily	Inspect	57.19-131	
Safety catches	Daily	Examine		75.1400-3(c)
	Daily	Inspect	57.19-132	
	At installation	Drop test	57.19-132	
	Every 2 months	Actuate with conveyance supported	57.19-132	
	Every 2 months	Test		75.1400
SHAFTS	Weekly	Inspect	57.19-133	
	Daily	Inspect		75.1400-3(f)

222

Table D.2. (Continued)

Item	Frequency	Mode	Regulation Metal/Nonmetal	Regulation Coal
MISCELLANEOUS				
Signal system	Daily	Test		75.1402-2
General test	After shaft or equipment repairs	Operate one round trip	57.19-130	
Escape hoist	30 days minimum	Test	57.11-56	

Table D.3. General Equipment Design, Applications, and Procedures

Item	Aspect Addressed	Regulation: Metal/Nonmetal	Regulation: Coal
HOIST MACHINERY (Chapter 2)			
General	Design—capacity	57.19-1 M	75.1401
	Installation—anchoring	57.19-2 M	
Drives	Design—type	57.19-3 M	
Clutches	Clutch/brake interlock	57.19-5 M	75.1403-3(a)
Brakes	Design—capacity	57.19-4 M	75.1400 75.1400-1 75.1403-2
Drums	Design—flanges	57.19-11	
	Design—grooves	57.19-12	
HOIST CONTROLS (Chapter 3)			
Power failure (electric) shutdown	Application	57.19-6 M	75.1400(?)*
Nonelectric drive shutdown	Special design requirement	57.19-13 M	
Overspeed, overtravel protection	Application	57.19-7 M	75.1400
	Special equipment for friction hoists	57.19-8	
Conveyance position indicators	Application	57.19-9 M	75.1401 75.1401-3
	Special equipment for friction hoists	57.19-8	
Speed control	Maximum speed	57.19-61/-76	
	Acceleration/deceleration	57.19-62	
Warning signs	Men working in shaft	57.19-107 M/-108 M	
SHEAVES, ROLLERS, DRUMS, AND WHEEL FACES (Chapter 4)			
Head frames	Design—height/clearance	57.19-36	
Head/turning/deflection sheaves	Design—diameters	57.19-39	
Sheave grooves	Design/maintenance	57.19-40	

*Author interprets phrase "automatic stop controls" to mean power failure shutdown.

224

Table D.3. (Continued)

Item	Aspect Addressed	Regulation: Metal/Nonmetal	Regulation: Coal
Elevated sheaves	Inspection platform	57.19-38 M	
Drum	Design—flange Design—diameter Design—rope grooves	57.19-11 57.19-39 57.19-12	
Rollers	Maintenance	57.19-135	
Fleet angles	Maximum	57.19-37	
HOIST ROPES (Chapter 5)			
Terminations	Prohibition against open hooks	57.19-75 M	
At conveyance	Procedures—clips/ poured sockets/thimbles	57.19-24 M(a through d)	
At drum	Procedure	57.19-23	75.1403-3(c)
Other attachments to rope	Procedures	57.19-24 M(e) 57.19-26 M	
Rope:			
General	Guidelines	57.19-20	75.1401-1
Selection	Safety factors for new rope	57.19-21 M	75.1400
Installation	Dead wraps Drum fastening	57.19-22 57.19-23	75.1403-3(c) 75.1403-3(c)
Break-in	Procedure	57.19-25	
Lubrication	Procedure	57.19-123	
Nondestructive inspection	Use of	57.19-127	
Removal	Criteria—safety factor Criteria—other	57.19-21 M 57.19-128 M(a through d)	
GUIDE AND TAIL ROPES (Chapter 6)			
Guide ropes	Construction	57.19-54 M	
CONVEYANCES AND COUNTERWEIGHTS (Chapter 7)			
Conveyances	Design—general Design—bonnet	 57.19-45 M	75.1403-3(d)

Table D.3. (Continued)

Item	Aspect Addressed	Regulation Metal/Nonmetal	Regulation Coal
	Design—car blocks	57.19-79 M	
	Design—self dumpers		75.1403-3(e)
Connections/links	Prohibition against open hooks	57.19-75 M	
	Procedures		75.1403-7(d)
CONVEYANCE SAFETY DEVICES (Chapter 7)			
Communication from cage	Provision	57.19-92 M	
Safety catches	Application		75.1400
Secondary safety connection to hoist rope	Application	57.19-27	75.1403-3(b)
	Procedure	57.19-26 M	
Chairs	Application	57.16-35	
GUIDES AND SHAFTS (Chapter 8)			
Guides	Application in inclined shafts	57.19-102	
Shaft landings/collar	Gates	57.19-100 M	75.1403-11
	Car blocks/derails	57.19-79M/ -101M	75.1403-8(e)
	Design—general	57.19-104/ -105 M	75.1403-9(e)
Dump facilities	Design	57.19-103	
Communication/ signal systems	Application	57.19-90 M	75.1600 75.1402/-1
	Use of	57.19-91	
SHAFT SINKING/DEEPENING* (Chapter 9)			
Sinking buckets	Design—general	57.19-50 M(a through d)	
Bulkheads	Application	57.19-110 M	
Platform/stage ropes	Strength	57.19-53 M	
	Construction	57.19-54 M	
ESCAPE HOISTS (Chapter 9)	Application and design	57.11-55 M/-56	75.1704-1(b)

*These are only specific cross-references; many other regulations also apply to buckets, etc.

226

Table D.3. (Continued)

Item	Aspect Addressed	Regulation Metal/Nonmetal	 Coal
ELEVATORS (Chapter 9)	Design—brakes		75.1403
	Design—general		75.1403-4(a) through d) 75.1704-1(b)
ALTERATIONS/REPAIRS	Affecting hoist capacity		75.1401-2
	Quality	57.19-122	

D.3 REGULATIONS

FEDERAL REGULATIONS PERTAINING TO HOISTING
IN UNDERGROUND METAL, NONMETAL, AND COAL MINES

Source: Code of Federal Regulations, Title 30, Mineral Resources*

Part 57—Health and Safety Standards—Metal and Nonmetallic Underground Mines

Section 57.11 Travelways and Escapeways

Section 57.16 Materials Storage and Handling (in part).

Section 57.19 Man Hoisting

Part 75—Mandatory Safety Standards—Underground Coal Mines*

Subpart O—Hoisting and Mantrips

Subpart Q—Communications

Subpart R—Miscellaneous

*As revised as of August 1, 1974.

D.3.1 PART 57—HEALTH AND SAFETY STANDARDS— METAL AND NONMETALLIC UNDERGROUND MINES

§ 57.11 Travelways and escapeways.

(in part)

57.11-55 *Mandatory.* Designated escapeways inclined more than 30° from the horizontal shall be equipped with stairways, ladders, cleated walkways, or emergency hoisting facilities.

57.11-56 Emergency hoisting facilities should conform to the extent possible to safety requirements for other man hoists, should be adequate to remove the men from the mine with a minimum of delay, be maintained in ready condition, and be tested at least every 30 days; records should be kept of these tests.

§ 57.16 Materials storage and handling.

(in part)

UNDERGROUND ONLY

57.16-35 Chairs should be used to land shaft conveyances when heavy supplies or equipment are being handled.

§ 57.19 Man hoisting.

The hoisting standards in this section apply to those hoists and appurtenances used for hoisting men. However, where men may be endangered by hoists and appurtenances used solely for handling ore, rock, and materials, the appropriate standards should be applied.

HOISTS

57.19-1 *Mandatory.* Hoists shall have rated capacities consistent with the loads handled and the recommended safety factors of the ropes used.

57.19-2 *Mandatory.* Hoists shall be anchored securely.

57.19-3 *Mandatory.* Belt, rope, or chains shall not be used to connect driving mechanisms to man hoists.

57.19-4 *Mandatory.* Any hoist used to hoist men shall be equipped with a brake or brakes which shall be capable of holding its fully loaded cage, skip, or bucket at any point in the shaft.

57.19-5 *Mandatory.* The operating mechanism of the clutch of every man-hoist drum shall be provided with a locking mechanism, or interlocked electrically or mechanically with the brake to prevent accidental withdrawal of the clutch.

57.19-6 *Mandatory.* Automatic hoists shall be provided with devices that automatically apply the brakes in the event of power failure.

57.19-7 *Mandatory.* All man hoists shall be provided with devices to prevent overtravel. When utilized in shafts exceeding 100 feet in depth, such hoists shall also be provided with overspeed devices.

57.19-8 Friction hoists should be provided with synchronizing mechanisms that recalibrate the overtravel devices and position indicators to correct for rope creep or stretch.

57.19-9 *Mandatory.* An accurate and reliable indicator of the position of the cage, skip, bucket, or cars in the shaft shall be provided.

57.19-10 *Mandatory.* Hoist controls shall be placed or housed so that the noise from machinery or other sources will not prevent hoistmen from hearing signals.

57.19-11 Flanges on drums should extend radially a minimum of two rope diameters and not less than 4 inches beyond the last wrap.

57.19-12 Where grooved drums are used, the grooves should be of the proper size and pitch for the ropes used.

57.19-13 *Mandatory.* Where any diesel or similar fuel-injection engine is used to power a hoist, the engine shall be equipped with a damper or other cutoff in its air intake system. The control handle shall be clearly labeled to indicate that its intended function is for emergency stopping only.

Wire Rope

57.19-20 The United States of America Standards Institute specifications cited in "Wire Ropes for Mines", M11.1-1960, or the latest revision thereof, should be used as a guide in the selection, installation, and maintenance of wire ropes used for hoisting, except in those instances where the recommendations cited herein are more stringent.

57.19-21 *Mandatory*. The following static-load safety factors shall be used for selecting ropes to be used for hoisting men and for determining when such ropes shall be removed from man hoists.

Length of rope in shaft (feet)	Minimum factor of safety (new rope)	Minimum factor of safety (remove)
500 or less	8	6.4
501-1,000	7	5.8
1,001-2,000	6	5.0
2,001-3,000	5	4.3
3,001 or more	4	3.6

57.19-22 At least three wraps of rope should be left on the drum when the conveyance is at the bottom of the hoistway. This provision does not apply to friction hoists.

57.19-23 The end of the rope at the drum should make at least one full turn on the drum shaft, or a spoke of the drum in the case of a free drum, and should be fastened securely by means of rope clips or clamps. This standard does not apply to friction hoists.

57.19-24 *Mandatory*. The rope shall be attached to the load by the thimble-and-clip method, the socketing method, or other approved method. If the socketing method is employed, zinc or its equivalent shall be used. The use of Babbitt metal or lead for socketing wire ropes is prohibited. If the thimble-and-clip method is used, the following shall be observed:

(a) The rope shall be attached to the load by passing one end around an oval thimble that is attached to the load bending the end back so that it is parallel to the long or "live" end of the rope and fastening the two parts of the rope together with clips.

(b) The U-bolt of each clip shall encircle the short or "dead" end of the rope and the distance between clips shall not be less than the figures given in the accompanying table.

(c) As a minimum the following number of clips or equivalent shall be used for various diameters of six-stand 19-wire plow steel ropes:

(Follow manufacturer's recommendations for other kinds of wire rope and clips.)

Diameter of rope, inches	Number of clips	Center-to-center spacing, of clips, inches
¾	4	4½
⅞	4	5¼
1	4	6
1⅛	5	6¾
1¼	5	7½
1⅜	6	8¼
1½	6	9
1⅝	6	9¾
1¾	7	10½
1⅞	8	11¼
2	8	12
2⅛	8	13
2¼	8	14

(d) For all ropes less than three-quarter inch in diameter, at least four clips or equivalent shall be used.

(e) When special conditions require the attachment of a sling to the hoisting cable to handle equipment in the shaft, the sling shall be attached by clips or equivalent in accordance with the table in paragraph (c) of this standard.

57.19-25 New ropes should be broken-in in accordance with the manufacturer's recommendations.

57.19-26 *Mandatory*. Safety device attachments to hoist ropes shall be selected, installed, and maintained according to manufacturers' specifications to minimize internal corrosion and weakening of the hoist rope.

57.19-27 Where possible, conveyances attached to single ropes used to hoist men should be provided with secondary safety connections.

Headframes and Sheaves

57.19-35 Headframes should be designed and constructed to withstand pulls by the hoists greater than the breaking strengths of the hoist ropes.

57.19-36 Headframes should be high enough to provide at least 15 feet of clearance between the bottom of the sheave or drum and the uppermost part of the highest rope connection of the conveyance when the conveyance is at its uppermost man-landing.

57.19-37 Fleet angles should not exceed 1½ degrees.

57.19-38 *Mandatory*. Platforms with toeboards and handrails shall be provided around elevated head sheaves.

57.19-39 Diameters of head sheaves and hoist drums should conform to the following specifications:

Rope construction	Diameter of sheave and drum: Recommended	Diameter of sheave and drum: Minimum
	Times rope diameter	*Times rope diameter*
6 x 7 classification	72	42
6 x 19	45	30
6 x 37	27	18
6 x 25 type B, flattened strand	45	30
6 x 27 type H, flattened strand	45	30
6 x 30 type G, flattened strand	45	30
18 x 7 classification	51	34

57.19-40 Head, idler, knuckle, and curve sheaves should have grooves that support the ropes properly. Before installing new ropes, the grooves should be inspected and where necessary machined to the proper contour and the proper groove diameter.

230

D.3.1 PART 57—HEALTH AND SAFETY STANDARDS— METAL AND NONMETALLIC UNDERGROUND MINES (Continued)

Conveyances

57.19-45 *Mandatory.* Man cages and skips used for hoisting or lowering employees or other persons in any vertical shaft or any incline shaft with an angle of inclination of forty-five (45) degrees from the horizontal, shall be covered with a metal bonnet.

57.19-49 *Mandatory.* Buckets shall not be used to hoist men except during shaft sinking operations, inspection, maintenance, and repairs.

57.19-50 *Mandatory.* Buckets used to hoist men during vertical shaft sinking operations shall have:

(a) A crosshead the height of which is at least 1½ times its width if used on wooden guides or a minimum height of 4 feet if used on rope or steel guides.

(b) Overhead protection when the shaft depth exceeds 50 feet.

(c) Sufficient depth or a suitably designed platform to transport men safely in a standing position.

(d) Devices to prevent accidental dumping where the bucket is supported by a bail attached to its lower half.

57.19-53 *Mandatory.* In shaft sinking where a platform is suspended by wire ropes, such ropes shall have an approved rating for the suspended load.

57.19-54 *Mandatory.* Where rope guides are used in shafts they shall be of locked coil construction.

Hoisting Procedures

57.19-55 *Mandatory.* When a manually operated hoist is used, a qualified hoistman shall remain within hearing of the telephone or signal device at all times while any person is underground.

57.19-56 When automatic hoisting is used, a qualified hoistman should be in attendance on the premises while any person is underground.

