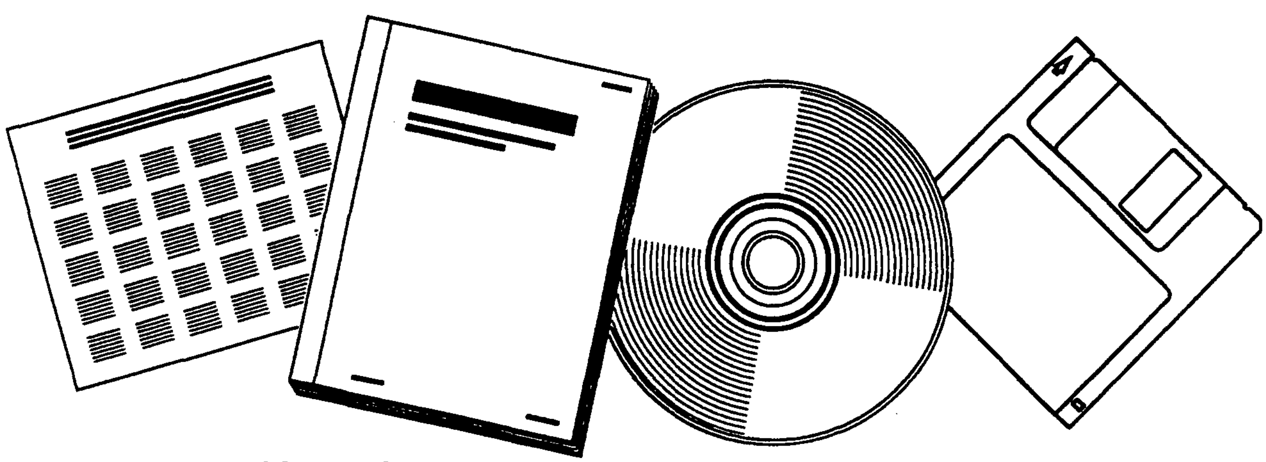
PB83-148056

PROCEDURES FOR HOIST AND SHAFT INSPECTION & MAINTENANCE - VOLUME II: INSPECTION & MAINTENANCE PROCEDURES, BUREAU OF MINES OPEN FILE REPORT 196(2)-82

V. B. COOK CO., INC.
ENGLEWOOD, CO

OCT 81



U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

A minerals research contract report
October 1981

BuMines OFR 196(2)-82

PB83-148056

PROCEDURES FOR HOIST AND SHAFT INSPECTION & MAINTENANCE VOLUME II

Inspection & Maintenance Procedures

Bureau of Mines Open File Report 196(2)-82

Contract J0100035
V.B. Cook Company, Inc.

BUREAU OF MINES ★ UNITED STATES DEPARTMENT OF THE INTERIOR
Minerals Health and Safety Technology

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Procedures for Hoist and Shaft Inspection & Maintenance. Volume II. Inspection & Maintenance Procedures

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7. Author(s) J. Cseff, W. J. Forbes, A. W. Mills III, L. Albert, and F. A. Penning

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
V. B. Cook Co., Inc.
508 - 5660 South Syracuse Circle
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Office of Assistant Director--Minerals Health and Safety Technology
Bureau of Mines
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Approved by the Director, Bureau of Mines, for placement on open file, November 3, 1982.

16. Abstract (Limit: 200 words)

This report discusses in general terms scheduled inspection and preventative maintenance of the hoists and ancilliary equipment described in volume I. Preventative scheduled inspection and maintenance procedures assist in the smooth operation of mine hoisting systems by the prevention of unscheduled or catastrophic equipment failure and its attendant downtime. Schedules and overall maintenance planning is required at the management level. Inspection, maintenance, and unusual operations or incidents must be recorded in records and equipment logs. A cross reference between MSHA regulations and various equipment components is included as part of the report. A discussion of the various nondestructive testing methods that may be applied to hoisting equipment is also included.

17. Document Analysis a. Descriptors

Mining	Shafts	Inspection procedures
Hoists	Headframes	Maintenance procedures
Control	Conveyances	Teating equipment
Communication	Rope attachments	

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group 08I

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FOREWORD

This final report was prepared by V. B. Cook Company, Inc., Englewood, Colorado under USBM Contract No. J0100035. The contract was initiated under the Metal and Nonmetal Health and Safety Research Program. It was administered under the technical direction of the Spokane Mining Research center with Mr. Eugene H. Skinner acting as Technical Project Officer. Mr. Phillip Silas was the Contract Administrator for the Bureau of Mines. This report is a summary of the work completed as a part of this contract during the period February 1980 to September 1981. This report was submitted by the authors in October 1981.

ACKNOWLEDGEMENTS

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SUMMARY

Volume II, "Inspection and Maintenance Procedures", is structured in a similar fashion as Volume I, "Systems Description", in order to relate the maintenance and inspection to the various components found in mine hoisting systems.

Section 1 is intended to give the reader a brief description of hoisting systems in order to identify the type of hoist and shaft facility being inspected. A checklist is provided to facilitate the collection of data for MSHA inspectors when they first inspect the hoisting facility.

Sections 2 to 6 discuss maintenance and inspection procedures for the various components encountered in shaft and hoisting systems.

Section 7 provides basic log books and record keeping information regarding the maintenance and inspection procedures discussed in prior sections. Included are the basic logs, namely the hoistman's log, hoist machinery log, electrical log, and the shaft inspector's record. These are felt to be minimum requirements for record keeping.

Section 8 is a series of cross reference tables which are designed to assist the MSHA inspector by pointing out the MSHA regulations in CFR30 57.19 (metallic and nonmetallic) and 75.1400 (coal), and relating them to specific items of equipment.

1. HOISTING SYSTEMS IDENTIFICATION

The text of this section follows, essentially, the same outline as that for Part I. The purpose of Part II is to elaborate on maintenance and inspection procedures for the mine operator and also to provide a guideline for hoist inspection to the MSHA inspector who is called upon to perform regular visits and to inspect hoisting and shaft operations for safety. It is obvious that the operator will be familiar with his own equipment, with regard to horsepower ratings, size, materials used, manufacturer's information and so on. However, the MSHA inspector may not be completely familiar, on the first visit, with the type of equipment in use. In this case, the inspector is immediately required to identify the type of system and to note the major components of which it is comprised. The purpose of Section 1 of Part II is to assist in the identification of the type of hoist and shaft system in use, and to direct the MSHA inspector to the various component inspections which he/she should perform.

In order for the MSHA inspector to identify the components of a shaft hoist system, he/she should be familiar with the components and systems described in Volume I of this report. The various options which may be encountered are briefly described in the following subsections. For a more detailed description see Volume I, Section I.

Single drum hoists may have either one rope or two wound onto the drum in opposite directions depending on the application. The single drum hoist has a single controller and may be equipped with either a set of drum (parallel motion or caliper) brakes or disc brakes. Gear reduction and one or more drive motions may be present. Figure 1.1 shows a typical single drum hoist and lists the major components. The hoist is usually ground mounted but in a few cases the drum hoist has been placed in towers over the shaft.

Double drum hoists are usually equipped with either one or both of the drums clutched. Brakes are present on both drums. The most commonly found brake is the parallel motion or caliper brake, but disc brakes can be used. Controllers must be present and one must be connected to each drum. A set of reduction gearing and single or multiple ac or dc motors are used to power the hoist. The double drum hoist is always ground mounted. Figure 1.2 shows a typical double drum hoist.

Friction hoists are equipped with either drum or disc brakes and require a single controller. The friction hoist may be either ground-mounted or tower-mounted over the shaft. In addition, the hoist is usually driven by a dc motor or motors and is driven either directly, or through a gear reducer.

Figure 1.3 shows a typical friction hoist installation.

Blair hoists are not yet used in the United States, but may in the future be used as shaft depths increase. Blair hoist drums may be either in-line, similar to a double drum hoist, or offset and driven through a set of reduction gearing. Current Blair hoists, mostly in South Africa, are driven with dc motors. Most commonly post brakes are used although disc brakes can be used. Figure 1.4 shows a typical Blair hoist. Like double drum hoists, a controller connected to each of the drums is required.

Bicylindroconical hoists are no longer manufactured but some are still in use in the U.S. The name describes the shape of the drum. The drums are usually offset, driven by two shafts emanating from reduction gearing. Because these types of hoists were constructed several years ago, the brakes are post brakes or caliper brakes in all cases. The drums may or may not be clutched. A controller must be connected to each drum. Figure 1.5 shows a typical arrangement.

Shafts may be either vertical or inclined. Headframes or hoist towers are required on all vertical shafts. In the case of inclined shafts with a steep angle (greater than 45°), a form of headframe structure may be required. In very shallow slopes (15° to 25°), there may be nothing more than a foundation for a headsheave or bull wheel.

Vertical shafts may be equipped with either fixed guides of timber or steel or both combined, for guidance of the conveyances. In other cases rope guides (friction hoist installations) may be used. Part of the shaft nevertheless is also equipped with fixed guides even in a rope guided installation.

In general, the items of shaft and hoisting equipment in the mining industry as a whole, are numerous and range widely in size and manufacture. The preceding remarks on systems are intentionally very general. More detailed inspections and maintenance of the individual components are shown in subsequent sections. A table showing possible component combinations is shown in Table 1.1

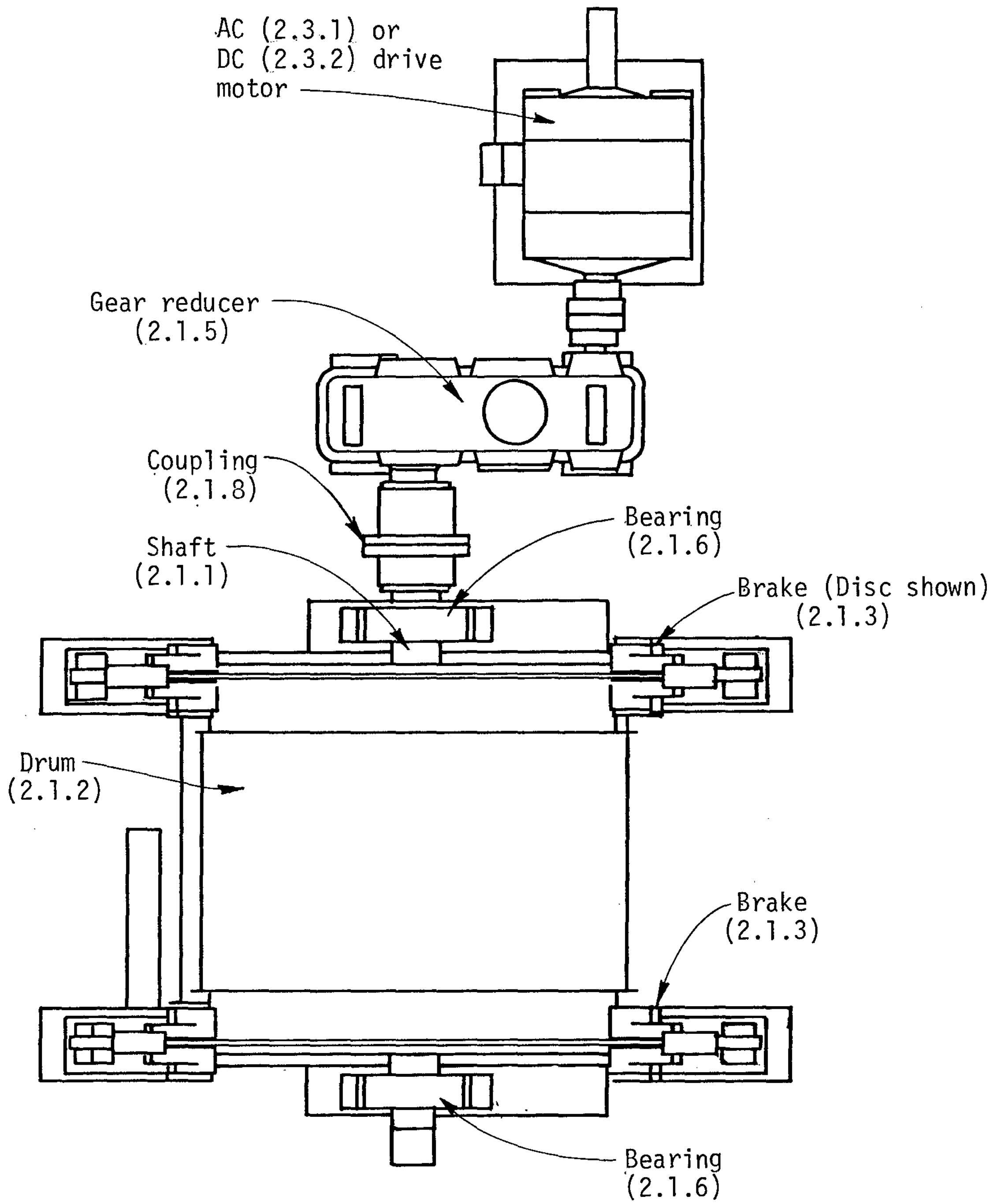
In conjunction with the Table 1.1, the MSHA inspector can prepare a checklist to be used as a permanent record for future inspections of the same facilities. What is basically involved is a checklist of the various components present. Figure 1.6 shows a checklist which may be used as a guideline.

Table 1.1 System Identification Table

HOIST	BRAKES		CLUTCH		AC DRIVE(S)	DC DRIVE(S)	GEAR REDUCTION		VERTICAL SHAFT		SLOPE SHAFT
	DRUM	DISC	FRICTION	TOOTH			YES	NO	FIXED GUIDES	ROPE GUIDES	
Single Drum	●	●			●	●	●		●		●
Single Drum (split face width)	●	●			●	●	●		●		
Single Drum (differential diameter)	●	●			●	●	●		●		
Double Drum	●	●	●	●	●	●	●		●		●
Friction (Koepe)	●	●				●	●	●	●	●	
Bicylindro-conical Drum	●		●	●		●	●		●		
Blair Multi[1] Rope Drum	●			●		●	●		●	●	

● Denotes a likely case of equipment combination in a hoisting system.

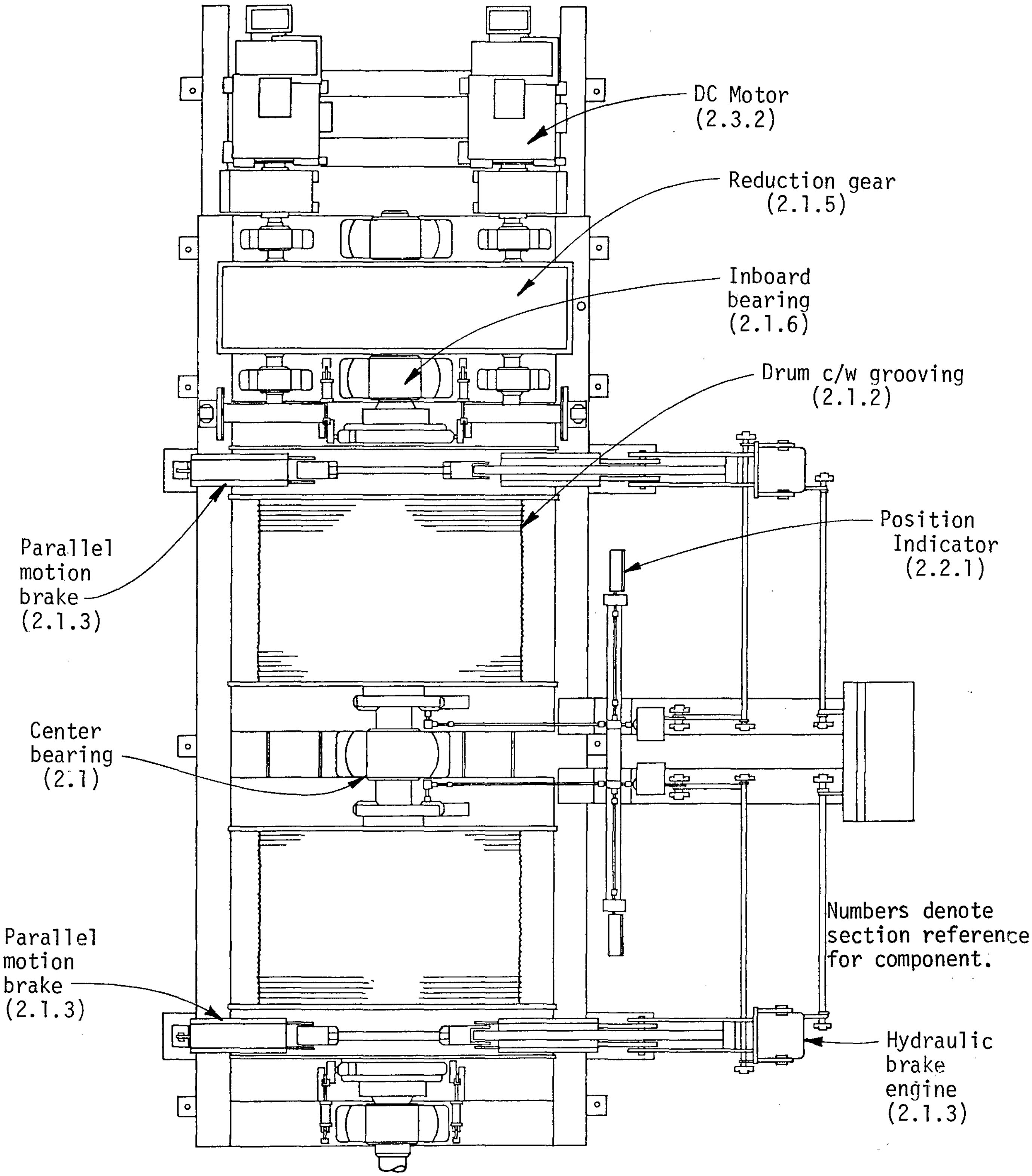
1 Experience with Blair multi-rope hoists is limited to South Africa and the United Kingdom.



Numbers denote section reference for component.

Courtesy: ASEA

Figure 1.1 Typical Single Drum Hoist Layout



Courtesy: Baylor

Figure 1.2 Typical Double Drum Hoist Layout

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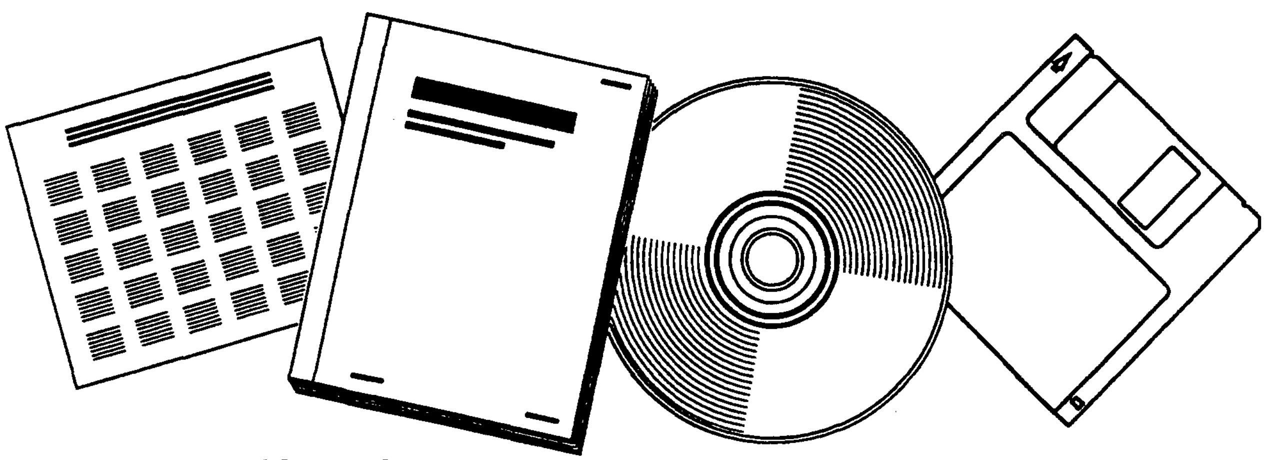

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Single Drum (differential diameter)	●	●			●	●	●		●		
Double Drum	●	●	●	●	●	●	●		●		●
Friction (Koepe)	●	●				●	●	●	●	●	
Bicylindro-conical Drum	●		●	●		●	●		●		
Blair Multi[1] Rope Drum	●			●		●	●		●	●	

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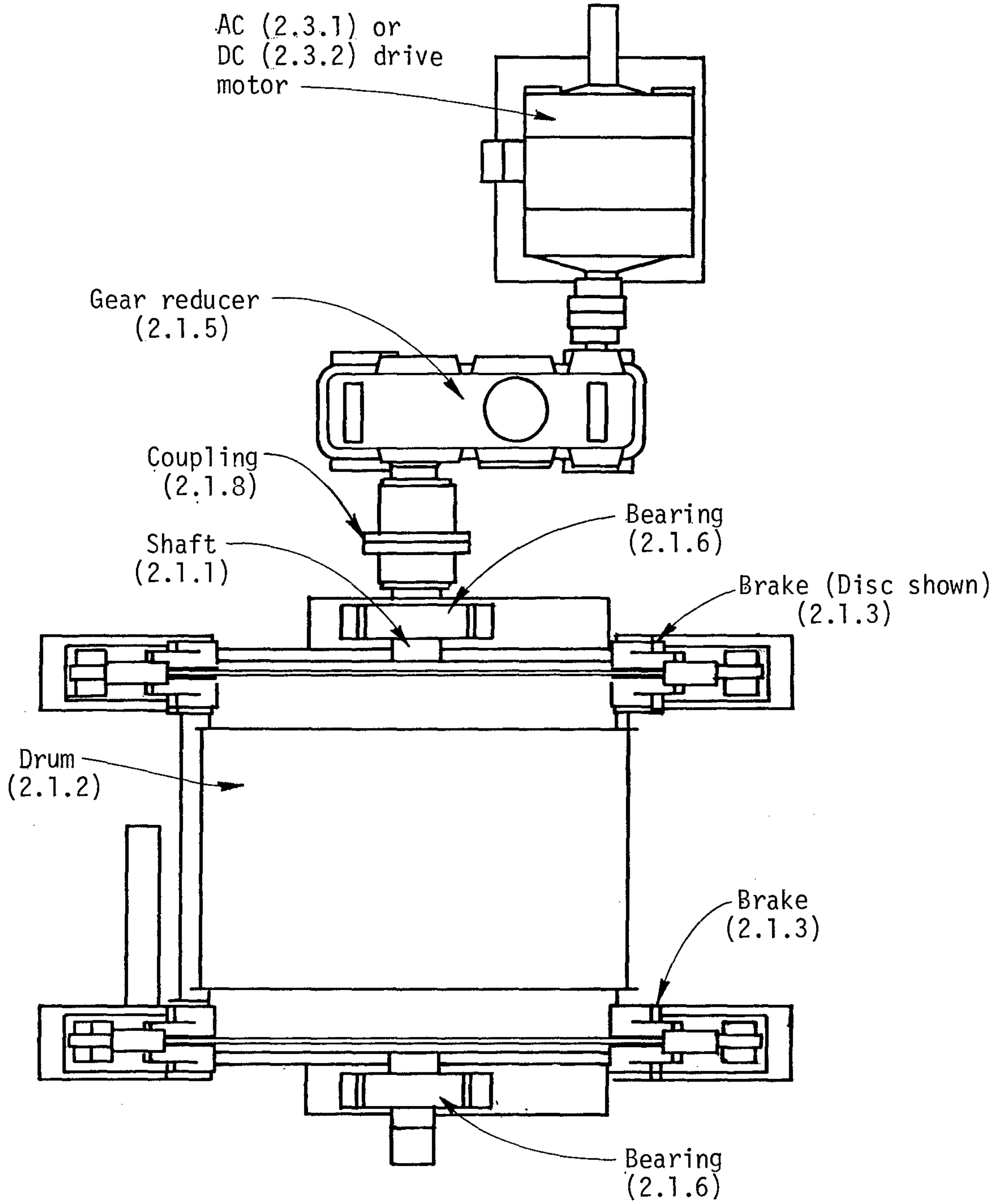
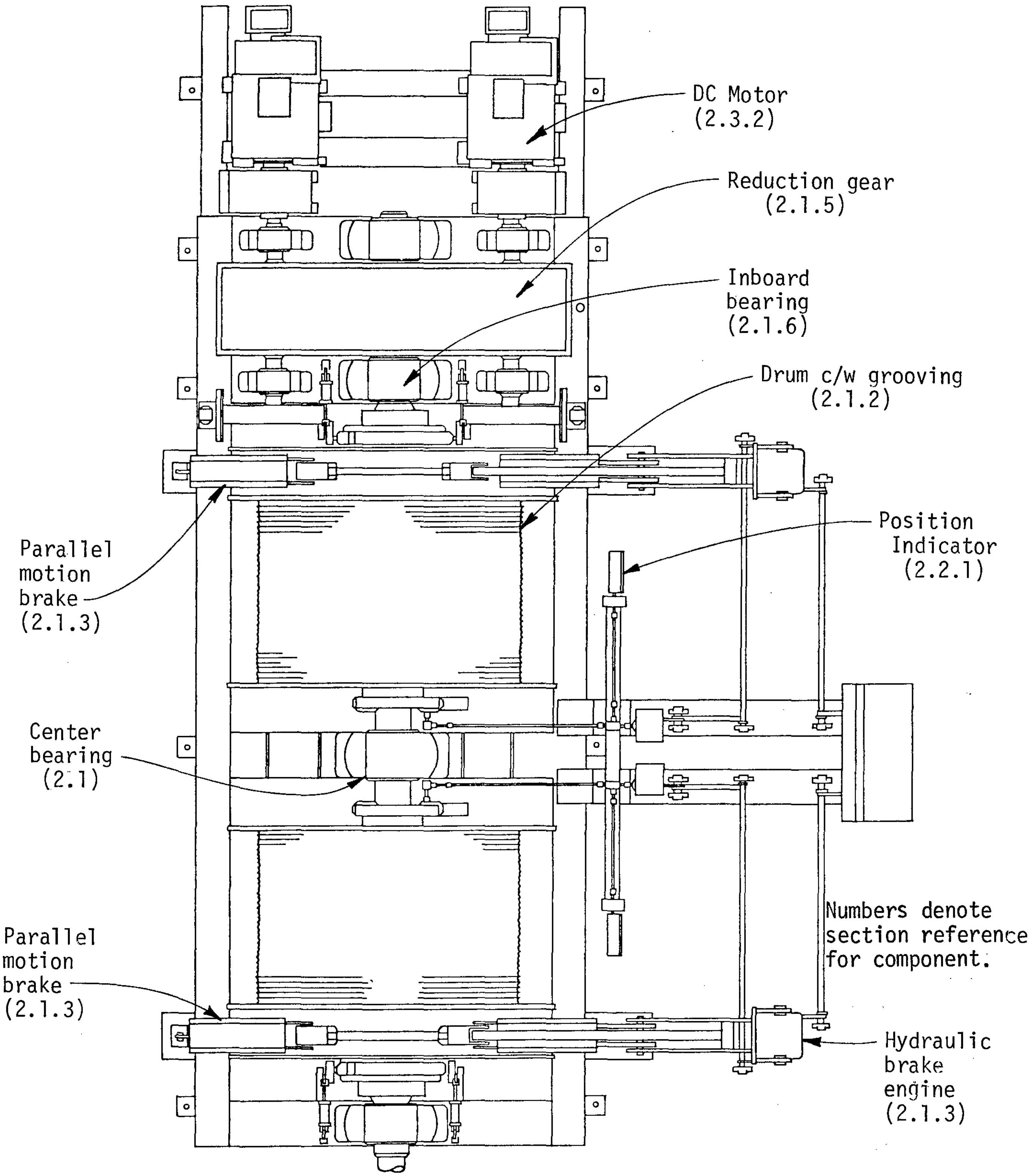


Numbers denote section reference for component.

Courtesy: ASEA

Figure 1.1 Typical Single Drum Hoist Layout



Courtesy: Baylor

Figure 1.2 Typical Double Drum Hoist Layout

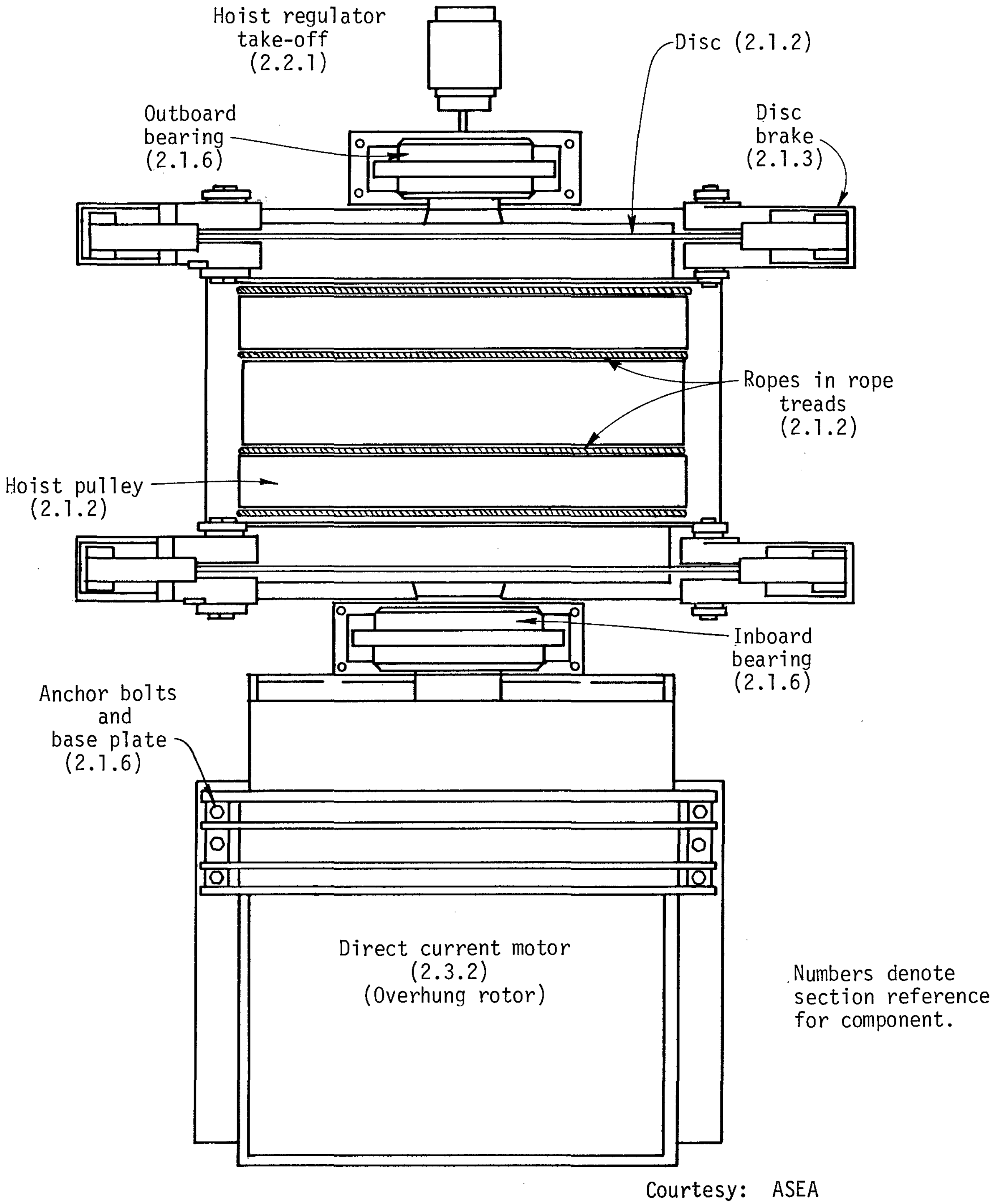


Figure 1.3 Typical Friction Hoist Layout

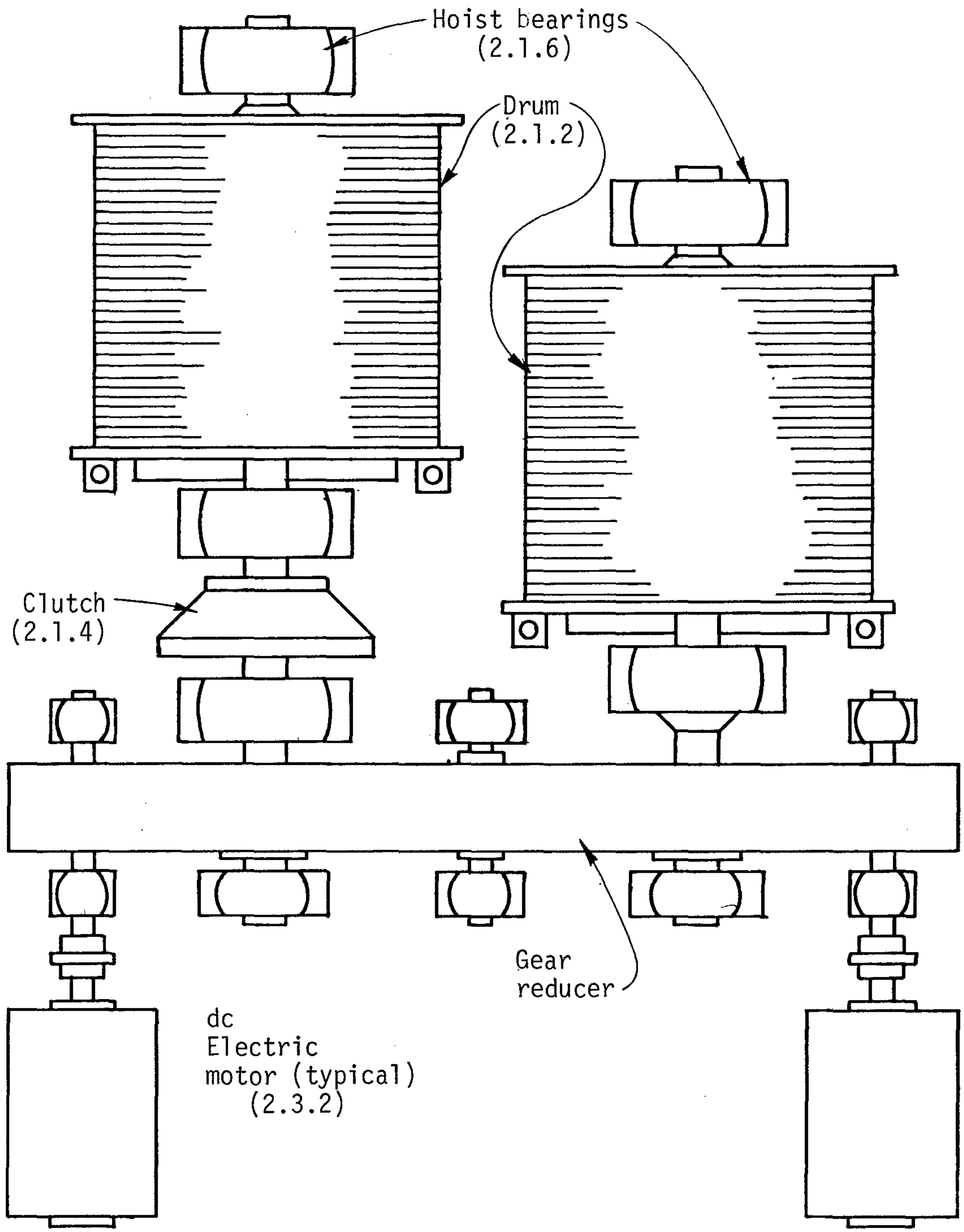


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Figure 1.4 Typical Geared Blair Hoist Layout