57.19-57 Hoistmen should be physically fit and should undergo yearly examinations to determine their continued fitness; certification to this effect should be available at the mine.

57.19-58 *Mandatory.* Only experienced hoistmen shall operate the hoist except in cases of emergency and in the training of new hoistmen.

57.19-60 Hoistmen should use extreme caution when hoisting or lowering men.

57.19-61 The safe speed for hoisting men should be determined for each shaft, and this speed should not be exceeded. Men should not be hoisted at a speed faster than 2,500 feet per minute, except in an emergency. be done while persons are on cages.

57.19-62 Maximum acceleration and deceleration should not exceed 6 feet per second.

57.19-63 Only authorized persons should be in hoist rooms.

57.19-65 *Mandatory.* Conveyances shall not be lowered by the brakes alone except during emergencies.

57.19-66 Management should designate the maximum number of men permitted to ride on a trip at one time; this limit should be posted on each landing.

57.19-67 Authorized persons should be in charge of all man trips.

57.19-68 Men should enter, ride, and leave conveyances in an orderly manner.

57.19-69 *Mandatory.* Men shall not enter or leave conveyances which are in motion or after a signal to move the conveyance has been given to the hoistman.

57.19-70 *Mandatory.* Cage doors or gates shall be closed while men are being hoisted; they shall not be opened until the cage has come to a stop.

57.19-71 *Mandatory.* Men shall not ride in skips or buckets with muck, supplies, materials, or tools other than small hand tools.

57.19-72 When combinations of cages and skips are used, the skips should be empty while men are being transported.

57.19-73 *Mandatory.* Rock or supplies shall not be hoisted in the same shaft as men during shift changes, unless the compartments and dumping bins are partitioned to prevent spillage into the cage compartment.

57.19-74 Men should not ride the bail, rim, or bonnet of any shaft conveyance, except where necessary for the inspection and maintenance of the shaft and lining.

57.19-75 *Mandatory.* Open hooks shall not be used to hoist buckets or other conveyances.

57.19-76 When men are hoisted, bucket speeds should not exceed 500 feet a minute, and should not exceed 200 feet a minute when within 100 feet of a landing.

57.19-77 *Mandatory.* Buckets shall be stopped about 15 feet from the shaft bottom to await a signal from one of the crew on the bottom for further lowering.

57.19-78 Buckets should be stopped after being raised 3 feet when men are hoisted from the bottom; a second hoisting signal should be given after the bucket has been stabilized. Hoisting should be at a minimum speed and the bellcord should be attended constantly until the crosshead has been engaged.

57.19-79 *Mandatory.* Where mine cars are hoisted by cage or skip, means for blocking cars shall be provided at all landings and also on the cage.

57.19-80 *Mandatory.* When tools, timbers, or other materials are being lowered or raised in a shaft by means of a bucket, skip, or cage, they shall be secured or so placed that they will not strike the sides of the shaft.

57.19-81 Conveyances not in use should be released and raised or lowered at least 10 feet from the floor of the landing.

Signaling

57.19-90 *Mandatory.* There shall be at least two effective approved methods of signaling between each of the shaft stations and the hoist room, one of which shall be a telephone or speaking tube.

57.19-91 Hoistmen should not accept hoisting instructions by telephone unless the regular signaling systems are out of order. During such an emergency one person should be designated to direct movement of the conveyance.

57.19-92 *Mandatory.* A method shall be provided to signal the hoist operator from cages or other conveyances at any point in the shaft.

57.19-93 A standard code of hoisting signals should be adopted and used at each mine.

57.19-94 *Mandatory.* A legible signal code shall be posted prominently in the hoist house within easy view of the hoistmen, and at each place where signals are given or received.

57.19-95 Hoisting signal devices should be maintained within easy reach of men on the shaft bottom during sinking operation.

57.19-96 *Mandatory.* Any person responsible for receiving or giving signals for cages, skips, and mantrips when men or materials are being transported shall be familiar with the posted signaling code.

Shafts

57.19-100 *Mandatory.* Shaft landings shall be equipped with substantial safety gates so constructed that materials will not go through or under them; gates shall be closed except when loading or unloading shaft conveyances.

57.19-101 *Mandatory.* Positive stopblocks or a derail switch shall be installed on all tracks leading to a shaft collar or landing.

57.19-102 Guides should be provided in each hoisting compartment in shafts inclined more than 45° from the horizontal.

57.19-103 Dumping facilities should be so constructed as to minimize spillage into the shaft.

57.19-104 Adequate clearance should be maintained at shaft stations tc allow men to pass safely and to allow materials to be handled safely.

57.19-105 *Mandatory.* A safe means of passage around open shaft compartments shall be provided on landings with more than one entrance to the shaft

57.19-106 Shaft timbers should be kept clean of rocks and other loose material.

57.19-107 *Mandatory.* Hoistmen shall be informed when men are working in a compartment affected by that hoisting operation and "Men Working in Shaft" sign shall be posted at the hoist.

57.19-108 *Mandatory.* When men are working in a shaft "Men Working in Shaft" signs shall be posted at all devices controlling hoisting operations that may endanger such men.

57.19-109 *Mandatory.* Shaft inspection and repair work in vertical shafts shall be performed from substantial platforms equipped with bonnets or equivalent overhead protection.

57.19-110 *Mandatory.* A substantial bulkhead or equivalent protection shall be provided above men at work deepening a shaft.

57.19-111 Substantial fixed ladders should be maintained as near the shaft bottom as practical during shaft-sinking operations. Chain, wire rope, or other extension ladders should be used from the fixed ladder to the shaft bottom.

Inspection and Maintenance

57.19-120 *Mandatory.* A systematic procedure of inspection, testing, and maintenance of shaft and hoisting equipment shall be developed and followed. If it is found or suspected that any part is not functioning properly, the hoist shall not be used until the malfunction has been located and repaired or adjustments have been made.

57.19-121 Complete records should be kept of installation, lubrication, inspection, tests, and maintenance of shafts and hoisting equipment.

57.19-122 Parts used to repair hoists should have properties equal to or better than the original parts; replacement parts should be designed to fit the original installation.

57.19-123 Ropes should be kept well lubricated from end to end as recommended by the manufacturer.

57.19-124 On other than friction hoists, ropes should be cut off and reconnected to the conveyance as often as necessary to assure adequate inspection of rope condition and to distribute wear of the rope. At least 6 feet should be cut from the rope above the highest connection; this portion should be examined carefully for corrosion, damage, wear, and fatigue by the rope manufacturer or a competent agency.

57.19-125 Hoisting ropes wound in multiple layers should be cut off and repositioned on the drum at regular intervals as necessary to distribute wear of the rope. The length of cutoff at the drum end should not be an even multiple of the circumference of the drum.

57.19-126 Ropes should be calipered at regular intervals as necessary to effectively determine the rate of wear and damage. Caliper measurements should be taken:

(a) Immediately above the socket or clips and above the safety connection.

(b) Where the ropes rest on the sheaves.

(c) Where the ropes leave the drums when the conveyances are at the regular stopping points.

(d) Where a layer of rope begins to overlap another layer on the drum.

57.19-127 Electromagnetic or other nondestructive rope testing systems should be used only as supplements to and not as substitutes for recommended inspection and tests.

57.19-128 *Mandatory.* Ropes shall not be used for hoisting when they have:

(a) More than six broken wires in any lay.

(b) Crown wires worn to less than 65 percent of the original diameter.

(c) A marked amount of corrosion or distortion.

(d) A combination of similar factors individually less severe than those above but which in aggregate might create an unsafe condition.

57.19-129 *Mandatory.* Hoistmen shall examine their hoists and shall test overtravel, deadman controls, position indicators, and braking mechanisms at the beginning of each shift.

57.19-130 Empty conveyances should be operated up and down shafts at least one round trip before hoisting men after any shaft or equipment repairs and before regular man trips are hoisted or lowered.

57.19-131 Rope and conveyance connections to conveyances should be inspected daily.

57.19-132 Safety catches should be inspected daily; drop tests should be made at the time of installation. Every 2 months the cage should be rested on chairs or proper blocking to check the operation or activation of the safety catches by allowing the rope to slacken suddenly.

57.19-133 Shafts should be inspected at least weekly.

57.19-134 Sheaves should be inspected daily and kept properly lubricated.

57.19-135 Rollers used in inclined shafts should be lubricated, properly aligned and kept in good repair.

232

D.3.2 PART 75—MANDATORY SAFETY STANDARDS—UNDERGROUND COAL MINES

Subpart O—Hoisting and Mantrips

(in part)

§ 75.1400 Hoisting equipment; general.

[STATUTORY PROVISIONS]

Every hoist used to transport persons at a coal mine shall be equipped with overspeed, overwind, and automatic stop controls. Every hoist-handling platforms, cages, or other devices used to transport persons shall be equipped with brakes capable of stopping the fully loaded platform, cage, or other device; with hoisting cable adequately strong to sustain the fully loaded platform, cage, or other device; and have a proper margin of safety. Cages, platforms, or other devices which are used to transport persons in shafts and slopes shall be equipped with safety catches or other no less effective devices approved by the Secretary that act quickly and effectively in an emergency, and such catches shall be tested at least once every 2 months. Hoisting equipment, including automatic elevators, that is used to transport persons shall be examined daily. Where persons are transported into, or out of, a coal mine by hoists, a qualified hoisting engineer shall be on duty while any person is underground, except that no such engineer shall be required for automatically operated cages, platforms, or elevators.

§ 75.1400–1 Hoists; brakes, capability.

Brakes on hoists used to transport persons shall be capable of stopping and holding the fully loaded platform, cage, or other device at any point in the shaft, slope, or incline.

§ 75.1400–2 Hoists; tests of safety catches; records.

A record shall be made in a book of the tests, required by § 75.1400, of the safety catches or other devices approved by the Secretary. Each entry shall be signed by the person making the tests and countersigned by a responsible official.

§ 75.1400–3 Daily examination of hoisting equipment.

The daily examination required by § 75.1400, of hoisting equipment, including automatic elevators shall include but not be limited to the following:

(a) A visual examination of the rope for wear, broken wires, and corrosion, especially at excessive strain points, such as near the attachments, where the rope rests on the sheaves and where the rope leaves the drum at both ends.

(b) An examination of the rope fastenings for defects.

(c) An examination of safety catches.

(d) An examination of the cage, platforms, elevators, or other devices for loose, missing, or defective parts.

(e) An examination of the head sheaves to check for broken flanges, defective bearings, rope alignment, and proper lubrication.

(f) An observation of the lining and all other equipment and appurtenances installed in the shaft.

§ 75.1400–4 Daily examinations of hoisting equipment; records.

Records of the daily examinations of hoisting equipment required by § 75.1400 shall be kept listing all items examined. Daily entries shall be signed by the person or persons making examinations. The reports of the examinations shall be read and countersigned by a responsible company official daily.

§ 75.1401 Hoists; rated capacities; ropes; indicators.

[STATUTORY PROVISIONS]

Hoists shall have rated capacities consistent with the loads handled and the recommended safety factors of the ropes used. An accurate and reliable indicator of the position of the cage, platform, skip, bucket, or cars shall be provided.

§ 75.1401–1 Hoists, standards for ropes.

The American National Standards Institute "Specifications For the Use of Wire Ropes For Mines," M11.1–1960, or the latest revision thereof, shall be used as a guide in the use, selection, installation, and maintenance of wire ropes used for hoisting.

§ 75.1401–2 Hoists; notification of changes affecting rated capacity.

Alterations or changes in a hoist which affect the rated capacity shall be made only with the approval of the Coal Mine Safety District or Subdistrict Manager.

§ 75.1401–3 Hoists; indicators.

The indicator required by § 17.1401 of this chapter shall be placed so that it is in clear view of the hoisting engineer and shall be checked daily to determine its accuracy.

§ 75.1402 Communication between shaft stations and hoist room.

[STATUTORY PROVISIONS]

There shall be at least two effective methods approved by the Secretary of signaling between each of the shaft stations and the hoist room, one of which shall be a telephone or speaking tube.

§ 75.1402-1 Communication between shaft stations and hoist room.

One of the methods used to communicate between shaft stations and the hoist room shall give signals which can be heard by the hoisting engineer at all times while men are underground.

§ 75.1402-2 Tests of signaling systems.

Signaling systems used for communication between shaft stations and the hoist room shall be tested daily.

§ 75.1403 Other safeguards.

[STATUTORY PROVISIONS]

Other safeguards adequate, in the judgment of an authorized representative of the Secretary, to minimize hazards with respect to transportation of men and materials shall be provided.

§ 75.1403-1 General criteria.

(a) Sections 75.1403-2 through 75.1403-11 set out the criteria by which an authorized representative of the Secretary will be guided in requiring other safeguards on a mine-by-mine basis under § 75.1403. Other safeguards may be required.

(b) The authorized representative of the Secretary shall in writing advise the operator of a specific safeguard which is required pursuant to § 75.1403 and shall fix a time in which the operator shall provide and thereafter maintain such safeguard. If the safeguard is not provided within the time fixed and if it is not maintained thereafter, a notice shall be issued to the operator pursuant to section 104 of the Act.

(c) Nothing in the sections in the § 75.1403 series in this Subpart O precludes the issuance of a withdrawal order because of imminent danger.

§ 75.1403-2 Criteria—Hoists transporting materials; brakes.

Hoists and elevators used to transport materials should be equipped with brakes capable of stopping and holding the fully loaded platform, cage, skip, car, or other device at any point in the shaft, slope, or incline.

§ 75.1403-3 Criteria—Drum clutch; attachment of ropes; cage construction.

(a) The clutch of free-drums on man-hoist should be provided with a locking mechanism or interlocked with the brake to prevent the accidental withdrawal of the clutch.

(b) The hoist rope attached to a cage, man car, or trip should be equipped with two bridle chains or cables connected securely to the rope at least 3 feet above the attaching device and to the cross-piece of the cage, man car or trip.

(c) The hoist rope should have at least three full turns on the drum when extended to its maximum working length and should make at least one full turn on the drum shaft or around the spoke of the drum in the case of a free drum, and be fastened securely.

(d) Cages used for hoisting men should be constructed with the sides enclosed to a height of at least 6 feet and should have gates, safety chains, or bars across the ends of the cage when men are being hoisted or lowered.

(e) Self-dumping cages, platforms, or other devices used for transportation of men should have a locking device to prevent tilting when men are transported thereon.

(f) An attendant should be on duty at the surface when men are being hoisted or lowered at the beginning and end of each operating shift.

(g) Precautions should be taken to protect persons working in shaft sumps.

(h) Workmen should wear safety belts while doing work in or over shafts.

§ 75.1403-4 Criteria—Automatic elevators.

(a) The doors of automatic elevators should be equipped with interlocking switches so arranged that the elevator car will be immovable while any door is opened or unlocked, and arranged so that such door or doors cannot be inadvertently opened when the elevator car is not at a landing.