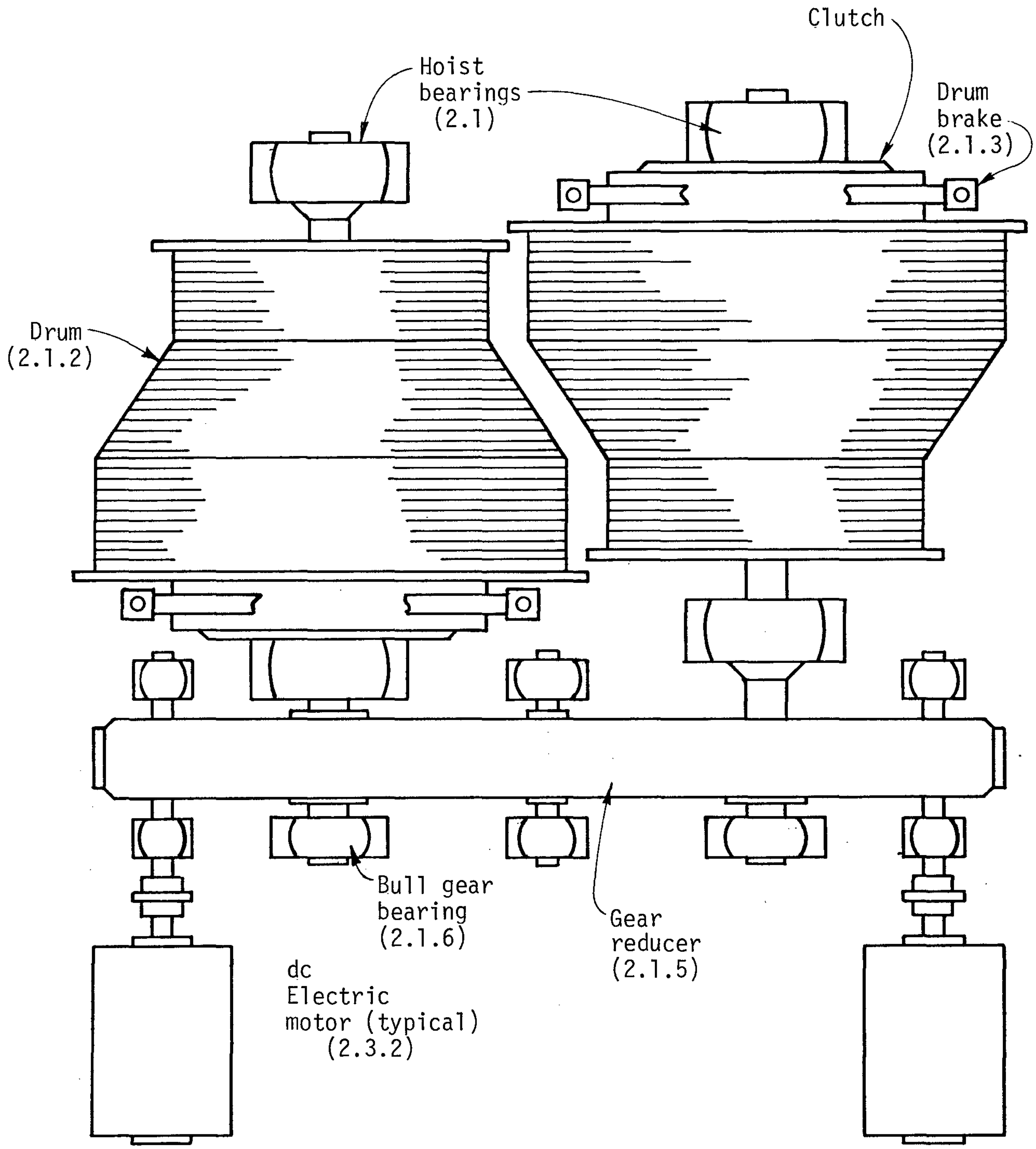

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Figure 1.5 Typical Bicylindroconical Drum Hoist Layout

Figure 1.6 MSHA Inspector's Hoisting System Checklist for Site Visits

HOIST DESCRIPTION

Location: Company Name: ____________________

Mine Name: ____________________ Shaft No. __________

Location: ____________________

Manufacturer: ____________________

Hoist Duty: Man [ ] Materials [ ] Rock [ ]

Hoist Type:

1. Single Drum (Conventional) [ ]
2. Single Drum (Split Drum) [ ]
3. Single Drum (Differential Dia) [ ]
4. Double Drum [ ]
5. Friction [ ]
6. Blair Multi-Rope [ ]
7. Bicylindroconical [ ]

Mechanical Equipment:				No. of Units
1. Drum Brakes	1.	Caliper (Jaw)	[ ]	______
	2.	Parallel Motion	[ ]	______
	3.	Disc	[ ]	______
	4.	Other (Band)	[ ]	______

Method of application

1. Weight Applied/Hydraulic Release [ ]
2. Weight Applied/Pneumatic Release [ ]
3. Spring Applied/Hydraulic Release [ ]
4. Spring Applied/Pneumatic Release [ ]

Figure 1.6 (Continued)

5. Pneumatically Applied/Pneumatic Release (With Weight Backup) ☐

6. System Pressure ________ psi.

2. Clutch(es)
   1. Friction
      (a) Lane Band ☐
      (b) Multiple Arm Disc ☐
   2. Positive
      (a) Radial Gear ☐
      (b) Longitudinal Gear ☐
      (c) Internal Gear Rack ☐
   3. Clutch Engine
      (a) Pneumatic ☐
      (b) Hydraulic ☐
      (c) System Pressure ________ psi.

3. Reduction Gearing
   1. Single Reduction ☐
   2. Double Reduction ☐
   3. Single input pinion shaft ☐
   4. Twin input pinion shafts ☐

4. Main Hoist Bearings
   1. Sleeve Bearings ☐
   2. Anti-friction bearings ☐

5. Drum
   1. Rope Diameter ________ in.
   2. Helical Grooving ☐
   3. Parallel Grooving ☐
   4. Lebus ☐
   5. Counterbalance ☐
   6. Drum Diameter ________ in.

(Figure 1.6 (Concluded)

6. Wheel (Friction)

   1. Rope Diameter ________ in.
   2. Tread Material ___________
   3. Wheel Diameter ________ in.

ELECTRICAL EQUIPMENT:

1. Motors

   1. Type of Driver motor AC |_| DC |_|
   2. If DC, type of conversion Motor Generator Set |_|
      Static - Thyristor |_|
   3. No. of Hoist Motors - __________
   4. Hoist HP Rating - _________ HP. or KW Rating - _________KW.
   5. Motor RPM at full hoisting speed - ______RPM.
   6. Insulation Data - _________________________.
   7. Forced Ventilation. Yes |_| No |_|
   8. Manufacturer _____________________.

2. Additional Equipment:

   1. Switchgear Manufacturer _________________.
   2. Transformer Manufacturer _________________.

2. HOIST COMPONENTS-MECHANICAL, CONTROL, AND ELECTRICAL

This section describes inspection and maintenance procedures and recommendations applied to the mechanical, control and electrical components. The hoistman should perform the routine tests required each shift. Those inspections performed on a daily, weekly, monthly or longer basis, should involve the mechanical or electrical maintenance personnel. Inspections of the hoist components outlined hereunder shall be recorded in the log books as outlined in Section 9 of Part II, and maintenance procedures performed shall also be recorded in the log books where applicable.

2.1 Mechanical Components

2.1.1 Shafts Inspection

Basically very little can be done as inspection of the main hoist shaft unless a detailed ultrasonic, magnetic particle or dye penetrant test is performed. To accomplish this, the shaft must necessarily be exposed and the drum or wheel, bearing caps and clutch mechanisms must be absent. For this reason shaft inspections are suggested only every 7 to 14 years depending on the severity of service. Since most recorded failures have been in areas of high shear stresses such as near bearings or drum bushings, the efforts of any such inspection should be directed principally to these areas. Sharp changes of geometry such as shoulders or bolting flanges should be closely examined for crack formation and propagation.

Since recorded shaft failures are usually attributable to fatigue, the number of cycles is the major determinant. A production hoist working on a three shift per day automated hoist cycle may, during the course of a year, accumulate in excess of 10,000,000 stress reversals. This condition would be a candidate for a seven year inspection frequency.

Conversely, hoist shafts which obtain relatively light duty, such as 2,000,000 stress reversals or less per year, may have their time between inspections extended to 14 years.

Other aspects also enter into an estimation of the severity. If the hoist is operating in less than optimum cleanliness, such as might be found in an underground hoistroom, consideration should be given to compressing the schedule somewhat.

Shaft maintenance is restricted to cleanliness particularly during those occasions when hoist bearing caps and drum bushings are removed. In the event that cracks are found through inspection, the depth and length of the crack should be noted. On smaller diameter shafts, the manufacturer should provide the guidance. On large diameter shafts (20" and larger) remachining may remove the crack without creating further stress risers. This can best be done by the manufacturer. Cracks of any size should never be ignored because of the potential for incipient fatigue failure. At any rate the manufacturer should provide design related information to determine whether the crack can be repaired. Surface cracks are important because bending stresses are highest at the surface. Shear stress distribution is highest in the center of the shaft and, therefore, flaws may propagate from this area as well.

MSHA Regulations 57.19-1 and 75.1401 merely state that hoist and components (implied) "shall have rated capacities consistent with the loads handled...." Hoist manufacturers have, to date, built hoist shafts with conservative design stress levels in recognition of the fatigue problem.

2.1.2 Drums/Wheels

Inspection of drums and friction wheels is carried out to look for bolt or weld failures. The primary failure areas which have occurred in the past include fatigue failure of the check plate stiffeners immediately below the drum shell. These failures have been noted in cast steel drums. Additional failures have occurred in the bolted connection between segmental drum sections. Brake paths for post brakes which are bolted onto the drum cheek plates also have similar geometry, and bolts should be checked as well.

Another area where fatigue failure may occur is around the hub of the drum where the cheek plates come into contact. This failure is attributed to the deflection of the shaft under load causing stresses to be transmitted between the hub and cheek plates. Figure 2.1 shows the areas where the structure should be examined.

Another area which warrants inspection includes the drum grooving. In some cases hoists have been retrofitted with grooving which is bolted on as a shell over the existing drum. Bolts may loosen with time, and could cause gradual damage to the rope if left unattended. In addition, the drum grooves should be examined for wear particularly near cross-overs and filler plates used for multi-layer winding.

In double drum hoists, the clutched drums ride on drum bushings located beneath the hub near the cheek plates. A creaking or squeaky noise during operation indicates that lubrication is required.

In the weekly inspections, bolts for cast steel or iron sectional drums should be sounded for tightness. The drum to shaft bolts on both cast drums and fabricated steel drums should be sounded. The sound of a loose or cracked bolt is immediately apparent.

Rope terminations at the drum should be checked to determine slippage over time. The simplest way to accomplish this is to apply match marks onto the rope and the drum and visually note if any slip is occurring.

On a five year basis, it is good practice to perform some type of crack detection tests using either dye penetrant methods or magnetic particle testing. Testing should concentrate primarily in the areas mentioned above. Older designs using radial spoke type cheek plates are particularly susceptible to fatigue crack development, as compared to the newer designs incorporating circular plate sections with much smaller access holes.

As far as friction hoist wheels are concerned the main inspection for these includes the same structural checks, with the exception of grooving.

The major additional check on a friction wheel includes the circumference of the rope treads. The collar to collar test should be performed as follows for Tower-mounted friction hoists.

1. Wind the conveyance down to midshaft and stop where the difference in elevation between the tops of the conveyance and counterweight is approximately equal to the length of rope in the headframe.

2. On the ropes above the conveyance which has been lowered mark all hoist ropes with a level mark using either tape or paint.

3. Reverse the direction of the wind, such that the level marks appear in the opposite shaft compartment. Care should be taken to brake gently.

4. Measure and record the mark displacement in relation to the highest mark.

For ground mounted friction hoists, the process is similar except that in step 1, the difference in elevation between the conveyances should be approximately equal to the total length from the hoist to the headsheave plus the length in the headframe.

The criteria for correctly grooved drums is based on groove lengths and headframe geometry.

$E = \frac{e}{R}$ E = maximum allowable error (in)

In the worst case where one rope is running in a short groove and the others are approximately equal, the three equal ropes absorb the tension difference. Therefore calculated net tolerance is as follows:

$E_{net} = \frac{4}{3} \times E$ for a 4 rope hoist

$E_{net} = \frac{6}{5} \times E$ for a 6 rope hoist

$E_{net} = \frac{8}{7} \times E$ for an 8 rope hoist

Once the net tolerance, E_{net}, is calculated, the maximum distance allowable between the highest mark and the lowest mark on the hoist rope is calculated, and becomes the criteria for determining whether or not the rope grooves should be machined.

The total number of hoist rotations during the test are calculated based on the distance the rope travels.

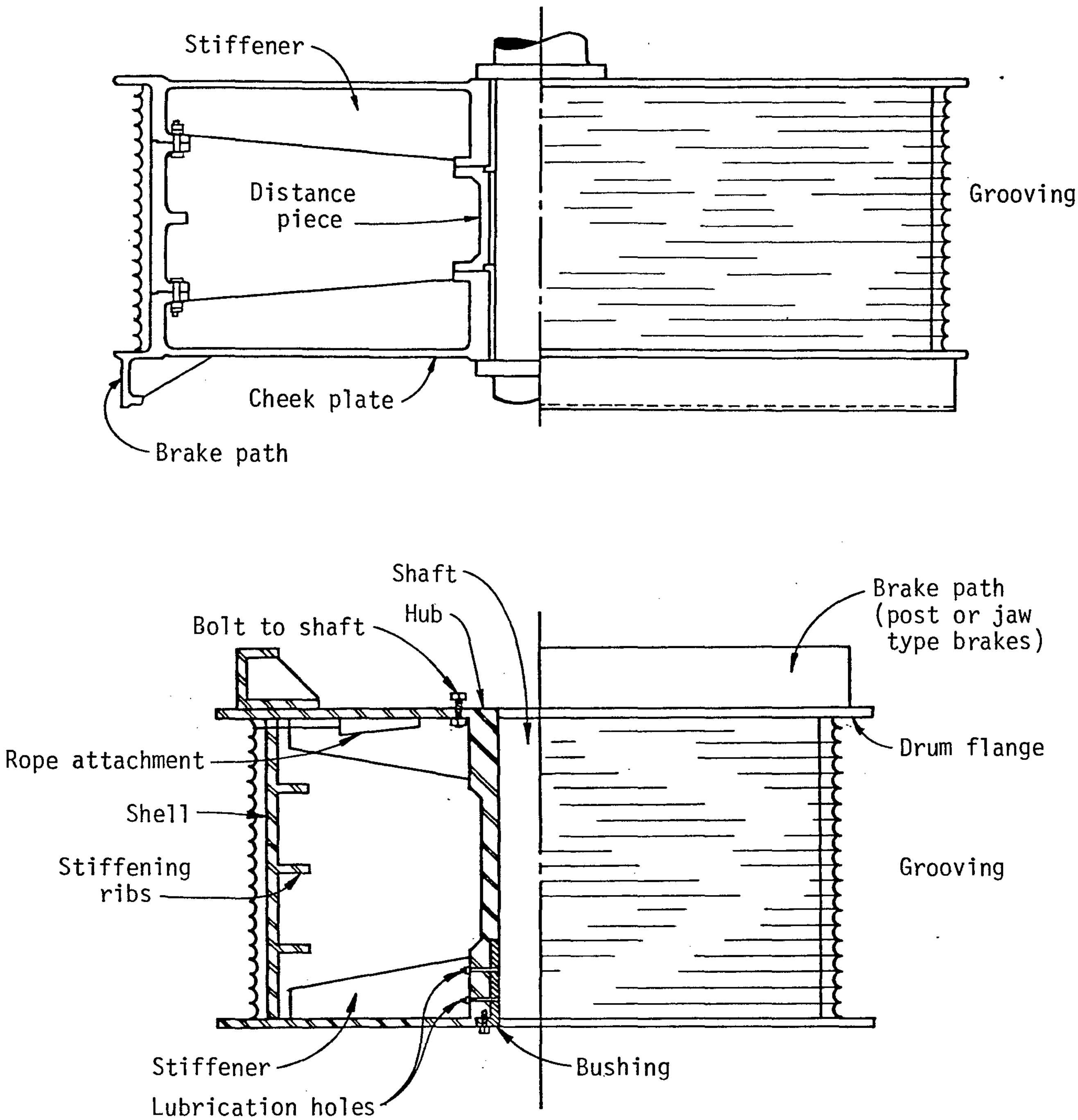


Figure 2.1 Inspection Areas on Drums and Hoist Wheels

Then the maximum distance criteria between high and low rope mark is:

$D_{max} = E_{net} \times R_{TEST}$ where R_{TEST} = number of hoist revolutions done during the collar to collar motion of the marker because with each revolution of the friction hoist, there is an accumulation of elastic stretch in the rope with the longest groove equal to the circumferential difference.

The following calculations will determine groove length maximum allowable error.

$$e = \frac{PL}{NEA}$$

Where e = elastic stretch (in)
P = Load (lbs) (Rope Wgt + Payload + Conveyance)
L = suspended rope length (in)
N = number of ropes
E = modulus of elasticity (P.S.I.)
A = area of circle which has a dia. equal to that of the hoist ropes. (in^2)

Calculated stretch, e, is between the hoist wheel and the top of the conveyance at its highest point in the headframe.

Calculate the number of revolutions in a normal wind as follows:

$$R = \frac{L_H(12)}{D} = \frac{in.}{in.}$$

R = Wheel revolutions per trip
Where L_H = total length of hoist (ft.)
D = hoist diameter (in)

Calculated gross error between circumferential groove lengths must not exceed the following:

To calculate the amount of machining required, perform the following calculation:

$$A = \frac{1}{2 R_{TEST}}$$

where A = depth of cut into tread(in)
1 = distance between highest (in) and lowest rope mark

This determines that the tread with the lowest rope mark must be machined to a depth A inches.

Maintenance of drums is limited to lubrication of the bushings. The bushings are generally best lubricated when the grease fittings are on the bottom. If loose bolts are found during inspection, these should be tightened to the torques specified by the manufacturer. Most manufacturer's operations manuals do not specify bolt torques for the drum, and the manufacturer should therefore be consulted, for torques on bolts at brake path connections, drum-to-shaft connections, bolt-together hubs, and grooving sections.

Should cracks be located, they may, if shallow enough, be ground out or their ends drilled out to reduce the probable further propagation.

Friction wheels which are bolted to the shaft, may also require bolt tightening as for drums. The remaining maintenance consists primarily of tread grooving as required by the results of the collar-to-collar test.

Tread grooving is generally accomplished by grooving tools mounted on a fixed pedestal next to the hoist. After calculating the required cutting depth micrometer-dialed cutters are advanced as the hoist wheel rotates and the appropriate material is removed. Figure 2.2 shows a grooving tool arrangement.

2.1.3 Brakes

Inspection and testing of braking systems should be based on the performance criteria which are generally established in the MSHA Regulations. The braking effort must be predictable, repeatable, and controlled to maintain the deceleration rates as outlined by the Regulations. These requirements are of greatest importance for man hoisting applications.

On a shift basis, the following inspections and tests are recommended.

1. The brake mechanisms for each hoist drum should be visually checked to see that all components are in place, and operating as usual. One check which can be easily made concerns the weight brake. When the brake is fully set, the gravity weight should still have some travel clearance left on the cylinder. Otherwise adjustment is required.

2. When the brake mechanisms are operated, the "feel" of the controls and the response of the system should be as it was following adjustments and corrections performed during maintenance. Because the hoistman works with the controls daily, the hoistman will be sensitive to changes in the performance, and should perform this check.

3. A static brake torque test should be performed with the conveyance(s) at midshaft.

Single Drum Hoist (Drum Brakes)

With two sets of drum brakes present on the drum, each set should be tested individually and the amperage recorded. Motor torque should be applied up to 150% of the normal maximum torque required to hoist a payload from the lowest level. Operating data should provide this value of current. Ammeters on the hoist console are used to measure this for dc drives. For ac drives, the rheostat control should be set at the required control point to obtain 200% of the available motor torque. The required control point must be determined from the motor speed/torque curves. From this it may be seen that total holding power should be in the order of 400% when both brakes are operated. If current limiting devices are installed on hoists, then the current applied should be equal to the limited value.

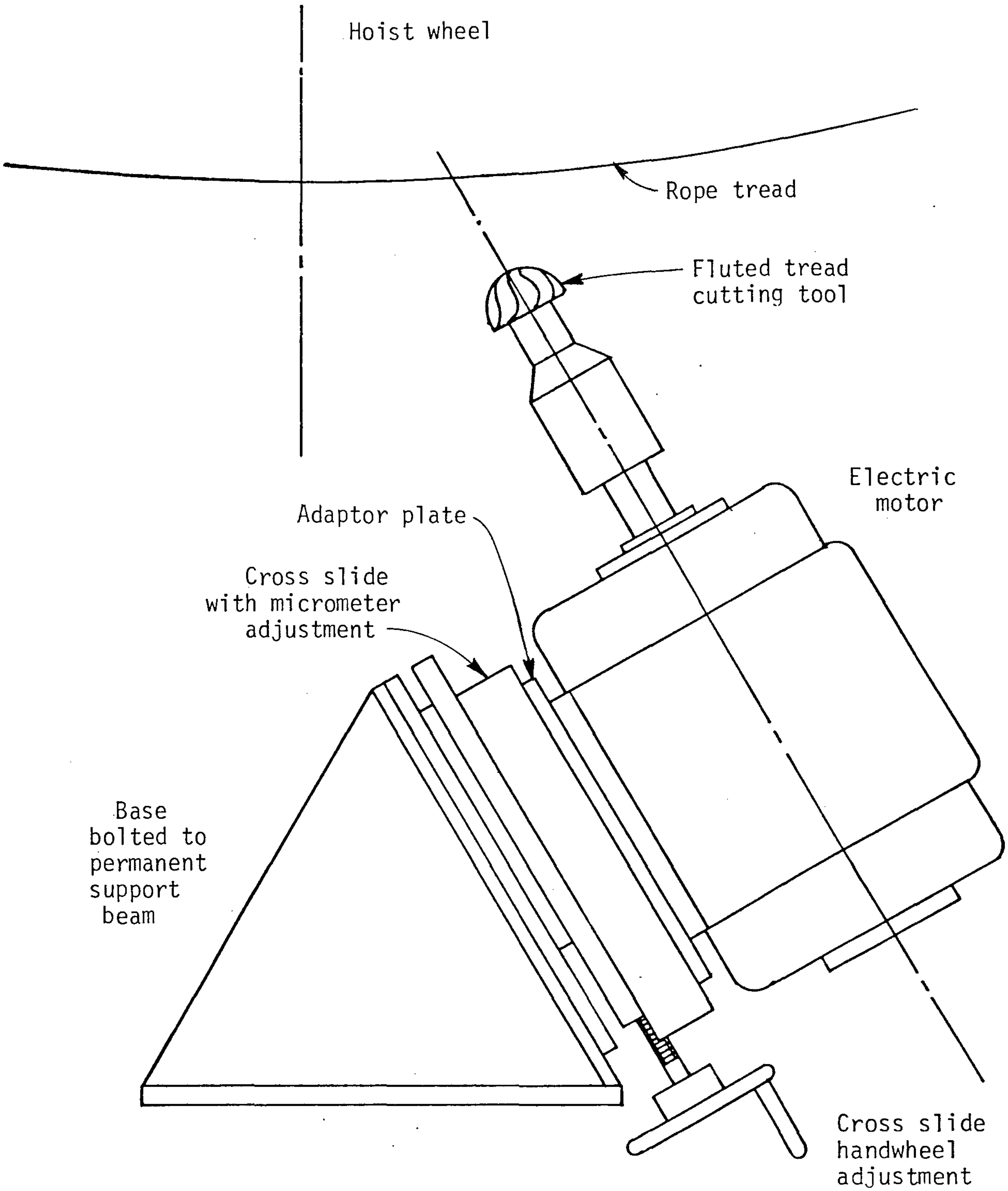


Figure 2.2 Typical Friction Tread Grooving Tool Arrangement

Double Drum Hoist (Drum Brakes)

The double drum hoist torque test is similar to the single drum hoist. Under normal circumstances, the single drum mode of operation is never used to lower a load. The required brake effort should be sufficient to stop the empty conveyance safely with 50% reserve braking capacity as an added measure of safety. Again, with dc drives, the torque can be related to the amperage applied and 150% of this torque should be applied to the drum against the brakes to check for movement. The ac torque required should be located on the motor speed-torque curve specific for the motor.

In the balanced case, loads may be lowered even when skip hoisting since muck has been known to "hang up" in a skip. On cage hoists, load lowering is part of normal function. Therefore, the torque developed by both brakes acting together on the drum should equal 400% of the worst static out-of-balance torque condition which is usually a loaded conveyance approaching the bottom of the shaft with an empty conveyance approaching the top of the shaft.

With the friction hoist, the brake torque test is essentially the same as for the single drum hoist. Where disc brakes are used, two independent brake systems are generally provided and these are to be so tested. With Blair multirope hoists and bi-cylindro-conical hoists, the test is similar to the double drum case.

On a daily basis, the brake path should be examined for the presence of scoring or scorching, for missing bolts, structural cracks or weld cracks, and contamination. On post type brakes, the brake shoes cover much of the path, but an effort should be made to examine the path closely.

On a weekly basis, the inspection should include a brake timing test, at various positions in the shaft. The "off-cam" position should be tested, as well as the "on-cam" position. The "off-cam" position denotes any position where the conveyance is travelling at full hoisting speed, and the "on-cam" position is at any point within the retardation zones, i.e., where the cam roller is running on the retardation cam on the hoist controller. The "on-cam" and "off-cam" positions are sometimes termed fast and slow braking zones respectively.

The brake timing test may be performed as follows:

1. The stroke of the cylinder on the drum type brake should be marked where the weight is in the full off position, in the prime position, or where the brake lining contacts the path, and, finally, where the brake is fully set, or where the brake weight stops its travel and the lining is fully compressed. Since this is a static test, one brake is applied to hold the drum while the other brake is released and set to perform the test. The "off-cam" position may be referred to as the slow braking zone.

2. The hoist is then driven to an "off-cam" position and stopped.

3. One brake is fully applied as a holding brake.

4. The other brake is timed from the initiation of the trip until movement occurs, from movement to take-up of slack in the linkages, and from take up to final fully set position.

The same basic procedure is applied to the "on-cam" position. Times and, consequently, speed of application should be faster for this case because the conveyance in the shaft is closer to the end travel position. The "on-cam" case may be referred to as the fast braking zone.

The static brake timing test may be used to determine the distance traveled between the time that the emergency trip is initiated and the braking effort begins to stop the hoist, (i.e., the brake pads or shoes come into contact with the brake path). However, the static test cannot determine the actual nature of braking application in the case of a moving hoist. In many cases, the hoist drum is stopped before the brake lining is fully compressed and the weight stops moving. Therefore, the time and, consequently, the distance travelled during deceleration to rest is not really known. The degree of protection near the ends of travel cannot be determined by this test.

Therefore, the use of dynamic tests on braking systems to determine actual performance should be carried out as outlined in Section 2.2.1 (Vol. II). The use of the tests outlined not only test braking capacity, but also test the interaction between safety controllers and brakes. Criteria for what is deemed safe braking as it relates to deceleration rates are also discussed in the Section 2.2.1.

With spring set disc brakes, the brake dead time and full on positions are difficult if not impossible to time. A dynamic brake test is the only way to really determine stopping distance and deceleration rates for such systems. The emergency stop brake test should be carried out at least daily to determine the rate of change of brake torque provided, in light of the fact, that routine brake timing and general visual operational checks are difficult.

The following describes such a test.

1. The conveyances are run into a full speed zone and purposely accelerated into an overspeed with a load present.

2. The final speed is recorded at the time the overspeed trip out is actuated.

3. The distance traveled by the conveyance, before coming to a complete stop, is measured either in drum revolutions or measured on the hoist dial indicator. (In a few hoists distance is actually measured by a console digital readout when the emergency stop is tripped).

4. The actual emergency stop by brakes is then calculated to note whether or not the system deceleration falls below the 16 ft/sec^2 as specified in MSHA regulation 57.19-62.

The simply applied calculation to determine deceleration rate, a, is as follows:

$$a = \frac{V_0^2}{2S}$$

V_0 = overspeed hoist speed in ft/sec as taken from the hoist speed indicator on console at time of trip

S = measured stopping distance once the brakes are applied

The importance of properly applied braking effort cannot be overstressed and the various problems which may occur if either too fast or too slow a braking effort is applied, are as follows:

1. The cage or skip especially on an ascending shallow slope wind may overrun the hoist rope if the drum is stopped too quickly. As a result, the conveyance may run up the slope, stop, and accelerate back down slope, possibly breaking the rope.

2. In vertical and sloped shafts, a sharply applied brake effort on a descending wind will cause the conveyance to bounce or rebound thereby increasing the g forces experienced by the occupants of the conveyance.

3. If brake regulation is not properly regulated to accept the many different torque requirements imposed by the system with the conveyance at various positions in the shaft, problems may arise. A single drum hoist lowering a full load near the shaft bottom requires much more braking effort than the same hoist winding an empty cage near the surface. The brake would have to be rated for the former, and if applied at the same rate, would cause too rapid a deceleration rate in the latter case.

Aside from the above tests for performance, other tests should regularly be performed. The following inspections are recommended on a weekly basis:

1. Drum brakes should be measured for clearance around the brake path. Figure 2.3 shows a typical set of measurement locations. Parallel motion brakes should essentially have equal total gaps in the system. Jaw brakes should be adjusted such that the gap is increased towards the top of the brake, (i.e., farther from the pivot point). The larger this gap, the more time required for take-up of the slack in the linkages.

2. The lining thickness should be measured. The minimum tolerable thickness depends on the manufacturers' methods of applying the lining to the shoe. If the bolts which hold the lining are countersunk into the lining surface, then there should be sufficient thickness to prevent the bolts from scoring the brake path. Because the trend has been to move away

from asbestos-based lining in recent years, manufacturers of new lining material should be consulted for each specific case. The lining should also be inspected for uneven wear, glazing or contamination.

3. A closer examination of brake linkages, pins and bell cranks should be performed for any signs of damage, wear or cracking. On the drum brakes, some critical areas include rods and clevices where sharp changes in section or the beginning of threading occur. Figure 2.3 shows some key areas to be examined. Out of roundness at major pin holes, missing or loose locking plates or cotters should be sought.

On an annual basis, it is recommended that specific items be disassembled and examined, or examined in place non-destructively using ultrasonic, dye penetrant, or magnetic particle inspection.

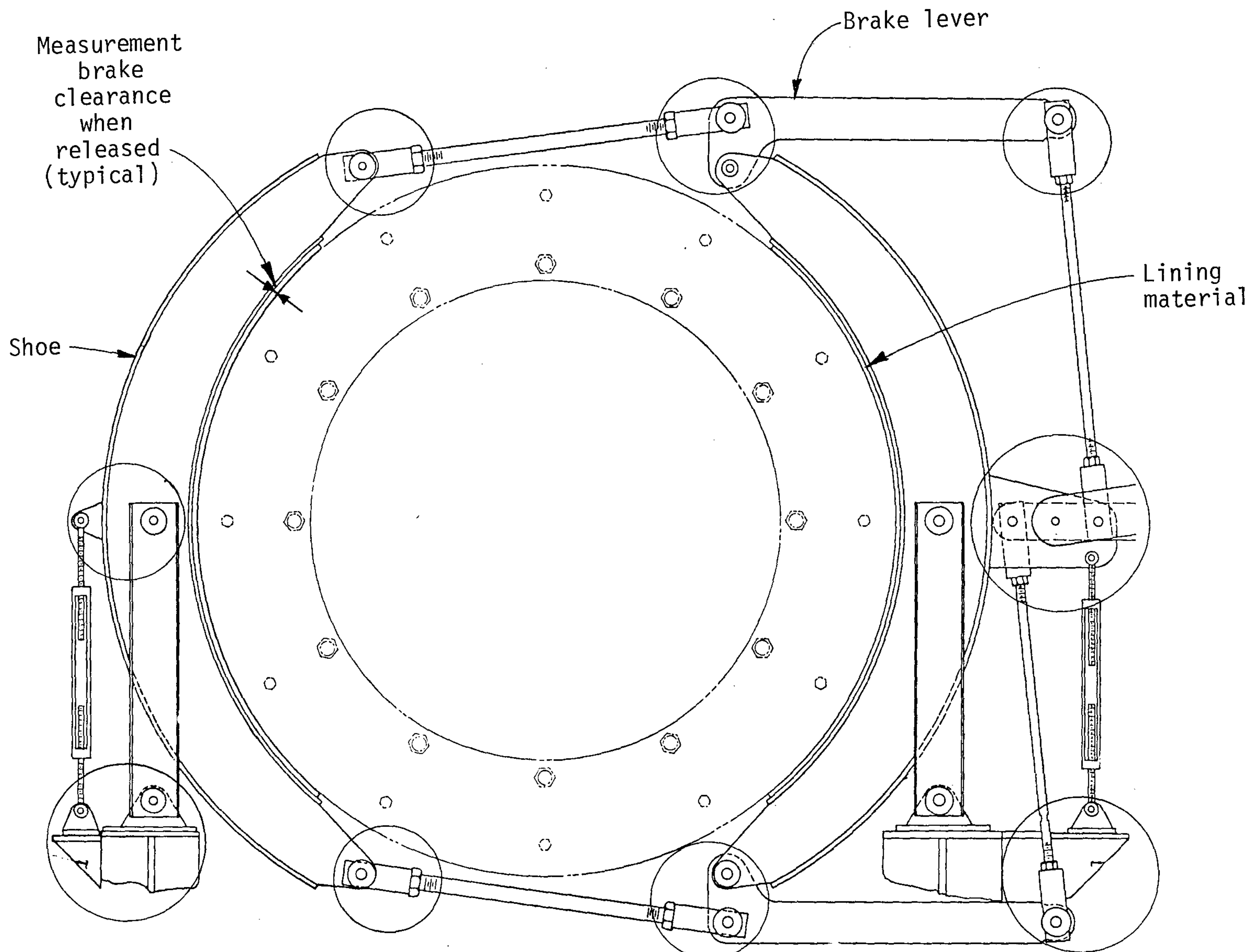
Major pins in the linkages such as those connecting the brake levers, brake shoes, and tie rods should be removed. Pins lend themselves to either magnetic particle or dye penetrant inspection while removed, or may be so machined as to permit inspection in place ultrasonically. Linkages, tie rods, clevises tangs, and bell cranks may be examined with magnetic particle inspection. Any cracks or flaws found should be measured and noted on a sketch.

Brake hydraulics are covered in the various inspections under Section 2.1.7.

Maintenance of the braking system consists primarily of adjustment of the clearances between the brake path and the shoe or pads as they wear. With parallel motion post brakes, the adjustment is made with the bars top and bottom. Some form of adjustment such as nuts or sleeves are tightened as the brake wears. As a result of this adjustment the brake sensing limit switches also require readjustment if any are present. It is important therefore to maintain accurate information on each of the switches in the system from manufacturers recommendations for adjustment.

With hydraulic disc brake systems, the pad clearance should be maintained between 0.04" to 0.12" (1mm to 3mm) and the total running clearance between both pads and the disc should be approximately equal on both sides of the pad. A normal difference of 0.04" (1mm) is sometimes tolerated. Pneumatically applied disc brakes, depending on the configuration, are normally set up within this range as well. Wear tolerances on the pad material vary with the construction of the pad holder. Basically under fully set conditions, any steel structure should not be allowed to come within 0.125" of the disc.

Brake adjustments must be made if the stated tolerances are exceeded. If the wear has reduced the pads to the above tolerances, then they should be replaced. The various manufacturers provide excellent manuals on the replacement and adjustment procedures and these should always be consulted when doing the work.



Note: Circled areas denote locations where NDT crack detection should be used.

Figure 2.3 Typical Brake Inspection Points

Similarly, Brake linings on drum type brakes are replaced when they become excessively worn down to the point where there is reduced braking capacity and before danger of metal-to-metal contact. Depending on the type of lining material and the newly installed thickness, the manufacturer can make recommendations in this regard to what amount of wear is tolerable.

If grease contamination of the brake path has occurred, isopropyl alcohol solvent should be used to clean it away. The source of the contamination should be traced and repaired or removed.

MSHA Regulations regarding brakes and their performance are as follows:

Section 57.1g dealing with man hoisting states in clause 19-4 that "any hoist used to hoist men shall be equipped with brakes capable of holding its fully loaded cage, ship or bucket at any point in the shaft". It is recommended that this be altered to read that it shall be "capable of safely stopping and holding...."

The clause the way it currently reads, does not recognize basic items such as the difference between static and dynamic friction factors for brake materials.

Clause 19-5 requires that a clutch brake interlock using either electrical or mechanical means be present to prevent disengagement of the clutch when the brakes are not set. No further comments or clarification should be required.

Clause 19-6 regarding "fail-safe" automatic brake application in the event of power failures to the hoist is also a reasonable requirement. It should, however, be kept in mind that Clause 19-62 limits emergency deceleration to 16 ft/sec^2. This is a value, selected to ensure the safety of the occupants of the conveyances, in an emergency trip. However, 19-62 does not state where the deceleration rate is measured. If it is measured at the conveyance then the drum deceleration must be less than this valuse (i.e., 8-10 ft/sec^2) due to the transient peak deceleration measured due to rope oscillation.

If the regulation is intended to apply to the hoist, then the peak conveyance decelerations which may be in the order of 32 ft/sec^2, must be considered acceptable.

Alternatively each conveyance/hoist system could be independently tested as to the minimum time required to stop it, for various hoisting speeds, loads, and shaft positions in the shaft. The conveyance deceleration could be monitored with decelerometers during one initial test. Braking rates could be set to ensure that this 16 ft/sec^2 deceleration is not exceeded at the conveyance, and this would become a characteristic of the system. During dynamic emergency brake tests, the time required to stop the hoist could not be less than a minimum established with the initial decelerometer test.

Clause 19-65 does not permit the lowering of conveyances with brakes alone except in emergencies. Post-emergency operation of the brakes however should be a concern. Brake path warpage due to overheating should be a concern. The rate of lowering, and consequently the rate at which brakes are applied and allowed to cool is important and should be addressed. Again, this subject is hoist specific. A qualified maintenance or mechanical engineer should be present to monitor the temperatures in such cases, if no temperature monitors are installed on the brakes.

Clause 19-83 relates to backout switches on the hoist controls, to prevent the release of the brakes until motor torque is proven in the correct direction to lower a conveyance from an overwind position.

The coal regulations of Section 75 are generally in agreement in terms of braking capability and basic interlocks such as the brake-clutch interlock. No reference is made to the emergency stop deceleration rates, the provision of emergency stop buttons within reach of hoistman, and torque-proving mechanisms for over-travelled conveyances. The braking function in coal vs. metal/nonmetal mines is the same and a uniform set of regulations should be adopted for both, incorporating these additional points in the coal regulations.

2.1.4 Clutches

Inspection and testing of clutches should be performed on daily, weekly, monthly and annual bases. On a shift basis the hoistman shall observe the operation of engagement and disengagement. On friction clutches, a torque test shall be performed by the hoistman as follows:

(a) A match mark is placed between the section of the clutch fixed to the floating drum and the section which is fixed to the shaft.
(b) The brake on the fixed drum is released.
(c) The brake on the floating (clutched) drum is set.
(d) Motor torque is applied such that it equals 1.5 times the peak torque required to raise a loaded conveyance in the unbalanced mode (unclutched). Torque is proportional to the applied current on a dc drive. A reference current reading should be determined from operating data, and is hoist specific.
(e) Note any slip which may have occurred at the match marks.

Positive engagement clutches should also be tested in the above manner to test for any tendency to disengage the spider, since they do not really have any slip problems.

Friction clutches depend on the coefficient of friction between the two friction materials. Contamination by oil, rope lubricant, or moisture will reduce the friction force between the clutch surfaces. Slip may be an indication of this type of contamination and, therefore, the friction bands and pads should be closely examined on a shift basis.

More detailed weekly inspections should include the testing of limit switches. These may be activated manually to test for operation. The indicator lights on the panel telling whether the clutch is engaged or disengaged should be operated by these limit switches and should be working. Match marks on the drums for engaging clutches, and any mirrors which might be used, should be clean and easily visible to the hoistman.

The clutch spiders fitted to the shaft should be examined for bolt tightness and the linkage pins in the throwring mechanism should be examined for any evidence of unusual play or "sloppiness". Spider teeth or gears should also be examined for broken or missing pieces.

Linkages, toggles and pins which are used in friction type clutches should all be examined for sound condition and proper operation. With multiple arm disc clutches the mechanism could still appear fully operational but at reduced capacity if problems developed in one of the linkages. For this reason it is important that all mechanisms be operational.

The annual inspection and testing of the hoist clutch mechanisms should include magnetic particle or dye penetrant testing of the linkages and toggles and might include ultrasonic testing in-place of the pins. Any crack, particularly in the friction clutches such as Lane band friction, or multiple arm disc clutches, should be viewed with suspicion, and the part should be replaced. In the Lane band clutch the most likely areas to look for cracks include the strap at the fixed and free ends, and in the toggle mechanism. In the multiple arm clutches cracks might be found in any of the cast linkage or pins which make up the individual arms.

Maintenance of clutches for friction clutches includes the periodic replacement of friction liners such as wooden blocks or pads. All linkages and pins should be regularly lubricated and care should be taken not to allow lubricant to contaminate the friction path. Lubrication should be done on a weekly schedule. Where required, solvent cleaning of the clutch friction paths should be done. A solvent which effectively cleans grease or oil but which leaves no residue should be used, i.e. isopropyl alcohol.

With positive engagement type tooth clutches lubrication is again vital. Lubricant must be applied not only to the throw rings and linkage on a weekly basis but should also be applied to the spiders and ring gears as required. The bonded lubricant used for the coating of gear teeth, should be applied to maintain a .0003 to .0005 film thickness. Depending on the frequency of clutching operations and the severity of service, this lubricant will be removed at varying rates. Such molybdenum-containing lubricants may usually be brushed on and set at room temperature in four hours.

If the fork which activates the throw ring is out of adjustment, readjust this so the teeth do not bottom out when fully engaged.

MSHA Regulations which apply directly to clutches require that on a man hoist, there be some form of mechanical or electrical interlock with the brake system to prevent accidental unclutching of the floating drum when the brakes are released. This applies to man hoisting specifically, but may also apply to hoists used for manriding such as skip hoists used during shaft inspection. (See 57.19 introductory remarks CFR 30, 1980). One may comment that such a feature is advisable, if not mandatory, even on hoists never used for man riding merely because of the potential damage to shaft, skips and fixed structures which might occur in the event of an accidental clutch disengagement. The above feature is mandatory under clause 57.19-6 CFR 30 of the Metallic and Nonmetallic Underground Mines and under clause 75.1403-3 (a) of the Underground Coal Mines regulations.

2.1.5 Reduction Gearing

Inspection for reduction gearing should be scheduled on a routine daily or weekly basis. The major inspections of detailed mechanical components should be carried out annually. The external inspection is done in two phases: one while the reduction unit is running and under load and the second when the unit is stopped and properly locked out. During the running phase, extreme caution must be exercised while in proximity to rotating parts. Loose or ragged clothing or a tie should not be worn near this equipment during checks. The running inspection must also be done while the unit is in normal operation so that its temperature is stabilized.

The running inspection includes the following:

1. Feel the temperature of the casing in several locations. If the unit is warm, its operation and thermal capacity are acceptable. If the unit is hot, its actual temperature must be determined, e.g. by contact thermometer, and this temperature must be verified to be within the recommended operating range of the original equipment manufacturer. If the temperature is greater than 200°F, the unit is operating too hot and must be corrected.

2. Watch for oil leaks or old oil leak marks on the casing which may indicate damaged seals or gaskets.

3. Listen for unusual noises or vibrations coming from the unit.

4. Watch for any give or movement in or around the foundation or supports of the unit, at the start up of a wind in particular.

5. If unusual noises or vibrations were present but not easily identified, do a bearing test with a shock pulse meter (SPM) or determine the vibration signature (instruments to determine these properties must only be used by persons qualified in their use.)

The external "not running" inspection includes the following:

1. A general visual inspection concerning the cleanliness of the unit and surrounding area. The cleaner the unit, the less chance of entry by abrasive contaminants and the better its ability to shed heat during operation.

2. A check on the level of oil in the unit. Some units will have sight glasses, others dipsticks. The oil level should be between the high and low marks of these indicators. If the level is too low, insufficient lubrication and subsequent gear wear will result. If the level is too high, unnecessary churning and excessive heat generation will result.

3. Clear breather vent if applicable.

4. Check auxiliary cooling systems to insure they are clean and functioning, e.g. fan cooling on the high speed shaft or an external oil cooling unit.

5. If an inspection port is available, open it and inspect the gears.

6. If any irregularities were noted or if the time period is greater than one year since the last internal mechanical inspection, then a full mechanical inspection is required.

The mechanical inspection of the reduction unit is an important procedure. When carefully and properly executed, this inspection serves to insure both the longevity of the unit and its continued, safe operation. The inspection includes the following items:

1. Removal of top half of gear casing. During this procedure, the casing is visually inspected for wear or damage.

2. Take a gear oil sample in a clean sealed container. This sample will be sent out for chemical analysis.

3. Visual inspection of gears for cracks, spalling, pitting, wear or broken teeth.

4. Visual inspection of gear joint bolts, keys and/or cotter pins for tightness.

5. Visual inspection of each gear shaft and bearings for wear, keyway and retainer tightness including pinion shaft(s), intermediate shaft and bull gear shaft.

6. Visually inspect ancilliary equipment, e.g. control levers, oil cooler passages, etc.

7. Check backlash using a feeler gauge. The result must be later verified to be within the required tolerances as specified by the AGMA.

8. Check root clearance using a tapered feeler gauge. This reading indicates relative movement between shafts.

9. Develop and record the gear wear pattern. "Machinist's Bluing" should be used, and the result recorded on a drawing. It is advisable that the same teeth on bull and pinion gears be blued, to develop a record over time of a wear pattern.

Maintenance of gear reducers involves the "topping up" of lubrication oil, and the changing of oil if contaminated or degenerated over time. The oil analysis described in the inspection section will generally indicate the quality of the oil, and the level of and source of contaminants which may be present.

The oil lubricant is generally a petroleum based product and may or may not contain extreme pressure additives. Gear manufacturers recommend that such lubricants be changed after three months from start up of new hoists, and at six-month intervals or 2500 hours thereafter although longer periods of operation may well be possible, where oil analysis indicates that no significant problems are present. With conventional single reduction gear cases a pipe cap is sometimes present in the bottom section. If this is removed and clean oil is added until some runout occurs, the oil will be at the correct level to keep the gear well lubricated. In gear reducers sight glasses are generally present to indicate when the oil is filled to the correct level. Reducers should also be checked for two separate lubricant compartments (primary and secondary) which are not connected. Lubricant should be changed in both compartments.

Gear contact patterns are indicative of alignment of the pinion gear and the bull gear shafts. A machinist bluing contact test, as described in the inspection portion, should indicate that a minimum of 80% contact is maintained for any given pair of teeth. This will ensure normal running wear. If the test indicates less than this, the pinion shaft bearings or support may require shimming or adjustment until it is brought within tolerance.

MSHA Regulations do not cover gear reduction specifically. In general terms, equipment should be designed to resist the applied loads for which it was intended. This is left up to the manufacturer on new equipment.

2.1.6 Bearings and Mountings

Inspection of bearings and mountings is done to ensure that all lubrication and monitoring systems are operating effectively. Bearings, aside from the main hoist bearings, are found in most of the machine components associated with the hoist. The two main types of bearings, namely sleeve-type and anti-friction (roller) type bearings require somewhat different inspections and care. Where sleeve or babbit bearings are used on a hoist, lubrication of the bearings is essential. Daily inspection of the lubrication is required. Since these bearings are often equipped with oil rings installed on the drum shaft, the ring should be checked daily for rotation through a sight hole which is provided. In some cases these oil rings fail to rotate due to cold lubricant (too viscous) and, as a result, no oil is deposited on the shaft. A bearing failure is likely to occur under these conditions.

A secondary lubrication system may sometimes be installed. This consists of a forced flood lube arrangement in which oil is pumped to the top of the bearing cap, then distributed through the bearing by flooding. This is sometimes achieved by a common pump arrangement or by each bearing having its own pump. Either way is acceptable, although the common system is preferred as fewer components are involved. It is also important with either system to have standby equipment, each with its own safety devices and alarms such that a pump failure would not shut the hoist down.

Safety controls such as pressure switches or flow indicators should be checked daily to ensure that the hoist can not operate if the lube system fails.

As part of the annual inspection routine a sample of return lube oil should be taken and analysed for metal content. If a high level of lead is found in the oil, it is likely that the bearing is developing a wear problem, or there is insufficient lubricant reaching the contact surfaces. An examination of the bearing is warranted in such cases.

Bearing failures of sleeve-type bearings may be evaluated from the condition of the bearing surface. Severe scoring indicates the presence of an abrasive gritty material. Uniform color, with a mottled surface finish with some pockets of material removed indicates that the bearing is failing due to fatigue. High temperature failures, caused by dirt or insufficient lubrication, are indicated by discolorations of the bearing material. Edge loading caused by shaft deflection is also possible if the bearing does not have a self-aligning capability.

Anti-friction bearings are lubricated either with grease packing or oil flood lubrication. With oil lubrication systems, the level of oil may be checked through a sight glass. With grease, the quality of the lubrication may only be checked when the pillow block cap is removed, or when the housing is provided with an access panel. The normal daily inspection should include a check of oil levels, hand test for bearing temperature, and a check for unusual noise or vibration.

On a monthly basis, another item should be checked. The presence of stray electrical currents or the improper grounding of arc welding equipment on a hoist may cause electrical pitting of roller bearings and sleeve bearings due to arcing. Insulation of the pillow block should therefore be checked to ensure that the possibility of stray electrical currents are minimized. This may be done by touching one end of a copper wire to the bearing housing and the other to the shaft. If a spark jumps, then there is a current present, and the bearing insulation must be replaced. Inspection of bearings should be carefully done to avoid potential contamination with dirt or grit. Opening up a bearing for the purpose of inspection and grease lubrication may be done annually, but should not be done more often, if all other routine inspections indicate that no problem exists, since this only increases the chances of contamination. On antifriction bearings the color and consistency of grease packing may be examined to note whether the running temperature has degraded the lubricant. If the grease appears black and shows signs of turning hard or rubbery, it should be replaced. The cause is a high running temperature, and this may indicate another problem which should be looked after. The bearing should then be cleaned and examined to determine whether damage has been done and if bearing replacement is required.

On sleeve bearings it is a good idea to check the condition of the oil ring for wear or out-of-roundness. In pumped oil systems, steady circulation of lubricating oil should be checked.

Mountings for machine components should also be inspected on a regular basis to ensure that all bolts are present and torqued to the correct value. The machine manufacturer will generally provide this information. Foundations should be checked for cracking and the removal of grout or concrete under and around base plates. Motion may be detectable by hand, under normal running conditions, and dial guages may be set up to monitor the degree of shift or motion in a problem area. If severe vibration under running conditions is present, mechanical vibration analysis may also be used to determine the degree of vibration present, and its source.

Anchor bolts for major machine components may be hammer tested for tightness. This is a routine test, which should not be overlooked, since misalignment and premature failure of bearings and rotating equipment may occur. A good example is the misalignment of pinion shafts in a reducer gear causing uneven gear wear.

Mountings such as sole plates and anchor bolts, if loose, should be tightened to the manufacturers recommended torques. If bolts are missing they should be replaced by bolts of equal size, and yield strength. This information is generally available from the manufacturer.

MSHA Regulations do not specifically discuss bearings and mountings and are only indirectly referred to in 57.19-2 stating that "hoists shall be anchored securely". The coal regulations refer to examinations required on headsheave bearings (75.1400-(e)). In addition, a similar requirement on rated capacity is made.

Without going into the design requirements of a mine hoist and its components, the MSHA inspector cannot and should not be required to judge the suitability of bearings for the purpose intended. He should, however, advise that he feels a problem may be developing due to lost oil, damaged or missing parts such as seals, and hot bearings caps. He might also note whether or not inspection reports show that bearings have been inspected.

2.1.7 Hydraulics

Inspection of hydraulic systems should include various daily, monthly and annual checks. Daily, the following items should be checked:

1. System pressure should be checked via the gauges present in the system. Oil levels in the reservoir should also be checked.

2. System leaks should be sought, particularly around lines, fittings, and components such as pumps and actuators.

3. The pump and electric motor should be checked for proper operation. Motors should run smoothly and quietly. Any noise should be checked out.

Misalignment may be causing a premature motor bearing or pump failure. If the alignment on the motor and pump is not within 0.005" total indication reading, the two units should be realigned. The alignment inspection will be described in Section 2.1.8 on couplings.

4. The hydraulic control cabinet should be checked for cleanliness.

5. The temperature of the oil should be checked under operating conditions. If the system is operating at temperatures higher than recommended by the manufacturer (160° maximum reservoir temperature) the addition of an oil cooler may be required. The normal operating temperature should be between 120°F to 130°F.

Some of the other general operating problems which may be noticed on routine checks are as follows.

1. Chatter caused by recirculation of air in the system,

2. Fluid leakages caused by using an oil with too low a viscosity and which consequently leaks more easily past seals,

3. Sluggish operation caused by oil which is too viscous, and

4. Sponginess of operation by accumulations of air in the system.

On a monthly basis the following items should be thoroughly checked.

1. All filtration and oil cleaners should be checked for cleanliness. (Also important is the air breather filtration to the tank reservoir). If significant amounts of ferrous (magnetic) materials are trapped by the magnetic oil cleaner, other wear or contamination problems may be developing.

2. Bolts should be checked for tightness, particularly on clutch actuating cylinders and brake actuating cylinders.

3. The free operation of valves should be manually checked. Sluggishness may indicate a number of problems including dirt in the lines and components, restricted flow in the drain lines, low pilot pressure in some cases, distortion of the valve body or spindle, or a malfunction in the solenoid (if the valve is electrically operated).

If the valve fails to move at all, excessive contaminant may be present, drain lines may be blocked or there may be no pilot pressure, bolts may have loosened, and the valve body may be misaligned to an extent where strains are built in which resist the movement of the spool.

4. The pump and motor unit should be checked for vibration noise, coupling problems, tight motor mounts and motor bearing lubrication.

5. All indicator lights which tell the operator the condition of various valves in a system should be checked for operation.

6. Check for free movement and proper lubrication of linkages and trunnion mounts for actuating cylinders.

7. Check the seals and rod wipers on actuators to ensure that no dirt is accumulating which could work past the seals.

Annual checks should not include anything different than the above checks. The only major inspection which should be done on an annual basis would be to have an oil analysis of the hydraulic fluid to test for deterioration and the presence of contaminants.

Maintenance of the hydraulic system will entail the following work if no problems have arisen which require major disassembly and overhaul.

1. Clean air breather cap filter on the reservoir on a regular basis. In a "dusty" environment this may be done on a monthly basis or more frequently as required. In a clean environment, this may only require three month intervals.

2. Filters at fluid intake(s) should be cleaned and magnetic cleaners should also be cleared of particles at approximately three month to six month intervals. Care should be taken that no additional contaminants are allowed into the reservoir.

3. Topping up the fluid in the reservoir to the level recommended by manufacturer of the hydraulic gear. Reservoir volume should be about 2.5 times the volume of the gpm output of the pump(s). For example if the pump is rated for 30 gpm the reservoir volume should be 2.5x30 = 75 gallons.

Usually the fluid level required should be marked either on a sight glass or some form of level indication.

4. If annual oil analysis indicates that the hydraulic fluid should be changed then this must be done. The best time to drain hydraulic fluid from the system is immediately after operation. This ensures that the oil is warm and consequently free flowing, and that dirt particles are suspended and are, therefore, flushed out. Frequently, transfer pumps can be used, to transfer new oil from the drum to the fluid reservoir.

MSHA Regulations relating to hoisting do not discuss specific requirements for hydraulic fluids and systems. Essentially, the system must perform the work for which it was intended. Hydraulics are primarily applied to braking and clutching mechanisms and these areas are covered in section 2.1.3 and 2.1.4 respectively.

2.1.8 Couplings:

Inspection may be limited to routine daily visual inspection, such as to note any escaping lubricant, missing bolts, loose keys or damage to the coupling. As described in Volume I couplings are used in several places on the hoist, particularly in connecting motor drives to pinion shafts. Although the main motor to pinion shaft coupling is very important other couplings on the hoist including those on take-off shafts for controllers and programmers are also very important and should not be missed.

Alignment checks should be performed periodically, perhaps on an annual basis, to determine whether any problems regarding foundation settlement might be occurring. This is most important on major couplings such as on the hoist motor.

One way to perform the check is as follows:

1. Angular misalignment may be checked by taking gap measurements at 90° intervals. A spacer bar may be inserted to the same depth between the two halves of the coupling. See Figure 2.5.

2. Offset alignment may be measured with a straight edge placed longitudinally parallel to the shaft axes. This should be done at intervals of 90° around the coupling. Ideally on large motor shafts, no gap should be present. On small motor shafts such as for hydraulic pumps using rigid couplings, the maximum offset misalignment should be less than 0.005". Greater accuracy of measurement is possible with a dial gauge indication fixed as shown in Figure 2.5. On flexible couplings such as flexible steel grid type, angular misalignments and offset misalignments may be tolerated to some degree. Such values are tabulated by manufacturers and these should be consulted and adhered to whenever a coupling is removed, inspected or lubricated.

Maintenance of well aligned couplings is limited to periodic correct lubrication. Manufacturers of gear and flexible grid couplings suggest lubrication intervals of 6 and 12 months respectively. Lubrication should be done with non-corrosive grease packing, which does not deteriorate either steel or gasket materials, such as Neoprene. Either smooth or fibrous grease may be used, with good resistance to centrifuging and oil separation because of the centrifugal action of the grease compartment in this machine component. Old grease should be removed with solvent and the recommended amount of fresh grease should be packed in.

Misalignment may result over time, and to realign the shafts within the limits recommended by the coupling manufacturers, it is likely that the motor shaft being the lighter of the components compared to gear reducers and hoist drum(s), will be aligned in relation to the hoist side of the coupling. The examination of alignment is a clue to potentially greater problems such as faulty anchorage of equipment or even differential foundation settlements, which could significantly affect other components such as bearing, shaft and gear life.

MSHA Regulations do not discuss coupling maintenance and inspection. Clause 57.19-3 states, however, that "belt, rope or chains shall not be used to connect driving mechanisms to man hoists". Although the intent appears to be to prohibit chain and sprocket connections between driving and driven shafts, this could be taken to prohibit chain type couplings, a specific coupling which incorporates a unit chain mounted on sprockets of the two shafts to be joined.

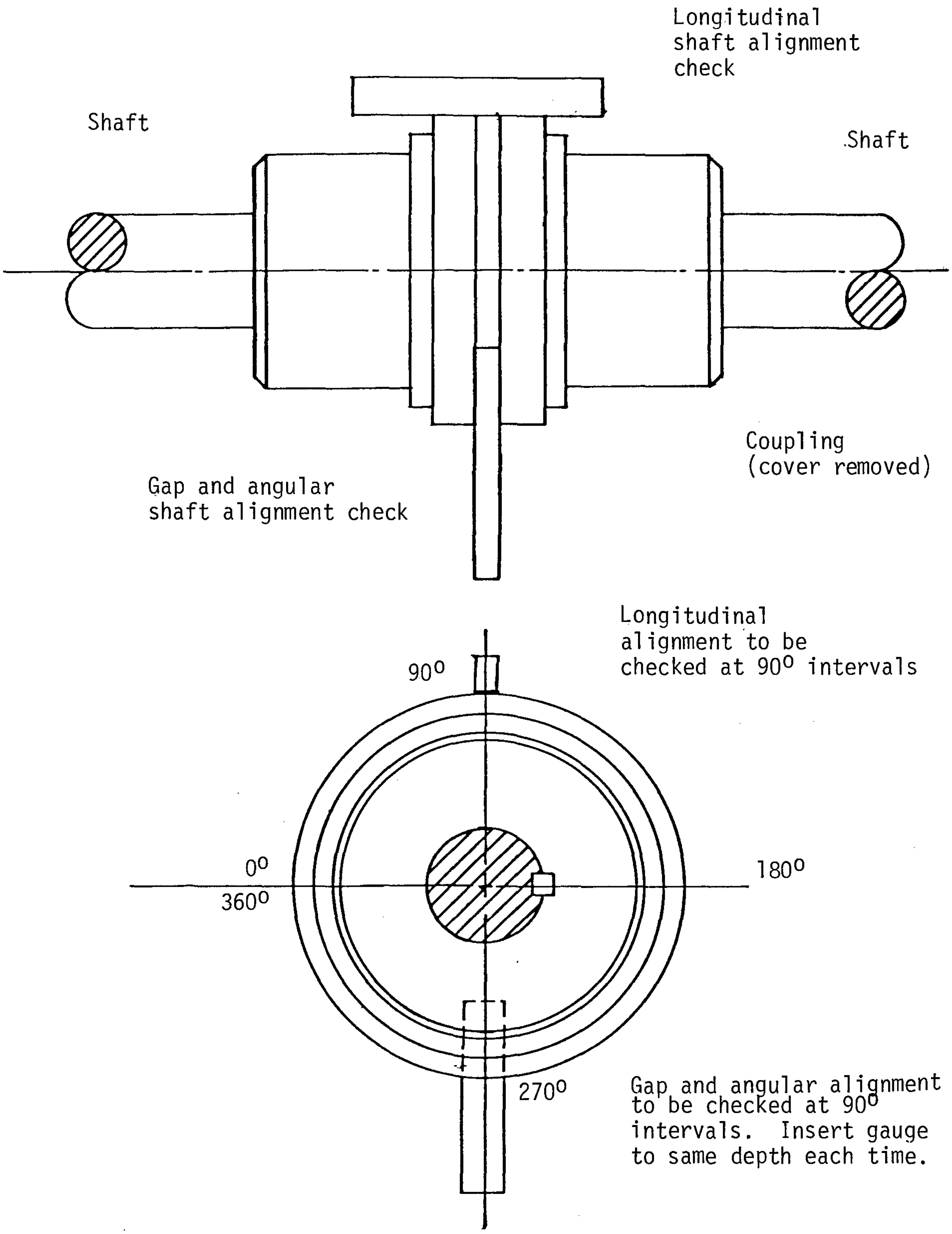


Figure 2.4 Coupling Alignment Checks

2.1.9 Lubrication

Inspection of lubrication systems installed on equipment which they must protect is also another function of the preventive maintenance crew. Frequently, hoists are refurbished with automatic or centralized greasing systems for brake pins and linkages, main bearings and clutch mechanisms, and many newer hoists have these systems installed during manufacture.

Inspection involves checking that sufficient grease or oil is being pumped to the required locations, and that no lines or fittings are damaged by crimping or sharp bending which would prohibit the proper flow of lubricant. The amount of grease in the reservoir should be checked to ensure that it is sufficient for operation until the next scheduled inspection.

Maintenance of automatic lubrication systems requires that the following items be done.