(b) A "Stop" switch should be provided in the automatic elevator compartment that will permit the elevator to be stopped at any location in the shaft.

(c) A slack cable device should be used where appropriate on automatic elevators which will automatically shut-off the power and apply the brakes in the event the elevator is obstructed while descending.

(d) Each automatic elevator should be provided with a telephone or other effective communication system by which aid or assistance can be obtained promptly.

§ 75.1403-7 Criteria—Mantrips.

(a) Mantrips should be operated independently of any loaded trip, empty trip, or supply trip and should not be operated within 300 feet of any trip, including another mantrip.

(b) A sufficient number of mantrip cars should be provided to prevent overcrowding of men.

(c) Mantrips should not be pushed.

234

D.3.2 PART 75—MANDATORY SAFETY STANDARDS—UNDERGROUND COAL MINES (Continued)

(d) Where mantrips are operated by locomotives on slopes such mantrips should be coupled to the front and rear by locomotives capable of holding such mantrips. Where ropes are used on slopes for mantrip haulage, such conveyances should be connected by chains, steel ropes, or other effective devices between mantrip cars and the rope.

(e) Safety goggles or eyeshields should be provided for all persons being transported in open-type mantrips.

(f) All trips, including trailers and sleds, should be operated at speeds consistent with conditions and the equipment used, and should be so controlled that they can be stopped within the limits of visibility.

(g) All mantrips should be under the direction of a supervisor and the operator of each mantrip should be familiar with the haulage safety rules and regulations.

(h) Men should proceed in an orderly manner to and from mantrips and no person should be permitted to get on or off a moving mantrip.

(i) Explosives and detonators should not be permitted on any mantrip or hauled within 5 minutes before or after any mantrip.

(j) Mantrips should not be permitted to proceed until the operator of the mantrip is assured that he has a clear road.

(k) Supplies or tools, except small hand tools or instruments, should not be transported with men.

(l) At places where men enter or leave mantrip conveyances, ample clearance should be provided and provisions made to prevent persons from coming in contact with energized electric circuits.

(m) The mine car next to a trolley locomotive should not be used to transport men. Such cars may be used to transport small tools and supplies. This is not to be construed as permitting the transportation of large or bulky supplies such as shuttle car wheel units, or similar material.

(n) Drop-bottom cars used to transport men should have the bottoms secured with an additional locking device.

(o) Extraneous materials or supplies should not be transported on top of equipment; however, materials and supplies that are necessary for or related to the operation of such equipment may be transported on top of such equipment if a hazard is not introduced.

§ 75.1403–8 Criteria—Track haulage roads.

(a) The speed at which haulage equipment is operated should be determined by the condition of the roadbed, rails, rail joints, switches, frogs, and other elements of the track and the type and condition of the haulage equipment.

(b) Track haulage roads should have a continuous clearance on one side of at least 24 inches from the farthest projection of normal traffic. Where it is necessary to change the side on which clearance is provided, 24 inches of clearance should be provided on both sides for a distance of not less than 100 feet and warning signs should be posted at such locations.

(c) Track haulage roads developed after March 30, 1970, should have clearance on the "tight" side of a least 12 inches from the farthest projection of normal traffic. A minimum clearance of 6 inches should be maintained on the "tight" side of all track haulage roads developed prior to March 30, 1970.

(d) The clearance space on all track haulage roads should be kept free of loose rock, supplies, and other loose materials.

(e) Positive stopblocks or derails should be installed on all tracks near the top and at landings of shafts, slopes, and surface inclines.

§ 75.1403–9 Criteria—Shelter holes.

(a) Shelter holes should be provided on track haulage roads at intervals of not more than 105 feet unless otherwise approved by the Coal Mine Safety District Manager(s).

(b) Shelter holes should be readily accessible and should be at least 5 feet in depth, not more than 4 feet in width (except crosscuts used as shelter holes) and at least the height of the coal seam where the coal seam is less than 6 feet high and at least 6 feet in height where the coal seam is 6 feet or more in height.

(c) Shelter holes should be kept free of refuse and other obstructions. Crosscuts used as shelter holes should be kept free of refuse or other materials to a depth of at least 15 feet.

(d) Shelter holes should be provided at all manually operated doors and at switch throws except: (1) At room switches, or (2) at switches where more than 6 feet of side clearance is provided. The Coal Mine Safety District Manager(s) may permit exemption of this requirement if such shelter holes create a hazardous roof condition.

(e) At each underground slope landing where men pass and cars are handled, a shelter hole at least 10 feet in depth, 4 feet in width, and 6 feet in height should be provided.

§ 75.1403–10 Criteria—Haulage; general.

(a) A permissible trip light or other approved device such as reflectors, approved by the Coal Mine Safety District Manager(s), should be used on the rear of trips pulled, on the front of trips pushed and on trips lowered in slopes. However, trip lights or other approved devices need not be used on cars being shifted to and from loading machines, on cars being handled at loading heads, during gathering operations at working faces, when trailing locomotives are used, or on trips pulled by animals.

(b) Cars on main haulage roads should not be pushed, except where necessary to push cars from side tracks located near the working section to the producing entries and rooms, where necessary to clear switches and sidetracks, and on the approach to cages, slopes, and surface inclines.

(c) Warning lights or reflective signs or tapes should be installed along haulage roads at locations of abrupt or sudden changes in the overhead clearance.

(d) No person, other than the motorman and brakeman, should ride on a locomotive unless authorized by the mine foreman, and then only when safe riding facilities are provided. No person should ride on any loaded car or on the bumper of any car. However, the brakeman may ride on the rear bumper of the last car of a slow moving trip pulled by a locomotive.

(e) Positive-acting stopblocks or derails should be used where necessary to protect persons from danger of runaway haulage equipment.

(f) An audible warning should be given by the operator of all self-propelled equipment including off-track equipment, where persons may be endangered by the movement of the equipment.

(g) Locomotives and personnel carriers should not approach to within 300 feet of preceding haulage equipment, except trailing locomotives that are an integral part of the trip.

(h) A total of at least 36 inches of unobstructed side clearance (both sides combined) should be provided for all rubber-tired haulage equipment where such equipment is used.

(i) Off-track haulage roadways should be maintained as free as practicable from bottom irregularities, debris, and wet or muddy conditions that affect the control of the equipment.

(j) Operators of self-propelled equipment should face in the direction of travel.

(k) Mechanical steering and control devices should be maintained so as to provide positive control at all times.

(l) All self-propelled rubber-tired haulage equipment should be equipped with well maintained brakes, lights, and a warning device.

(m) On and after March 30, 1971, all tram control switches on rubber-tired equipment should be designed to provide automatic return to the stop or off position when released.

§ 75.1403–11 Criteria—Entrances to shafts and slopes.

All open entrances to shafts should be equipped with safety gates at the top and at each landing. Such gates should be self-closing and should be kept closed except when the cage is at such landing.

Subpart Q—Communications

§ 75.1600 Communications.

[STATUTORY PROVISIONS]

Telephone service or equivalent two-way communication facilities, approved by the Secretary or his authorized representative, shall be provided between the surface and each landing of main shafts and slopes and between the surface and each working section of any coal mine this is more than 100 feet from a portal.

Subpart R—Miscellaneous

(in part)

§ 75.1704 Escapeways.

[STATUTORY PROVISIONS]

Except as provided in §§ 75.1705 and 75.1706, at least two separate and distinct travelable passageways which are maintained to insure passage at all times of any person, including disabled persons, and which are to be designated as escapeways, at least one of which is ventilated with intake air, shall be provided from each working section continuous to the surface escape drift opening, or continuous to the escape shaft or slope facilities to the surface, as appropriate, and shall be maintained in safe condition and properly marked. Mine openings shall be adequately protected to prevent the entrance into the underground area of the mine of surface fires, fumes, smoke, and floodwater. Escape facilities approved by the Secretary or his authorized representative, properly maintained and frequently tested, shall be present at or in each escape shaft or slope to allow all persons, including disabled persons, to escape quickly to the surface in the event of an emergency.

§ 75.1704–1 Escapeways and escape facilities.

This section sets out criteria by which District Managers will be guided in approving escapeways and escape facilities. Escapeways and escape facilities that do not meet these criteria may be approved providing the operator can satisfy the District Manager that such escapeways and facilities will enable miners to escape quickly to the surface in the event of an emergency.

(a) Except in situations where the height of the coalbed is less than 5 feet, escapeways should be maintained at a height of at least 5 feet (excluding necessary roof support) and the travelway in such escapeway should be maintained at a width of at least 6 feet. In those situations where the height of the coalbed is less than 5 feet the escapeway should be maintained to the height of the

D.3.2 PART 75—MANDATORY SAFETY STANDARDS—UNDERGROUND COAL MINES (Continued)

coalbed (excluding any necessary roof support) and the travelway in such escapeways should be maintained at a width of at least 6 feet.

(b) Each escape shaft which is more than 20 feet deep shall include elevators, hoists, cranes, or other such equipment, which shall be equipped with cages and buckets. When such facilities are not automatically operated, an attendant shall be on duty during any coal-producing or maintenance shift. An "attendant" as used in this subsection means a person located on the surface in a position where it is possible to hear or see a signal calling for the use of such facilities and who is readily available to operate such facilities or to readily obtain another person to operate such facilities.

(c) Stairways shall be installed in all escape shafts which are 20 feet or less in depth; however, in shafts 5 feet or less in depth, ladders may be substituted for stairways. Stairways and ladders shall be installed and maintained as follows:

(1) Stairways shall be of substantial construction, set on an angle not greater than 45 degrees with the horizontal and equipped on the open side with suitable handrails. Where landing platforms are necessary, they shall be at least 2 feet wide and 4 feet long and properly railed.

(2) Ladders shall be anchored securely, set on an angle of not more than 60 degrees and be substantially constructed and maintained in good condition.

Appendix E
Bibliography

238

Appendix E
Bibliography (Abstracted and Annotated)

E.1 INTRODUCTION

Most documents treating mine hoisting cover several topics, and there is no simple way to organize them according to specific topics. The following bibliography is organized from the general to the specific. Each entry appears only once under a heading that indicates the major, but not necessarily the only topic covered. Thus, a paper under Conveyances/Safety Catches may also mention hoist ropes and vice versa. Papers listed under any of the General headings cover several of the specific topics associated with the main heading.

In the abstracts, words or statements enclosed by brackets, [ ], are solely the comments and/or opinions of the author of this handbook.

239

E.2 HOISTING

E.2.1 GENERAL

Accidents from Hoisting and Haulage at Metal and Nonmetallic Mines, Metal and Nonmetallic-Mine Accident Prevention Course—Section 3, revised by Frank E. Cash, Miners' Circular 53, Bureau of Mines, United States Government Printing Office, Washington, revised January 1955.

> The section on hoisting covers accidents; hoists and safety devices; ropes; shaft sinking; cages, skips, and buckets; signaling; shafts stations and loading pockets; safe hoisting practices; and trends in hoisting installations. The discussion of rope treats size and length, attachments, clips and thimbles, socketing, sheaves, drums, lubrication, inspection, reattaching and discarding.

Accidents from Hoisting and Haulage in Bituminous-Coal Mines, Coal-Mine Accident Prevention-Course—Section 3, Miners' Circular 49, Bureau of Mines, United States Government Printing Office, Washington, revised March 1954.

> The sections dealing with hoisting cover signaling, hoists, ropes, cages and skips, shaft equipment, slope and inclines, haulage, and incline and slope rollers. The discussion of rope covers size, materials, length, attachments, resocketing, life, inspection, and lubrication.
>
> [In this and the previous publication the subject is approached from the standpoint of recommending equipment applications and operating procedures for minimizing accidents; they read much like a set of regulations and, in fact, contain many items covered by law. Equipment is treated essentially from a design or applications standpoint; e.g., "cages should also be equipped with ...". There is much good advice in these publications and the fact that most of it has all been said many times before does not detract from them. There are some departures from generalities into specifics, particularly in the discussions of hoisting rope.]

Baker, T. J., "Hoisting Safety in Ontario Mines with reference to The Mining Amendment Act, 1970", Ontario Department of Mines and Northern Affairs, April 1971.

> Baker discusses major rule changes affecting hoisting safety and reviews some older regulations together with examples of operating practice and problems that either led to the regulatory changes or well illustrate the situations.
>
> The paper covers conveyances, mine hoists, sheaves, ropes, hoist electronics specifications and special testing, maintenance, hoisting practice and procedures, accidents, and codes.

Baker, T. J., "Revised Regulations Promote Safer Hoisting for Ontario Mines", Canadian Mining Journal, September 1971, pp. 70–88.

> A journal presentation of the preceding paper.

Bellamy, N. W., and Phillips, B.D.A., "An Investigation Into Flange Forces in Winch Drums", Proc. Instn. Mech. Engrs., 1968–69, Vol. 183, Part 1, No. 27, pp. 579–590.

The paper describes a series of experiments to investigate the forces on a winch drum during multilayer winding under tension. Flange forces are the major concern. Tests involved several rope constructions, rope tensions, and plain- and LeBus-grooved drum faces. The authors present suggested design curves to aid predicting flange-failure limits.

[The paper would appear to be more useful in designing winch drums than hoist drums. Among other things, the former tend to have far more layers of rope and no brake path either attached to the flange or an integral part of it—a situation that stiffens the flange. However, some small mine-hoist drums and, particularly, those often used for sinking stages, more resemble winches than mine hoists.]

Breil, W. D., and Ison, C. B., "Hoisting at Alwinsal", the Canadian Mining and Metallurgical Bulletin for October 1972, pp. 92–96.

The paper describes a twin, multirope, friction-hoist installation at a Canadian potash mine. Included are the layout of the units, arrangement of the controls, drive drums, disc braking, ventilation system, D.C. supply, speed control, hoist ropes and attachments, rope lubricators, skips and loading apparatus. The reason for choosing a Ward-Leonard system versus a static-converter supply is explained.

The drive drums are shell structures, and the design of the friction blocks and retainers eliminates bolting through the drum. The disc brakes are cup-spring (Bellevillle washers) applied, hydraulic-pressure released, and automatically regulated. The drive-control system uses tachometer generators to monitor both drum and rope speed and power is cut off and brakes applied if the two signals differ.

Corey, E. D., "Safety Aspects of the Koepe Hoist", Transactions of the National Safety Congress, Mining Industry, 1958, pp. 31–33.

Writing at about the time Koepe hoists were first being installed in the U.S., Corey briefly discusses the main features of their design and operation and concludes that Koepe hoists using two or more hoist ropes and proper safety devices will be as safe or safer than a drum hoist. Topics covered are rope slip and creep, jammed conveyances, overtravel, rope breakage, and safety catches.

Craib, S., "Winding from Deep Levels in South Africa", Transactions of the Fourth International Mining Congress, Paper D2, 1965.