1. Grease and lube oil reservoirs should be kept filled to the proper level required for operation.

2. The lines, if plugged, should be cleared to permit the unrestricted flow of lubricant.

3. Kinked, constricted, or otherwise damaged lube lines should be replaced with comparable lines.

4. Fittings should be maintained sufficiently tight to prevent leakage of lubricant at joints.

5. On "dead-end" lines such as might be used on pins in a post brake assembly, fresh grease is basically forced into the joint displacing older grease. Care should be taken that the excess grease does not contaminate the brake paths or other vital parts. Cleaning up the excess grease is good practice. This should be done as required.

6. The general maintenance of electric motors, lubricant pumps, and valves and electrical controls is as required for the similar equipment found in other parts of the hoist.

MSHA Regulations for metal, non-metal, and coal mining do not discuss the lubrication of hoisting mechanical equipment specifically. It is essentially left to the owner to decide on the installation and maintenance of such systems and the above guidelines are to be used in this regard.

2.2.1 Introduction Controls and Communications

The inspection and maintenance of hoist controls and communications equipment requires a thorough understanding of equipment functions and operation. Up-to-date drawings and complete manufacturers' manuals are a must. Inspection and testing may be straightforward as in the case of signal systems and automatic hoist systems, or it may require production downtime and special adjustments to limits, etc. as in the case of testing trip points on hoist controllers or other devices.

For maintenance of sophisticated equipment, (e.g. thyristor drives) or mechanical (e.g. Lilly Controller), manufacturers' training courses are highly recommended. Control is an area where a little knowledge can be a dangerous thing. A seemingly insignificant adjustment to a control system to cure a minor problem can result in endangering personnel safety and equipment because the equipment function and adjustment are not fully understood.

The relationship between different pieces of equipment must also be appreciated. For example, the settings on the Lilly controller are related to brake performance. An increase in brake deadtime can invalidate controller settings.

Daily, a visual inspection should be made of the hoist and its associated equipment by an experienced mechanic and electrican to observe if the hoist is operating in a normal manner. Reports of their findings are to be recorded in the appropriate log book. Weekly detailed inspections should be made of all control equipment. A planned system of control system maintenance and testing should be implemented based on manufacturers recommendation. While a lot of control equipment requires minimal maintenance, prevention is preferable to failure (where it is possible) and neglect can be fatal. Many major problems are the result of simple things like water, dirt, loose bolts, etc.

2.2.2 Hoist Safety Devices

All devices that monitor the hoist operation that are considered part of the safety circuit shall be tested or examined at a specified interval. The following must be tested for operation daily:

1. Overwind and underwind devices.

2. Slack hoist rope devices.

3. Independent slowdown devices in end zones.

4. Loop switches on friction hoist balance ropes.

5. Jammed conveyance detectors on friction hoists.

6. Tread wear devices.

7. Brake-clutch interlock on drum hoists.

The following must be tested for operation weekly:

1. Track limit switches.

2. Overtemperature switches on bearings.

3. Ventilation switches.

It should be noted that all safety devices when they operate should cause a relay to activate or a valve to function to automatically remove power from the hoist and to immediately begin a brake application, respectively, so as to stop the hoist.

Part of the inspection and maintenance includes the examination of relays and valves to be sure that they operate freely. Specifically, these valves and relays are part of the braking system.

The following devices must be inspected and tested daily. Details are as follows:

(a) Lilly Controllers or equal:

(1) Test - overwinds (upper limit of travel).

(2) Test - underwinds (lower limit of travel).

(3) Test - overspeed governors. See weekly procedure in section 2.2.4.

(4) Test - retardation warning (upper and lower).

(5) Examine position of retardation cams.

(6) Examine all gearing to controllers.

(b) Slack Rope Device (drum hoists):

Test manually. (These are usually installed in the ropeway in the hoistroom).

(c) End Zone - Independent Slowdown Devices:

Test daily by simulation.

(d) Loop Rise Detectors - Friction Hoists:

Test daily - by simulation. This is performed by manually going to the area; inspecting the conditions; then lift the trip cord to test the trip circuit. (See Figure 2.49, Volume I).)

(e) Jammed Conveyance Detectors - Friction Hoists:

Test daily - These devices are usually in the dump so that if the conveyance does not move due to a jammed conveyance condition, the safety circuit will shut down. This is one of the most important devices on a friction hoist. This device can prevent the total loss of the hoisting plant.

(f) Tread Wear Detectors - Friction Hoists:

This device is inspected and tested. Some friction hoists do not have these.

(g) Brake Clutch Interlocks - Drum Hoists:

The interlock prevents the release of the brake when the drum is unclutched and it also ensures that the brake is fully applied before the clutch is disengaged from the drum. This is a very important safety device. See Figure 2.48, Volume I.

The following must be inspected or tested weekly. Details are as follows:

(h) Track Limit Switches:

These are tested by physically operating the switch or trip wire. The trip wire operated magnet limit switch is recommended for reliability. See Figure 2.45, Volume I.

(i) Overtemperature Switches:

Inspect devices and test.
These are usually installed on motor bearings, hoist bearings, MG set bearings, motor stators or magnet frames.

(j) Ventilation Switches:

Inspect vane or pressure switches.
These are usually installed in ventilation ducts.

2.2.3 Hoist Programmers:

With mechanical programmers, check the transmission, cams, contacts and connections, and follow the manufacturers' recommended maintenance schedule.

There are few things to consider on an electronic system. The important thing to check is the pulse generator mounting and coupling. Here again follow the manufacturers' recommendations for system maintenance.

2.2.4 Lilly Controllers

The Lilly controller is a complex piece of machinery. Adjustments should be made only by those who understand its operation and the significance of the adjustment. A training course is highly recommended for those individuals charged with its maintenance - refer to the manufacturer.

Weekly inspection is not onerous - the manufacturer issues a set of instructions to ensure that the controller is operating and will function in case of overspeed or overtravel.

At this time only Great Britain calls for periodic dynamic testing of the overspeed device and brakes. This is done by creating a false level in the shaft (by relocating the retardation cams) and by accelerating the conveyance to cause a trip out. A series of overspeed trips at different distances and speeds results in a winder trip curve of speed vs distance (from the landing) while nine points are taken to generate the master trip curve, after this only three points are checked in regular testing.

A few articles have proposed inclusion of dynamic testing in South African hoisting regulations. One of the objections to dynamic testing in South Africa related to overheating of the brake paths and resultant fade, particularly with deep shafts. Objections to dynamic testing in Canada and the United States relate to the feeling that dynamic testing creates high stresses on equipment including the hoist, conveyance and guides, and can result in creating an unsafe situation. The ropes bounce, and the conveyance can wedge sideways in the guides. There is also concern about activating the safety dogs with the sudden stops.

Some companies test the Lilly Controller trip points by driving the controller with a small dc motor and recording the RPM at which the controller trips. By moving into the retardation area a trip curve can be obtained. This proves the operation of the Lilly controller and does not cause any problems with the hoist or shaft equipment. However, it does not show the relationship between the Lilly Controller and the brake system. It is often written that the controller has yet to stop a hoist - only the brakes can do that. Of course this is obvious - but it must be remembered that the relationship between Lilly trip, brake operating time, and stopping distance is critical in preventing overwinds. Provided separate tests are also performed to establish stopping distances and ensure brake performance and consistency, this method of testing the controller is fine. However, many believe that the interests of safety would be served by doing actual dynamic tests on manhoists in the retardation section by use of a false level, with three tripouts at 5 fps, at 40% full speed and at 100% full speed. This would prove total system protection and would prove the stopping distances and show the resultant margin of safety. (Margin of safety can be defined in different ways but it relates the total distance to the end of travel at an emergency trip to the stopping distance. This ratio should be in the order of 2 to 1 to allow for uncertainties such as changes in brake operating time, contamination of brake paths, etc.).

The British produced a model code for the testing of drum winding engines* and propose dynamic testing at three month intervals. In view of the many objections to dynamic testing, an annual dynamic test should be recommended.

Another subject, related more to brakes than controllers, but relevant to emergency stopping is that of allowable deceleration. MSHA regulation 57.19-62 limits normal acceleration and deceleration to 6 feet per second per second and limits deceleration during emergency braking to 16 feet per second per second. However the deceleration is not defined as being at the

*Safe Mandriding in Mines, part 1B, section 32, page 139.

hoist or the conveyance. With rapid application of full braking force, it is found that oscillations are induced in the rope and that the deceleration at the conveyance can be twice that at the drum. It has been determined* that decelerations at the cage of 16 feet per second per second due to rope oscillation, and of 12 feet per second per second for steady deceleration is reasonable, although up to 24 feet per second per second can be endured. This would suggest an average deceleration at the drum of 6 to 12 feet per second per second. Average deceleration is not determined by the time from the Lilly trip until the hoist stops. It is determined by the time the brakes are actually applied to the drum. Deadtime on brake application can alter the Figure significantly.

The best way to determine the deceleration at the cage is to use a telemetering decelerometer. These are available for purchase or from service companies. The hoist is run at full speed in midshaft with the conveyance descending and the Lilly overspeed is tripped. The decelerometer records the reactions at the cage. If the deceleration is not within range (up to 16 feet per second per second) the brakes are adjusted and the test is repeated. The decelerometer gives positive assurance that decelerations on emergency stop will not result in personnel injury due to rapid deceleration. The decelerometer is also useful for determining the lateral accelerations from shaft guides, and a survey of the shaft will reveal guide misalignments and problems.

It should also be noted the Lilly retardation cams must be profiled to give stopping distance and adequate margin of safety with retardation not exceeding 16 feet per second per second at the cage. Limiting decelerations is not usually a difficult matter except in deep shafts and in unbalanced hoisting. The Figures given assume a full man load equivalent on the descending cage.

Daily inspections and tests are listed in section 2.2.2.

The following is an example of routine weekly inspection of a type D Lilly controller on a drum hoist:

Cams - Ensure that the cams are set at the correct position on the dial to function properly during the retardation period and at the limits of travel.

Overspeed Switch - Ensure that when the hoist is at end of travel, with a retarding cam on top of the roller, the overspeed switch contact is set so that the warning contacts are approximately 1/32" apart.

Governor - Under the conditions described in step 2, observe that an alarm is sounded when the governor balls are raised slightly. Raise the governor balls higher and observe that the safety circuit is opened by the overspeed switch.

Governor and Overspeed Switch - With the hoist at rest at an intermediate point and with the retarding cams away from the roller, raise the governor

*"Escort - a Winder Braking System" T. Harvey, P. S. Laubscher, SAIEE Vol. 56 Feb 1965.

balls to an angle slightly above the angle at which they operate when the hoist is at normal hoisting speed. The alarm shall sound. Raise the balls slightly higher and observe that the safety circuit is opened by the overspeed switch.

Governor and Overspeed Switch - Ensure that when the hoist is at full normal speed the governor arms have a margin of movement for overspeed, and that the overspeed switch contacts are approximately 1/32" apart.

General Inspection - Ensure that all linkages, spur gears, bevel gears, worm gears, and shafts are in good condition and have not developed lost motion.

Similar inspections can be drawn up for the other controllers. More detailed inspections and tests can be carried out if desired.

2.2.5 Shaft Communications:

First and foremost, it is essential that maintenance personnel be thoroughly familiar with the principles of operation of the equipment. They should study, know and follow all manufacturers recommendations. In the case of some of the more sophisticated systems, the manufacturer may have training programs available for maintenance personnel.

Secondly, maintenance schedules must be drafted and maintained. Records form an important part of maintenance. If a Megger insulation tester is used, care must be taken when working with semiconductors. Overvoltages destroy semiconductors. When working with semiconductor circuits, a high impedance meter is required.

Moisture can be a major problem. In some cases, this problem may be overcome by installing drains and heaters in the equipment. In some of the warmer more humid mines, circuit boards and other equipment may require special chemical coatings to prevent fungus growth.

The importance of stocking sufficient spare parts cannot be over-emphasized. Some system components have extremely long delivery times.

Signal and cage call systems should be tested once a week. Slurring of the signal usually indicates moisture problems either in the cable or one of the boxes. On ungrounded systems, a flickering of a ground lamp should be investigated. This may be indicative of moisture problems.

Cage trailing cables are subject to damage. During each shaft inspection, the trailing cable should be inspected for twists, nicks and abrasions. Equipment onboard the cage and at the surface should be tested weekly.

The telephone system should be tested on a weekly basis. Again, moisture in cables and boxes will produce slurring and attenuation. If the lines run too close to power lines, an unpleasant 60 cycle hum will result. The only solution is to separate the lines. Handsets will require replacement from time to time.

On multiplex data systems, a coded signal is used. Part of the code is used to detect errors in the transmission. If an error is detected, the transmission is rejected and trouble indication is provided. These errors can be the result of moisture, cross-talk, or voltage spikes.

If programmable logic is used, it is essential that spare circuit boards or units be stocked. The program should be stored on a cassette. Maintenance personnel should be trained in trouble shooting procedure using the keyboard interface. The power supply for the controller has a certain amount of built-in protection against spikes and surges in the ac system. Under extreme conditions, these spikes and surges can cause loss of memory or memory error.

Voltage spikes can have several sources. Large thyristor converters, such as might be found in a hoist drive, feed voltage spikes and high frequency harmonics back into the ac line. The switching of large contactors can also introduce interference on the line. If this problem should evidence itself, there are a number of manufacturers who make products ranging from low capacitance transformers to some fairly advanced electronic devices to condition the power supply. Some suppliers provide a free consultation service.

Signal inputs and outputs for multiplexers and programmable controllers should be optically isolated. This will protect sensitive electronic circuitry. Optical isolation is a standard feature for many of the units currently available.

Care must be taken when working with intrinsically safe devices. They must not be modified in such a way as to destroy their rating.

Qualified and regular maintenance is essential.

2.3 Electrical Equipment

Proper maintenance of the electrical equipment at an industrial facility is essential for operations and safety. Often electrical equipment is neglected until a major failure occurs, causing physical damage, loss of production, and possibly personal injury. In particular the incoming substation and protective switchgear may be neglected for years. The protective devices are expected to operate as required even though the mechanisms may not have been tried or tested since installation. There are numerous examples of fires and accidents due to the failure of protective equipment to operate when required.

In some mine installations it may be difficult to persuade mine production personnel that electrical shutdowns are necessary for proper maintenance. However, management must recognize that occasionally a total outage is required to service the incoming substation equipment. Other electrical equipment in the plant can be maintained during planned shutdowns in the specific area. Obviously, it is necessary to coordinate electrical maintenance with mechanical maintenance. Large plants usually have formal maintenance programs. Work is scheduled in advance, planning meetings are held, and everyone is informed of the necessity of the work to be done.

A systematic program of maintenance will improve operations and as important, will ensure protective devices act when required. The fact that equipment has given trouble free operation for years is no reason for neglect. The reader is referred to maintenance handbooks for information about establishing a maintenance program.

One of the necessary items in an organized maintenance system is a set of records. These should list the equipment by nameplate data, location and date installed. Spare parts for the equipment should be listed, and a maintenance record kept. If any major maintenance is done on the piece of equipment it should be noted on the card. This history can be very valuable in assessing problems, planning maintenance, and possibly planning modifications or replacement. Detailed recording of settings and adjustments of controls and switches during commissioning and subsequent maintenance is very valuable. Any system of records must be efficient and require minimum effort. A cumbersome system will encounter the opposition of plant personnel and soon will be neglected.

Why is maintenance required?

Many pieces of electrical equipment operate well for years. Most electrical gear is stationary, with few if any moving parts. Electrical equipment is continuously subject to the elements present in the environment such as dust, moisture, and chemicals. These, alone or in combination, can create problems over time by causing moving parts to seize and by contaminating stationary insulating parts until tracking occurs, leading to total insulation failure. The combination of chemicals and water may lead to corrosion and total failure of connections over a period of years - and this may not be noticed at all on a system such as the equipment grounding system. Thermal cycling or vibration may lead to loose connections over a period of time, resulting in further problems associated with overheating due to the bad electrical connection. In enclosed equipment such as oil circuit breakers or transformers, deterioration of the insulating medium can be occurring without any external indication being given. Relaying or auxiliary contacts in switchgear may be contaminated so that while a mechanical contact is made, the electrical connection is absent. And some pieces deteriorate with age. Particularly on very old equipment it is necessary to watch for deterioration of coils and insulating parts.

What equipment should be maintained?

The answer to this question is everything, but of course, frequency depends on local conditions and the term "maintained" must be defined further. For example, inspection, routine servicing, testing and repair, all qualify as maintenance.

Start where the power comes into the plant. There may be a substation owned by the plant with insulators, disconnects, fuses, current transformers, lightning arrestors, circuit breaker, transformer, and buswork. The substation is surrounded by a fence and all equipment is tied into a grounding system.

Proceed next to the distribution switchgear. For an industrial installation this is usually metalclad switchgear although this does certainly depend on the age of the plant. This switchgear may contain metering for the plant and/or utility, potential transformers for metering and control, circuit breakers for distribution feeders, relaying for the individual circuits, buswork connecting the cubicles to the supply, incoming cables to the circuit breakers, and batteries for control.

From this point it is necessary to consider the various loads in the plant. This may include unit substations with disconnects, transformers and circuit breakers, high voltage motor starters, motor control centers or starters for 440V motors, lighting transformers and distribution, etc. Beyond the motor starters or equipment feeders it is necessary to consider the control equipment including relays, limit switches, pushbutton stations and so forth, and the motors themselves. The cables, cable trays and conduit between the main substation and utilization must also be considered.

The equipment specifically associated with a hoisting and shaft installation includes the following items:

1. hoist drive motor
2. hoist power supply
3. hoist auxiliaries
4. hoist controls and limit switches
5. hoist signal system
6. shaft controls, switches, and cables

The equipment will be discussed in later sections.

What frequency is required for maintenance?

This is a matter for judgement based on local conditions and personal experience. It may also depend on regulations. A substation near a smelter or subject to other industrial contamination may have to have insulators cleaned annually. In other locations insulators may be fine for years.

Incoming disconnects should be inspected, operated, and lubricated every year. Oil in power transformers should be sampled annually.

On the other hand, some switches on the hoist must be checked daily, and some equipment weekly.

The recommended frequency of maintenance for various pieces of equipment will be covered later.

What maintenance is to be done?

Some maintenance is simply inspection - to assure cleanliness, structural integrity, or to look for the unusual. Other maintenance involves procedures recommended by the manufacturer such as cleaning, lubricationand overhaul. Testing may be required such as on protective relays and circuit breakers to assure proper operation. Repair and parts replacement may be necessary on defective equipment. Routine replacement of operating parts may be in order - e.g. brushes on a dc machine.

The maintenance required depends on the manufacturer's recommendation, experience, and the timing - requirements vary widely from the weekly to the annual inspections.

Who should maintain the equipment?

The matter of who maintains the equipment depends on plant size and on the nature of the equipment. If qualified electricians are available on site then they will have primary responsibility for electrical equipment maintenance. They will certainly handle routine maintenance, inspections, overhauls and repairs.

However, on occasion, maintenance is required where the expertise or specialized equipment is not available on site. In this case, the wise thing to do is to hire a contractor specialized in the area. For example, some large industrial sites contract with power companies for high voltage substation maintenance. Also companies contract for protective relay and circuit breaker testing. A particularly useful service that can be contracted is the infrared survey. This involves a survey of all plant electrical connections from the main substation down to motor starters, to detect hot spots. This survey can reveal potential trouble spots and enable corrective action prior to failure. Oil testing for transformer oil is another function best handled by contract.

When a contractor comes on site to do work he should be accompanied by a plant electrician at all times, both for information and protection purposes. It will also be valuable to the accompanying personnel as a learning experience.

In plants where there are not electricians on site then it is definitely recommended that a maintenance contractor be hired for periodic inspection and maintenance purposes.

In plants with large crews it is recommended that specific individuals be selected to specialize in hoist maintenance. This will enable them to become intimately familiar with the hoist and its operation and to be sensitive to changes that occur over time. They will also be more aware of the consequences of their actions.

With regard to plant modification of equipment, it is recommended that the manufacturer be contacted prior to making changes.

A maintenance plan for electrical equipment must be drawn up and adhered to. This plan will include a plan for a one or two year period and will cover all major areas of electrical maintenance. Then in detailed sections, monthly, weekly, and daily routine maintenance can be listed.

A plan like this insures that items of major maintenance such as relay testing or transformer oil testing, which only occur once every year or two, are not forgotten. It also aids in drawing up a maintenance budget, particularly if contractors will be involved. Maintenance training should also be allowed for in this budget.

Purchasers of electrical equipment should specify maintenance manuals and parts lists as part of the original equipment order. The manufacturers recommended maintenance procedures should be incorporated into the maintenance plan.

Sources of general information on electrical maintenance include the Maintenance Engineering Handbook published by McGraw Hill, and Westinghouse Electrical Maintenance Hints published by Westinghouse Electric Corporation. These books form a guide for qualified personnel. The use of qualified personnel in all electrical maintenance is a necessity in the interests of safety.

On special problems the manufacturer should be consulted. Companies that specialize in electrical maintenance can also be of assistance.

Maintenance manuals and drawings must be freely available to maintenance personnel. The maintenance people must be trained in the use of the drawings and become familiar with what information is available, as well as learning the location of equipment shown on the drawings.

Where manufacturers information is inadequate the optimum solution is to prepare an instruction manual in-house.

2.3.1 AC Motors

Fractional HP AC Motors

These motors can be single phase or 3 phase. They require little in the way of maintenance other than keeping them clean and dry. Lubrication of the bearings may be required. Normal faults on these motors include bearing failures, failure of the starting switch, and winding failure and, in the case of three phase motors, single phasing. Depending on cost and specialized features such as a unique frame size, these motors may or may not be rewound if failure occurs. In-stock spares are suggested for these motors.

Integral HP Squirrel Cage Induction Motors

These motors are reliable and require minimum maintenance. Again, cleanliness is important. Buildup of grease and dirt on stator windings will result in poor heat transfer and in local overheating of windings. Bearings must be lubricated on occasion. Excessive vibration may indicate a problem with the driven load, or a failing bearing. It is important to change out faulty bearings prior to total failure in order to avoid damaging the stator winding.

Many problems with induction motors, particularly overload situations, are related to the driven load. If overload results in continuous or frequent trip outs, it is necessary to monitor load with a clip-on ammeter or a recording ammeter. If necessary, uncouple the motor. No load current is small in larger hp motors but may be significant up to the 3 hp range. Continuous resetting of an overloaded motor will simply result in motor failure. Blaming the motor when there are mechanical problems in the driven load will give no satisfaction.

Single phasing can result in overloading. A three phase motor will continue to run if the motor single phases during operation. Single phasing can be a result of the incoming supply, a defect in the starter, or a problem in the cable, or connection box. A three phase motor will not start when single phased, and repeated attempts to start it will result in rapid overheating and burnout.

Air gaps should be checked during major maintenance and should be symmetrical. Unsymmetrical gaps can result in large unbalanced torques.

It is possible to develop problems with the squirrel cage rotor. These might be revealed by overheating, reduced output torque, or strange noise during operation. Possible problems include cracked bars and loose connections at the short circuiting rings.

Synchronous Motors

Large synchronous motors such as used on mg set drives offer years of trouble free service if properly applied and maintained. It is necessary to check the brushes on the slip rings every week to assure proper operation. Bearings must be checked during the daily visual check for signs of overheating. The maintenance of sleeve and roller bearings is covered elsewhere in the text. However, when starting an mg set with sleeve bearings after a long shutdown, pour some oil on each bearing to avoid damaging the bearing surface.

Few problems will develop during normal operation unless there are control problems. The motor synchronizing circuits must function properly or the starting winding (ammortisseur winding) will overheat and fail. Field current must be monitored to detect field failure, to any cause, such as power supply, fuses, connections, brushes. Otherwise keep the machine clean and check connections and windings for unusual problems on a routine basis. Clean the slip rings as necessary.

Wound Rotor Motors

The same general rules apply to wound rotor motors as to synchronous motors.

Ventilation

In motors supplied with forced ventilation, check the system regularly for plugged filters. Other problem times are spring (when the heat may be left on) or fall (when heat may be required depending on geographic location). It is helpful if motors have overtemperature detectors embedded in the windings. Forced air systems should have temperature alarm switches. The calibration of these switches should be checked annually.

Insulation Monitoring

Prior to starting a motor after a prolonged shutdown or after a brief shutdown in a wet area, the stator winding should be meggered. On some occasions it is necessary to supply heat to motors that have absorbed moisture during shutdown. Electric forced air heaters usually are adequate.

Some maintenance departments hi-pot motors in the 2300-4160 volt class periodically and keep a record of values obtained. Care must be exercised in applying high potentials to old windings. ANSI Standard C50.22-1972 "IEEE Standard Guide for Testing Insulation Resistance of Rotating Machinery" covers insulation testing. The minimum recommended insulation resistance for ac and dc machine windings can be determined by formula

$$Rm = Kv+1$$

where Rm = recommended minimum insulation resistance in megohms at 40°C of the entire machine winding and Kv = rated machine potential in kilovolts. Reference to the quoted standard is encouraged.

Note: High potential testing of motors presents a danger to anyone near the machine being tested. Exercise safety precautions when performing tests.

2.3.2 DC Machines - Motors and Generators

The area that requires regular inspection and attention is the commutator. Problems occur because you have current carrying carbon brushes riding on a rotating surface. Good commutation is necessary to minimize maintenance problems.

The other areas where problems can arise include the bearings, and the windings. It is also possible for a problem to arise in the connection box due to a bad or broken connection.

Daily:

Machines should be inspected, in operation, looking for any unusual conditions. Commutation should be watched particularly closely. Check bearings for signs of overheating or vibration.

Monthly:

1. Check brushes for length, and any indications of unusual wear. Check for free movement in the brush boxes, problems with springs or

pigtails. Caution: Line switches feeding the power supply to the machine must be open.

2. Commutator: Observe condition of commutator. Check for roughness, streaking, markings.

3. Check mechanical connections.

4. Visually inspect windings, risers, and brush arms for any problems, excessive dirt and presence of grease or oil.

5. Check bearings for leaking oil or grease. Check oil level in sleeve bearings.

6. Check ventilation system. On force ventilated motors clogged filters can create severe overheating problems.

7. Check for loose bolts, particularly field pole bolts.

Every 6 months:

1. Perform insulation tests.

2. Blow out dust from commutator, risers, and accessible areas of windings.

3. Wipe off deposits occurring on windings, brush holders, or other areas of motor.

4. Check all electrical and mechanical connections for tightness.

5. Check shaft keyway for cracks.

6. Check for excessive vibration.

7. Test oil in sleeve bearings.

Yearly:

1. Perform major maintenance on sleeve bearings and change oil.

Additional Notes: If there are no electrical or mechanical problems with the machine, good commutation depends on proper brush grade, proper brush pressure, and proper brush spacing and position. The importance of these items to good commutation cannot be overemphasized.

With regard to the suggested maintenance follow manufacturers' instructions and use maintenance references for proper procedures. The above is intended only as a guide.

2.3.3 Ancilliary Equipment

Outdoor Substation

Maintenance of the incoming substation will require the disconnecting and grounding of incoming lines by the supply authority. It is sometimes possible to contract high voltage substation maintenance to the supply authority. Maintenance required will depend on the size and type of substation, and what equipment is involved. The following are possible items:

Note: Work on towers requires experienced personnel and use of safety equipment. If necessary, obtain a qualified contractor to do this work.

1. Tower mounted insulators: Should be cleaned on the basis of experience - in areas of severe contamination, use of insulator grease should be considered.

2. Gang operated disconnect switches, grounding switches: These should be serviced annually. Lubricate, operate and check contacts and pressures.

3. Fused disconnects: Check contacts. Check fuses for corrosion. Lubricate pivot mechanism.

4. Lightning arrestors: Tighten connections. Inspect. Clean insulators.

5. High voltage circuit breaker: Follow maintenance instructions of supplier. Check all connections. Check and lubricate operating mechanisms. Perform oil test annually on oil circuit breaker. If problems develop such as leaking bushings or suspected contact problems, a manufacturer's representative should be contacted.

6. Current and potential transformers: Clean off, check connections, inspect for corrosion.

7. Bus bars: Check for contamination and tightness of connections. Megger secondary bus.

8. Check cable connections and potheads. Megger cables. Hi-pot cables and keep record of results.

Note: Use of infrared surveys will reveal overheating due to bad connections and will demonstrate the requirement for specific maintenance on the substation. It may be possible to lengthen the interval between shutdowns if no problems are shown by the survey, depending on local conditions. In very simple incoming substations, maintenance requirements are minimal.

Transformers

1. Dry type: The dry type transformers require little maintenance. On an annual basis they should be electrically isolated and the dust cleaned out. Connections should be checked for tightness, particularly on thyristor power supplies. The temperature guage should be checked for accuracy.

During normal operation the temperature should be recorded. It should be watched more carefully during periods of heavy load or high ambient temperature. Because overtemperature shortens insulation life very significantly, fans should be used if temperature rise exceeds rating.

Transformer insulation can be tested by Megger or by high potential test.

Note: Follow manufacturers instructions for maintenance and follow safe working procedures. Lock out the power supply and ground the transformer terminals prior to starting work.

2. Oil filled transformers: On an annual basis the transformer should be de-energized. Bushings should be cleaned. The transformer should be inspected for oil leaks, corrosion, and other problems. It may be necessary to repaint, or touch up, radiators on the transformer. Take care not to damage the cooling tubes. If the transformer is equipped with a tap changer that is operated regularly then this should be inspected and maintained. The temperature and gas pressure relays should be checked for proper operation. Fans should be cleaned, checked for proper operation, and lubricated, if required. Controls can be calibrated and tested.

It is suggested that a manufacturer's representative be contacted for any major work such as gasket replacement, bushing problems, etc.

The oil should be sampled annually and tested by a laboratory equipped for testing transformer oil. It can be field tested if equipment is available. A record of these tests must be kept and compared from year to year to detect long term problems.

On a weekly basis, oil level in the transformer and bushings should be checked. Transformer operating temperature should be checked. If local personnel are not familiar with the transformer and its devices, a maintenance contractor is recommended. If oil tests reveal problems developing, it is possible to recondition oil on site if proper equipment is available. Contractors do have this equipment.

Note: If the transformer contains a synthetic oil containing PCB's, then great care must be taken not to spill any oil or to contaminate the environment. It is suggested that the transformer supplier be contacted for advice on the situation.

Note: When working on the transformer, lock out the power supply source and ground all terminals.

Switchgear

This section deals with metal clad switchgear which distributes incoming power to the plant. This might include oil or air circuit breakers in the 480V, 2300V, 4160V or 6900V range, protective relaying and possibly incoming metering. Such switchgear does not operate with great frequency and does not require regular maintenance and inspections except visual checks for burnt out indicator lamps and any signs of distress or change. This should be done daily.

On a semiannual basis it is recommended that the switchgear be cleaned and inspected. Terminals and connections should be checked for tightness. Disconnect switches, breakers, and relays should be checked for proper operation. Look for burn marks and other signs of problems. Infrared surveys should be done annually on substations switchgear, breakers, and motor starters, and more often if experience warrants it.

Every two years the switchgear should be inspected and overhauled. Breakers and disconnect switches should be serviced per manufacturer's recommendations. Relays should be tested as per relay calibration curves before and after settings recorded. Draw-out 480 volt breakers should be tested for proper operation on a circuit breaker tester.

Proper isolation and grounding is necessary prior to starting work. In this area the owner is advised to hire specialists for guidance as this maintenance is not a regular procedure and no familiarity is gained from one day every two years. Nevertheless, the importance of this maintenance to the integrity of operations can not be overemphasized.

Grounding system

A grounding system is designed and installed with the basic objectives (1) of:

1. Assuring freedom from dangerous electric shock voltages.

2. To provide adequate current carrying capability to accept ground fault current permitted by the overcurrent protection system without creating a fire or explosive hazard to the building or contents.

3. To contribute to the superior performance of the electrical system.

The system performs very important functions. However, because it is seldom used, it can deteriorate without being noticed. A good ground system is not only required for safety, but it is also necessary for proper operation of protective relaying - particularly ground detection equipment.

It must be remembered that in addition to the ground electrodes and ground loop cables, that other equipment such as conduit and cable tray can, and often do, form part of the grounding system. The bonding in tray systems and to conduit must be checked when going over the system. Conduits can break, or rust away in wet areas, leaving a break in the ground return line, particularly on older installations.

Inspect and test system annually. Record values obtained so that it can be determined if resistance is increasing or remaining constant. Check all ground beds and individual ground rods for corrosion and broken connections. Check fences and equipment for broken wires and bad connections.

Measurement of ground resistance is discussed in IEEE Std. 142-1972 "IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems" and in the "Standard Handbook for Electrical Engineers" by Fink and Beatty, McGraw Hill.

(1) Important Functions Performed by an Effective Equipment Grounding System - Kaufman IEEE IGA 6-6.

Low Voltage Motor Starters

These should be inspected and cleaned annually. Connections should be checked. Contactors should be checked for free operation with no sticking or binding. An infrared survey will aid in revealing overheating which may not be visible. Megger the starter for grounds. Basically, motor starters require little in the way of maintenance. Follow manufacturer's recommendations re lubrication, etc.