Craib discusses deep-level hoisting in South African gold fields (majority of shafts range from 2500 to 5500 feet deep) and some of the recent trends.

He describes the advantages and disadvantages found with Koepe hoists and some problems encountered with hoisting and tail ropes. Experience points to an apparent

241

E.2.1 GENERAL (Continued)

critical depth between 3500 and 4500 feet when using stranded hoist ropes; beyond this critical depth some unexpected unlaying problems were encountered.

The author also talks of recent experience with Blair multi-rope hoists and the methods used to assure equal rope tension. (Blair hoists are double, cylindrical-drum hoists using two ropes per drum for each conveyance.)

The paper also includes brief discussions of South Africa's relatively complex rope-safety-factors practice, rope fatigue testing, electromagnetic inspection; and presents examples of shaft and hoist layout to provide large rock output from deep levels.

Crandall, W. E., "How Hecla Mining Modernized Its Hoisting Facilities at the Star Mine", Mining Engineering, July 1971, pp. 77–81.

Crandall discusses some of the design, selection, and construction features of an underground, vertical-shaft hoisting facility in northern Idaho. The inline, double-drum hoist is capable of hoisting over 7000 feet at speeds up to 2000 fpm. A rapid-response brake system provides precision control through 3 brake-capacity ranges and limits deceleration to 6 to 12 ft/sec^2 under any of the wide variety of load and balance conditions that can occur. A special, universal conveyance frame permits rapid exchange of skips and cages in this multipurpose system.

[See paper by D. J. Beck under Hoist Braking for a more detailed description of the brake system on this hoist.]

Crook, A. E., "Safety Aspects of Winding Apparatus in Mines", Transactions of the Thirty-Ninth National Safety Congress and Exposition of the National Safety Council (Chicago, Illinois, October 1951), Mining Industry, pp. 10–35.

An in-depth review of mine hoisting practice and equipment in Great Britain with some comparisons with practices in other countries, particularly Germany. Conclusions include a number of hoist system design recommendations as well as author's opinions of feasibility of various alternatives.

Curth, Ernest A., "Cause and Prevention of Transportation Accidents in Bituminous Coal Mines", U.S. Department of the Interior, Bureau of Mines, Bureau of Mines Information Circular 8506, 1971.

Circular covers track haulage, non-rail haulage, conveyors, hoisting (including shaft sinking), railroad yards, and automotive and front-end loader operations. Attention is given to accidents from 1956–66.

[Under hoisting, the majority of the information simply describes equipment or practice and is presented without comment relative to safety.]

242

Curth, Ernest A., "Hoisting", (unpublished ms., circa 1970).

A recapitulation of hoisting practice and design from many sources.

Egawa, Tadashi, and Taneda, Motoharu, "External Pressure Produced by Multi-Layers of Rope Wound about a Hoisting Drum", Bulletin of the Japanese Society of Mechanical Engineers, Vol. 1, No. 2, 1958, pp. 133–138.

The authors discuss the procedures and results of theoretical and experimental investigations to determine the pressure on a hoisting drum induced by multilayer winding under tension. Theory and experimental results are in good agreement.

The authors point out the scarcity of work or design guidelines in this area, referencing a paper by E. O. Waters (Rational Design of Hoisting Drums", Trans. ASME, Vol. 42, 1920, pp. 463–485) as the only one seemingly reliable. [Other occasional references to this work are found in the literature.] The authors state that Waters' results have been generally adopted for designing hoisting drums, but that his results differ somewhat on the dangerous side from theirs.

Gerity, C. E., "Ozark's Haulage System Gets the Lead Out", Mining Engineering, November 1972, pp. 41–44.

Gerity discusses the face-to-surface transport of ore in a Missouri lead-zinc mine. The system uses rubber-tired, diesel-powered, front-end loaders; rail haulage; and automatic balanced-skip hoisting.

The section on the head-frame-mounted friction hoist describes the general features of the automatic and manual control systems; drum design; ropes, rope tensioning and terminations; some features of the safety controls; and the head frame. The companion man-and-materials hoist is not described.

Greenouth, G. K., Jeffrey, R., Wall, T. L., and Winder, G. E., "The Strength of Haulage and Suspension Components for Coal Mines", The Mining Engineer, December 1966, pp. 159–174.

The authors discuss typical loads on haulage and hoisting suspension components and how these relate to the loads that are likely to cause failure, particularly in fatigue. Components involved are those between the hoist or haulage rope and the vehicle, and between haulage vehicles.

Fatigue-property data for wrought steels for colliery use are given and a design technique to ensure adequate fatigue strength is outlined. Design and test data for representative components are given and the advantages of standard components briefly discussed.

[Only British practice is covered.]

Gronseth, James R., and Hardie, Robert, "How Modern Mine Hoists are Selected", Engineering and Mining Journal, June 1965, pp. 183–191.

243

E.2.1 GENERAL (Continued)

Engineers from Nordberg Manufacturing Company discuss the basic features of mine hoists and review the considerations and calculations needed to determine the characteristics of various parts of the hoist system.

[Much of the material is identical to what can be found in Norberg's hoist catalogue and description literature.]

Gyngell, A. H., "Hoisting Equipment and Shaft Design in Deep-Level South African Gold Mines", The Candian Mining and Metallurgical Bulletin for January 1968, pp. 15–25.

The paper deals with contemporary South African practice with hoists and shaft layouts. Discussed are friction (Koepe) and double-drum Blair (twin-rope) hoists, the trade-offs between single- and split-lift hoisting from great depths, and rate of hoist braking and the ESCORT braking control system developed in South Africa. Other sections deal with hoist utilization, skip and cage design, hoist rope problems and experience, and shaft guide and bunton design. Some modern South African shaft designs and hoisting equipment are described and diagrammed.

Harrington, D., East, Jr., J. H., "Safe Practices in Mine Hoisting", Miners' Circular 61, U.S. Department of the Interior, Bureau of Mines, 1946.

A comprehensive coverage of hoisting discussing hoist machinery; signaling; handling, storage, lubrication, attachments, inspection, and maintenance of hoist ropes; sheaves, drums and rollers; conveyances and safety catches; hoisting speed; shaft guides; shaft protection; and shaft sinking and deepening. It concludes with a list of suggested safety rules.

[Much of the material comes from regulations and is design-related in the sense "this should be equipped with that", or "this should be built thus and so". There is also much material that is simply good practice and the sections dealing with hoisting rope give many useful details. A few things are somewhat dated (e.g., the discussion of safety catches) and fewer yet no longer recommended (e.g., reversing hoist ropes).]

Hendry, W., "Non-Fatal Hoisting Accidents in Ontario Mines 1965–69", Ontario Department of Mines.

A review of the 299 nonfatal hoisting accidents that occurred in Ontario from 1965 thru 1969. Hendry groups these accidents as follows:

Errors of Cage Tenders and Deckmen, 82 accidents
Errors of Hoistmen, 53 accidents
Errors of Maintenance Personnel, 17 accidents
Faulty Equipment or Maintenance, 104 accidents
Undetermined Primary Causes, 43 accidents.

Under each category typical examples are given and conclusions or recommendations made when possible.

[The information is taken from the Report of Non-Fatal Shaft and Hoisting Accidents, an annual publication of the Ontario Department of Mines and Northern Affairs, that provides a brief but illuminating summary of each such accident during the year along with conclusions and comments relative to improved hoisting safety.]

Hoists, Bulletin 314B, Nordberg Manufacturing Company, Milwaukee, 1969.

A manufacturer's publication describing types of hoists, drum grooving, shaft-guide arrangements, wire-rope design and selection data, hoist drive and braking systems, and some specific features of the manufacturer's product.

Holl, G. W., and Fairon, E. G., "A Review of Some Aspects of Shaft Design", Journal of the South African Institute of Mining and Metallurgy, May 1973, pp. 309–324.

The authors discuss some of the basic aspects of and trends in shaft design, drawing mainly on South African experience over the last several decades. Among their conclusions are that vertical shafts are superior to inclined shafts in virtually all circumstances, that circular and elliptical (and quasi-elliptical) shafts are the shapes of the future, that shafts 13 meters (42.5 ft) and over in diameter will probably be sunk without difficulty in the future, and that the Blair winder (two ropes per conveyance per drum) is the most economically suitable hoist for rock, man, and material from a depth of about 3000 meters (about 9800 ft).

Many factors relating to shaft design are discussed and the authors support their conclusions with much data. The comparison of Koepe, Blair, and conventional drum hoists is succinct. A graphical relationship between hoisting depth and type of hoist is given in terms of percentage attached load versus shaft depth, taking the conventional drum hoist as the reference.

Investigations Regarding the Safety of Hoisting Equipment and Hoisting Practice in Ontario Mines, Ontario Department of Mines, Toronto; three volumes: Bulletin No. 138, 1947; Bulletin No. 138, Appendix II, 1947; and Bulletin No. 138A, 1949.

The reports of the investigations of the February 1945 hoisting accident at Paymaster Consolidated Mines carried out by the Committee Appointed by the Province of Ontario, the Ontario Mining Association, and the (Ontario) Inspector of Mines constitute this three-volume work. It provides a detailed examination of all aspects of mine-hoist operation, inspection, and maintenance with special emphasis on the manufacture, use, and behavior of hoist ropes and the design and performance of conveyance safety catches.

245

E.2.1 GENERAL (Continued)

The initiator of the accident was the failure of the hoist rope due to internal corrosion, undetectable from the exterior. Following rope failure the conveyance safety catches failed to stop the conveyance; sixteen men died. Among the many specific recommendations made in these documents are that Ontario encourage investigation of the merits of electromagnetic methods of examining mine hoist rope and the development of improved safety devices. [Both goals were actively pursued and met.]

Martin, W., "Shaft Design and Hoisting Equipment for a Deep-Level South African Gold Mine", The Canadian Mining and Metallurgical Bulletin for January 1968, pp. 28–37.

Martin describes the shaft configuration and hoisting equipment for a recent, 7500-foot-deep South African gold-mine shaft. Detailed descriptions include shaft layout, hoists, brattice-wall design, head sheave design, use of ultrahigh tensile hoist ropes, conveyances and attachments, and cage-location and speed-monitoring devices. Other new hoist and shaft developments are briefly described.

Mining Engineers' Handbook, Edited by Robert Peele, Third Edition, Two Volumes, John Wiley and Sons, Inc., New York, 1941, "Section 12, Hoisting Plant, Shaft Pockets and Ore Bins" (William M. Weigel and Philip B. Bucky), Vol. 1, pp. 12–01 to 12–136.

All aspects of the hoist system are treated and illustrated by examples from [then] current practice. Methods are presented for computing duty cycles and motor or engine requirements for cylindrical, conical, and cylindro-conical drums.

[This is *the* current edition of this well-known book. Most of the material on hoists is seriously out-of-date.]

Osthof, H., "Drum Winder or Koepe Winder", Journal of Mines, Metals, and Fuels, Mechanization of Mines—Special Issue, 1962, pp. 198–206.

The basic types of drum and Koepe (friction) mine hoists and the basic operational limitations of each are discussed in this paper. The discussion of advantages and disadvantages of drum and Koepe hoists treats only the hoist-house machinery and stresses the size of components. A brief and basic discussion of types of drives, brakes, and safety devices is included.

[A primer and somewhat simplistic—there is much more to the differences, and to the advantages and disadvantages than those relative to the hoist-house machinery.]

Rice, George S., and Hartmann, Irving, "Coal Mining in Europe", U.S. Department of the Interior, Bureau of Mines, Bulletin 414, 1939.

[There have probably been some changes since this report was written. While it says little about hoisting technology it provides some insight into basic philosophy. Most mines described tended to be deep, ranging from an average of 1000 feet in Britain to

246

2000 feet in Belgium. Most mines (then) were expected to have lifetimes of a least 75 to 100 years so topside installations were designed with a view toward long life. The majority were entered through vertical shafts and the tendency was to have few but well-built and maintained shafts and much underground haulage. This philosophy indicates why, for example, there is presently much emphasis in British and Continental practice on getting the most out of a hoist rope (consistent with safety) and why common British practice has head-sheave-to-rope diameters in the range 100–120—i.e., fatigue is minimized.]

SME Mining Engineering Handbook, (Two Volumes), Arthur B. Cummins, Chairman, Editorial Board; Ivan A. Given, Editor; Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, 1973. Section 15, "Hoists and Hoisting Systems" (James H. Harmon), Vol. 1, pp. 15–2 to 15–69.

The section on hoists and hoisting systems covers types of mine hoists (drum and friction); hoist selection and usage; technical considerations in selecting a hoisting system; and skips, cages, shaft guides, and hoist accessories.

[This section is good as far as it goes but it is decidedly lopsided in favor of hoist-house machinery, domestic practice, and design details (e.g., gears, motors). Several of the thorny problem areas in hoisting are either not mentioned at all or given cursory treatment; e.g., respectively, control of braking rates and reliability of conveyance safety catches, and wire-rope inspection and removal. The author's stressing the need to consider a hoist plant as a system—a group of interrelated rather than independent components—is commendable.]

Idem, Section 10, "Opening and Development" (Victor L. Stevens), Vol. 1, Subsection 10.1.4A-Muck Removal, pp. 10-3 to 10-6; and Subsections 10.1.4E-Mucking and 10.1.4F-Sinking Stage, pp. 10-9 to 10-13.

[The hoisting aspects of shaft sinking are covered in the above subsections; there isn't much.]

Idem, Section 24, "Maintenance" (Jack M. Ehrhorn), Vol. 2, pp. 24-2 to 24-63.

This section covers basic principles, organization and manpower, shops and facilities, planning and schedules, and reports and records.

[The treatment covers the whole of the mining and processing operation which includes hoisting. There is a discussion of the pros and cons of breakdown and preventive maintenance philosophies, i.e., fixing a failure or maintenance to prevent a failure.]

Tiley, G. L., "The Case for Tower-mounted Friction Hoists", Engineering and Mining Journal, June 1967, pp. 177–182.

Paper deals primarily with factors affecting the reliability of tower-mounted friction hoists. Discussed are drives and couplings, ventilation, wheels, shafts, bearings, rope

247

E.2.1 GENERAL (Continued)

treads, lubrication, brakes, auxiliaries, design factors affecting rope life, and rope lubricant problems. Author provides some cost data to support his thesis that being too cost-conscious during hoist system layout, design, and construction can be economically disadvantageous in the long run.

Van Rooyen, G. T., "Materials for Winding Plant Components", Journal of the South African Institute of Mining and Metallurgy, November 1972, pp. 117–126.

The author discusses the effects of ductility, resistance to brittle fracture, strain aging, heat treating and normalizing, and fatigue in steels used in critical hoisting-installation components (e.g., rope terminations). He states that tensile-test data alone is not sufficient for design purposes, and that impact testing also is necessary if the incidence of brittle fracture is to be avoided. As a criterion, he suggests that the brittle transition temperature (B.T.T.) determined by impact testing should be well below the lowest anticipated service temperature in all cases.