Medium Voltage Motor Starters

These should be inspected and cleaned annually. The main contactor should be inspected and condition of the contacts observed. If the contactor is oil filled, then the oil should be tested. Follow manufacturer's recommendations re maintaining contactor. A service representative is recommended if major problems occur with a contactor in this class.

The control section should be cleaned and inspected. Check connections. Check timing relays for proper operation. In the case of synchronous motor starters, check the voltages on the field supply. On start up check that the synchronizing control works properly. Test the field failure circuit for proper operation.

Check auxiliary contacts with an ohmmeter. If necessary, dress contacts following manufacturer's recommendations. It is important that auxiliary contacts function as intended. In a corrosive environment where contacts are infrequently operated, a surface deposit may cause faulty operation.

DC and AC Wound Rotor Control Boards

These should be inspected during shutdowns preferably monthly. Because of the frequent operation of contactors special care should be given to inspecting operation and contact condition of relays and contactors.

Lubricate only as per manufacturers instructions. Also check contacts for tightness as the continuous vibration tends to loosen connections.

Resistor Assemblies

Most resistors are of the metallic type. Check connections, look for signs of overheating, and clean. Proper ventilation is required to maintain resistor life. Ensure that it is not blocked off inadvertently.

General

Maintenance of control components such as contactors is covered in manufacturer's literature. Good coverage is also given in Chapter 23 of Westinghouse Maintenance Hints.

Maintenance of Electronic Controls

Electronic controls should be kept clean. Some are supplied with forced air through a filter. Care should be taken to clean the filter. If the controls are to be blown free of dust then be sure to leave circuit boards in their sockets. Dust can be blown into empty sockets and cause bad connections. Check connections for tightness.

Because thyristor drives are reliable and seldom break down, plant electricians do not become familiar with circuitry and functions. One way to overcome this is to hire and/or train an electronic technician or specialist and to have him routinely take test readings at various points in the circuit. (Use test points specifically supplied for the purpose - or add resistance limited test points). The purpose of this is to maintain familiarity with the circuit but care must be taken to do this during maintenance operation, and care taken not to induce faults by improper procedure. In order to properly service a thyristor drive it is necessary to understand its operation and the function of all components. Secondly, it is necessary to have adequate test equipment. This might include a digital multimeter, an oscilloscope, and possibly a chart recorder. A Polaroid camera can be used to take oscilloscope pictures of wave forms at various points in the circuit when the drive is operating well in different modes, and these can form a standard or reference for future work. However, the functioning of the drive must still be well understood by the technician or the pictures will not help.

Most problems with drives will occur outside the drive proper, with switches, connections, tachogenerators, grounded cables, etc. These obvious sources of problems must be checked carefully before getting into the drive internal control circuitry.

If the drive circuits must be reviewed, a systematic trouble shooting guide must be followed. If you do not have one, get together with your supplier and develop one. Thyristor drive problems are like other maintenance problems. With proper observations and measurements the source of trouble can be pinpointed to specific circuitry. The use of spare, already set up, boards can reduce downtime but be sure to have the manufacturer's service representative repair the defective unit and return it to inventory. Keep a good supply of thyristor fuses on hand. While these seldom fail, certain faults do blow several fuses at one time, depending on the type of drive.

In major or unusual problems contact your drive service representative as quickly as possible. Because they work with several drives and have been exposed to many types of faults they often can solve a problem much more quickly than the plant personnel even though the plant personnel are quite competent.

One source of problems on thyristor drives is the operator control console. This must be vacuumed out and inspected routinely. In particular, check the speed setting rheostats and linkages and any moving controls to assure proper operation.

Pushbutton control stations located in the shaft areas must be protected from mechanical damage and should be dust and water tight. The many limit switches associated with hoist control can also be one of the major sources of drive problems.

The main thing when faced with drive problems is to resist the temptation to twiddle knobs in the thyristor controls. Do not adjust regulator settings or limits "to see what happens" because catastrophic damage can result.

3. HEADFRAMES

The inspection and maintenance of the headframe or hoist tower includes those functions related to both the components housed in the structure, and the physical structure itself. Mechanical items such as deflection sheaves, headsheaves and ore bin gates and chutes are essentially composed of components which each have their required maintenance and inspection procedures. The headframe structures themselves should be subject to normal building maintenance and inspections.

Because, in some cases, the headframe is essentially an open frame structure, the supported components are subject to the elements and as a result require more maintenance than normally required by similar equipment in a controlled environment. This is a consideration which is important in the establishment of maintenance schedules and procedures.

3.1 Headsheaves

<u>Inspection</u> of headsheaves is one of the most important tasks in hoist system maintenance. Daily, monthly, six-monthly and annual inspections make up a good routine preventive maintenance schedule, as a starting point. In addition, a thorough inspection of the headsheave is recommended before each rope change.

Headsheave inspection and maintenance on both drive and ground-mounted friction hoist arrangements is paramount to good rope life and good system performance. Regardless of the type of sheave construction, there are basic inspections which should be performed.

Daily inspections should include the following tasks:

1. Routine daily bearing checks for excessive noise and/or temperature should be done. (See Section 2.1.6, Vol. II)

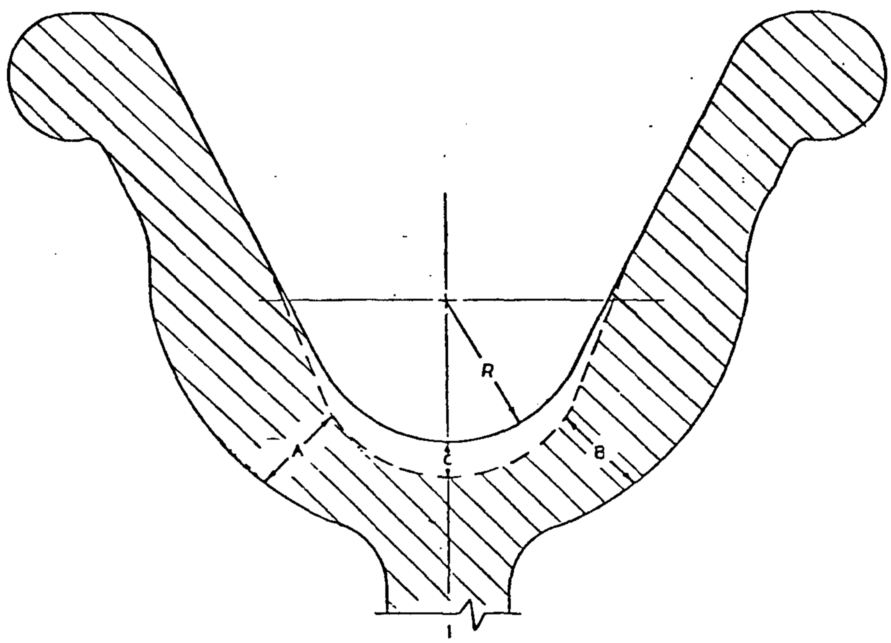
2. The rim should be inspected for broken flanges, cracks, imprints from the rope, and missing or loose bolts for replaceable tread liners or splices.

3. Spokes on bicycle type sheaves should be visually checked for cracks. In addition, excessive pinging noise when running indicates that some spokes are not equally tensioned.

The importance of the daily inspection cannot be stressed enough. Because the headsheaves are located in the headframe it may be neglected in some instances where the only access is several long flights of stairs.

Monthly inspection should include at least a detailed bearing check including the use of a sounding rod for detecting noise level differences between bearings.

At six month intervals, a detailed groove wear measurement should be made on the rope groove, at the points noted in Figure 3.1. This measurement



R = Nominal Rope Radius + 10%

Maximum Safe Limits of Groove Wear

Nominal Rope Dia.	A or B (Minimum)	C (Maximum)
2 1/4	1 1/8	3/4
2 1/16	1 1/32	11/16
2	1	21/32
1 7/8	15/16	5/8
1 3/4	7/8	9/16
1 1/2	3/4	1/2
1 1/8	9/16	3/8

Figure 3.1 Sheave Inspection

applies to cast rims. The measurements may be made with a lock joint transfer caliper and scaled. Due to irregularities in the outside of the sheave rim surface, the location of the minimum measurement should be marked with paint, and subsequent measurements should be made at that point. Figure 3.1 also shows a set of guideline measurements which if exceeded will mean that more investigation of the sheave is required to determine when it should be removed from service.

In the case of sheaves with replaceable liners the examination should determine whether the liners have worn to the point where the rope may come into contact with fasteners.

Another inspection which should be carried out at the six-month interval includes hammer testing of anchor bolts, bearing cap bolts, shrink rings, and adjusting screws.

Finally, if the sheave bearings are babbit bearings, a feeler gauge should be used to determine the clearance between the top center of the shaft and bearing cap. If the difference between the noted distance and the previous measurement is greater than 0.030 inches, the bearing cap should be removed, the bearing taken out and refitted.

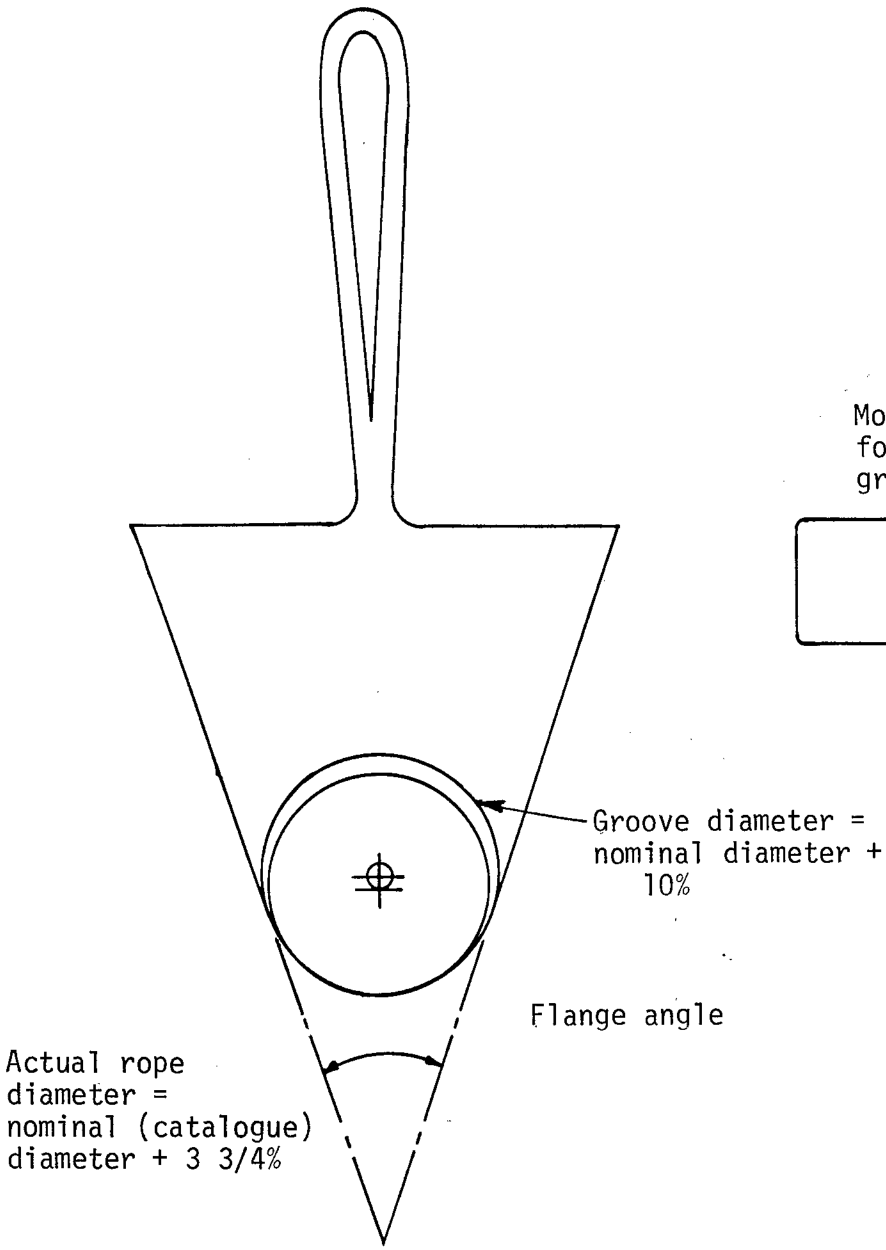
Annual inspection of the headsheave should include an ultrasonic test of the shaft. In addition, it is recommended that bearing caps be removed, the bearings thoroughly cleaned, the rollers and races examined for flaws or developing problems. The clearance between rollers and races should be measured and recorded.

The last scheduled inspection of the headsheave should be made before a rope change. Rope groove gauges and sheave profile gauges may be made when a new sheave is installed. The two gauges are shown in Figure 3.2. These become the reference for the determination of groove wear over the life of the sheave. The sheave profile gauge yields dimension C (See Figure 3.1) and the rope groove gauge will determine whether rope milking may occur, particularly prior to installation of a new hoist rope.

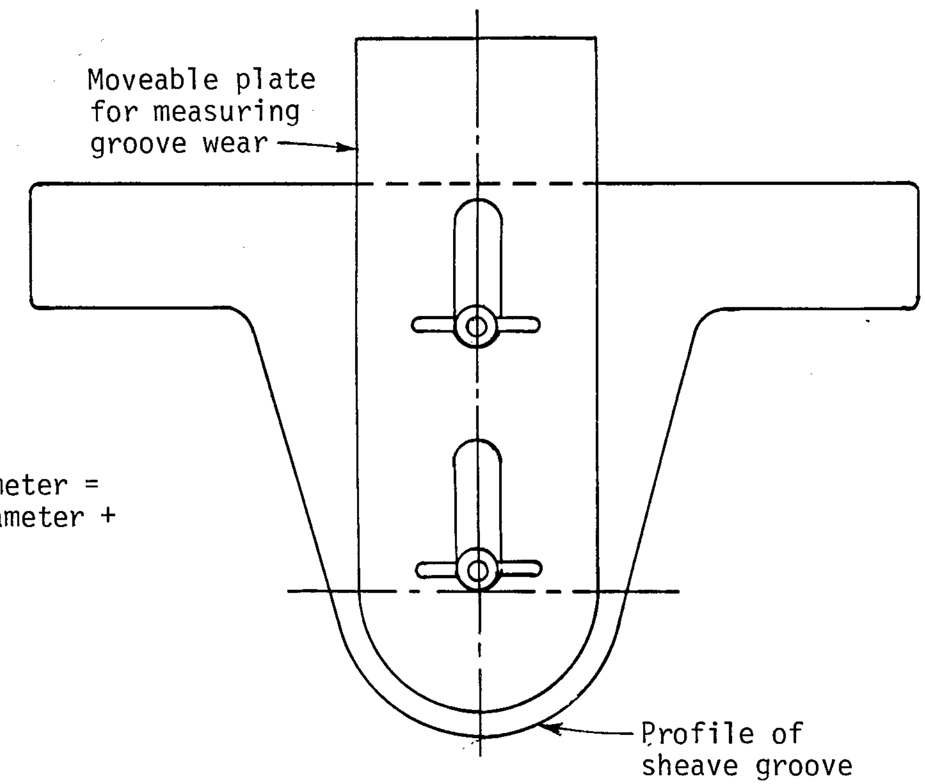
The rope groove gauge may be used to indicate the amount of rope groove machining required to prevent pinching. It should be noted that any machining should be done on the sides of the grooves only. The bottom of the groove should be left alone.

A check of sheave axle alignment is also suggested since many sheave pillow blocks are provided with wedge-type adjustments for levelling and positioning over the shaft compartment. The inspection should be done at least annually. In fact, severe rope wear and sheave wear may occur on high speed hoisting installations if the axle is not levelled within approximately 0.005 inch from one end to the other.

The relationship of the sheave with respect to the drum, is also an important consideration. The centerline of the sheave, perpendicular to the axle should ideally pass through the center of the drum. If this cannot be attained, the fleet angles should be held to within 1.5° where possible.



(a) Rope Groove Gauge (1 3/4" Rope)



(b) Sheave Groove Wear Profile Gauge

Figure 3.2 Rope Groove Gauge and Sheave Groove Wear Profile Gauge

Figure 3.3 shows the fleet angle arrangement which is desirable for good rope and sheave life.

Maintenance of headsheaves includes the basic function of bearing lubrication. Sleeve bearings and roller bearings each require periodic lubrication. Generally, lubrication is not automated as it may be on main hoist bearings. Grease is applied normally with grease guns.

Sleeve bearings in most installations should be lubricated daily. Duration between lubrication change in roller bearings may be as much as six months if the bearing is properly sealed and if operating temperature or noise do not indicate a problem.

Tensioning nuts on spokes should be adjusted to equalize spoke tension if the pinging noise during operation is excessive.

If hammer tests indicate loose or broken bolts in the sheave supports and pillow blocks, then they should be immediately tightened or replaced with bolts of equal yield strength, and torqued to manufacturer specifications.

If the rope groove gauge indicates a pinching condition due to the oversize of new rope, then the groove should be machined along its edges. One method of accomplishing this is to provide a frame which mounts onto each end of the axle, where it emerges from the sheave hub. The tool is mounted to the frame at a fixed distance from the axis of rotation and the sheave is rotated. The tool may be a grinder which is motor-mounted and adjustable to grind off the required amount of material.

Finally, the bolts which hold the split hub or the two halves of a split sheave in place should be torqued to the manufacturer's specifications if they are found to be loose.

Essentially, headsheaves for multi-rope friction hoists require the same maintenance. In addition, there is the requirement that "free-floating" headsheaves not keyed directly to the shaft be lubricated. These sheaves are frequently provided with lubricating headers and grease fittings emerging at the rim for easy access and lubricant should be added daily in the amount required by the manufacturer's recommendations.

MSHA regulations regarding headsheaves are discussed under Section 57.19-37 through 40. The discussion is limited to dimension of sheaves with respect to sheave to rope diameter ratios, and rope groove profiles. The regulation 57.19-134 requires that "sheaves in an operating shaft shall be inspected weekly and kept properly lubricated." Where headsheaves are open to the elements or located over internal shafts, underground daily inspection is recommended, however, because of the difficult environment. Ground-mounted headsheaves for slope shafts are particularly susceptible to dust and contamination. The coal regulations (75.1400-3) require daily examination of the headsheave "for broken flanges, defective bearings, rope alignment and proper lubrication". Perhaps because of the large number of

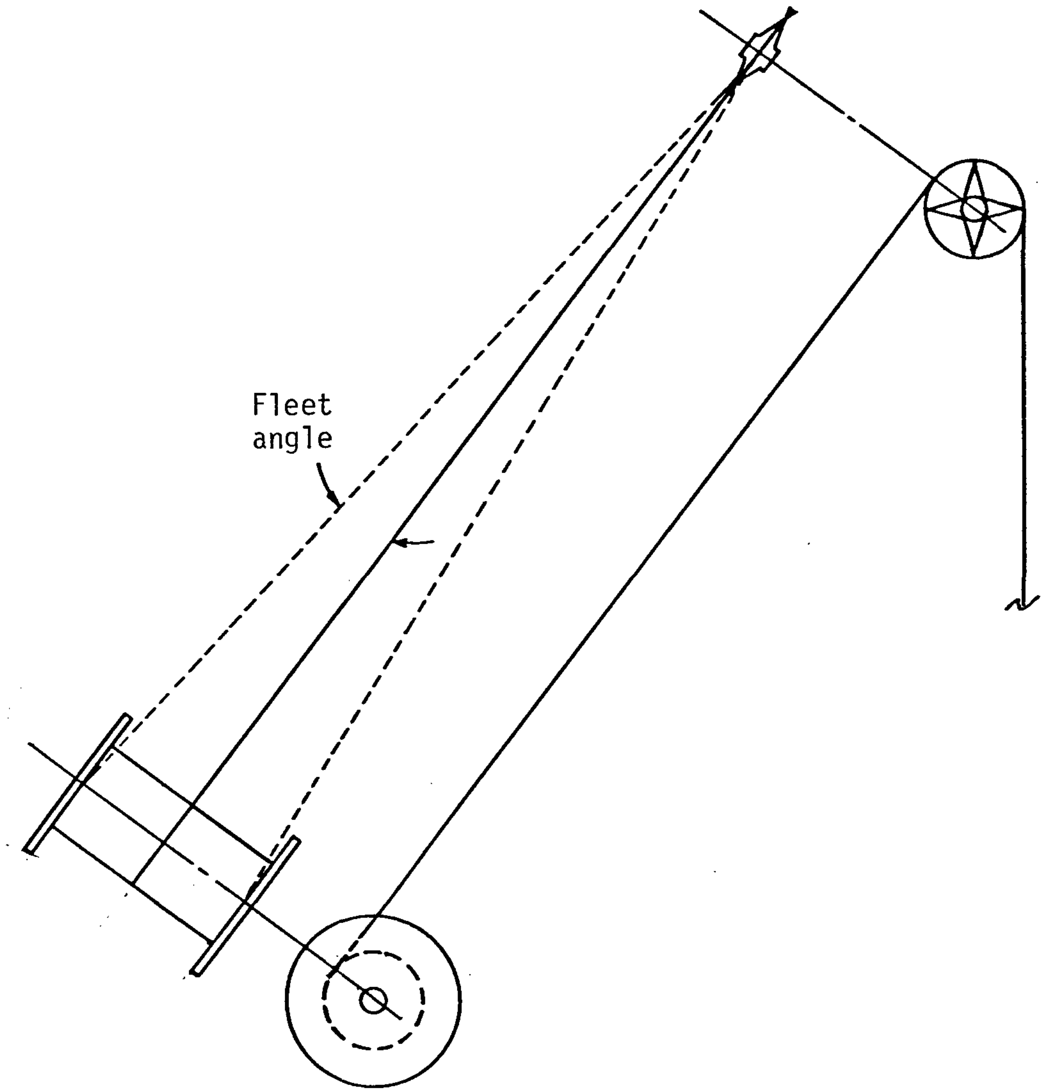


Figure 3.3 Fleet Angle

slope hoist installations in the coal mining industry and the hoist environment, the daily inspection is mandated.

Some form of daily inspection should be performed on the headsheave since it is a very important component of the hoisting system. The coal regulations should be applied to metal and non-metal mines in this case.

3.2 Deflection Sheaves

Inspection of deflection sheaves is basically the same as for headsheaves. The sheave axle is generally dimensioned lighter than the corresponding headsheave axle, due to the lighter loads applied and as a result, stress levels may be similar to headsheave axles.

Efforts on crack detection, bearing inspection and bolt tensioning should therefore be just as stringent. Because deflection sheaves are used with friction hoists primarily, tread liners of wood or polyurethane materials are used as opposed to plain steel rope grooves. These liners must be inspected for wear on a monthly basis so that wear rates may be estimated, and replacement can be planned as required.

Maintenance of deflection sheaves is also similar to headsheaves. Bearing maintenance and lubrication is as previously described. "Free-floating" sheave construction is also used in deflection sheaves and regular lubrication of these sheaves is also required.

MSHA regulations discuss sheaves in general in 57.19-134 stating that mandatory weekly inspection and lubrication is required. As previously mentioned regarding headsheaves, daily inspection is recommended.

Coal regulations do not specifically discuss deflection sheaves. The above-noted recommendation should be applied to coal mining plant as well.

3.3 Headframe Structures

Inspection of steel and concrete headframe structures should be similar to the basic inspection of any industrial plant structure. In addition to the conventional effects of wind, rain, dust and snow, the mine plant environment may contain additional corrosion-causing elements.

General inspections might be carried out on a six-month basis.

1. Sources of moisture should be traced. These might include leaking roofs, leaking or clogged roof drain lines.

2. In the case of severely corroded steel, the steel should be cleaned of corrosion material and measured to determine what strength remains available in comparison to the original design. This determination should be made for selected structural members.

3. In addition to structural steel work, the presence of bows or bumps in masonry walls adjacent to steel columns may indicate a rusting or

corroded column which tends to build up thickness and consequently pressure on the masonry.

4. Cracks and iron stains on reinforced concrete structures should be sought and an inspection made to determine the extent of reinforcing steel corrosion.

5. Foundations for headframes, such as the pads and pillars for the backlegs, should be examined for damage corrosion and missing or loose anchor bolts.

6. The alignment of the headframe foundation should be checked periodically with a level to determine whether significant settlement is occurring. If a six-month inspection shows that no problems are occurring, then this inspection frequency might be decreased to annual or two-year intervals.

Inspections noted above may not turn up any significant structural problems. If some of the structural faults such as concrete cracking and staining, severe corrosion of exposed structural members, or other such problems are occurring, then it is advisable to review the situation with a qualified structural engineer to determine whether the structure is sound enough to resist the applied loads.

Other areas in headframes and hoist towers which warrant inspection include the basic building services such as electrical, mechanical, heating, ventilating and air conditioning (HVAC), lighting and lightning protection.

Good practice and codes dictate the installation requirements for structure electrical and mechanical systems. Maintaining electrical circuits is basically done on a breakdown maintenance process where repairs are made when damage or failure has occurred.

Building HVAC requires various maintenance functions which are also outside the scope of this report.

Maintenance of headframe structures may include the following:

1. Cleaning of clogged drain lines and roof drain covers.

2. Painting of steelwork, masonry and reinforced concrete surfaces in highly corrosive environments.

3. Replacement of lighting.

4. General clean-up and janitorial services.

5. Repair and/or replacement of faulty ladders, stair treads, hatch covers, guard rails, hand rails and cat walks related to building and equipment access.

MSHA Regulations regarding headframes state that they shall be capable of resisting all the loads which may be applied (Clause 57.19-35). The geometric requirements are noted in 57.19-36 stating that headframes shall be high enough to provide "clearance for over-travel and safe stopping of the conveyance". Although this latter clause has to do with the design of the headframe, it must also be considered when disassembling and re-erecting used steel headframe structures at another site, a process which is frequently used. "Safe stopping" is not clearly defined for the retardation zones beyond the normal travel of the conveyances. This distance is determined by hoisting speed. Further discussion of safe stopping considerations in overwind cases is made in Vol. I, Section 2.2. Coal regulations do not specifically mention headframes.

3.4 Overtravel Protection

Inspection of overtravel protection devices in the headframe is relatively simple.

The testing and inspection of such items as track limits is discussed in Vol. II, Section 2.2.2. Once the conveyance has passed all the track limits, then the remaining equipment installed for retardation must combine with the braking effort to bring the conveyance to rest in the headframe. The equipment may be tapered timber guides, timber retarders with shaft mounted dogs, or some form of rail friction clamp device.

1. A thorough examination of the timbers for major cracks, splits, rotting or other problems.

2. An examination of timber fasteners for tightness.

3. An examination of timber dogs for correct position and structural integrity (i.e., welds, bolts and members).

4. With friction clamp devices, a check of freedom of movement of interconnecting hooks, the presence of all clamping bolts and nuts, and the presence of severe corrosion on either the rail or the clamp device itself.

5. Examination of the supporting steelwork. The remaining structures in the headframe which provide overwind protection include the crash beams. These should be inspected on a six-month schedule as they are generally part of the headframe or hoist tower structure. The following items should be sought:

   a. Missing or damaged bolts or welds and
   b. Severe or unusual corrosion.

Catch gear which may be used with friction hoist installations should be tested weekly for smooth operation. There is generally a lever provided to manually actuate the device and upon release the pawls which engage the conveyance should fall freely back into the shaft compartment.

Maintenance of overtravel equipment should include the following items:

1. The replacement of split, rotted or otherwise faulty timber arrestors, as these may provide only severely reduced arrestment capacity in the event of overwind.

2. The replacement of broken, corroded or missing fasteners.

3. Periodic cleaning and painting of arrestor gear mounted in the headframe.

4. With clamping arrestor devices, dirt build-up, removal and movable mechanisms lubrication on a regular basis depending on the shaft environment (monthly in hostile environment).

5. With catch gear, lubrication on a similar schedule as the clamping arrestors in point 4.

The overtravel devices and crash beams require little inspection and maintenance by comparison to other hoist and shaft components, but they should not be overlooked because they may be required in an emergency.

MSHA regulations regarding overtravel devices relate primarily to safety circuit components such as track limits, and do not address other physical arrestment devices used at the end of travel. Clause 57.19-18 discusses the requirement of an overtravel backout switch which essentially restores power to the hoist under manual operation to allow the overwound conveyance to be lowered to normal travel position. The switch automatically opens when released. Clause 57.19-14 discusses a tapered timber retardation system as being mandatory on friction hoist installations. It is not clear what other approved device might be as stated in the regulation. In addition, there is no recommendation of such.

Coal regulations do not discuss overtravel devices in the headframe. The inspection of specialty devices such as catch gear on friction hoist installations should be mandatory because of their emergency function and such inspection should be mentioned in both the metal, non-metal and coal regulations. Such devices have a tendency to be neglected.

3.5 Dumping/Loading and Unloading

Inspection of the dumping, loading and unloading areas in the headframe refers to the dump rollers, scrolls, chutes and bins, for the skip dump, and the equipment such as shaft gates, enclosures and miscellaneous gear found adjacent to the shaft for man and equipment cages.

Daily dump area inspection is recommended. In some cases, television monitors provide the hoistman with a TV screen view of the dump operation, but this is not sufficient to note the development of other problems.

Daily inspection routine should be as follows:

1. Visually inspect the dump rollers for wear or damage. These rollers are frequently bolted to the headframe structure. Because of impact and falling materials they may be bent, misaligned or otherwise unsuitable for intended function.

2. Visually inspect the scroll plates for bent plate, damaged or missing stiffeners or support bolts.

3. Chutes and bins shall be visually examined for wear on abrasion resistant liner material.

4. Finally, the general smoothness of operation of the skip in the dump cycle should be observed. This is essentially a "running check". Unusual noises and the presence of obstructions should be noted.

Maintenance of skip dump areas should be reasonably minimal if the skip is well aligned with the scrolls or dump plates and rollers. Maintenance may be limited to daily lubrication of dump rollers, movable chutes, or mechanisms. In the case of air-actuated skip dumps, shaft-mounted air couplings, liners, and yokes should be cleaned on a regular basis depending on the degree of build-up. Rock or fines which may be lodged in an area near scroll plate entries or dump rollers should be immediately removed.

MSHA regulations do not address the dump area specifically in either metallic, non-metallic or coal mining, since the major concern with most safety-related hoisting regulations is directed toward manriding. The requirement for detailed inspection of dump areas then is mainly to prevent production losses by unscheduled downtime.

Inspection of loading and unloading of cages or manriding cars should include the following basic daily tasks:

1. Check that any shaft gate interlocks are operational. Generally these are interconnected with the hoist electrics to prevent the hoist from operating in the event that a shaft gate is open or ajar.

2. Visually check that the shaft gate is self-closing where required (i.e., coal mining regulation).

3. Visually inspect that the shaft area is clear of debris, which may be kicked or pushed into an open shaft compartment.

4. Visually check that rail sections are intact where rail vehicles are moved into cages.

5. Check that the positive derailer switch is operating.

6. All signs and warnings shall be clearly visible.

Maintenance of the cage loading and unloading area is basically limited to the following tasks:

1. Hinge pins, rollers and latch mechanisms should be lubricated weekly, or monthly, if the duty is lighter and the shaft environment is not extremely corrosive.

2. Grooves for trackage should be periodically cleaned of fines and debris to prevent derailment of cars.

3. Obstructions and debris should at all times be removed from areas adjacent to the shaft.

MSHA regulations for metallic and non-metallic mines discuss hoisting procedures in Clauses 57.19-55 through 57.19-83. Those relating to cage loading and unloading include 57.19-68 regarding orderly procedures for manloading, and 57.19-70 regarding the closing of gates during man hoisting. There is also 57.19-79 that requires a method of blocking cars adjacent to the shaft.

The coal regulations discuss "self-dumping cages, platforms or other devices" required to have a locking pin to prevent the "tilting when men are transported" in Clause 75.1403-3(e). In various other clauses similar references are made to safety in manriding. Orderly loading is stressed in 75.1403-7(h) and the provision of sufficient clearance to prevent persons from contacting "live" electrical circuits while loading in Clause 75.1403-7(1). Drop-bottom cars, used largely in the coal industry, should be provided with additional locking devices to prevent the dumping of men. Section 75.1403-7 is mainly a list of criteria and not a set of statutory requirements.

The regulations reflect some of the differences between hoisting in coal and metallic and non-metallic mines. The requirements particularly relating to hoisting procedures and additional safety latches on conveyances could all be unified for both coal and metallic and non-metallic mines. Basically, the bulk of hoisting in non-coal mining is through vertical shafts, while in coal a larger percentage of hoisting is through sloped shafts. The result is that sloped shaft conveyances have been given a separate discussion under mantrips and that the criteria which apply under the regulations are in addition to other discussions on conveyances used in vertical shaft hoisting.

4. SHAFTS

4.1 Vertical Shafts

Inspection of shaft equipment such as guides and buntons is one of the most important inspections to be performed in any hoisting installation. Compared to sloped shafts, vertical shaft conveyances run at generally higher speeds. As a result, the effects of misalignments and faulty guides and buntons are very critical to the smooth operation of conveyances. Misalignment, damage and wear of the shaft equipment not only tend to increase themselves in severity, but may also result in damage to the conveyances in the form of lost guide shoes and rollers.