The results of an experimental evaluation of a number of steels are presented and discussed, and recommendations made.

[This paper seems to have roots in South African experience with brittle or brittle-like failures of critical components. A South African regulation covers all connectors between conveyances and ropes and other conveyances, requiring them to be annealed or otherwise heat treated every six months or to be discarded. For some steels the heat-treat interval can be extended with official permission. However, the author points out that heat treating can substantially raise the brittle transition temperature of some steels. This regulation was written before there were any practical, effective nondestructive testing techniques. The author recognizes this and in one place suggests an alternative to heat treating, namely, annual nondestructive testing of all vital components.

Heat treatment of critical connectors is suggested in older American publications, but not in recent ones.]

Walker, (Jr.) W. Dan, and Stahl, R. W., "Recommended Procedures for Mine Hoist and Shaft Installation, Inspection, and Maintenance", U.S. Department of the Interior, Bureau of Mines, Information Circular 8031, 1961.

[A very brief and highly qualitative discussion of a very comprehensive and complex subject.]

Zelenka, Micoslav, "Main Features of the Present Production of ČKD Winding Engines", Czechoslovak Heavy Industry (English Edition), November, 1973, pp. 41–46.

A review of the major design, operating features of, and options available in the machinery and control equipment produced by the leading Czechoslovakian manufacturer of mine hoists.

[Little is said about hoist brakes although shoe and disc types are made. Photos included reveal a somewhat atypical but simple arrangement of operating levers on jaw brakes. Though the paper states that two air-actuated brake engines per brake are available—one for hoist (i.e., service) and one for safety braking—there is no discussion of braking control. Otherwise, available hoist equipment seems to encompass all current technology. Regrettably, the English edition is awkwardly translated.]

E.2.1.1 SHAFT SINKING

———, "New Mid-Shaft Sinking-Loading Concept", Mining Engineering, January 1970, p. 74.

Three paragraphs discuss a method for loading buckets mid-shaft while sinking crews work in the shaft bottom. The major equipment and the intricate set of safety devices used are discussed. The concept permitted a considerable reduction in sinking time.

[Paper by Muirhead under Shaft Sinking discusses project for which concept was devised.]

Muirhead, Williams, "Shaft Sinkers Digs Deep at Three South African Mines", Engineering and Mining Journal, February 1972, pp. 84–89.

Muirhead reviews the sinking of three deep-shaft projects in South Africa. He briefly discusses many details of the permanent shaft layouts, and the sinking equipment and procedures used.

Redpath, J. S., "Sinking the Creighton No. 9 Shaft at Sudbury", Mining Congress Journal, March 1971, pp. 66–70.

Redpath reviews the methods used, problems encountered, and things learned in sinking a 7137-foot deep vertical shaft. He presents a summary of the time required for various tasks, and ends with a discussion of some problems needing solutions and some of the major general factors that affect the economics of shaft sinking.

Redpath, J. S., and Dengler, W. R., "The Mechanical and Electrical Aspects of Sinking the Creighton No. 9 Shaft", The Canadian Mining and Metallurgical Bulletin for December 1968, pp. 1403–1418.

The authors present a detailed account of the equipment used and the electrical mechanical problems encountered in sinking a 7137-foot deep vertical shaft.

The hoisting aspects of the job constitute a major portion of the paper. The three hoists used—a double-drum temporary muck hoist, the permanent hoist that replaced it, and a Blair-stage hoist—are fully described. The authors discuss the problems encounted with ropes, terminations, buckets, crossheads, and guides, and the solutions devised.

249

E.2.1.1 SHAFT SINKING (Continued)

Wells, H. M., "The Influence of Economics on the Design of Mine Shaft Systems", Journal of The South African Institute of Mining and Metallurgy, May 1973, pp. 325–338.

The paper reviews some of the more important economic criteria that must be considered when planning the number, type, size, and distribution of the shafts or shaft systems required to exploit an ore body.

[The paper says nothing about hoisting plants per se. The author does comment near the end that there appears to be no reason why a very large mine cannot be served by one central shaft system, and that economically the bias appears also to be in this direction. Such a situation, of course, has an important ramification for the hoist-plant design, namely in not making too many trade-offs in favor of costs between long-run operational and maintenance considerations versus initial, fractional cost savings.]

250

E.2.2 HOIST MACHINERY, CONTROLS, SAFETY DEVICES

E.2.2.1 CONTROLS AND SAFETY DEVICES

MINECOM Mine Hoist Systems, Canadian Westinghouse Company Limited, Electronics Division, Bulletin BH-7186, circa 1960.

The publication describes an electronic system providing communication between cage personnel and the surface, using the hoist rope as a transmission line. The system provides voice communication as well as a fail-safe signal for use with an alarm, a slack-rope warning device, or a signal to stop the hoist from the conveyance in an emergency.

[The system is no longer marketed; there are, however, similar ones manufactured by other manufacturers.]

Hazan, P. L., and Mace, D.G.W., "A Transistorized Fail-Safe Alarm for Mine Shafts", Electronics and Communications, September 1958, pp. 69–71.

Authors describe the basic features and present schematic diagrams of the system described in previous reference.

Edgington, C. T., and Jones, R. R., "Deep Level Gold Mining—A Modern Electric Hoist Installation at President Steyn", Mining Magazine, Vol. 122, No. 2, February 1970, pp. 96–105.

The article describes the electric drives and control equipment for a South African gold-field hoist. The shaft is 7700 feet deep and the Blair-type hoist raises 19-ton skip loads at an average top speed of 3000 ft/min.

The author states that the installation typifies the Anglo-American Corporations' present practice in Ward-Leonard control of high-output, deep-level hoisting, and makes extensive use of solid-state components. Technical advances incorporated include thyriston power units directly feeding the field circuits of the synchronous motors of the MG sets.

Gent, A. G., "Mine-Winder Control from the Mine Shaft", GEC Journal of Science and Technology, Vol. 39, No. 3, 1972, pp. 137–142.

The author describes several schemes for automatic control of mine hoists from the cage and/or shaft stations. In the cage control systems, signals are transmitted by indicative coupling to a 2-wire antenna that runs the length of the shaft; no trailing cables are used. Block diagrams of the schemes are presented and many features of the equipment and controller programming are discussed. The author also comments briefly on applying such control systems to existing hoists, the reliability and safety of such systems, and the future for modern control-system techniques and solid-state electronic devices in hoisting applications.

E.2.2.1 CONTROLS AND SAFETY DEVICES (Continued)

[The paper illustrates the trend in hoist-control technology away from essentially simple, electromechanical devices and simple control systems to modular, miniaturized, solid-state devices and complex systems. The trend is not usually readily accepted by people familiar with the old methods. However, the reliability and flexibility achievable with solid-state devices, and the capability for self-monitoring that can simplify inspection and maintenance, are well worth the retraining and familiarization efforts that must accompany the introduction of such equipment.]

The Lilly Hoist Controller, Model C and Auxiliary Equipment, Catalogue and Manual C-44; Logan Engineering Company, Chicago, Illinois, 1944.

Idem, Model D and Auxiliary Equipment, Catalogue and Manual D-44.

These manufacturer's publications describe widely used, automatic, hoist-safety equipment that provide speed, braking, and overtravel limit protection.

Each book includes a description of the controller and auxiliary equipment, illustrations of typical installations, and detailed instructions for their installation, adjustment, and maintenance.

[Though printed 30 years ago, the booklets are still current. As of 1971 manufacturer operates under the name Logan Actuator Company.]

E.2.2.2 BRAKES/BRAKING

Beck, Donald J., "Controlled Braking—A Deep Shaft Hoisting Requisite", paper presented at the 1969 Pacific Northwest Metals and Minerals Conference, Coeur d'Alene, Idaho, April 18, 1969.

Beck briefly discusses the need for brake control on clutched, double-drum hoists operating in deep shafts. With each drum brake capable of stopping and holding a loaded unclutched skip in the bottom of the shaft, there is excess brake capacity when operating in balance, particularly midshaft, and emergency stops can cause injury and damage. He briefly mentions two brake-controller systems that solve the problem and goes on to describe the essential features of a third that his company chose to install on a new, deep-lift system in northern Idaho.

The system uses two hydraulic engines per brake. One controls a dead weight which applies the brake only in emergency stops or when the drum is unclutched and is arranged much like the traditional gravity-set, pressure release engine. The other is a service brake engine that is pressure set and pressure released, of large diameter and short stroke, and in this system, pin-connected to the main actuator lever at the point where this lever's fixed pivot is normally placed. Thus, the engine not in use at the moment provides the fixed pivot for the actuator lever. The service engine's proximity to the brake-actuating rod provides almost equal movement for both and, thus, reduces application time. The hydraulic actuating system is pneumatically controlled and provides rapid, precise control of braking effort.

The system provides three levels of braking effort. Level I is rapid application of full torque from one brake for unbalanced lowering. Level II provides 50 percent maximum torque for each brake in about 10 seconds for balanced hoisting midshaft. Level III provides a low-braking rate that builds up to Level I or II maximum in different times depending upon whether hoisting is unbalanced or balanced; it is provided automatically for emergency stops only under the conditions where the configuration hoisted will have a natural tendency to slow and stop if power is removed from the hoist motor. The system is designed to provide a deceleration of from 6 to 12 ft/sec^2 under all hoisting conditions.

[See paper by W. E. Crandall under Hoisting General for other details of the hoist involved.]

Bellairs, G. ff., and Gericke, M. R., "A Telemetering Instrument for the Measurement of Acceleration and Deceleration of Mine Hoists", The Transactions of the S. A. [South African] Institute of Electrical Engineers, June 1953, pp. 149–183.

Paper describes a South Africa-developed instrument that measures acceleration of conveyances, and transmits the data via the hoisting rope to the surface for recording and interpretation.

Results of measurements of conveyance accelerations and damping as a function of hoist braking characteristics are also presented and discussed; varied were depth of conveyance at brake application, hoisting speed, and rate of brake application for systems with electrical and mechanical brakes. The magnitude of the shock waves induced in a hoist rope during skip loading from a steep chute is also discussed.

The paper is followed by a lengthy [and informative] discussion among the authors and a number of commentators.

Bradley, D. W., "An Automatic Controlled Mine Hoist Braking Regulator", Canadian Mining Journal, Vol. 91, September 1970, pp. 51–55.

Bradley discusses the general problem of too much braking in emergency stops on double-drum hoists under certain balanced-hoisting conditions and describes how an automatic braking regulator solved the problem on an International Nickel Company hoist in the Sudbury, Ontario area. [The regulator itself is not described.] He presents graphs obtained with a cage-mounted telemetering accelerometer in the course of adjusting the braking controller to minimize the deceleration at the conveyance. The author reports that the controller has operated reliably and satisfactorily since August 1968.

[The controller is manufactured by Canadian General Electric. It takes a tachometer-generator signal proportional to drum speed, differentiates it to give a voltage proportional to deceleration, and compares this voltage to a fixed voltage that

E.2.2.2 BRAKES/BRAKING (Continued)

represents the desired deceleration. The difference between the actual and desired deceleration signals (the error signal) is amplified and used to operate a servo-valve that controls the brakes. Solid-state devices process the electrical signals.]

Cooper, L. O., "Slow Braking of Mine Hoists", The Engineering Journal, January 1952, pp. 15–17.

Where safety catches are actuated by loss of hoist rope tension, actuation really occurs when the hoist rope tension drops below some limit determined by the force required to compress the actuator springs. It is, therefore, possible for the safety catches to actuate if the hoist brakes are applied too quickly either manually or automatically.

Cooper derives an equation for computing how quickly (stopping time) a hoist can be braked to a stop without actuating the safety catches. Parameters are hoisting speed, weight of conveyances and load, safety-catch spring tension, and weight of rope in shaft.

Wilde, D. H., "Effects of Emergency Braking on Multi-rope Tower-mounted Friction Winders—Part II", Colliery Guardian, February 26, 1965, pp. 289–297.

[A long and rambling paper which says that hoist braking will induce vertical cage oscillations that will produce non-linear speed-versus-time curves, that these curves vary with position of conveyance in the shaft at trip-out, and that these curves are much affected by the rate of application of the brakes.

The author's main concern is not clear. In general, however, the rate of braking is known to have an effect on people and rope stresses, and potential rope slip in the case of friction hoists. Furthermore, the advantages of rapid actuation but slow buildup have been amply and more cogently demonstrated in other papers notably from Ontario and South Africa.]

McKnight, W. J., "Testing Gravity-Operated Mine Hoist Braking Systems", paper presented at the Annual General Meeting of The Canadian Institute of Mining and Metallurgy, Toronto, Ontario, March 1965.

The paper presents data produced by a cage-mounted telemetering decelerometer during trip-out tests (emergency stops) of hoist-brake performance. The results of data analysis are included. Some additional data is presented showing cage acceleration in the vertical and both horizontal directions during normal travel.

The author concludes: (1) "The time-lag between the initiation of an emergency stop and the contact of brake shoes with the brake path should be reduced to a safe minimum; (2) the braking effort and the rate of buildup of braking effort should be such that the deceleration rates they produce will not be dangerous to personnel and equipment".

E.2.3 ROPES (HOIST, GUIDE, RUBBING) AND ASSOCIATED MACHINERY (SHEAVES, DRUMS, WHEELS, ROLLERS)

E.2.3.1 GENERAL

Barrett, C. M., "Testing of Mine Hoisting Ropes in Ontario", Ontario Department of Mines and Northern Affairs, circa 1964.

> A brochure describes facilities, services, equipment and procedures of the wire-rope testing laboratory operated in Toronto by the Government of Ontario. The facility is primarily for use by provincial mine operators who, by statute, are required to periodically test hoist-rope specimens. Examples of test-report and certificate forms are shown.

Beneitone, L. B., "Rope Changes on the Main Ore Hoists at San Manuel", Mining Engineering, April 1968, pp. 68–69.

> The method used to change both hoist ropes on a double-drum ore hoist in about four hours is described. Rope break-in procedures and rope-clip retightening schedule are also discussed.

Cassell, L. Dean, "Elastomeric Sheave Liners Extend Wire-Rope Life", Coal Age, May 1963, pp. 130–132.

> Author describes field experience, mainly European, with elastomeric liners for aerial tramways, chair lifts, and ski tows. Noiseless operation, greatly increased cable life, and reductions in maintenance costs are reported.

Drucker, D. C., and Tachau, H., "A New Design Criterion for Wire Rope", Journal of Applied Mechanics, Vol. 12, No. 1, March 1945, pp. A33–A38.

> Using available experimental and field data, authors show that a dimensionless bearing pressure variable, B, appears to be of more importance in the choice of wire rope than such oft-mentioned indicators as average tensile stress, nominal bending stress, nominal maximum combined tensile and bending, and others.
>
> This variable is defined as:
>
> $$B = \frac{2T}{\mu d D}$$
>
> where T = rope tension
> D = sheave (drum) diameter
> d = rope diameter, and,
> μ = wire tensile strength.