The following daily checks are recommended for any shaft equipment, either timber or steel:

1. On a shift basis, if more than one shift per day, the hoist man shall run the conveyance through one complete trip at start of shift to ensure that the shaft is clear of obstructions. No men are to be on the trip during this test.

2. Regulations differ between coal and metallic and non-metallic underground mines as to the frequency of a shaft inspection. In any case where the shaft is lined or timber supported and lagged, weekly shaft inspection should be sufficient to spot any trouble such as loosening guides, and wall rock movement. The shaft should be examined closely during these inspections and conveyance travel speed should be about 200 feet/minute or less.

The following items should be noted carefully.

1. The shaft lining should be examined for the development of cracks or bulges (i.e., for concrete and timber lagging) or loose or missing bolts and brackets (i.e., steel tub lining).

2. The shaft lining should be examined for sources of water and build-up of deposits from solutions. Particularly important are flows which may damage electrical cable suspended in the shaft.

3. Water rings, if present, should be checked for free flow of shaft water to the collection points.

4. Pipe hangers and wall-mounted pipe and cable supports should be examined for damage from falling debris and leaks.

5. Shaft steel support brackets and bunton and divider connections should be inspected for missing bolts or looseness.

6. Guides should be inspected for looseness. Timber guides may be sounded with a hammer or axe, to test for soundness and tightness. All guides should be checked for obvious misalignment, particularly at joints.

7. Guide wear should be examined with attention being given to differential wear on each guide.

Wear limits that are predetermined for each guide type are maintained. When wear reaches the set limits, the guides are replaced.

Wear limits are established by two conditions:

(a) The depth that safety dogs penetrate the shaft guides following engagement. (A further discussion of guide-safety dog interaction is found in Section 5.0 on conveyances.)

(b) The amount of running clearance that exists between the closest part on the conveyance and the closest contact point in the shaft compartment which is usually but not always the divider bracket.

For a well-maintained high speed hoisting shaft, the following guide wear tolerances are recommended:

(a) Maximum allowable wear on face of the guides is 1/4".

(b) Maximum allowable wear on each side of the guide is 3/8".

These figures can be applied to most wooden guide installations.

In addition to guide wear, the face to face guide measurements should be kept within 1/8" of normal and guides should be plumb and centered in the compartment. Sharp deflections at the guide joints cause problems with the smooth operation of the conveyance and excessive rope vibrations, particularly in high speed hoisting shafts.

In addition to weekly scheduled inspections, a new technique is now being employed to assist shaft inspectors with their inspection of the shaft compartments. A decelerometer mounted on the shaft conveyance that travels with its rated load and speeds measures the acceleration in areas where misalignment is not visible to shaft inspectors. Misalignment is caused by either ground movement or poor installation, and results in additional forces between conveyance and guides. In addition to measuring acceleration, there may sometimes be a second pen on the strip chart recorder unit which traces the rate of change of acceleration (i.e., g/sec = ft $/sec^2/sec$). This recording is an indication of the "jerkiness" of the ride of the conveyance. Some correlations have been made between this g/sec and the service life of various shaft and conveyance components such as guide shoes and rollers.

The "hard copy" trace of the decelerometer test gives a permanent record of the shaft compartment guides. "Before and after" tests can be run to check the quality of any repairs effected. The test could be run on a three-month or six-month schedule.

8. Shaft compartment partitions should be investigated for loose, missing, or bulging panels.

9. Shaft station gates should be investigated for damage to hinges and latches. Particular attention should be paid to any interlocked switches on shaft gates if these are used.

10. The shaft bottom area below the last landing or loading pocket should be examined for damage to arrestment timbers.

11. Keps or other chairing devices should be examined for proper operation. They should automatically retract when the cage is raised from the station. Chain chairing devices should be examined at the hook, the support and over the length of the chain for cracks or deformation.

12. In friction hoisting shafts, the tail loop dividers should be examined for wear. If they are at the point of wearing through, such as on timber sections, replacement is required.

13. The timber used to protect the tail loop switch on a friction hoist should be examined to ensure that it in fact provides enough protection for the trip wire and switch and that it in no way interferes with the tail ropes.

Essentially, the weekly inspection for major problems in linings, guides and buntons should uncover most problems which may evolve. Detailed periodic decelerometer testing will point up significant misalignment problems, and are recommended especially for higher speed hoisting operations (1500 fpm or higher). The above inspections apply to fixed guide shafts, and those portions of rope-guided shafts where fixed guides are installed.

Rope-guided shafts have the same basic inspection requirements for shaft liners, any fixed piping and electrical conduit, and partitioned off manways and so on. There are basic inspections which should be made on the rope guides. Weekly inspections should include the following:

1. An examination of the entire rope length for broken or exposed wires, scuffing of spots on the ropes caused by falling debris, should be undertaken.

2. The suspension glands in the headframe should be examined for any rope slippage. This may be easily done by measuring and recording dimensions between the wedges and the block bolted to the rope just above the gland.

3. The cheeseweight tensioning and/or spring tensioning located in the shaft sump or headframe should also be examined weekly as part of the shaft inspection. The most important thing to look for is whether or not sufficient muck has accumulated to allow cheeseweights to rest thereby reducing the desired rope tensions. Another important item to look for is the corrosion of the cheeseweight slabs. Severe corrosion in one case resulted in the fracture of the suspension rods, due to the build-up of oxidized material between the weight slabs. Finally, the retaining frame located in the sump to hold the guide ropes in the same relative position should be checked for damage from fallen debris, accumulation of moisture and muck around ropes, and loose or missing fasteners.

Maintenance in vertical shafts requires the following basic tasks be performed.

1. With timber-guided installations, worn, split, rotted or otherwise damaged timbers must be replaced.

2. Alignment of timber or steel guides is required in those areas where inspection has indicated alignment problems.

3. Sources of water may have to be controlled through grouting or installation of additional water rings and/or pumping facilities. This is a function requiring considerable downtime and specialized equipment outside ordinary maintenance.

4. Periodically solids which are deposited from solubles in the mine water, muck, and fines may have to be cleared from the shaft liner, water rings and shaft equipment.

5. In problem areas where timber sets are used, lagging frequently crushed by squeezing should be replaced, wedges for sets may have to be reset, and backfill packing may have to be added.

6. Sump areas which have no permanent muck-handling facilities may have to be cleared of spillage in other ways such as hand mucking where space is restricted.

7. Any damaged partitions should be repaired or replaced, and should be done immediately in the case of manways.

The shaft work required in maintenance and inspection is somewhat more difficult and more dangerous than most other maintenance tasks on the hoisting system. Any successful maintenance program should therefore stress safety. Men working in the shaft wear safety harnesses and other safety equipment. Care shall be taken to close off the shaft carefully and completely, to prevent articles or debris from falling on men working below. The hoistman must be made aware that men are working in the shaft and no hoisting is to be undertaken other than for planned shaft inspection trips.

MSHA Regulations for metallic and non-metallic mines require a weekly shaft inspection, while coal mining regulations require a daily inspection. Because of the additional problems of roof control in slope shafts found predominantly in the coal mines, daily inspections for sudden failures may be warranted. Regulation 57.130 presents the requirement for weekly shaft inspections in metallic/non-metallic while Regulation 75.1400-3(f) states that coal mines shall inspect shafts on a daily basis. In the case of some coal mine shafts, particularly vertical ones, the detailed shaft inspection might be extended to the one week interval, if historically few problems have occurred based on the daily inspections.

Regulations 57.19-100 to 119 (Reserved) deal with various aspects of the shaft and its appurtenances, particularly with safety during inspections (57.19-107 to 109). In addition, a requirement for shaft guides for conveyances is stated (57.19-102).

Regulation 57.19-123 deals with wire rope dressing under inspection and maintenance. Shaft guide ropes and rub ropes are essentially wire ropes which require lubrication in a shaft environment.

Coal regulation 75.1403-3(g) and (h) also dictate that some plan of safe practice for men working in the shaft be adopted. It is advisable to adopt the approach used in metallic/non-metallic regulations where signs are posted at the hoist and the shaft, that men are working there.

4.2 Slope Shafts

Inspection of slopes and inclines is essentially similar to the basic inspection requirements for vertical shafts. Roof rock problems may cause additional concern and result in closer inspections. Also the inspection of rail guides and ties is somewhat different than vertical guides.

Track should be inspected for the following items on a weekly schedule.

1. Rail joint bars should be inspected for missing or loose bolts.

2. Loose or missing tie plates and loose spikes should be sought.

3. Switches at the turnouts should be inspected for missing or loose fasteners and battered rail. The switch linkages should be examined for proper function.

4. Car stops, derails and bumping posts should be examined for soundness and proper function.

5. Transverse rail cracks should be sought as these are an indication of inadequate support due to failed ties.

6. Arrestment devices such as third rails should be inspected for looseness, binds or cracks.

7. Guide rollers and knuckler sheaves in a sloped shaft require close inspection for smooth operation and wear of the rope groove. Where rubberized roller surfaces are used to protect the hoist rope, inspectors should look for removal of material to bare metal. Where metal rollers and sheaves are used, the sheaves should be inspected for cracks or breaks in the flanges. Detailed measurement of wear on each roller in the shaft is rather onerous and at first principle, is not as cost effective as merely replacing failed rollers.

These inspections basically cover track type guides for sloped shafts. Where applicable, other shaft inspections should be included as described for vertical shafts (Section 4.1).

Maintenance functions on sloped shafts are also generally similar to vertical shafts with the basic difference lying in the types of guides and attachments.

1. The replacement of broken or worn rail sections and hardware is the primary maintenance task.

2. Roof control is sometimes required. This will require the placement of steel or timber or combinations thereof as support, and where required the use of roof bolting.

3. Lubrication of rope rollers and knuckler sheave bearings is a most important maintenance function in slope shafts.

Weekly lubrication is advisable, as the shaft environment is extremely hostile, particularly in most coal mines.

4. If loose, the guide rollers are to be properly aligned and retightened.

5. Where in-shaft arrestment devices such as third rail-and-clamp systems are used, the rail shall be cleared of debris or obstructions and shall be kept correctly aligned and supported at all times.

MSHA Regulations might maintain the current daily inspection schedule if the nature of the ground is such that roof falls into the slope are frequent. Otherwise, extending the scheduled inspection may be possible. Sloped hoisting facilities generally carry larger payloads at slower hoisting speeds, and therefore the forces are somewhat more predictable. Problems due to some misalignment are not as likely to develop as quickly at slower speeds, as they may at high speeds.

5. CONVEYANCES

5.1 Skips

Inspection of skips is required on a daily and weekly schedule because of the severe service conditions skips face in normal operation. Daily inspections may be confined to visual examination, but weekly inspections require a close-up investigation of the skip structure. When skips are removed from service for bucket relining or welding repairs a more intensive examination employing non-destructive testing methods can also be made, to try to locate areas where as yet hidden cracks may lead to future failures.

A new skip is expected to be trouble-free. It is after repeated exposure to the shaft environment and after many skipping cycles that skips begin to deteriorate. Inspection and maintenance must give consideration to the environmental factors that caused material degradation. Such factors are: dynamic loading; repeated loading; acidic, basic, neutral, or salt water; and abrasive, sliding, and gouging wear.

Inspection of a skip must consider the load points. The most complex skip is the swing out bottom dump skip. Other skip designs such as the fixed body bottom dump and the overturning skip will have similar forces applied. Figure 5.1 shows a typical skip body and Figure 5.2, a typical skip bail.

When examining the load points the inspector should look for the four signs of distress; cracks, distortion, wear and corrosion. Cracks can be caused by overstress or fatigue. Distortion can be from overstress or abuse. Wear causes surface removal of material. Corrosion is caused by the environment and can cause early cracking and loss of material.

The Crosshead is a bending element anchoring the hoist rope(s) and supporting the skip body and muck. Rope attachments such as pins and bolts should be examined for the four signs of distress. Disassembly may be required for adequate examination. This may best be accomplished during a skip relining or repair process.

The ends of the crosshead fasten to a pair of members, called the bail. The joint between the crosshead and bail transfers loads that can cause cracks.

Frequently the crosshead will be covered with wet fines. Examination of the horizontal surfaces requires removing the material to sound metal. The center and ends of the crossheads are the more highly stressed areas.

A problem area may exist at the center of the crosshead during loading. The flanges of the channels that form the crosshead may be worn away by muck striking the channels during loading. A straight edge will show distortion as well as the amount of material lost to abrasion.

The bail is made of a pair of members running from the crosshead downward to the door support. The bail provides: the body pivot for

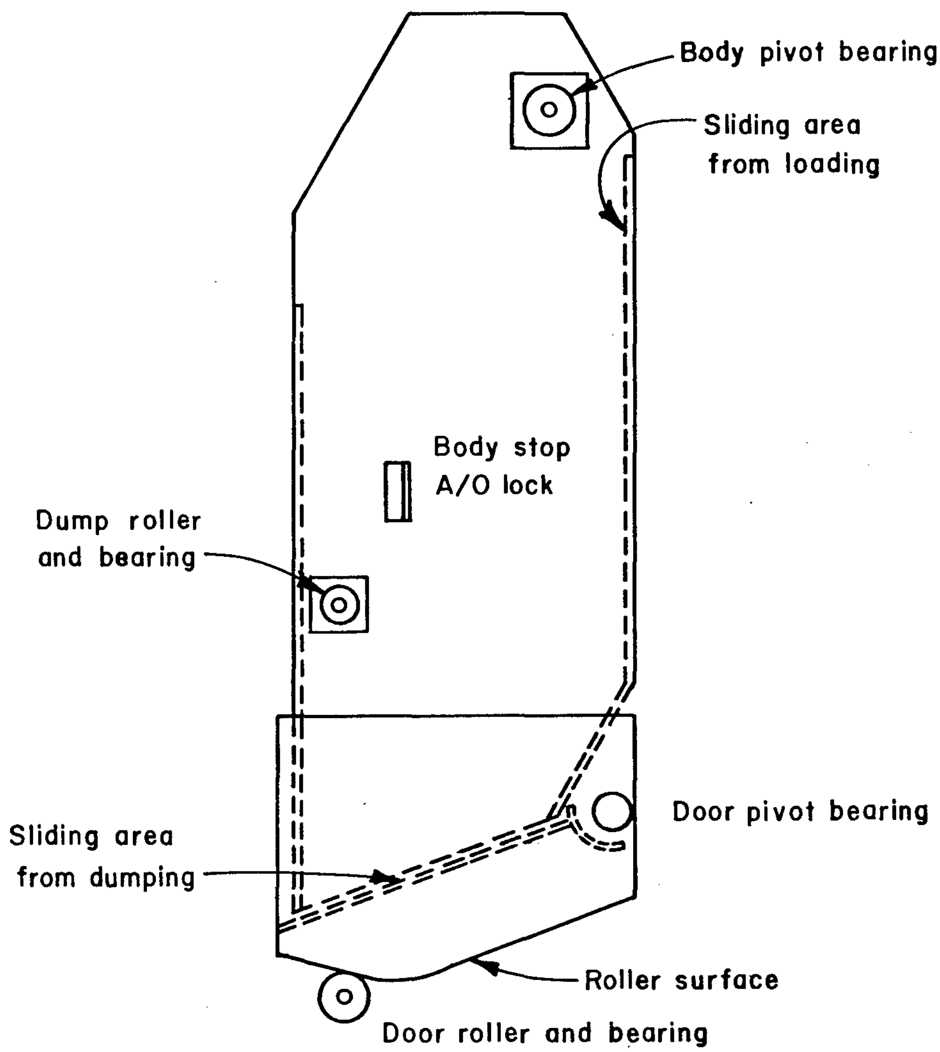


Figure 5.1 Skip Body Wear Locations

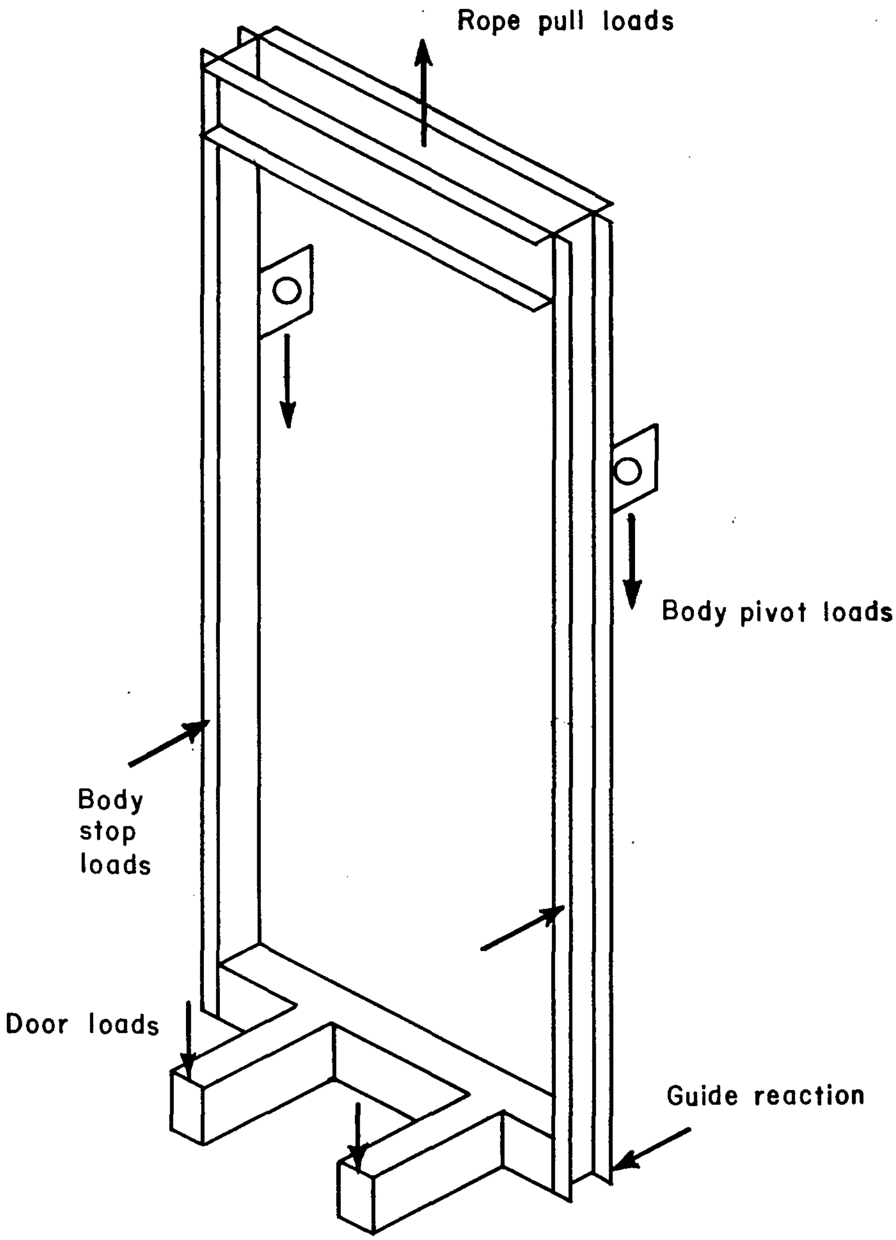


Figure 5.2 Skip Crosshead

swing-out body skips, the support for the door, the body stop, the attachment points for guide shoes, and guide rollers. Stresses in the bail are bending, shear, and tension from the skip body applied statically and dynamically under repeated cyclic loading in a corrosive environment.

Loads on the bail from either a full or empty skip are shown in Figure 5.2. Rope pull, pivot loads, body stop and door loads exist at the same time. Their magnitude changes for a full skip or empty skip and whether the skip is stopped or running. Also the loads change due to guide alignments and whether the skip is running with or without guide rollers.

The body loads are shown in Figure 5.3. At the back of the body near the top there is a wear area caused by loading. In addition to wearing, if there is insufficient stiffness, the body will bulge. Wear or bulging should be noted in an inspection.

Load concentrations occur at the pivots, the dump rollers and the body stop. These should be examined for the four signs of distress.

The door must withstand the shock of material being dropped into the skip from a loading pocket. Hoisting accelerations also add to the door loads. During loading the door is subjected to gouging abrasion. During dumping the door undergoes sliding abrasion. Signs of excessive loss of material due to abrasion must be part of an examination. Doors may or may not have replaceable liners.

Problems associated with the door are shown in Figures 5.4 and 5.5. The "nutcracker" action in Figure 5.4 can happen for two reasons. One is a very small clearance between the body plate and the door whereby muck buildup on the door will prevent the door from closing. The other reason for the nutcracker action is too small a dump angle on the door whereby the door does not clean properly. Even though the clearance between the body and door may be adequate, the muck remaining at the back of the door may jam between the body and the door. Very large forces applied to the door may result in distorting the skip and still not close the door. The dump angle must be increased to clean the skip.

As shown in Figure 5.5, muck may be forced between the liner and the door and between the liner and the body. Although the dump angle may be sufficient to clean the door, fines may remain on the edge of the door liner shown by Figure 5.5a. As the door closes, if the edge of the body liner is too close to the buildup of fines, the result will be a gradual forcing of material between the liner and the door and/or body. A sufficient amount of material can cause the liner to come off and/or to distort the body plates. A solution is to provide adequate clearance when the door is closed.

Rubber belting, such as conveyor belting, has been used to provide a seal at the back of the door. This appears to have limited success in preventing buildup. After some time the muck builds up under the belting and must be cleaned or the problem starts again. In addition to rubber belting, heavy canvas has been used to act as a flexible seal to keep muck out of joints. The same problems apply to muck getting in under the canvas.

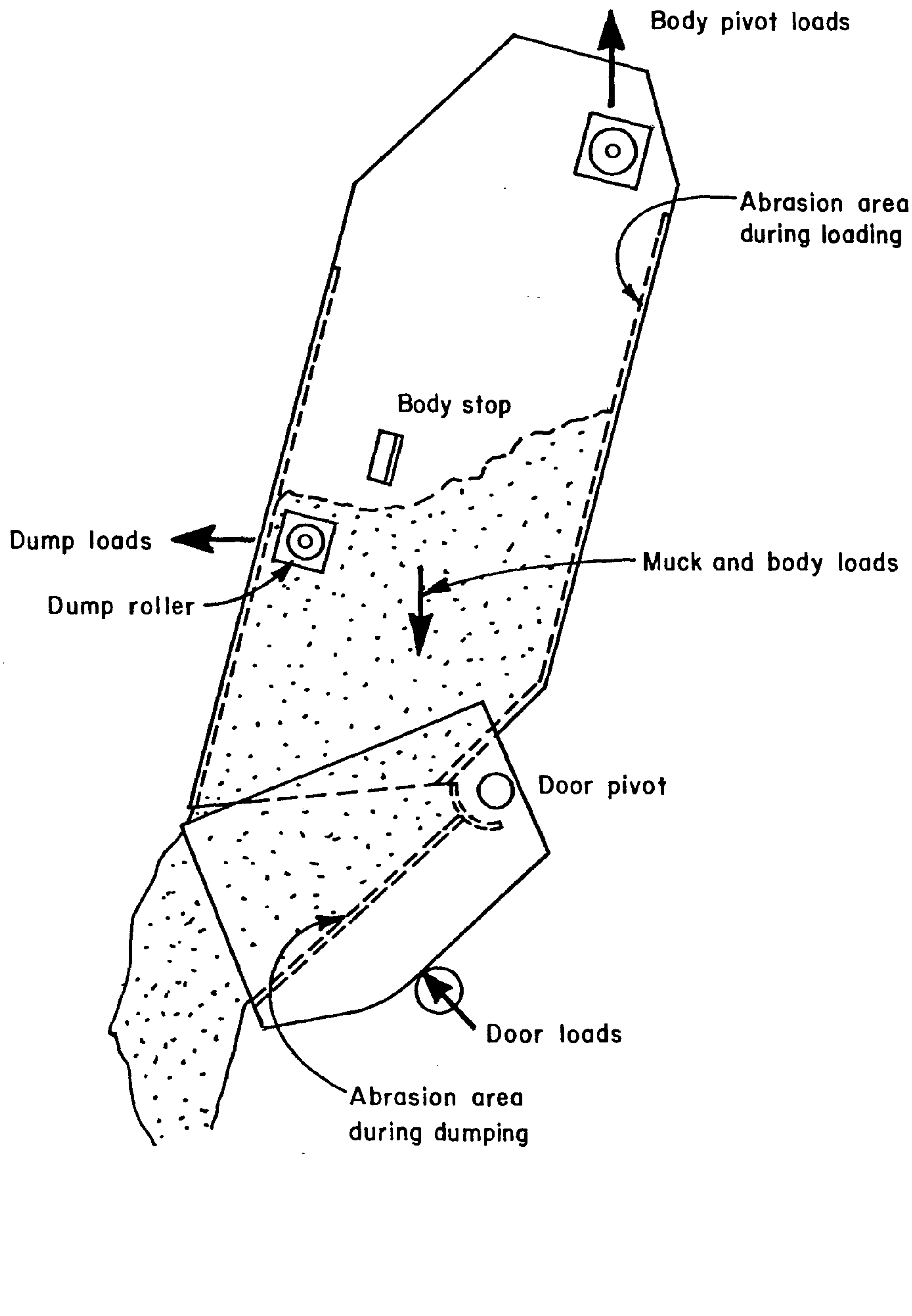
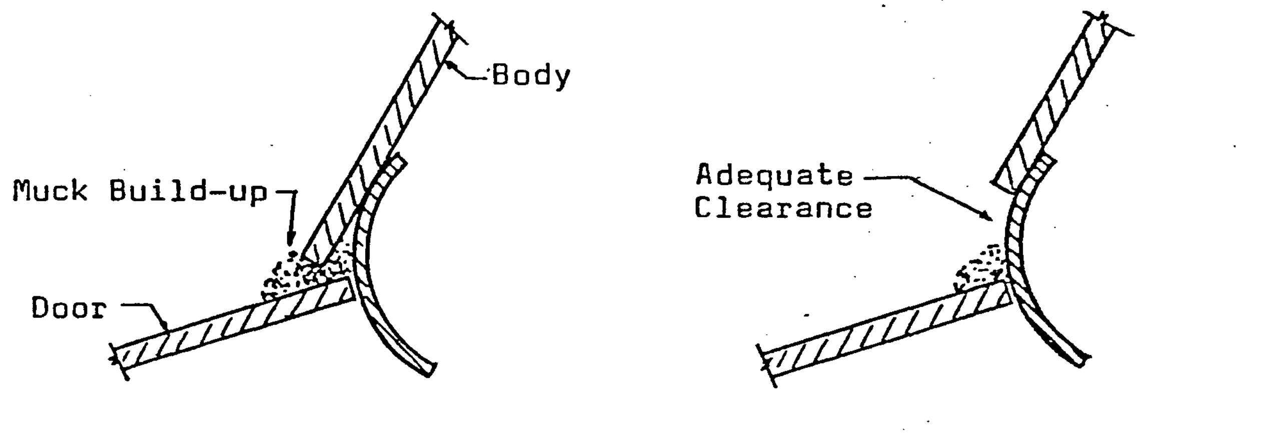
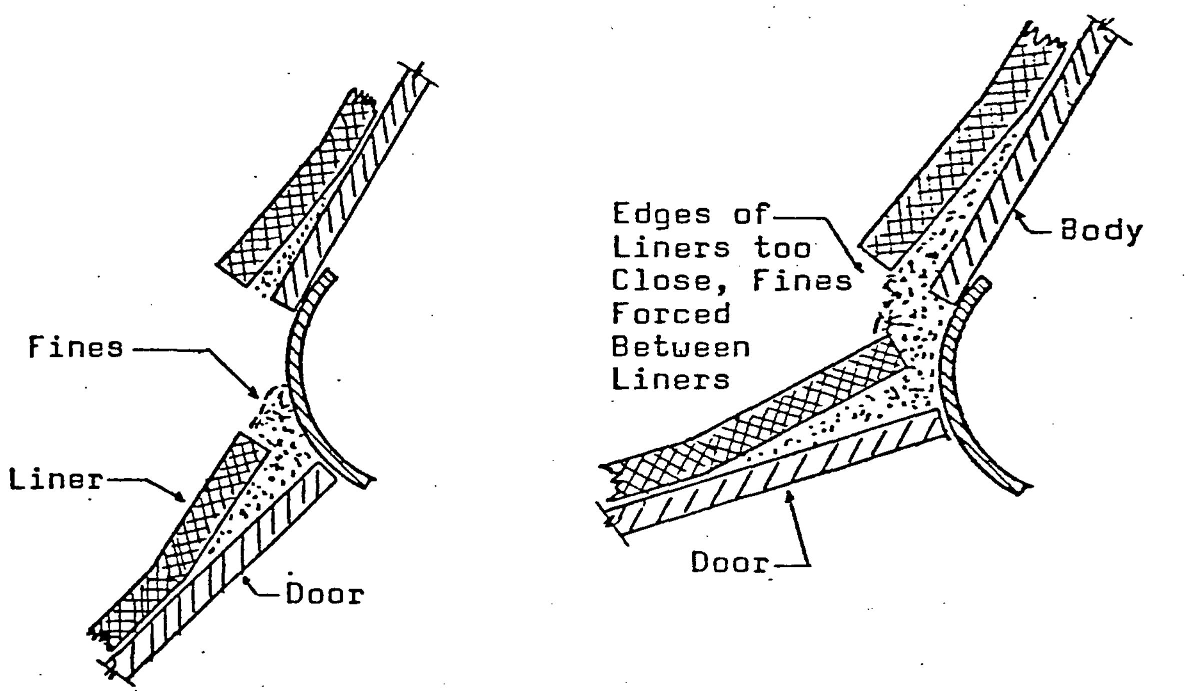


Figure 5.3 Typical Loads to Skip Body



(a) Door will not close properly (b) Door closes properly

Figure 5.4 Skip Door "Nutcracker" Effect



(a) Door opened (b) Door closed

Figure 5.5 Muck Build-up Under Liners Tends to Pull Off the Liners

The door may be supported on a roller as shown in Figure 5.3. It is possible for the surface on which the roller rolls to become worn or indented. This can become a problem for keeping the door closed. For doors supported by links the pivots in the links are subjected to high loads and the pivots may become worn resulting in excessive clearances. These should be examined for such wear.

Bearings are used at the several rotating points of the swing-out bottom dump skip. The top bearing is the body pivot point. It supports the body weight, part of the door weight, and a portion of the muck weight. It must swing through an arc of several degrees when the skip dumps and returns.

The back of the door is supported by a bearing that must go through a rotation of 45 to perhaps 60 degrees or more. The front of the door is supported by either a set of rollers or a link, depending on design. The door rollers will undergo several revolutions as the door opens and closes. Links will go through a rotation of several degrees. These should be examined for proper operation and signs of distress.

The scroll rollers, one on each side, pull the body out for dumping. They see many revolutions for each entry into and exit out of the scrolls.

Maintenance of skips is generally confined to lubrication of all bearings on a regular basis. Daily lubrication is recommended for severe shaft environments and extremely abrasive muck. Weekly lubrication may be sufficient in cases where duty cycles are less severe and the shaft and muck are dry. In any case lubricants which resist washing out are recommended for this service.

The only other major maintenance required on the skip is periodic relining of the body. This is done when the wear approaches the point of wearing on the liner bolts.

MSHA Regulations do not discuss basic inspection procedures for skips in either the coal or metallic/nonmetallic regulations. Regulation 57.19-45 does mention the requirement for bonnets when using skips to lower men. However a reasonable standard of care in inspection and maintenance should be applied to skips as well as man conveyances because of the possiblity of man riding.

5.2 Cages

Inspection and maintenance of cages must consider that cages can be used in several ways; i.e., man cages, or material cages, or man and material cages. Certain items are common to all cages such as doors, floors, bonnet, crosshead, and slides. Daily and weekly inspections are recommended.

5.2.1 Doors

Three common types of doors are used; the sliding, hinged and overhead. They all have catches, and all require lubrication.

The sliding door has a track on top and is guided at the bottom. The rollers, track and guides must be kept clean, straight, aligned, and lubricated. The door(s) must not be bent. All movable parts must slide past each other without binding. Some cages have provision to remove the doors, and the overhead track. When reinstalling these items all the fasteners must be replaced and retightened, and the doors put back into the guides.

Hinged doors swing into the cage when opened. A stop prevents the doors from opening into the shaft. This stop occasionally may be removed for convenience or may be damaged. It should be replaced. Hinged doors may be designed to be made removable by lifting the door at the hinges and disengaging it from the hinge pins. When replacing the door all hinge points must be reengaged.

Overhead doors may rise vertically or may clear the entrance by rising and becoming horizontal. In many installations a counterweight will be used to help move the door. The attachment to the counterweight (wire rope) should be examined for signs of wear or loose fittings. Tracks to guide the door should be kept clear and straight. Any rollers or guiding attachments should be examined for wear.

Combinations of sliding and hinged doors may be used for convenience in loading. All tracks and pins should be examined for wear and should be kept straight and aligned.

Catches on doors are required to prevent accidental opening while the cage is in motion. These are subject to wear and abuse and may not hold properly after use. A number of designs are used whereby the latching mechanism may be operated from either the inside or the outside of the cage or only from the outside by someone outside the cage or by reaching through. Some cages have more than one lock such as a bar across the doors and a pin into a hole in the floor. All should be kept in good repair.