255

E.2.3.1 GENERAL (Continued)

Results indicate that B approximately equal to 0.0015 expresses a kind of endurance limit for bending fatigue. That is, systems designed or ropes selected so that B is less than this number would eliminate bending fatigue as a primary cause of rope failure. Fatigue as a secondary cause would still be present, however, since wear and corrosion could reduce wire diameter and induce stress concentrations.

Final Report of the Sub-Committee on Wire Rope, Ontario Research Foundation, Toronto, 1956.

Report presents results of investigations into the causes and detection of mine hoist-rope defects. Work was spawned by February 1945 Paymaster Consolidated Mines hoisting accident. Experiments comprised cyclic bend-over-sheave fatigue tests with various rope tensile loads, sheave sizes, and lubrication conditions, all using 5/8-inch diameter rope. Attempts to simulate corrosive conditions failed. Some work with available non-destructive devices was included.

[Program started from scratch and included the design, construction, debugging, and learning process with the fatigue test machine. Results are interesting, mixed, and although they confirm many qualitative observations, they are difficult to translate to field application. Notable, however, is the observation that light oil versus heavy lubricants "considerably" increased rope life, and that there is a definite correspondence between a localized decrease in the lay length and loss of strength.]

Fuller, C.N.L., and Wainwright, E. J., "Recent Developments in Steel Wire Ropes for Hoisting from Great Depths", The South African Mechanical Engineer, June 1967, pp. 238–245.

Authors discuss recent developments in South African design and manufacture of wire rope for use on drum, Blair, and multi-rope friction mine hoists in deep shafts. Experience with galvanizing, ultrahigh-tensile ropes, and non-spin designs is included.

Ingalls, W. R., Douglas, J., Finlay, J. R., Channing, J. Parke, and Hammond, John Hays, "Rules and Regulations for Metal Mines", U.S. Department of the Interior, Bureau of Mines, Bulletin 75, 1915.

The final report of a committee set up in 1906 to draft a law governing quarrying and metalliferous mining that could be recommended to the states for adoption.

[The sections dealing with hoisting ropes are particularly significant as the technical data relating to hoist-rope selection, hoist-rope removal, and hoisting speeds form the basis for or are the origin of most present rules and regulations or specifications in these areas. Furthermore, and most important, the reasoning behind the recommendations is clearly presented.]

Kudlich, R. H., Hood, O. P., "Safe Practice in Using Wire Ropes in Mines", U.S. Department of the Interior, Bureau of Mines, Technical Paper 237, 1919.

[This paper covers most aspects of hoist rope technology but is essentially a much-abstracted version of the sections dealing with hoist ropes presented in U.S. Bureau of Mines Bulletin 75, 1915 (Ingalls, W. R., et al). It contains nothing that isn't presented in a modern wire-rope catalogue and, in fact, much less.

Jehmlich, Gunter, "The Effects of Lubrication, Corrosion Protection, Rope Construction, and Pully Material on the Durability of Mine Winding Ropes", Wire, Issue 95, June 1968, pp. 130–134.

The author discusses the effects of the four factors named in the title on hoist-rope life determined from statistical observations of field service and laboratory experimental work.

A combination of heavy galvanizing and the lubricant Elaskon (manufacturer: Richtor Co., Dresden) was found much better than either alone. The author states that statistics show no improvement in rope life with commercial-quality galvanizing (i.e., light coatings) compared to bright rope.

Ordinary lay ropes of Seale-Warrington and Seale-compound construction with longer than normal lay lengths were tried in the field to minimize the load-twisting effects. These ropes in combination with heavy galvanizing and the lubricant Elaskon lasted significantly longer, up to three times former service life in some cases. Jehmlich comments on the use of ordinary, longer lay ropes in spite of their inferior durability in bending-fatigue machines, suggesting that in the latter the effects of load-induced twisting cannot be simulated.

A comparison of rope life with and without non-metallic sheave-groove liners shows an average increase in rope life of 25 percent with non-metallic liners.

[Jehmlich wisely points out that it is probably not possible to evaluate exactly all the factors bearing on rope performance in service and this is perhaps why various authors reach contradictory conclusions relative to hoist rope performance. There are many changes in the variables from one installation to another. However, within one installation under controlled conditions much can be learned.

A case in point: the paper is German and a brief comment in it is the only indication that the author is probably talking about Koepe hoist ropes. This would probably not change the general validity of the lubrication/galvanizing conclusions, but the ordinary long-lay rope constructions might behave poorly in multi-layer drum winding.]

Larsen, C. H., Egen, R. A., Jones, R. D., and Cress, H. A., "Wire Rope Applications and Practices Associated With Underground Coal Mining in the United States", USBM Contract No. H0101741, Final Report from Battelle Memorial Institute to the Pittsburgh Mining and Safety

E.2.3.1 GENERAL (Continued)

Research Center, Bureau of Mines, June 22, 1971 (National Technical Information Service No. PB-204 077).

The discussion of wire-rope use is separated into hoisting and nonhoisting applications, the former receiving the greatest emphasis. The discussions treat aspects relative to hoist operators, equipment builders, rope manufacturers, and state and Federal regulations. Foreign practice and laws are also covered. Report includes a discussion of the state of the art in electromagnetic nondestructive inspection of hoist ropes.

The authors conclude that hoisting technology in the U.S. coal industry has become generally stagnant and that many aspects of hoisting practice, codes, and regulations need to be updated and rationalized.

Layland, C. L., Rao, A.R.S., and Ramsdale, H. A., "Experimental Investigation of Torsion in Stranded Mining Wire Ropes", K.G.F. (Kolar Gold Field) Mining and Metallurgical Society, Vol. 3, 1952, pp. 323–342.

Authors present results of laboratory investigations into torsional properties of mine-hoist ropes using samples ranging from 1/2- to 7/8-inch in diameter. Authors conclude that more work needs to be done on torsional characteristics.

[While theoretically interesting, this paper has little that can be applied.]

Matheson, J.A.L., "The Mechanics of Locked-Coil Wire Ropes", Engineering, Vol. 165, 1948, pp. 578–581 and 601–604.

Matheson theoretically and experimentally investigates the elongation and twist behavior of locked-coil wire ropes under tensile loads on straight samples (i.e., no bending around sheaves). Rope diameters are in half-inch range. Predictions from theory developed agree reasonably well with experimental data for round-wire portions of rope, and the importance of tightness of construction is clearly demonstrated. Shaped-wire layers were much stiffer than anticipated and results tentatively indicate that z-wires (the full-lock layer) must be assumed free to undergo deformation due to direct tensile stress only if theory and experiment are to be in close agreement. From this result Matheson shows that the outer full-lock layer may carry about 80 percent of the load on the rope and suggests that the layer can be easily stressed beyond the elastic limit under working loads and, hence, become longer and lead to the waviness often seen in worked full-locked coil ropes.

McClelland, A. E., "Wire Ropes in Mining Engineering", The Mining Electrical and Mechanical Engineer, Proceedings of the AMEME, December 1964, pp. 139–144.

Statistics of British hoisting and man-haulage rope failures for the previous 20 years are presented and the causes of these failures discussed. Brief observations of mineral haulage, balance (tail) and guide ropes are included. Methods of controlling deterioration are discussed and summarized.

The most prevalent cause of failure is cc rosion or corrosion-fatigue and out of 26 instances cited, all but one rope was ungalvanized. Author strongly recommends galvanized finishes where corrosion is a real or potential hazard.

McClelland, A. E., and White, M. C., "Deterioration of Friction Winding Ropes in Service", Safety in Mines Research Establishment (British), Research Report 269, 1971.

The results of detailed examination and testing of 42 hoist and 8 tail ropes removed from British friction (Koepe) hoist installations are presented. The ropes were locked coil and stranded; all were galvanized.

The study was performed to check the suitability of the statutory length of service and the reliability of traditional methods of inspection during service. The results show that the traditional methods of inservice inspection (principally the examination of rope samples cut from the conveyance end and visual inspection of the rest) cannot be relied upon, particularly where fatigue or corrosion fatigue predominates. The authors conclude that the traditional methods should be augmented by non-destructive testing.

Petit, J., "A Technological Approach to the Mechanical Design, Application, and Use of Equipment Used with Steel Wire Ropes in Coal Mines", The Mining Engineer, July 1969, pp. 611–622.

Petit discusses some of the criteria governing the mechanical design and use of hoist ropes, rope-cage connectors (cappings), and some haulage components for use in British coal mines.

Pine, G. I., "It Pays to Know the Ropes", POWER, Plant Maintenance and Management Section, June 1958, pp. 120–123.

A qualitative discussion of many factors affecting care of wire ropes for any use.

Rajan, P., "Some Aspects of Wire Rope Choice and Design", The Wire Industry, August 1964, pp. 779–783.

This Indian author draws heavily on Japanese practice in discussing some of the factors by which round-strand mining ropes are designed.

Covered are factor of safety, breaking strength, aggregate breaking strength of wires, composition of steel, types of lay, rope and wire diameters, rope stretch, and core construction.

[Paper contains much data recommended for use in selecting ropes but it appears to conflict seriously in places with practice elsewhere in the world. For example, the recommended minimum ratio of drum/sheave-to-rope diameter for 6x19 class ropes is 26! Western practice supports a minimum of 80 and preferably 100–120.]

259

E.2.3.1 GENERAL (Continued)

Richards, C. C., "Steel Wire Ropes for Hoisting Machinery and Lifts", Machinery, December 5, 1962, pp. 1302–1309.

A qualitative review of the characteristics, use, and maintenance of wire ropes for cranes and elevators with special references to the British Standards Institutions' recommendations.

[In British parlance, "winding" is equivalent to hoisting in a mine sense; "hoisting" refers to derricks, cranes, et al.]

———, "Ropes for Deep Shafts", Mining Magazine, Vol. 114, No. 3, March 1966, pp. 209–210.

This article is a summary of a paper by J. M. Downton titled "Wire Ropes for Deep Shafts" delivered at a symposium in Toronto in March 1965 on the "Design and Operation of Deep Shafts" sponsored jointly by the Metal Mining and Mechanical-Electrical Divisions of the Canadian Institute of Mining and Metallurgy.

The article touches on rope problems and developments in deep shafts (5000 to 7000 feet) in South Africa. Difficulties arose from unpredictable rope behavior in deep shafts and the two factors deemed of prime importance are briefly discussed relative to drum and friction hoists. These factors are: (1) a strength/weight ratio of the rope and (2) the torque developed under load.

Specifications for and Use of Wire Ropes for Mines, U.S.A.S. M11.1—1960, United States of America Standards Institute, New York.

This is the domestic specification for wire ropes for mines covering material and workmanship; general and detailed requirements; practice for storage, handling, installation, and maintenance; underground mining; and open-pit, strip, and surface mining.

[Federal codes governing hoisting for both coal and metal and nonmetal underground mines cite this code as the guide to use in selecting, installing, and maintaing mine-hoist ropes, except where Federal regulations are more restrictive.

In the sections dealing with the removal of hoist ropes this specification is highly qualitative and of little practical value.

Efforts to revise this code are in the preliminary stages.]

Tiley, G. L., "Friction Hoists for Deep Shafts", The Canadian Mining and Metallurgical Bulletin for December 1965, Montreal, pp. 1283–1286.

Tiley discusses some aspects of the behavior of hoist and tail ropes on friction hoists in deep shafts. Covered are spin of head (hoist) ropes, effects of unequal wheel tread

diameters (multi-rope hoists), and the effect of the earth's rotation on the behavior of tail ropes. A brief discussion of the differences between drum and friction hoists is also included.

[The comparison of drum and friction hoists is too simple and could be misleading.]

Wire Ropes in Mines, Proceedings of a conference held at Ashorne Hill, Leamington Spa, Warwickshire, September 1950, The Institution of Mining and Metallurgy, London, 1951.

A voluminous report (828 pages) of an international conference of 225 people from 15 countries to discuss experience and problems relative to hoist ropes in vertical and inclined shafts. A wide range of information, opinions, and proposals are presented in 18 papers, 9 discussion sessions, and 18 pages of conclusions and recommendations.

While rope is emphasized there is a wealth of information on all aspects of mine-hoist construction and operation, including field and laboratory research work into the fundamental aspects of rope and hoist performance.

E.2.3.2 INSPECTION AND MAINTENANCE

Dean, Humphrey, "An Introduction to High-Tensile Mine Hoisting Ropes", The Canadian Mining and Metallurgical Bulletin for December, 1968, pp. 1419–1426.

The paper provides a general knowledge of the characteristics and behavior of high-tensile-steel mine hoisting ropes (flattened strand and locked-coil ropes) and some field experience with them. Drum risers and fleet angles, lubrication and rope cutting, and maintenance of head sheaves are discussed in general.

Dean, Humphrey, "Hoist-Rope Stress Analyses and Preventive Maintenance for Multi-Rope Friction Hoists", The Canadian Mining and Metallurgical Bulletin for October, 1970, pp. 1143–1155; also, Paper #58 presented at the 72nd Annual Meeting of the Canadian Institute of Mining and Metallurgy, Toronto, April 1970; also, Transactions of the Canadian Institute of Mining and Metallurgy, Vol. LXXIII, 1970, pp. 277–289.

Dean discusses how unequal groove diameters and rope lengths can lead relatively rapidly to structural deformities in either stranded or locked-coil hoist ropes on multi-rope friction (Koepe) mine hoists, particularly service hoists, and presents procedures for inspection and maintenance to prevent such problems.

Also discussed are the applicability of automatic rope tension equalization, the value of graphic records or rope stretch as an indicator of progressing fatigue deterioration, and the value of rope lubrication.

261

E.2.3.2 INSPECTION AND MAINTENANCE (Continued)

Dingley, W., "Laboratory Development of Corrosion Inhibiting Coatings for Mine Hoist Wire Rope", Corrosion, September 1961, pp. 22–27.

> The results of laboratory experiments indicate that a compound of asphalt, zinc chromate pigment, and trichlorethylene in the proper proportions substantially increases corrosion resistance of zinc-coated mine hoist rope and shows greater protective value than commercial compounds also tested.
>
> Author states that field tests on mine hoist ropes are about to begin.

Goodwin, Robert E., "Making the Most of Wire Rope", Society of Mining Engineers, Mining Engineering, May 1964, pp. 72–74.

> [A very brief and qualitative recapitulation of factors entering into rope selection, use, and maintenance.]

Illsley, L. C., and Mosier, McHenry, "Inspection and Maintenance of Mine Hoisting Ropes", U.S. Department of the Interior, Bureau of Mines, Technical Paper 602, 1940.

> A comprehensive treatment of the use of wire rope for mine hoisting covering materials and manufacture of rope, selection, handling and storage, deterioration, lubrication, lubricating equipment, end attachments (thimbles and clips, and sockets and socketing procedures), sheaves and drums and appropriate groove clearances, inspection, and examples of mining company procedures and requirements.
>
> [The removal criteria are notably sketchy. The paper is a compilation of information from two much earlier Bureau of Mines publications updated with then-current information from mine operators, and lubricant and rope manufacturers.]

Installation and Care of Shaft Hoist Ropes, Engineering Department Number AM-48, John A. Roebling's Sons Division, The Colorado Fuel and Iron Corporation, August 1953, revised March 1961.

> This booklet covers installation, break-in, spin control, conveyance attachments and instructions for their use, head and roller sheave maintenance, cutting and reattaching, and lubrication. The lubrication section covers rope cleaning and cleaning devices, lubricants, and methods for application including drawings of lubricator equipment. Light-bodied lubricants continuously drip-applied to periodically cleaned rope are favored.
>
> [Roebling's recommendations dealing with mine-hoist ropes are highly respected and in common use. The Company is out of business, and publications are no longer available.]

Ropeman's Handbook, Second Edition, National Coal Board in collaboration with the Safety in Mines Research Establishment, Ministry of Power (British), 1966.

This handbook deals with the construction, installation, and maintenance of the various types of rope used for mining work according to British practice. It was prepared for the colliery ropeman to guide him in his examination and maintenance duties. Types of ropes—e.g., winding (hoisting), haulage, guide and rubbing, and balance ropes—are dealt with in individual chapters. Separate chapters cover storage, seizing, capping (terminating) with molten white metal, and capping with inserted cones and tails. The major sections of each chapter dealing with a type of rope cover choice, installation, capping (termination, recapping), forms of deterioration (and prevention), maintenance, examination, and when to discard. Photographic illustrations abound.

Sutherland, Burns, "Rope Maintenance on Drum Hoists", The Canadian Mining and Metallurgical Bulletin for October, 1970, pp. 1156–1163.

Sutherland discusses the most common sources of problems with ropes on drum-type mine hoists and describes preventive and corrective maintenance methods. Included are: drum spooling and grooving, flanges, layer-to-layer transition, cross-over points, dead wraps, drum spout, head-sheave grooving, lubrication, and rope cutting.

White, M.C., "Research Report No. 249—A Survey of the Wire Ropes Examined by SMRE After Failure or Serious Deterioration During the Five-Year Period 1961–1965", Ministry of Power (British), Safety in Mines Research Establishment, 1967.

White summarizes the examination of 76 failed or seriously deteriorated wire ropes; all but three were either hoist, haulage, balance or guide ropes from vertical shaft drum or friction hoists. Probable causes of rope breaks or deterioration are indicated and preventive measures are suggested.

[A significant number of the breaks or deterioration are traced to failure to follow recommended procedures, notably, in making white metal cappings (poured sockets) and watching for developing problems at a known damaged point, or in simply removing an obviously badly deteriorated rope. In the latter instances many haulage ropes were involved and in some cases fatalities accompanied failure. The nearest U.S. relative to British haulage practice is inclined-shaft hoisting and both are prone to and evidence much the same kinds of rope damage.]

Whiteley, N. I., "Wire Rope Lubrication", paper presented at the United States Steel Lubrication Engineers Meeting, Pittsburgh, Pennsylvania (June 2, 1954).

This paper discusses steps in the manufacture of wire ropes including the lubrication process, the need, methods, and equipment for field lubrication, the types of lubricants used, and some general comments on rope maintenance.

263

E.2.3.2 INSPECTION AND MAINTENANCE (Continued)

[A very qualitative presentation with some good photos of wire-rope manufacturing machines and a lot of talk about lubricants and how to apply them. The paper begs the question "Fine, but how do these different lubricants and methods work out in practice?"]

E.2.3.2.1 NONDESTRUCTIVE TESTING (NDT)

Barrett, C. M., "Non-Destructive Testing of Mine Hoisting Ropes in Ontario", Ontario Department of Mines, July 1964.

The author briefly discusses the history of the introduction and development of electromagnetic (E.M.) nondestructive mine-rope testing in Ontario and describes the device [then] in use. Eleven examples of nondestructive tests with ropes are shown and compared with tensile-test results. The E.M. device is described as being particularly sensitive to corrosion and other mechanisms reducing rope diameter, but not particularly sensitive to broken wires.

[Periodic E.M. testing of hoist ropes has been mandatory in Ontario since January 1, 1963, as a supplement to visual inspection and measurement of diameter and lay-length changes.]

Corden, C.H.H., and Roebuck, B., "Magnetic Inspection of Wire Ropes", Lift, September/October 1972, pp. 188–189.

The authors describe a device developed by SMRE (Safety in Mines Research Establishment—Great Britain) called a "rope fault position indicator". The device works in conjunction with the MD6 Deflectograph and automatically operates an aerosol paint spray can, marking suspected places on a wire rope and, thus, eases subsequent visual examination. A circuit diagram for the device is presented and the authors believe it is readily adaptable to other types of nondestructive rope inspection equipment.

Harris, D. O., and Dunnegan, H. L., "Acoustic Emission Testing of Wire Rope", Dunegan/Endevco, Livermore, CA, Technical Report DE-72-3A.

The authors present the results of acoustic-emission monitoring of tensile-fatigue, and fatigue-with-periodic-overloading tests on wire rope. The results show a one-to-one correlation between wire breakage and acoustic-emission events, and that damaged cables consistently produced more emissions at a given load than undamaged ones. The continuous monitoring of cyclically loaded rope provided a warning of impending fatigue failure at as early as half the lifetime. The authors suggest that this technique is well suited to nondestructive evaluation of wire rope.

264

Higginson and Butler, "Non-Destructive Examination of Steel Wire Ropes", paper submitted to Safety-in-Mines Research Board (British), March 1969.

The authors summarize an evaluation of various electromagnetic nondestructive wire-rope inspection devices carried out in Britain from 1957–1966. The work was predominantly laboratory based and involved locked-coil hoisting ropes. The authors conclude that such routine nondestructive testing cannot be considered at present (in Britain) because of a lack of experience with hoist ropes in service; they recognize a need to correlate nondestructive test data with destructive test data to establish the validity of the technique.

Lang, J. G., "The Principle and Practice of Electromagnetic Wire Rope Testing", The Canadian Mining and Metallurgical Bulletin for April 1969, pp. 415–424.

Lang outlines the principles of an A.C. (alternating current) E.M. (electromagnetic) wire-rope nondestructive testing device developed in Ontario and shows how it is used in mining and other applications.

Case histories of the examination of mine hoist ropes that are presented and discussed include rope-strength deterioration due to corrosion, peening wear, and broken wires. Also discussed are rope deterioration anomalies peculiar to drum and friction hoists, tests of locked-coil ropes, and experiments and developments in the area of low frequency (10 Hertz) testing. A major section addresses the instruments' response to broken wires: author states that where fatigue occurs and a fatigue crack appears in the absence of corrosion or appreciable wear the device will not indicate the fatigue condition; however, experience indicates that the more common case is fatigue breaks accompanying some degree of flattening, plastic wear, peening or abrasion, conditions to which the instrument is sensitive and, as a result, with which broken wires have been found by visual inspection subsequent to the instruments' indicating a problematic area.

Lang, J., "Progress Report No. 3, Electromagnetic Rope Tests, Ontario, May 1961 to August 1962", McPhar Geophysical Limited, September 1962.

The third report of a program sponsored by the Ontario Mining Association and the Ontario Department of Mines to develop a reliable alternating-current, electromagnetic, nondestructive wire-rope inspection device.

The report describes the new instrument, experiments to determine the effect of rope loads (stress) on the instrument's response, and experiments with steel tubing directed toward increasing instrument sensitivity to conditions in locked-coil hoisting ropes. Finally, the results of inspecting 52 hoist ropes (in and out of service) are presented and compared with the results of tensile tests to failure.

Morgan, J. P., "Investigations on Wire Ropes in Mine Hoisting Systems", The Australasian Institute of Mining and Metallurgy, Proceedings No. 215, September 1965, pp. 59–85.

Morgan deals with nondestructive testing (NDT) of mine ropes and mine-rope research in general. An interesting and illuminating history of NDT devices and

265

E.2.3.2.1 NONDESTRUCTIVE TESTING (NDT) (Continued)

research is presented, together with results of current investigation and the author's enumeration of the gaps between research and practice. A policy outline for general rope research is presented and discussed. [This approach appears to place the emphasis on rope but a systems-view is taken and all aspects of the hoisting operation and machinery are included. Thus the policy could just as well be considered as a systematic approach to hoisting research in general.]

Paper includes the questions and answers and general remarks of a post-paper discussion.

Morgan, J. P., and Symes, H.E.J., "The Development and Future Significance of Non-Destructive Testing of Winder Ropes in Australia (with discussion)", The Australasian Institute of Mining and Metallurgy, Proceedings No. 221, March 1967, pp. 61–69.

The authors discuss Australian development work on electromagnetic nondestructive test equipment with emphasis on its application to friction (Koepe) hoist ropes. A discussion of fatigue and the tension behavior in Koepe ropes is included.

Operations Manual for Mitsui Steel Wire Rope Tester, LF No. F6802, Mitsui Miike Machinery Co., Ltd., Tokyo, circa 1971.

The manual describes equipment, procedures for use, and how to interpret output data for a D.C. (direct current) electromagnetic nondestructive wire-rope inspection device. Although the material indicates the instrument can detect potential rope problems due to corrosion and wear, it stresses heavily the instrument's sensitivity to broken wires; data interpretation aids treat only broken wires.

Ross, A. C., "The Use of the Magnetic Defectograph, M.D.6", Wire Rope Industries of Canada (1966) Limited, Vancouver, 1968.

Ross discusses principles, construction, and use of a European-developed D.C. (direct current) nondestructive wire-rope inspection device that uses permanent magnets rather than a D.C. powered coil to provide the primary field. He also describes how to relate the output data to rope degradation through the use of charts.

[There are some strong claims made here relative to determining the "exact" condition of the rope regardless of whether the "fault" is at the center or on the surface. These claims are not substantiated with data or references.]

DiSantolo, Domenico, "A Miniature Magnetic-Inductive Instrument for Inspecting Ropes While in Service on Ropeways", Lift, March/April 1973, pp. 53–56.

The author describes a small, highly-portable D.C. (direct current) nondestructive wire-rope inspection device developed in Italy (it uses permanent magnets). It was designed as a supplement to a much larger "standard" instrument to permit greater frequency of use at less cost to the user; it can accommodate ropes to 40 mm (1.01-inch) diameter. Included are comparisons between the results obtained with this and the "standard" instrument.

Semmelink, A., "Electro-magnetic Testing of Winding Ropes", the Transactions of the South African Institute of Electrical Engineers, Vol. 47, Part 7, July 1956, pp. 206–244.

The results of experiments with an A.C. (alternating current) nondestructive wire-rope inspection device designed and built in South Africa are described. Included are descriptions of the basic principles and construction of the device with circuit diagrams; operational methods; a detailed discussion of results and methods of interpretation; a discussion of the relation between actual breaking load and instrument indications; results of observations of lay length versus rope condition; and, finally, a series of examples of electromagnetic test results and comparisons with destructive test results.

[Several years after this paper appeared, Semmelink was associated with McPhar Geophysical of Ontario and involved with the development and field investigation of A.C. devices in Ontario using very similar if not identical apparatus.]

Semmelink, A., "Progress Report, Electromagnetic Rope Tests, Ontario, August 1958 to April 1960", McPhar Geophysics Limited, April 1960.

First report of a program sponsored by the Ontario Mining Association and the Ontario Department of Mines to investigate an A.C. (alternating current) electromagnetic nondestructive method of testing mine hoist ropes. Report contains a short description of the principles, design, and method of operation of the instrument, a discussion of the interpretation of the output data and the method for estimating from it the breaking strength of the rope, and finally, the result of tests with 25 hoist ropes which include a comparison of the estimated and actual breaking strengths.

Symes, H.E.J., "Non-Destructive Testing of Winder Ropes—A Survey of Present Methods", Queensland Government Mining Journal, March 1960, pp. 100–103.

Symes briefly discusses the major A.C. and D.C. nondestructive wire-rope inspection techniques and instruments and how their development has been influenced by hoisting conditions in the countries of their origin. The advantages and disadvantages of the techniques are discussed and some possibilities for future development presented.

E.2.4 CONVEYANCES, GUIDES, AND SAFETY DEVICES

E.2.4.1 CONVEYANCES

Smith, W., "Pneumatic Guides Provide Smoother Skip Travel", Engineering and Mining Journal, Vol. 147, No. 4, April 1946, pp. 106–107.

Smith describes the design and installation of pneumatic tires to replace steel guide-shoes on ore skips. Five year's experience showed smooth and almost noiseless skip travel, less wear and fouling of wood guides, little tire wear, and reduced time required for shaft guide and skip repairs.

E.2.4.2 SAFETY CATCHES

Albert, L., "Free-Fall Test Results on Three Different Types of Wood as Guide Material", May 1970 (unpublished company report).

Albert reports the results of International Nickel Company's (Ontario) in-house tests with British Columbia fir, mahogany, and Australian Karri wood as shaft-guide materials in conjunction with the Ontario-type single-tooth dog for conveyance safety catches.

The report shows the need to design single-tooth dogs according to the characteristics of the wood used for guides. The test dogs designed for use with British Columbia fir stopped the test vehicles in all three woods but somewhat more rapidly in mahogany and Karri wood. Mahogany and Karri spoil did not foul the dogs, but it did not break up as it did with British Columbia fir and it tended to clog the dog-actuating mechanisms so that the spoil had to be cleared before the cage could be lifted and the dogs would retract. The grain of the mahogany was not parallel to the longitudinal axis of the guide and the dogs tended to follow the grain and twist the cage as it stopped. Thus in non-parallel grain woods where the dogs act on the guide faces nearest the conveyance the dogs could run out of the guides if the guide-spacing were greater (e.g., due to wear) than the design distance. The guide and dog layout and, particularly, the guide faces on which the dogs work is thus an important design consideration.

Cooper, L. O., "Some Notes on the Design of Safety Dogs", Transactions of The Canadian Institute of Mining and Metallurgy, Volume LI, 1948, pp. 252–254; also, The Canadian Mining and Metallurgical Bulletin for October 1948, pp. 570–572.

Cooper discusses the development of a design for a safety-catch dog for use with British Columbia fir guides that provides a stop of known deceleration. An empirically determined design equation is presented.

268

[The empirically determined equation is

$$Z = 2000x + 450y$$

where Z = total force on dogs, lb
x = total dog area, in.^{2}, and
y = total dog cutting edge, in.^{2}.