5.2.2 Floors

There are several types of cage floors, which, depending upon their use, have specific problem areas that should be inspected at regular intervals determined by experience.

Cage floors, in addition to supporting personnel and materials, may also;

1. Receive rail cars, with rails set in the floor.

   Problem area: Flange clearance at rail filled with muck.

2. Have removable sections for suspended loads under cage.

   Problem areas: Floor distorted at open section. All fasteners not used to replace removable section.

3. Be hinged so that floor can be swung out of the way for large loads.

Problem areas: Counterweight lines (ropes) and counterweight guides may show wear. Pulleys may be worn or not lubricated. Latch to secure floor in raised position may not be functioning.

4. Have tie down points to secure large loads in the cage.

   Problem area: Fastening device may be corroded, or bent, or broken.

5. Have attachment point under floor for suspended loads.

   Problem areas: Integrity of weld holding attachment point to the floor members. Cracks at pin hole of attachment. Wear or distortion of pin hole and pin.

Inspection of a cage floor should consider the condition of the floor plate, whether bent or corroded and the supporting members beneath. The fastenings (welds, bolts, rivets) of the floor members to the side members should be inspected for cracks or loose fasteners.

In double or triple deck cages the upper floors must have a functioning trap door to permit escape from the lower decks.

5.2.3 Bonnet

A covering is required at the top of the cage. This cover must have an operable escape door to permit access to the top of the bonnet.

Shaft inspection bonnets on top of the regular bonnet should be examined for adequate fastening to the cage, secure hand rails or guards, and undamaged canopy.

5.2.4 Crosshead

The crosshead supports the cage floors through the sides and secures the rope attachment device.

All attachments, such as welds, bolts or rivets at the joints that connect the horizontal members to each other and to the vertical members should be examined for integrity. Cracked, loose or missing fasteners or welds should be repaired.

Some crossheads support auxiliary hoists to handle interior loads. All features of such hoists should be inspected for wear, corrosion, bent, or broken parts. The controls should be in good operating condition. Mechanical stops should be in place and functioning.

Also crossheads may have attachment points to suspend loads. The holes and pins at these points should be looked at for wear, cracks, or distortion. In addition the fastenings of the load point to the crosshead members should be inspected for soundness of the connection.

The hoist rope(s) is(are) fastened to the crosshead in several ways. Where a pin is used directly to the main support member, the pin and the hole area should be free of defects. When a draw bar is used the entire bar should be looked at for distress at the pin hole and where the bar leans against the crosshead. For multiple rope hoisting the fasteners used to connect the rope termination to the crosshead should be examined for adequate bolt torque and corrosion, and the crosshead member inspected for distortion in the vicinity of the connection.

5.2.5 Sides

Included in the sides of the cage are guide shoes and guide rollers. These have been covered in Section 5.1 on Skips. The purpose of the sides is twofold. One is to connect the floor(s) to the crosshead through vertical members, and the other is to protect the contents in the cage by a covering.

Connections at the top and bottom of the vertical members should be free of cracks, corrosion, distortion, and not bent. All holes for fasteners should be filled with bolts of the proper size and grade.

Sides of the cage may be of solid sheets or a type of open metal grating type. The sides should be free of tears, bulges and all panels should be in place. The fastening of the metal sides to the frame should be sound. Welds should not be broken and where mechanical fasteners are used they should all be present and all should be tight.

Where ladder rungs for access to the escape door in the bonnet are fastened to the sides they should be securely fastened and kept in repair to provide hand and foot holds for climbing.

Maintenance on cages is basically restricted to structural repairs, lubrication of mechanisms such as gate latches and rollout floors, and general cleaning and upkeep. If cracked or bent drawhead pins are found, these are to be replaced with pins of equal strength and manufacturing quality. The same applies for any lifting lugs, shackles or devices used for slinging loads or tying down rail and equipment cars.

MSHA regulations deal very little with inspection and maintenance of cages. Various safety features are required by metallic/nonmetallic regulations, including the posting of maximum cage man-carrying capacity, the use of cage gates, and means of communication between the cage and the hoist operator. Coal mining regulations state that a daily inspection of the cage for defective parts is required (75.1400-3d). Additional safety features are stipulated, such as gates, safety chains, door interlocks and safety latches on drop bottom cars used for manriding.

Although not stated in the metallic/nonmetallic regulations it is recommended that some form of daily inspection of the general conditon of the cage be required, perhaps in conjunction with the daily safety dog inspection.

5.3 Skip/Cage Combinations

A single conveyance acting as a skip with the floor up and a cage with the floor down should be inspected and maintained as per the combined requirements for a skip and a cage. The hinge at the back or sides of the floor, the counterweight and the counterweight ropes and pulleys should be checked for signs of distress. The floor supports, when the floor is down, should be clear of muck to prevent excessive load on the hinges. The latch to secure the floor in the raised position should be in good repair to prevent accidental lowering of the floor. The doors and sides of the cage should be free of damage that may occur when loading the skip.

For skip-cage combinations where the skip and cage are separate units the individual skip and cage procedures apply, however, the connections between units are important. Where cages are routinely put on and taken off as trailers, the condition of the pin and pin hole can be readily determined. They should be free of cracks, distortion, wear and corrosion. Where the units are not taken apart but operate assembled, the inspection of the connecting pin and pin holes should be on a routine basis. Pins and pin holes may have a tendency to wear because of the movement between the units.

Where the skip is above the cage the top of the cage should be kept free of fines that may spill down the shaft. Besides adding weight to the unit, the accumulation on top of the cage may hasten corrosion and may prevent opening the emergency door in the bonnet.

MSHA regulations regarding skip/cage combinations in metallic/nonmetallic mines are procedural. No requirements are outlined for inspection and maintenance. Hoisting at 1000 fpm maximum speed and prohibition of man and muck hoisting at shift change are stated in regulation 57.19-72.

5.4 Counterweights

Counterweights may be used for either double drum hoisting or friction hoisting. The integrity of the counterweight requires a sound rope connection and a crack-free frame to carry the weights. Detailed weekly inspection should concentrate on these items.

For double drum hoisting the counterweight does not normally have a balance rope, therefore, there is only one rope connection at the top of the frame. The pin, pin hole, and rope attachment are points to inspect and maintain.

For friction hoists there will be two or more rope attachments at the top of the frame each with pins requiring attention to pin and pin hole conditions. In addition, the bottom of the counterweight frame will have balance ropes. These ropes will be fastened with a swivel connection at both the counterweight and the skip or cage. The swivel must be as friction-free as possible to prevent the ropes from looping in the shaft. A daily lubrication program is recommended.

The counterweight frame may or may not have guide rollers but it will have guide shoes. The section on skip guide rollers and shoes applies to counterweights.

Generally there is a notch in the frame to add or remove counterweight bars. This notch if not smooth and radiused is a stress concentration that may be subjected to cracking. Examination of the notch should be made for cracks or distortion. The entire frame should be straight and flanges used to keep the counterweight units in the frame should be sound to prevent weights from falling out.

MSHA regulations for either coal or non-coal mining do not specifically deal with counterweights.

5.5 Loading Pocket/Flasks

A loading pocket generally measures by volume, however, it may load by weight. It consists of the flask, a gate with an operating mechanism for opening and closing, a chute, and a stand. A regular weekly inspection of the loading pocket area is recommended.

5.5.1 Flask

A rectangular box is used to store the muck prior to loading in the skip. This box can be loaded by conveyor, or feeder, or surge bin, or slusher trench. When filled, the muck exerts a pressure on the sides and bottom. Generally the sides and bottom are flat plates reinforced by stiffeners. If the stiffening is not adequate and/or the plates too thin, they may bulge and bend. In wet conditions stress corrosion at highly stressed areas such as the corners and near the center of the plates may become badly corroded. This results in a loss of strength because of loss of material. These areas should be closely inspected for signs of such corrosion.

Abrasion also results in strength loss of flat plates. If the plates become worn they may bulge and perhaps fail from muck pressure and impact.

Loss of material can be determined by knowing the original thickness and measuring the existing thickness periodically to determine problem areas.

Liners in the box may be used to reduce or eliminate the wear on the side plates. If the liners become worn through, the body plates will wear. Also, if the liners become too thin the fasteners may come out of the liner and the entire plate may come off, resulting in potential damage from tramp metal.

Fastened to the flask are bearings or slides for the gate. Local distortion at the bearings or slide points may indicate excessive loading or mechanical features that may lead to failure.

5.5.2 Gate

Several styles of gate are used to open and close the flask. Virtually all gates are operated by an air cylinder either pulling or pushing the gate or moving an arm. Correct operation of the entire mechanism should be visually checked on a daily basis.

The fastenings for the air cylinder should be inspected for the fasteners being properly tightened and all fasteners installed. Generally the proper size and number of fasteners are determined by the manufacturer. The piston in the cylinder pushes and/or pulls a rod. The holes in the end of the rod and the connecting pin are subject to wear, and should be inspected.

Seals at the end of the cylinder should be maintained to prevent excessive leakage causing improper action of the gate.

Any auxilliary compressed air equipment which may be present, may be inspected as noted in part 2.1.7 on pneumatics.

The gate itself should remain straight and not show signs of wear. Straightness is required to properly seal the flask during loading. Excessive wear may cause improper sealing during loading. Also, a sliding gate not being straight may cause jamming in the guides.

Gate designs may incorporate some means of keeping the gate tight against the flask by allowing for wear. Weekly inspection of the clearances between the gate and the flask should be made to determine when adjustments may be needed.

Where arms, rollers, and other mechanical devices are used, they should be inspected for wear daily.

Daily lubrication of the gate bearings is recommended in high capacity multiple shift operations. Discretion may be used in extending this time in less severe duty. Adjustments to gate clearances may be done as required by the inspection.

5.5.3 Chute

The chute directs the muck from the loading pocket to the skip. Chutes are subjected to sliding abrasion and frequently are lined. Once installed and adjusted they require maintenance and inspection of the liners and of the attachments. Proper tightening of the fasteners is required to prevent the chute from falling off the pocket or moving out into the shaft.

In some instances the chute may extend into the shaft for loading. The bearings and operating mechanism should be inspected for wear and for missing fasteners. The interlock mechanisms to prevent chute and skip interference must be inspected and tested daily.

5.5.4 Stand

Generally the loading pocket will be supported on a stand anchored to concrete at the loading station. In some instances the top of the flask will be supported by overhead beams or into concrete. Because of the shock loading during filling all fasteners should be checked for proper torque.

In some installations the weighing system is part of the stand, or support. The integrity of the electronics (or hydraulics) of the sensors requires frequent attention because of the severe environment in which they operate. A rough check on the weighing system can be made by marking the inside of the flask to where a given weight should fill the box. Care must be taken when ore and waste have different densities, thereby requiring two marks, one for the heavier and the other for the lighter material.

Anchor bolts of stands should be checked for proper torquing of the nuts, the grouting under base plates, and bending or chewing of the bolts.

The connection between the stand and the box and the chute should be checked for bending, tightness and all fasteners installed.

Some stands support part of the gate operating mechanism. Local bending and overall integrity should be examined, to ensure that gate operation is not impaired.

MSHA regulations do not mention maintenance and inspection procedures for loading equipment, such as loading pockets. The greatest concern with loading pockets is that chutes and movable bodies form an obstruction in the shaft if not properly functioning.

5.6 Guide Shoes

Wear of guide shoes is directly proportional to the load on the guide shoe and inversely proportional to the hardness of the softer material. Excessive wear may be considered that condition where the fasteners are almost worn away or when the structural material being protected by the shoes is showing signs of wear.

An item of concern for maintenance and inspection is the method of fastening the shoes to the bail. Generally the shoes are counter-sunk to receive flat-head bolts. If the shoes wear badly, the bolt heads, which may be of harder material, can act as gouges, particularly on wood guides, and cause excessive guide wear. If the guide shoes and bolt heads wear away excessively, the shoes may fall down the shaft.

An additional consideration is the problem of removing the bolts to replace the guide shoes. Access must be provided to put a wrench on the nuts. This may mean access holes on the sides and back of the bail. Also, the problem of keeping a flat head bolt from turning must be considered when replacing guide shoes. One of the solutions has been to use plow bolts or other special bolts designed to prevent rotation.

In a well-aligned shaft with properly adjusted guide rollers the guide shoes do not touch the guides. At some mines any indication of shoes touching the guides calls for local realignment of the guides.

MSHA regulations pertaining to coal mining require a daily inspection of the cage in general for missing or defective components. The guide shoe is one of the most important components on a cage since it prevents the cage from moving out of its compartment. Failure or defects of guide shoes must certainly be considered a cause for immediate repair action.

5.7 Guide Rollers

Some installations have kept the guide rollers away from the guides by about a half inch, the purpose being to prevent guide wear due to constant contact. Other mines with guide rollers preloaded against the guides have felt there was no appreciable guide wear from constant contact.

5.7.1 Tires and Springs

Two basic principles are used to keep the rollers in contact with the guides. One is to mount the roller on a rigid arm and rely on the flexibility of the tire to provide the springing action. The other system is to keep the roller in contact with the guide by a spring pushing the roller against the guide. This scheme is shown schematically by Figure 5.10, Vol. I. A combination of an external spring and tire flexibility is also used.

The tires on guide rollers have been difficult to design. Generally there is a conflict between a large diameter tire, adequate shaft clearance, and largest cross section of the conveyance. Unless a decision is made to use a certain size of tire and let other dimensions be governed accordingly, the tire will be small. The range of tire sizes appears to be from a minimum of six-inch diameter to 12- or 14-inch diameter.

Smaller tires require more frequent replacement. Also, as tires wear, the tension must be adjusted. At this time there is no measure of how much force nor what the spring constant should be to have the "correct" guide roller system. Experience, judgement, maintenance, and using what works are what make some installations successful.

Guide roller tires, solid or pneumatic, are subject to wear. Heat is the biggest problem in keeping good tire life. The temperature of a tire is directly dependent on the load on the tire, the speed at which it is travelling, and the temperature of the surrounding air. Tires are being rated on a load-mile per hour basis, which becomes lower as temperature increases.

For a given temperature, if the speed is doubled, the load would have to be reduced by half, and so forth. This is the reason for the greater success with larger diameter tires. When the air temperature increases from 60 to 120 degrees F, the load-mile per hour rating drops off by about 30 percent. A good cold weather guide roller system may not stand up in hot weather.

Guide rollers are called upon to take out the reaction caused by rope twist. Some mines with heavy duty guide rollers, high contact loads, and large diameter guide rollers have no problems with rope twist. Conveyances without guide rollers will show signs of wear on one side as the guide shoes are forced against the guides by the twist. There have been cases of steel guides being worn through from constant dragging of the guide shoes on one side of the guide. Some mines, running without guide rollers, will install rope with the opposite lay when changing ropes to put the wear on the other side of the guide.

Many designs have been used to keep rollers against the guides. The proper selection of spring force, spring constant, and damping is a function of velocity, mass, skip and bail size, bunton spacing, and guide flexibility as well as guide alignment.

5.7.2 Bearings

Guide roller bearings may rotate for thousands of miles of travel during their lifetime. Guide rollers may have changes in their load pattern, depending on their adjustment and changes in guide alignment.

This section will not attempt to incorporate the well established design formulas used for selecting bearings. The several bearing manufacturers have excellent technical sections as a part of their bearing catalogs. Nor will this section make any recommendations or suggestions for types of bearings to be used.

Bearings have a basic static load rating and a dynamic rating. Loads on a bearing can be either radial loads or thrust loads or a combination of both. The basic static load is limited by permanent deformation of the load-carrying surfaces or by fracture of various parts of the bearing.

Dynamic loads on a bearing are identified by the speed, magnitude, and direction of the load. Also to be considered is a varying bearing load as opposed to a constant load. These factors - load, speed, loading history - affect the life of the bearing.

Relationships between load, speed, and bearing life are not linear. In general, if the load is doubled, the bearing life is reduced to about one-tenth. Conversely, if the load is by one-half, the life is increased about ten times.

Doubling the speed reduces bearing life by one-half. Reducing the speed by one-half doubles the bearing life.

Bearings are rated differently by the various manufacturers. When comparing bearings, the number of hours at a given RPM or a total number of revolutions must be considered. The basis for rating can be as different as one million revolutions to 90 million revolutions.

Where possible, bearings should be sealed. The shaft environment is very hostile to bearings.

Proper consideration for regular lubrication must be given to bearing life. Grease fittings in easily accessible locations will aid field maintenance which will improve bearing performance.

Bearing replacement must be considered in the design. It is fairly easy to weld a bearing into an assembly that later will require major surgery to remove and replace.

5.8 Safety Devices

Each of the three principal guide systems requires its own test procedure to determine if the arrestment device is in operating order. To be acceptable, the arresting system must be properly designed, fabricated and installed. All systems considered here will be spring operated.

5.8.1 For Wood Guides

To engage the wood guide, the spring force at the time of touching must be sufficient to crush the surface of the wood. This should be a calculated value determined at the time the cage and safety dog mechanism are designed.

Having determined the force required to crush the wood perpendicular to the grain, this value should be checked to verify the setting springs are at their design loads at engagement. Figure 5.6 shows the several forces involved at the time the tooth contacts the guide. In this illustration the setting spring is a compression spring pushing on the linkage that moves the bellcrank downward.

A test at the mine would be to verify the value of the Setting Force, F , or the Indent Force, F_I. Note the forces are related such that:

$$F_S \times A = F_T \times B$$

However, the Tooth Force, F_T, has as a component the Indent Force, F_I, or,

$$FI = FT \cos \theta$$

Knowing what F_I should be, it can be measured directly or it can be verified by measuring F_S. The minimum value of F_S should be:

$$F_S = \frac{B}{A} \times \frac{F_I}{\cos \theta}$$

Note these values are for one safety dog. For two guides there are four dogs and for four guides there are eight dogs.

Tension springs break from fatigue or will lose tension due to creep. Generally they are fully exposed so their soundness can be observed. On the other hand compression springs may be encased to provide stability to keep them from buckling out of line when they are compressed. They also lose

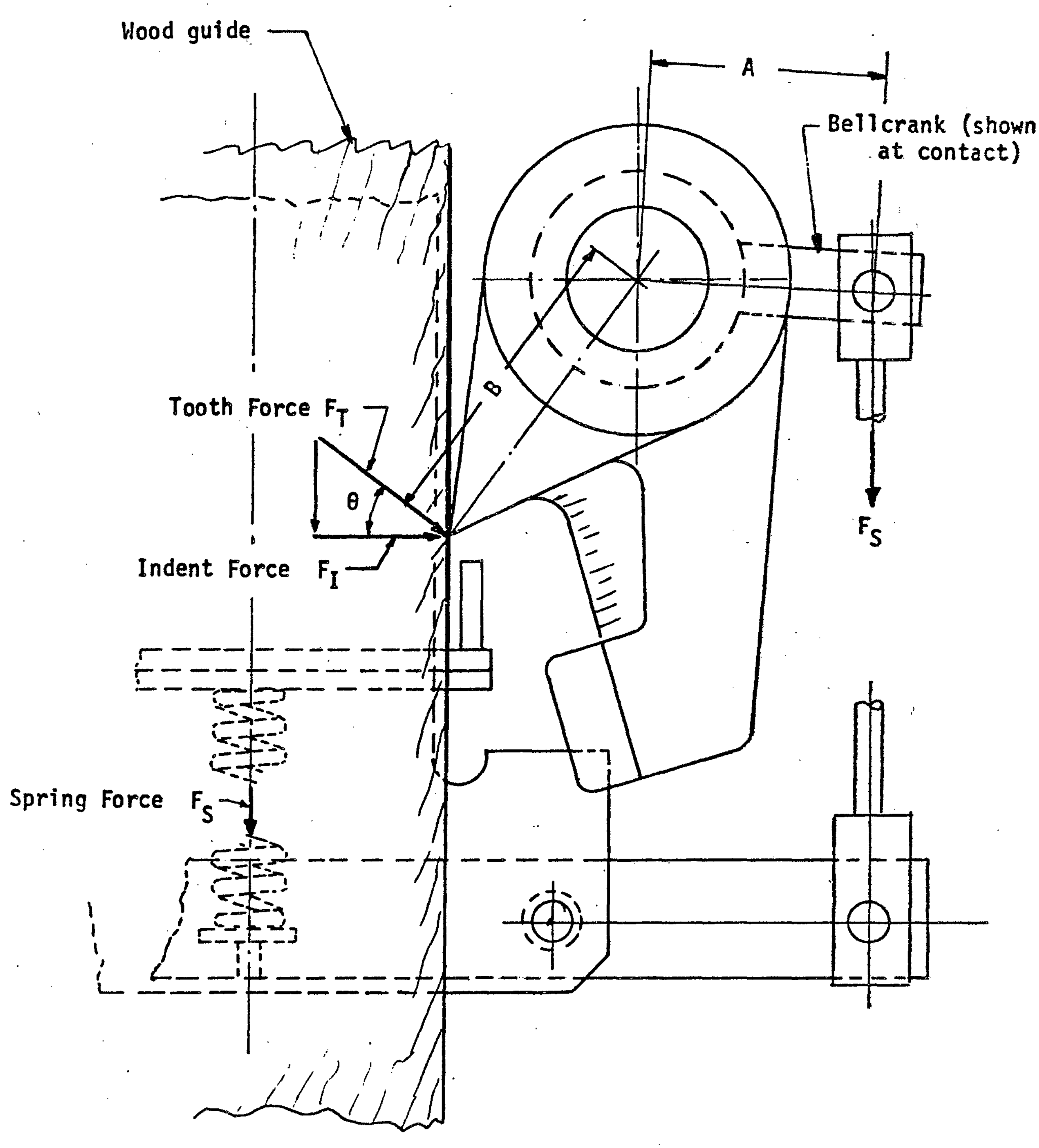


Figure 5.6 Safety Dog Operation

compression, and in addition there are reports of the springs breaking in their encasing cans. The fact they have broken is not easily detected visually. A force test will show that one or more springs have failed or have lost a part of their compressive loads. Leaf springs are also used to set safety dogs. They are subjected to creep and to broken leaves from fatigue or overstress. In some designs torsion springs are used, and they are also subject to failure. Inspectors should try to locate any such faults.

Another test is to measure the sharpness of the cutting edge of the tooth. One means of doing this would be to use a template to establish how much loss of edge would be permitted before sharpening the dog. Note that sharpening can have an effect on the total penetration, the crush angle, and the contact angle θ of Figure 5.6.

Loss of sharpness can be caused by occasional scraping of the guide, corrosion, or frequent chairing where loss of rope tension permits the dogs to engage the guides. This latter condition can be modified by putting a groove in the guide to permit the tooth to enter without touching the wood. The amount of rounding permitted must be determined for each dog geometry and by the factors and assumptions made when establishing the design value of the Indent Force, F_I.

Further testing should verify the full penetration of the tooth until the heel of the dog hits. A groove is required to permit the dog to rotate until the heel is resting against the guide. This will establish whether the linkage is free to allow sufficient rotation permitting full tooth penetration.

After the guides are worn, the tooth will not penetrate as far into the guide. The amount of permissible guide wear is based on dog geometry. In addition, the species and condition of the wood guide affect the stopping force.

Dogs must remain on their shaft to restrain the falling conveyance. Because rotation brings the safety dog into contact with the guide, the shafts are circular. To fasten the dog to a circular shaft, they are keyed and held with set screws. Set screws must be checked periodically to ensure the dogs and keys are secured to the shaft.

Proper centering, based on the face-to-face of guides, design dimensions, and adequate fastening, is required to ensure the dogs not coming out of the guide. The test for this condition should be done during routine daily inspections.

Three other factors can cause the dogs to come out of the guide during the stop. All of these affect clearance. One is wear of the guide shoes; another is wear of the guides; and a third is variations in the face-to-face guide dimension.

If guide shoes are sufficiently worn, it is possible the amount of wear plus the original design clearance is sufficient to allow the dog to come out of the guide. The test for this condition is to measure the total clearance between the guide and guide shoes by pushing the cage against one guide and measuring at the other guide. The original design must be consulted to find the nominal clearance.

A similar condition exists when guides are worn. For this condition the guide must be measured to determine how much wear is allowed before the guide must be changed. Tolerances for guide wear are discussed in Section 4, Vol. II.

The most critical portions of the shaft would be where a combination of guide shoe wear, guide wear and guide misalignment combined for the greatest clearance. The test for this is to measure these parameters. After measuring, the results must be compared to a predetermined allowance. The total clearance will be found to be either acceptable or not acceptable.

The maintenance required will be to change to new guide shoes, change to new guides, or to realign the guides. Any one or two or all three may be required.

One way to test for the soundness of the mechanism and dogs is a free fall test with arrestment initiated at the hoisting velocity. An alternate procedure is to put weights in the conveyance until the parts when in the arrestment position are stressed to the peak g loading, not the average g loading. This level of load will be different for shafts, links, safety dogs, etc., because the dynamic response of each part is different.

A static approach to testing for soundness presents the problem of imposing the highest level of load on all parts when that particular part is being tested. In addition, the point of maximum stress may not be stressed because the static mode shape and dynamic mode shape may be different. Further, the static and dynamic material properties very often are different. For this approach to be successful, a complete dynamic analysis is required to prescribe all the loads and to identify all the critical parts.

After the conveyance has been stopped, it must be retrieved. When applying tension to the haul rope to reset the safety dogs, many of the members will undergo a stress reversal. Where tension members have performed adequately during the stop, they may fail in compression when trying to rotate the dogs out of the wood guides. The loads applied to some of the parts during retrieval may be considerably higher than during arrestment when only the setting springs were acting.

After being in operation, the parts may be attacked by corrosive elements, resulting in a loss of section and a rough surface subject to stress concentrations. Testing should be on a routine basis to detect deterioration that may be the cause of failure during arrestment.

Free fall testing appears to be the most reliable way of testing the soundness of the arrestment mechanism and the safety dogs. In addition, the retrieval capabilities are tested.

5.8.2 For Steel Guides

For wedges to function, the surface of the wedge must come in contact with the surface of the guide. This is accomplished by springs forcing the wedge upward and inward. All wedges must contact at the same time for the stopping forces to be uniformly applied. To test for uniform contact, the cage must be secured (chaired) and the hoist rope slacked to permit the operating mechanism to set the wedges. Inspection may be accomplished by using a feeler gage to find if gaps exist between a wedge and the guide.

If there are openings, adjustments should be made to make all wedges contact at the same time. The kind of adjustment will depend on the design. If no provision has been made for such adjustments, the solution will depend on the ingenuity of those who want to correct the situation.

The need for adjustment may exist because the wedges were not set correctly at the time of manufacture or a wedge may have worn during hoisting, or the supporting brackets may have been damaged or an adjustable mechanism may have moved inadvertently or items such as shims may have fallen out.

Some of the factors affecting the performance of safety wedges are the spring force, the spring constant and pre-load, the coefficient of friction between the wedge and counterplane, friction between wedge and guide, clearance between the wedge and guide, and the wedge angle. On an operating conveyance the spring characteristics can be checked, the contact area between the wedge and counterplane can be maintained, and the clearances can be measured.

Before any of these values can be measured and interpreted, they must be predetermined. If, however, the arrestment system has been manufactured without engineering analysis, then one approach is to test and replace the springs to maintain the as-built condition, keep all contact surfaces clean, adjust all clearances to the as-built dimensions. For systems with an analytical design a range of acceptable values should be established and the components kept adjusted within their limiting values.

The two modes of failure, excessive guide deformation and fracture, can compromise the performance of the wedge arrestment system. To verify that neither mode will occur during an arrestment, it appears that free fall testing at the design load and speed is required. Due to the nature of the friction device, it does not seem feasible to attempt static load tests to verify the integrity of the system.

Further, should the system be activated in the shaft, it should be verified that the wedges will release when the haul rope is tensioned. There are reports of jammed wedge systems being released by removing major portions of the crosshead. In a shaft this could be a difficult task and would require rebuilding after the conveyance was brought to the surface.

Corrosion of the surfaces may affect the soundness of the mechanism and the freedom of rotation at hinge points. Inspection and routine maintenance should be exercised to keep the arrestment device in the as-built condition.

5.8.3 For Rope Guides

Clamps, one set on each rope, should be checked for uniform engagement. By chairing or blocking the conveyance in the shaft, the clamps should be activated by releasing tension on the haul rope. With tension fully off the rope, both sets of clamps should be tight against the guide rope. One way of checking this is by using a feeler gauge, verifying there is no clearance between the clamps and the guide.

Another method is to remove the conveyance from the guide rope and to insert a piece of guide rope into each clamp. If each piece of rope is securely held when haul rope tension is relieved, then both sets of clamps are engaging the guide ropes.

Where springs are used to provide the clamping forces, they should be tested for proper tension (or compression) forces when fully retracted and also when the clamps have engaged the rope. Broken or fatigued springs when acting in a system designed for certain values of force cannot perform to the design requirements.

For force limiting systems, as used on this program, the value of either a force limiting spring or hydraulic system should be checked. Force transducers can be applied to a force limiting spring and pressure gauges can be incorporated in a hydraulic system.

Should the clamps become worn from rubbing on the rope, the angles change for the clamping bars. There are limits in which rope arrestment systems appear to function adequately. Measuring the angle at time of contact of the main actuating links should be a maintenance procedure. If, however, these limits have not been specified in the design, they cannot be verified during a test at the mine site.

The need for the several pieces to remain in the as-built condition without fracture or excessive deformation can be verified by a free fall test. It does not appear practical to use static loading to verify the adequacy of the design, fabrication, assembly, and maintenance of the system.

Free fall testing appears to be the only means of establishing whether the mechanism will fail during arrestment. Stopping a properly loaded conveyance travelling at the maximum hoisting velocity can provide the most reliable measure of performance and durability. Other means may be subject to uncertainties that may be difficult to interpret.

In releasing the mechanism after an arrestment, tension on the haul rope will generally put reverse stresses on the linkage. Members designed for tension when put into compression may fail by buckling. This has occurred during retrieval of a test on rope guides. A test at the mine site could consist of locking the clamps on the rope and hauling upward to check the release action and the adequacy of the pieces.

Corrosion of the materials could affect the amount of material and introduce stress concentrations. Freedom of movement may become restricted where corrosion has affected pinned joints. Keeping the mechanism in the as-built condition is probably the surest way of keeping it sound.

MSHA Regulations for both coal and metallic/nonmetallic mining require that some form of test be carried out on cage-mounted safety devices. Daily inspection is required in both sets of regulations. The operation of safety devices must be tested weekly by activating the mechanism, in non-coal mining operations. In coal mining operations, the mechanism requires testing only every two months. It is recommended that coal regulations as well adopt a weekly inspection of the safety devices mounted on the cage.

6. ROPE ATTACHMENTS

Inspection of rope attachments should be carried out on a daily basis. Visual inspection for such daily routine inspection is all that is required. Where there are simple thimble and clip or clamp connections, there is no requirement for extensive additional disassembly and inspection. However, on the more complex wedge type cappels and multiple piece toggles annual non-destructive testing procedures are recommended. Either magnetic particle inspection or dye penetrant inspection are suited for this work.

6.1 Thimble and Clips

Inspection and maintenance of a thimble and clip installation requires frequent attention to the torque on the nuts and the presence of broken wires. After clips have been installed they loosen because the wire rope becomes smaller in diameter as it is used. New ropes require periodic retorquing during the first few hours of operation.

Manufacturers provide recommended torque values for the bolts in the clips. From Table 6.I the torque is different for U-bolt and fist-grip clips. Also given is the recommended wrench length for applying torque.

It is possible to put the U-bolt clips on incorrectly. The incorrect and correct ways are shown in Figure 6.1.

Table 6.1 Torque for Rope Clips

Dia. of Rope (in.)	Torque (ft lb) 1/		Length of 2/ wrench (in.)
	U-bolt	Fist-grip	
3/4	120	220	18
7/8	220	220	18
1	220	220	24
1-1/8	220	360	24
1-1/4	360	360	24
1-3/8	360	500	24
1-1/2	360	500	24
1-5/8	430	-	30
1-3/4	590	-	30
1-7/8	750	-	30
2	750	-	30
2-1/8	750	-	30
2-1/4	750	-	30

1/Establishing Standards for Effective Wire Rope Clip Installations, Bureau of Mines Report of Investigation, R17789, 1973.
2/CF&I Roebling Wire Rope Handbook, CF&I Steel Corp. 1966

The minimum number of clips and spacing for various rope size is regulated in CFR 30, Section 55.19-24 for six-strand, 19 wire, plow steel ropes. Other references 1/ 3/ recommended one additional clip for ropes from 1 to 1-5/8 in. dia.

The AISI, Wire Rope Users Manual (Ref. 3) also states that if a pulley is used in place of a thimble for turning back the rope, add one additional clip.