As a result of subsequent work the equation was modified (by 1955) as follows (private communication):

$$Z = 1730x + 542y.$$

Although the equation is presented in terms of the total force for all dogs associated with a conveyance, it can be applied to one dog as well so long as x and y refer to one dog. The dog area, x, is the projected area of the tooth that moves through the wood; for a single-tooth dog this is the width of the tooth *times* the depth of penetration into the guide; for a two-tooth dog this is twice the width of one tooth times the depth of penetration. The dog cutting edge, y, for a single-tooth dog is twice the depth of penetration *plus* the width of the tooth; for a two-tooth dog, the value is twice that for one of the teeth.]

Details of Practical Mining, Editorial Staff, First Edition, McGraw-Hill Book Company, Inc., New York, 1916, "Chapter IX, Shaft Conveyances", pp. 371–376.

[Though mainly of historical interest, experience with the Munzner safety catch is discussed. The device acted on the principle of knife edges cutting wood from a guide. Despite continuing years of controversy the author then recognized (1916) that the Munzner knife-like safety dogs ". . . offer the advantage as against the ordinary type of toothed-cam safety dog, of stopping the cage with a slower, braking action instead of with a sudden grip and they more perfectly fulfill the requirements of a good safety catch, namely, that it be positive and reliable, quick to come into action, but slow to complete its action . . . It is urged against the cam dog that it acts so quickly as to tend to injure the men riding on the cage and to tear out the guides. It [the multi-toothed cam dog] also is likely to fill with wood and possibly become inoperative."]

Grove, G. W., Ash, S. H., and Ristedt, E. J., "Some Haulage Safety Devices for Use on Grades, Slopes, and Inclined Shafts", U.S. Department of the Interior, Bureau of Mines, Miners Circular 43, 1942.

[This paper, though interesting, is mainly historical. The large number of devices described and pictured roughly fall in two categories: those designed to hold or block standing vehicles; and those intended to slow or stop an out-of-control conveyance. As there are always ample circumstances for wanting to block and hold cars, the former group of devices is generally still applicable and, in some form or another, the ideas are much in use. The latter group, the safety catches, evidence old technology

269

E.2.4.2 SAFETY CATCHES (Continued)

and, except for two devices, are definitely unsafe as they would tend to impart a high impact load to a moving conveyance and probably either derail it or tear something apart. The exceptions, a braked capstan using extra ropes running the length of the shaft, and a tooth dog engaging wooden guides paralleling the rails, have modern equivalents that are much improved technologically.]

Lancaster, A. W., "Mine Cage Safety Dog with Predictable Deceleration", Canadian Mining Journal, November 1946, pp. 1039–1042.

The paper presents the results of an equipment manufacturer's work to develop a safety catch actuated by loss of hoisting tension and producing a calculable deceleration.

[The paper appeared early in Ontario's general effort to provide a reliable safety catch and many of the features of the design discussed are incorporated in the safety dog now almost universally used in Ontario.]

Larsen, C. H., Egen, R. A., and Cress, H. A., "Investigation of Requirements and Performance of Safety Catches on Wire-Rope Suspended Man-Carrying Conveyances in United States Coal Mines", USBM Contract No. H0111810, Final Report from Battelle Memorial Institute to The Pittsburgh Mining and Safety Research Center, Bureau of Mines, September 27, 1972 (National Technical Information Service No. PB-218 067).

This report presents the results of a comprehensive investigation of conveyance arrestment devices (safety catches) used in United States coal mines. Treated are availability and use of equipment, performance, inspection, maintenance, testing procedures, and regulatory requirements. Portal elevators and traditional mine hoists (inclined and vertical shafts) are covered.

The results indicate that only two types of conveyance-arrestment devices have been proved reliable for stopping a conveyance without damaging equipment or injuring passengers. One is the single-toothed dog for wood guides developed in Ontario; the other is type Type B, wedge-clamp elevator safety. The authors suggest application, design, actuation, stopping-performance, and testing and inspection criteria as a guide to eliminating the general inadequacies of safety catches and other conveyance safety brakes.

The authors distinguish between the ability of a safety catch or equivalent to actuate (i.e., move from rest position into contact with the guides) and to stop a conveyance (i.e., the actual braking performance). Their conclusion—that only two devices have been proved reliable—is based primarily on existing braking-performance data obtained from tests with moving, loaded conveyances. They state that these data show that many types of safety dogs will probably not stop a moving conveyance and/or will do much damage in the attempt. Further, they state that the performance of some types of dogs and arrestment devices cannot be judged because tests to demonstrate their stopping capabilities are not made.

Mine Plant Designs, McGraw-Hill, New York, 1949, "Chapter VII, Safety Catches" (Wm. Westly Staley), pp. 250–277.

Chapter VII covers the design of safety catches and actuating mechanisms for vertical shaft conveyances and includes many engineering drawings of specific examples. There is a short discussion of inclined shaft practice.

[With a few notable exceptions, the safety dog information is dated and misleading. The information about actuating mechanisms is generally fair to good.]

Mine Safety Board, "Mine Safety Board Decision 28: Safety Catches and Arresting Devices for Cages, Skips, and Cars in Mine Shafts and Slopes", U.S. Department of the Interior, Bureau of Mines, Information Circular 7002, April 1938.

This policy statement recommends use of safety catches in vertical and steeply inclined shafts used to transport men, and use of "arresting devices, other than ordinary brakes" in slopes where men are transported, all actuating in the event of a rope break or other loss of connection.

The board reemphasizes good rope practice in view of their knowledge of no reliable safety catches or arresting devices.

Stothart, A.B.C., "Mine Conveyance Safety Dogs", The Canadian Mining and Metallurgical Bulletin for December, 1950, pp. 675–677.

Stothart discusses some of the major aspects of the development of safety catches in Ontario from 1945 through 1948, including the impetus for progressive development of a specific type, free-fall testing, and anti-trailing rope device. Data included show the rapid improvement in performance of safety catches throughout the province.

Vaughan, J. A., "Safety Catches for Mine Cages", circa 1912.

Vaughan presents and discusses various official opinions about the reliability and use of safety catches and discusses the results of some experiments showing that one type (the Undeutsch device) is reliable.

[Vaughan was a member of the Transvaal Rope and Safety Catch Commission which reported in 1907 that it was not wholly satisfied that any of the safety catches tested entirely met the requirements of such a device, but that it saw that the possibilities of a satisfactory device had been established. The report of this Commission was widely circulated, often quoted, and is occasionally still referenced. Vaughan had been deeply involved with the tests made. He writes to express and substantiate his opinion which differed from the collective one of the Commission as well as to "resurrect some of the truths which have in the past been established by commissions of enquiry with respect to safety catches, and which have since then lain buried in blue-books . . .".

271

E.2.4.2 SAFETY CATCHES (Continued)

His declaration of the requirements of a good safety catch have been almost completely proved correct, and the Undeutsch dog that he championed clearly expressed these requirements, also, almost completely. This device worked with wood guides and Vaughan clearly saw that the kind of guide used was of great significance and that regional variations in the kinds of guides in general use (i.e., wood, steel, rope) were often at the root of the difference of opinion as to the reliability and utility of safety catches.

The Undeutsch device is no longer a viable concept. The single-tooth dog developed in Ontario during the late 1940's and early 1950's incorporates not only the Undeutsch principles but others since discovered; it is a technologically superior device.]

E.2.4.2.1 SAFETY CATCH TESTING

Baker, T. J., "Free Fall Testing of Mine Hoisting Conveyances in Ontario", Ontario Department of Mines, May 1963.

The author begins with vertical shaft systems. Step-by-step procedures with diagrams are given for free-fall testing of safety catches on light and heavy conveyances. The recommended method for evaluating catch performance is discussed and illustrated with a sample report form. Sketches of components for rapid release of conveyance and delayed action of safety catches are included.

The procedures apply specifically to the single- and double-tooth safety dog developed in Ontario for use with British Columbia fir guides. These procedures and dog designs grew out of the investigations, research, and development work following the 1945 Paymaster Mine hoisting accident in which 16 men were killed.

The author points out that the test is severe and designed to simulate a worst condition, that is, a fully loaded man conveyance descending at rated maximum speed in a region of worn, wet guides. He cautions against applying the test to "old style safety dogs" (i.e., multi-toothed cams and wedges), stating that the single- and double-tooth designs are the only ones found reliable.

The author then turns to safety catches for inclined shaft conveyances, treating their testing and Ontario's requirements for their application.

Next is a discussion of the types of safety catches and operating mechanisms [then] in use with a detailed discussion of anti-trailing rope mechanisms.

The author then briefly discusses some of the major aspects of guides relative to safety-catch performance.

The author concludes with a discussion of European and South African safety devices for conveyances on inclines and gives his general opinions of how to adapt and apply available safety devices and associated equipment to incline conveyances.

[The Ontario Mining Act has been modified since this paper was written and some details of the testing procedures are no longer required. Also, only single-tooth dogs are now recommended and anti-trailing rope devices are no longer recommended. The use of double-tooth dogs and anti-trailing rope devices is dying out.]

Baker, T. J., "Free Fall Testing of Mine Hoisting Conveyances in Ontario Mines", Canadian Mining Journal, November 1958, pp. 63–68.

Baker, T. J., "More About Safety Dogs—A Supplement to 'Testing of Mine Hoisting Conveyances' Which Appeared in the November 1958 Issue of Canadian Mining Journal", Canadian Mining Journal, November 1963, pp. 63–68.

These two journal presentations cover the previous paper; the first treats vertical shaft conveyances only, the second the remainder of the paper. The second paper includes illustrations of two types of British-made incline man cars equipped with safety-brake devices that were not included in the original paper.

Harrington, D., and East, J. H., Jr., "Safety-Catches on Mine Cages and Methods of Testing Them", U.S. Department of the Interior, Bureau of Mines, Bureau of Mines Information Circular 7436, February 1948.

This paper reviews some U.S. state laws and regulations governing safety catches, and concludes that they are inadequate because of their vagueness; it discusses at length some of the findings of the Ontario Mining Association Committee's review of the hoisting accident at the Paymaster Consolidated Mine (February 1945, 16 killed); and reviews in depth the methods and special equipment involved in the testing of safety catches at some eastern U.S. bituminous coal mines and in the U.S. Lake Superior District. The authors conclude that the [then] present methods of testing safety catches are inadequate as they do not represent worst conditions (i.e., a loaded conveyance, moving at speed).

Pearce, Clyde E., and Cash, Frank E., "Testing Safety Catches on Mine Cages, Lake Superior District", U.S. Department of the Interior, Bureau of Mines, Information Circular 7325, June 1945.

The circular presents a detailed discussion of the testing of safety catches at 13 mines in the Lake Superior District. Illustrations show the usual type of safety-catch dog and operating mechanisms in use, and the "tripping hooks" used by the various mines to rapidly release the conveyance during the safety-catch test.

All tests are of the drop type (i.e., upon release of conveyance the safety-catch mechanism is immediately permitted to actuate) and most are conducted without disconnecting the hoist rope and with an empty cage. The authors conclude that such drop tests are adequate and sufficient but point out that a more severe test would involve actuation when the conveyance is moving down at its maximum normal speed

273

E.2.4.2.1 SAFETY CATCH TESTING (Continued)

while normally loaded. But as they feel that such a test would only determine the strength of the safety catches and the wooden cage guides they don't believe such tests are warranted in view of the cage-accident history in their district.

[The performance of a safety catch *is very much* dependent upon the strength of the catch as well as the guide. If both cannot withstand the forces developed, there is no stopping.]

Sloman, H. J., "Testing Safety Catches on Mine Cages at Some Eastern Bituminous Coal Mines", U.S. Department of the Interior, Bureau of Mines, Information Circular 7290, July 1944.

A detailed discussion of safety-catch testing at 11 eastern bituminous coal mines is presented in this circular. Illustrations show the types of safety catches and actuator mechanisms in use, and the methods and mechanisms used to rapidly release the conveyance during the test.

All tests are either drop tests (i.e., upon release of conveyance safety-catch mechanism is immediately permitted to actuate and the hoist rope is not disconnected); or simple mechanism actuation (e.g., by chairing cage and slacking the rope), all using empty cages. Safety-catch dogs described are either multi-toothed cams or serrated wedges.

The author recognizes that none of the tests, particularly the actuation test, simulate the most severe conditions likely to exist in an emergency calling for safety-catch performance, i.e., fully loaded conveyance descending at its maximum speed. Though he feels simulating these conditions in a test is impractical [no justification] he does argue for performing the drop test with a simulated maximum conveyance load. He also stresses testing versus visual inspection as the only way to determine safety-catch effectiveness.

274

E.3 ELEVATORS

American Standard Safety Code for Elevators, Dumbwaiters, Escalators, and Moving Walks, A17.1—1965, Seventh Edition, the American Society of Mechanical Engineers, New York, 1965; and supplements USAS A17.1a—1967, USAS A17.1b—1968, USAS A17.1c—1969, and ANSI A17.1d—1970.

This nationally recognized industry code covers design, construction, installation, operation, inspection, testing, maintenance, alteration, and repair of the items mentioned in the title.

American Standard Practice for the Inspection of Elevators—Inspectors' Manual, A17.2—1960, Third Edition including 1965 Addendum and 1967 Supplement, The American Society of Mechanical Engineers, New York.

A manual intended to serve only as a guide for the general use of elevator inspectors. It generally is based on A17.1 (see above) but contains recommendations for the inspection of equipment that is not required to conform to A17.1.

[Mine portal elevators are built to conform to A17.1 with the exception of more elaborate car enclosures and the substitution of moisture-proof wiring and treating of the shaft equipment. Where maintenance is contracted to elevator manufacturers of specialists, the general inspection and maintenance practices follow A17.2, although exact procedures vary with the type of equipment furnished and the environment.]

275

E.4 HAULAGE

Belloch, J. D., "Manriding Underground With Particular Reference to the Weetslade Colliery Installation", The Mining Electrical and Mechanical Engineer, May 1964, pp. 275–286.

Idem, "New Developments in Manriding Underground", *ibid.,* June 1964, pp. 311–315.

Idem, "Some Aspects of Underground Haulage and Transport", *ibid.,* in two parts, September 1968, pp. 179–186, and October 1968, pp. 199–211.

These three papers deal essentially with problems and practice in underground haulage. A wide variety of conveyance types in use in Great Britain and Europe are fully described, with emphasis on the safety brake (safety catch) features.

[The similarities between haulage and slope hoisting would make these papers particularly useful during the conceptual design of a slope hoist system since some of the solutions presented for safety braking and derail prevention cannot be retrofitted, but must be built in initially.]

Crook, A. E., "Safety Aspects of Underground Transport in Coal Mines", Transactions of the Institution of Mining Engineers, Vol. 118, 1958–1959, pp. 245–274.

This paper is predominantly a discussion of accident statistics relative to underground haulage and related safety standards in Britain. Appendix 2 of the paper briefly discusses design requirements for haulage rope, couplings, and draft gear. A design safety factor of 5 is applied to the gross weight corrected for inclination and acceleration.

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