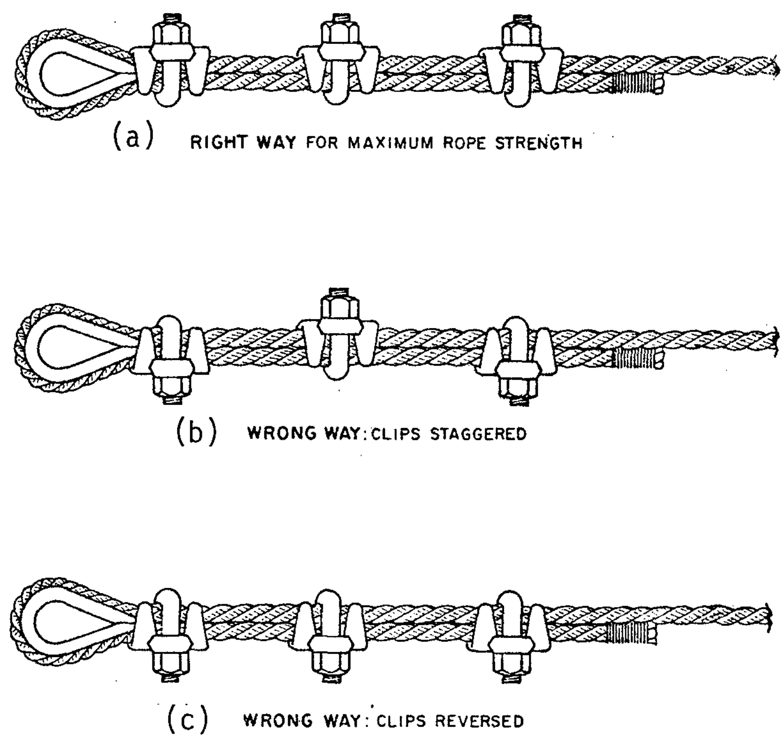


Figure 6.1 Clips Applied to Wire Rope

The number of clips (Ref. 3) 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 in Ref. 3 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, it may be necessary to add additional clips.

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

Recommended installation procedure is to turn back the specified amount of rope from the thimble. The first clip applied is the clip farthest from the thimble and is fully torqued. The next clip is the one closest to the thimble with the nuts tightened but not torqued. The remaining clips are installed equally spaced, then all are fully torqued.

The new procedure which might be of value is to put the first clip on as above, put the second clip on with reduced torque adjacent to the thimble, and apply the remaining clips.

6.2 Thimble and Clamps

Clamps when used on a thimble rope termination have to be checked for bolt torque. The proper value is determined by the manufacturer. Frequent checking is required with new ropes. Checks after the first hour of full operation are recommended.

Any sign of corrosion, or broken wires, or wear at the clamps should be detected as soon as they occur. Any slippage of the clamps should be corrected at once.

Wear and corrosion of the pin and hole in the thimble should be looked for when the rope is removed for replacement or when a cut is made.

6.3 Thimble and Mechanical Splice

The rope at the end of the splice should be examined for broken wires, corrosion, and signs of wear. The loop around the thimble should be snug.

The thimble should be examined for wear and corrosion of the pin and in the pin hole.

3/Wire Rope Users Manual, Committee of Wire Rope Producers, American Iron and Steel Institute, 1979.

6.4 Thimble and Hand Splice

All thimble inspections should be the same regardless of splice.

For a hand splice the inspection should be for slackening of the loop around the thimble and for tucks of strands coming out of the splice. Inspectors should look for broken wires and corrosion.

6.5 Spelter or Resin Socket

The rope immediately coming out of the socket should be examined for broken wires and for corrosion. The surface of the socket should be examined for any voids or signs of the material being pulled down the cone.

6.6 Wedge Socket

The rope in a wedge socket should be examined for broken wires. In the event there is no load on the rope the wedge should be securely locked into the socket. Sudden loads should be avoided on this connection, especially when applying load to a new installation.

The wedge and socket should be inspected for rough edges or burrs that may damage the rope.

The end of the rope should not be welded. If it is welded, the weld should be cut off. If it is not cut off, the end of the rope cannot adjust for the sharp bend as it is brought around the wedge. The high strands and waviness will work themselves up the live part of the rope.

It is possible to install the wedge socket incorrectly as shown in Figure 6.2a and 6.2b. The live end of the rope is directly in line with the attaching pin at the end of the wedge socket.

If a rope clip is used on the dead end of the rope, the U-bolt should bear against the dead end and the saddle of the clip against the short extra piece.

6.7 Swaged Socket

Wires at the end of the swaging should be examined for broken wires and corrosion. Any signs of socket slippage should be noted.

6.8 Wedge Cappel

Looking for broken wires at the end of the cappel and the presence of corrosion should be part of the examination. Bolts should be tested for torque. Any signs of slippage should be noted.

Hoisting operations that tend to unload the rope may cause wedge cappels to slip.

Cracks in any of the parts of the cappel should be looked for.

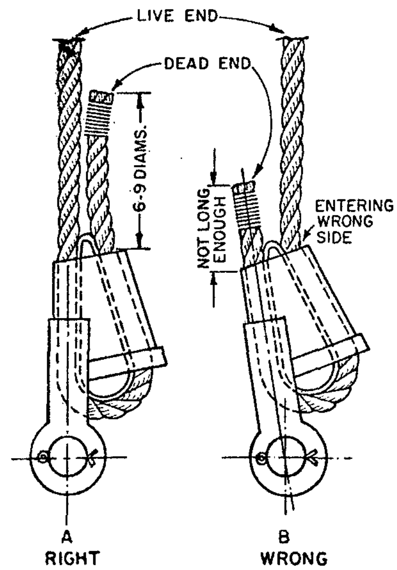


Figure 6.2 Wedge Socket Assembly

6.9 Tension and Length Adjustment

The need for changing rope lengths to equalize the tension on friction hoists can be checked by marking a line on all the ropes at mid-shaft and observing whether all marks are in line at the collar or in the sump.

If slippage is sufficiently severe, the liner on the drum will show excessive wear, changing the drum diameter.

Where the drum diameters are different because of different amounts of wear, changing rope lengths will not solve the problem. The drum will have to be regrooved.

6.10 Secondary Rope Attachment

The top of the secondary rope attachment should be checked for broken wires and rope corrosion. Excess slack in the ropes or chain connecting the secondary rope attachment to the conveyance should be avoided. The fastening of the rope or chain to the top of the conveyance from the secondary rope attachment should be sufficiently sound and strong to withstand the breaking strength.

The secondary rope attachment fitting should be examined to determine that all wedges are securely seated and would not slip in the event the fitting was suddenly loaded.

6.11 Swivel

Swivels at either end of balance ropes should be examined for free rotation. Slight friction can cause balance ropes to loop in the sump. In addition to being friction-free, the swivel must maintain mechanical integrity. Pins and pin holes should be looked at for wear and corrosion. Any signs of cracks or distortion of the swivel body should be noted.

6.12 Pins

Pins are the most common attachment between rope and conveyance and between conveyances. The design of pins is in double shear; therefore, the loading is symmetric.

Pins should be examined for distortion, wear, cracks and corrosion. This can only be done by removing the pin. Measuring instruments are needed for wear determination, however wear can be detected by eye.

If the pin is no longer straight but has been bent, it has had too great a load for its size. Other materials or redesign may be needed.

Non-destructive testing techniques can be used for crack determination. Dyes, sonics, magnetics, and X-rays are some of the techniques used. Cracked pins should be replaced and the cause determined.

Corrosion may cause loss of material and the fitting introduces stress concentration. It should be avoided by taking protective measures.

The fastening that holds the pin in place should be examined. Any signs of wear or distress should be corrected.

6.13 Rope Detaching Hooks

The operation of the detaching hook should be checked with the cage properly secured. Examination of the hook should consider the free operation of the mechanism and whether there are signs of distortion or cracks in the material.

6.14 MSHA Regulations for inspection of rope attachments are clear in both coal and metallic/nonmetallic mining.

7. HOIST INSPECTION AND MAINTENANCE LOG BOOKS AND FORMS

Log books serve to communicate the status of the hoisting equipment to all concerned. They act as the formal information channel and their consistent use assures that important information is not lost or forgotten. Information concerning unusual events or problems, maintenance requirements, etc., should be recorded in writing in the appropriate log book.

Suggested forms for daily, weekly and monthly inspections are also included in this section. They serve to formalize the inspection procedure.

7.1 Log Books

Log books are required for each hoist for the various disciplines for recording special events related to maintenance and operation of the hoists.

The following log books are required:

(a) Hoistman's Log Book

(b) Electrical Log Book

(c) Hoist Machinery Log Book

(d) Hoist Rope Log Book

(e) Shaft Inspector's Log Book

A brief description of these log books follows.

(a) Hoistman's Log Book

The book is arranged as per Figure 7.1. Each hoistman notes and signs the previous shift entries as he comes on shift. He also records all pertinent events that occur during his shift for information to the oncoming hoistman.

He also records the condition of the hoist during his shift. All activities of an unusual nature that occur in the shaft compartments are also noted.

This includes any special obstructions that may have been installed or removed from the shaft compartment during his shift. All daily tests to the hoist are recorded in this daily log book. Special instructions are also noted for the oncoming hoistmen.

Figure 7.1 Hoistman's Log*

COMPANY ______________ MINE ____________ HOISTMAN'S LOG SHAFT NUMBER HOIST NUMBER

date ____________ shift from ____ to ____

SPECIAL INSTRUCTIONS INVOLVING SAFETY OF PERSONS:

START SHIFT

I have read and noted all entries made by the previous shift hoistman and all special instruction at ________(time).

I tested the hoist brakes at ______(time) and report as follows: __________________

I noted that the overwinds and underwinds were tested at (time) on (date)

or

I tested the overwinds and underwinds at (time) and report as follows: _________

I took the following action at (time) concerning any faulty tests: ____________

I made the following trial trips and report as follows (give times): ______________

MID SHIFT

The working condition of the hoist, including the brakes, clutches and their interlocks; depth indicators, and all other safety devices and fittings was as follows: ____________________________________

The working conditions of the signalling equipment was as follows: ______________

END SHIFT

Questionable or incorrect signals were as follows (give times): ______________

Abnormal hoisting conditions or circumstances were as follows: ______________

Special notes to succeeding hoistman regarding operation or safety of persons: _____

Date:

Signature of Hoistman:

Signature of Authorized Person:

*Form similar to Province of Ontario form.

(b) Electrical Log Book

All work performed on the hoist electrical equipment must be recorded in the Hoist Electrical Log Book as per Figure 7.2. This includes all tests and unusual events. The entries must be signed by the electrician and the supervisor.

(c) Hoist Machinery Log Book

All work performed on the hoisting plant must be recorded in the Hoist Machinery Log Book as per Figure 7.3. This includes all hoist parts, sheaves, hoisting ropes, dump equipment and conveyances.

All tests performed and inspections made shall be entered by the person making the tests and inspections and countersigned by his supervisor. All unusual occurrences shall also be entered in this book such as damage to conveyances or hoist ropes. Alterations or adjustments to equipment shall also be recorded.

(d) Hoist Rope Log Book

All work performed on hoist ropes such as rope changing, lubrication, inspection and measurement shall be entered in the log book. Any damage incurred by the rope shall also be recorded. Work performed on attachments such as recapping shall be recorded in this log book. The person conducting the inspection and maintenance shall sign the log book which will be countersigned by his supervisor. The wire rope log, however, is not discussed further because it is not in the scope of this report.

(e) Shaft Inspector's Log Book

A shaft inspector's log book as per Figure 7.4 is maintained for keeping records of all work performed in each shaft compartment.

Each week, a complete inspection is made to each compartment by an experienced shaft crew to insure the integrity of the shaft, to observe if all guides, timber, linings, steel, services, etc., are in good repair. If damage or wear is noted, repairs are made as required.

At periodic intervals, shaft guide alignment and wear is measured in the face-face and on the side-side plane. Adjustments are made to compensate for wear. Guide wear must not exceed specified limits.

All work carried out in the shaft must be recorded in the log book.

ELECTRICAL LOG*

COMPANY ____________ MINE __________ SHAFT NO. _____ HOIST NO. _____

	EQUIPMENT	CHECK	
DRUM AND FRICTION HOISTS	Hoist Motors Control Equipment Brake Solenoids Overwind Devices Underwind Devices Overspeed Devices Track Limits Man Safety Devices Auxiliary Controls Warning Signals Backout Device Emergency Switch Ammeter		DATE SIGN. OF CHIEF ELECTRICIAN
FRICTION	Jammed Conv. Device Level Indic. Device Tread Wear Device Synchronous Device		DATE
SIGNALS	Signal System Shaft Telephone Cage Calls P. B. Stations Level P. B. Stations Conv. Trailing Cable Shaft Gate Interlock Conv. Door Interlock		SIGN. OF EXAMINER

Remarks, Repairs, Corrections, Failures, Accidents:

*Form similar to Province of Ontario

Figure 7.2 Electric Log

HOIST MACHINERY LOG BOOK

COMPANY ________ MINE ___________ SHAFT NO. ______ HOIST NO. __________

MONTH ___________

DAY OF MONTH	COMPARTMENT: HOIST ROPES & ATTACHMENTS	TAIL ROPES & ATTACHMENTS	SAFETY DEVICES ON CONVEYANCES	I have this date made the regular daily examination of the hoisting equipment as required by MSHA and company procedures. Remarks, Repairs, Correction - Failures or Accidents:	SIGNATURE	DATE
1						
2						
3						
4						
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26						
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28						
29						
30				*Form similar to Province		
31				of Ontario		

Figure 7.3 Hoist Machinery Log Book

SHAFT INSPECTION RECORD (Sheet 1)

Company.................................... Mine.................................... Shaft.................................... Date.................................... 19.........

I have on the following dates completed weekly shaft inspections.

DATE	COMPARTMENTS (Check by using "OK" or "SEE NOTE" as required)						Signature Examiner	Signature Person in Charge

Report of Examinations and Corrective Action taken Signed by Examiner ....

Remarks and Notations by Person in Charge of Shaft ....

I hereby certify that I have read the above reports, and that they contain notations of dangerous conditions (if any), and that the examination and corrections herein recorded have been made.

DATE.................................... SIGNATURE.................................... PERSON IN CHARGE OF SHAFT.

Figure 7.4 Shaft Inspection Record

SHAFT INSPECTION RECORD (Sheet 2)

Company.............................. Mine.............................. Shaft.............................. Date.............................. 19........

I have this date completed the monthly examination required.

ITEM EXAMINED	COMPARTMENTS (Check items by using "OK" or "SEE NOTE" as required)					
Guides & Attachments						
Shaft Timber						
Wall Rock						
Shaft Lining						
Compt. Partitions						
Conveyance Clearance						
Ladders & Landings						
General Condition						
Examiner's Signature						

Report of Examination and Corrective Action taken—Signed by Examiner ....
(Note location of any dry sections of shaft timber)

Remarks and Notations by Person in Charge of Shaft ....

I hereby certify that I have read the above report, and that it contains notations of dangerous conditions (if any), and that the examination and corrections herein recorded have been made.

DATE.............................. SIGNATURE.............................. PERSON IN CHARGE OF SHAFT.

7.2 Hoistman's Shift Inspection

Special tests are conducted by the hoistman on each shift to ensure that safety devices and braking systems are functioning normally. These are as follows:

At the start of his shift, the hoistman must:

(1) Test for the satisfactory performance of the hoist brakes.

This is done by applying power to the hoist motor with brakes applied to observe if sufficient braking capacity is available: i.e., the hoist must not move before a prescribed load (amps) is attained. The minimum amperage is calculated for each hoist. If the hoist moves before the prescribed amperage is attained, the hoist must not be used until the brakes have been examined and repaired.

The hoistman during his shift must report in the log the:

(1) working condition of:

- (a) The hoist brakes, clutches and clutch/brake interlocks,
- (b) The depth indicator,
- (c) The signal system,
- (d) The hoist controls,
- (e) The overwind and underwind devices,
- (f) Other devices which may affect safe hoist operation.

(2) Instructions given to him affecting hoist operations.

(3) Unusual circumstances in connection with the operation of the hoist.

(4) Results of any tests prescribed by Regulations.

(5) Trial trips.

(6) Inadvertent stops.

(7) Starting and finishing time.

The hoist operator shall:

(a) Note and countersign all entries in the hoistman's log for the preceding two shifts, and

(b) Sign in the hoistman's log for his period of duty.

A person issuing instructions to the hoist operator shall record and sign such instructions in the Hoistman's Log Book.

The supervisor in charge of a mine hoist shall review and countersign each working day the entries in the Hoistman's Log Book for the preceding 24-hour period.

8. MSHA REGULATIONS CROSS REFERENCES

This section is included to provide a cross-reference between the equipment categories as outlined in the two volumes of this report, and the Mine Safety and Health Administration regulations which govern primarily hoisting and man trips in underground coal mines, and man hoisting in metallic and nonmetallic underground mines. Table 8.1 is a tabulation of both metallic/nonmetallic regulations and underground coal regulations corresponding to the equipment categories. Table 8.2 tabulates equipment categories versus the underground coal mining regulations and Table 8.3 tabulates equipment categories versus the metallic/nonmetallic mining regulations.

One can note from Table 8.1 the major similarities between the coal and non-coal regulations. The major components of equipment are virtually similar. Basic statutory requirements include the brake/clutch interlock, hoist indicators, dual signal systems, braking effort, the determination of safe shaft speeds, and safety devices. Also recognized is the requirement for and importance of inspection and maintenance and the recording of the tests and inspection for a specified period of time.

Differences pointed up in the cross referencing include required inspections and frequency. The major differences are weekly versus daily shaft inspection in non-coal versus coal operations, weekly versus daily headsheave inspection for non-coal mines, the inclusion of elevators as a special manhoisting system in coal mines. Other major differences relate to the method of hoisting employed in the two types of mines. Where metallic/nonmetallic mines have a large portion of vertical shaft hoisting, the coal mines have a larger number of hoists running in sloped shafts. The result is that conveyances are different and consequently are treated differently in the regulations. A good example is the requirement for additional locking devices on self-dumping cars as stated in the coal regulations.

Neither set of regulations discusses the friction hoist system to any great extent. Friction hoists require resynchronization due to accumulation of slip in the system as described in the metallic/nonmetallic regulations as well as a method of overtravel protection. Friction hoists are not mentioned in the coal regulations even though a significant number are currently operating in the coal industry.

In general, the regulations for coal and non-coal mining evolved separately and the results are evident in the following tables.

TABLE 8.1 - MHSA Regulations - Cross Reference

Item	Metallic & non metallic		Coal	
	Ref. No.	Comment	Ref. No.	Comment
1. Hoisting systems general	57.19-1	Rated equipment capacity commensurate with loads applied	75.1401	Rated equipment capacity commensurate with loads applied
	57.19-3	Connection of drives to drums		
2.1.1 Shafts	57.19-1	Implied for mechanical components	75.1401	Implied for all mechanical components
2.1.2 Drums	57.19-1	See 1. comments	75.1401	See 1. comments
2.1.3 Brakes	57.19-4	Brake or brakes required for holding load	75.1400-1	Brakes are required to stop and hold load for man hoisting
	57.19-5	Brake/clutch interlock required		
	57.19-6	Fail-safe braking required	75.1403-2	Same as 1400-1 but for material hoisting
	57.19-17	Emergency braking required	75.1403-3a	
	57.19-62	Braking deceleration rates permissible under normal and emergency braking		
	57.19-65	Lowering load brakes only is not permitted except in emergency		
	57.19-83	Back-out switch and brake interlocks		
2.1.4 Clutches	57.19-5	Brake/clutch interlock required	75.1403-3a	Brake/clutch interlock required
2.1.5 Reduction gearing	--	No regulation specifically dealing with this item	--	No regulation specifically dealing with this item
2.1.6 Bearings/ mountings	--	No regulation specifically dealing with this item	75.1400-3e	Reference to bearings on headsheaves but not to hoists or other equipment
2.1.7 Hydraulics	--	No regulations specifically dealing with this item pertaining to hoisting		No regulations specifically dealing with this item pertaining to hoisting

TABLE 8.1 - MHSA Regulations - cross reference (Continued)

Item	Metallic & non metallic		Coal	
	Ref. No.	Comment	Ref. No.	Comment
2.1.8 Couplings	57.19-3	Prohibition of chain rope or belt to connect drive to manhoists	--	No regulations specifically dealing with this item
2.1.9 Lubrication	--	No regulation specifically dealing with lubrication	75.1400-3e	Reference to headsheave lubrication
2.2.5 Shaft communications	57.19-95	Applies to shaft sinking only	75.1403-4d	Communication device (i.e. telephone to be installed in each automatic elevator car
	57.19-96	Signallers and those receiving signals to be completely familiar with signal code		
3.1 Headsheaves	57.19-134	Headsheaves to be inspected and lubricated weekly. This does not correspond to daily inspection required by Coal Regulations	75.1400-3e	Headsheaves to be inspected and lubricated daily.
	57.19-39	Limitations on the sheave/rope diameter ratios for rope speeds greater than 200 fpm and non-emergency hoists. (Applies only to hoists installed after 11/15/79)		
	57.19-40	Rope groove contour to be suitable to diameter of rope used		material hoisting
3.2 Deflection sheaves	57.19-39) 57.19-40) 57.19-134)	All apply to deflection sheaves (See 3.1 Headsheaves)	--	No regulation dealing specifically with this item.
3.3 Headframe structures	57.19-35	Designed and constructed to a suitable set of design loads	--	No regulation dealing specifically with this item.
	57.19-36	Height requirement for overtravel clearance and safe stopping of conveyance		
	57.19-37	Fleet angle requirement a function of hoist/headframe special arrangement		

TABLE 8.1 - MHSA Regulations - cross reference (Continued)

Item	Metallic & non metallic		Coal	
	Ref. No.	Comment	Ref. No.	Comment
3.3 Headframe structures continued	57.19-38	Toeboard and handrail requirement for elevated platforms		
	57.19-39	Sheave to rope diameter		
3.4 Overtravel protection	57.19-7	States the overtravel protection requirement	75.1400	General requirement for overtravel protection is stated.
	57.19-8	Recalibration of overtravel device required on friction hoist		
	57.19-14	Requirement for tapered guides or other overtravel protection on friction hoists		
	57.19-18	Overtravel bypass switch must move to open position if released, to reactivate all other overtravel protection devices		
	57.19-36	Headgear to be provided with overtravel clearances		
	57.19-83	Manually operable torque proving device requirement for removing an overtravelled conveyance from the overwind position		
3.5 Dumping loading unloading	57.19-79	Blocking of mine cars at stations, collar and conveyance	75.1403-3e	Lockouts required to prevent dumping of man-carrying cars.
	57.19-101	Positive stop blocks on all tracks leading to shaft	75.1403-7n	Similar locking device for drop-bottom cars.
	57.19-103	Dumping and loading facilities to be designed to minimize spillage of rock	75.1403-8e	Positive stop blocks on all tracks leading to shaft.
	57.19-104	Suitable clearance for safe movement of men and equipment at shaft station	75.1403-10e	Similar to 75.1403-8e.
4.1 Vertical shafts	57.19-54	Ropes guides to be some type of locked coil construction	75.1403-8e	Positive stop blocks on all tracks leading to shaft.
	57.19-61	Safe hoisting speed to be determined for a given shaft (not to exceed 2500fpm)	75.1403-103	Similar to 75.1403-8e.
			75.1403-11	All shafts to have self-closing safety gates.
	57.19-100	Shaft gates at landings to be present and kept closed during hoisting		
	57.19-102	Shaft guides are required (rope, wood or steel)		

TABLE 8.1 - MHSA Regulations - cross reference (Continued)

Item	Metallic & non metallic		Coal	
	Ref. No.	Comment	Ref. No.	Comment
4.1 Vertical shafts continued	57.19-106	Shaft sets to be kept in good repair and cleaned of hazardous materials		
	57.19-109	Substantial shaft repair platforms and overhead protection required		
	57.19-120	Requirement for systematic procedures for shaft inspection		
	57.19-121	Records for shaft inspection to be kept for 3 years		
	57.19-130	Requirement for checking that shaft is clear after (a) hoist or shaft repairs (b) hoisting oversize or overweight equipment (c) blasting in or near the shaft (d) remaining idle one shift or longer		
	57.19-133	Weekly shaft inspection requirement		
4.2 Slope Shafts	57.19-61 57.19-100 57.19-102	As for 4.1	75.1403-7f	Shaft/slope conditions to determine hoisting speeds
	57.19-106 57.19-109	Applies particularly where steep slopes are used ie 45° where accumulated material may fall substantial distances	75.1408-8	Criteria for track haulage roads (possible to interpret as trackage in a slope
	57.120 57.121 57.130 57.133	As for 4.1	75.1403-8e	Positive stop block or derailers to be installed at all tops and landings
	57.19-40	Idler, knuckle and curve sheave found in slope shafts to have suitable rope groove contours	75.1403-8e	Positive stop blocks on all tracks leading to shaft.
			75.1403-10e	Similar to 75.1403-8e
	57.19-135	Lubrication of shaft rope guide rollers (on inclines) required	75.1403-11	Safety gate required at top and landings.

TABLE 8.1 - MHSA Regulations - cross reference (Continued)

Item	Metallic & non metallic		Coal	
	Ref. No.	Comment	Ref. No.	Comment
5. Conveyances				
5.1 Skips	57.19-45	Bonnet required on any conveyance (skip included) used for lowering men in a vertical or steeply sloping incline		No regulation dealing with this item
5.2 Cages	57.19-45	As 5.1	75.1400-3d	Daily inspection requirement for loose, missing or defective parts
	57.19-66	Requirement for posting the maximum number of persons in any shaft or steep slope (45°) based on 1.5 ft^2 of floor area per person	75.1403-3d	Requirements for cages regarding enclosures, gates, safety chains for hoisting men
	57.19-70	Cages to be equipped with gates (implied) for man hoisting	75.1403-4	Interlocks requirement to prevent inadvertent opening of elevator doors while hoisting
	57.19-79	Provisions required for blocking of mine cars riding in cage	75.1403-7n	Drop bottom cars require additional locking device for manriding service
	57.19-92	Cages to be provided with means of communication with hoist operator		
5.3 Skip/Cage combinations	57.19-72	Cage portion to be enclosed, and hoisting speed to be reduced to a maximum of 1000 fpm when hoisting both men and muck	75.1403-2e	Self dumping cages require a lock to prevent tilting when man hoisting
		Prohibition of man and muck hoisting during shift changes	75.1403-7n	Similar requirement for drop-bottom cars
5.4 Counter-weights	--	No regulations dealing specifically with these items	--	No regulation dealing with these items
5.5 Loading pockets	57.19-103	Loading facilities to minimize spillage of muck	--	No regulation dealing with this item

TABLE 8.1 - MHSA Regulations - cross reference (Continued)

Item	Metallic & non metallic		Coal	
	Ref. No.	Comment	Ref. No.	Comment
5.6 Guide shoes	--	No regulations dealing specifically with these items	75.1400-3d	Cage parts are referenced
5.7 Guide rollers		No regulations dealing specifically with these items	75.1400-3d	Cage parts are referenced
5.8 Safety devices	57.19-132	Performance drop test of the safety catches to be made in the shaft or on a mock up of the shaft Performance certification in writing required from manufacturer or a registered professional engineer Requirement for weekly operational test of safety catches Requirement for daily visual inspection by competent person	75.1400 75.1400-2 75.1400-3c	General requirement for safety devices and 2-month test requirement Recording of test results required in 75-1400 Daily examination of safety catches
6. Rope Attachments 6.1 Thimble and clip attachment	57.19-24	Required method of rope attachment to conveyance Nature of thimble and clip connection Number and spacing of clips Special slings attached to hoist rope with clips	75.1400-3b 75.1403-7d	Daily inspection of rope attachments required Connection of hoist rope to conveyance by wire rope or chains
6.5 Spelter and resin socket	57.19-24	Alternative method of rope attachment		
6.6 Wedge socket	--	As per 6.2		
6.7 Swaged sockets	--	As per 6.2		
6.8 Wedge cappel	--	As per 6.2		

TABLE 8.1 - MHSA Regulations - cross reference (Continued)

Item	Metallic & non metallic		Coal	
	Ref. No.	Comment	Ref. No.	Comment
6. Rope attachments (Contd) 6.9 Tension and length adjustments	--	No specific regulation dealing specifically with this equipment		
6.10 Secondary rope attachments	57.19-26	Secondary attachments to be selected, installed, and maintained per manufacturers recommendations, although no implied requirement for such equipment	75.1403-36	Requirement for bridle chain or wire rope secondary rope attachment
6.11 Swivels	--	As per 6.9		
6.12 Pins	--	As per 6.9		
6.13 Rope detaching hooks	--	As per 6.9 although no regulation prohibits the use of such devices		
Hoisting procedures	57.19-55	Hoist operator requirement for any manually-operated hoist when there are any men underground	75.1403-7a	Procedures for mantrip operation and proximity to other trips
	57.19-56	Hoist operator "readily available" to hoist controls when there are men underground	75.1403-7b	Sufficient mantrip cars to prevent overcrowding
			75.1403-7c	Man trips not to be pushed
	57.19-57	Certification of health and fitness to perform duty of hoist operator by qualified physician	75.1403-7e	Safety goggles required on open mantrips
	57.19-58	Experienced hoistman to operate hoist with exception of training of new hoist operator or in event of emergency	75.1403-7g	All mantrips under supervision and operator to be familiar with the haulage rules
	57.19-61	Safe speed to be determined by shaft conditions - hoisting of men not to exceed 2500 fpm except in emergency	75.1403-7i	Procedures regarding safety in handling explosives

TABLE 8.1 - MHSA Regulations - cross reference (Continued)

Item	Metallic & non metallic		Coal	
	Ref. No.	Comment	Ref. No.	Comment
Hoisting procedures (Contd)			75.1403-7j	Operator not to proceed unless mantrip has clear road
			75.1403-7k	Supplies and tools not to be transported with men on mantrip
	57.19-63	Only authorized persons to be in hoist room	75.1403-7o	Criteria regarding transport of extraneous material or supplies on top of equipment
	57.19-65	Lowering of conveyances by brakes only with the exception of emergency situations prohibited		
	57.19-66	Determination of and posting of the number of men riding a conveyance in a shaft at greater than or equal to 45° slope		
	57.19-67	Authorized person to be in charge of mantrips		

TABLE 8.2 - Coal Regulations - Cross Reference

Regulation referenced	Item referenced	Index No.	Comment
75.1400 (Statutory Provisions)	hoist, general	2.	General requirements for hoists are established. Emphasis is on any hoists used to transport persons.
	overspeed protection	2.2.4	
	overtravel protection	2.2.2	
	automatic "stop" control	2.2.2	Safety catches overspeed and over-travel protection to be provided on such hoists.
	brakes	2.1.3	
	skips	5.1	
	cages	5.2	Automatic stops are required on any such hoists.
	platforms	-	
	safety catches	5.8	Safety catches to be provided and tested.
	elevators	-	
	daily inspection	-	Daily inspection requirement is stated.
	hoisting procedures	-	
75.1400-1	brakes	2.1.3	
75.1400-2	safety catches	5.8	Recording of tests.
75.1400-3	hoisting equipment - general	2.	Daily examination requirements.
75.1400-3(a)	ropes	-	Not within scope of this report.
" -3(b)	rope attachments	6.	Daily examination requirement.
" -3(c)	safety catches	5.8	" " "
-3(d)	cages, elevators platforms	5.2	" " "
-3(e)	headsheaves	3.1	" " "
-3(f)	shafts	4.1/4.2	" " "
75.1400-4	daily inspection	-	Recording of daily examinations.
75.1401	hoists, general	2.	Rated capacity commensurate with loads.
	position indicator	2.2.2	Required on all hoists.
75.1401-1	ropes	-	Not within the scope of this report.
75.1401-2	hoists, general	2.	Changes affecting rated capacity.
75.1401-3	position indicator	2.2.2	Clear view by hoistman.
75.1402	communications	2.2.5	At least two means of communications.
75.1402-1	communications	2.2.5	Audible signal requirement.
75.1402-2	communications	2.2.5	Daily testing requirement.
75.1403	other safeguards	-	Any safeguards deemed necessary by secretary or authorized representative.

TABLE 8.2 - Coal Regulations - Cross Reference (Continued)

Regulation referenced	Item referenced	Index No.	Comment
75.1403-1(a)	Other safeguards	-	Subsequent sections 1403-2 to -11 set out criteria by which hoisting plant is evaluated for required safeguards.
75.1403-1(b)	" "	-	Establishment of a time limit dependent on the addition of a safeguard.
75.1403-1(c)	" "	-	Withdrawal order still operational in the event of imminent danger.
75.1403-2	Hoists, general	2.	
	Brakes	2.1.3	Brakes are required, having ability to stop and hold.
75.1403-3(a)	Clutches	2.1.4	Brake/clutch interlock required on man-hoist.
	Brake/Clutch interlocks	2.2.2	
75.1403-3(b)	Secondary rope attachments	6.10	Secondary rope attachment should be present.
75.1403-3(c)	Hoist drum	2.1.2	Rope termination at drum should have dead wraps plus a fixed attachment to drum.
75.1403-3(d)	Cages	5.2	Cages used for hoisting men to have equipment such as side enclosures, safety gates and chains.
75.1403-3(e)	Self-dumping equipement (i.e. skips)	5.1	Locking device requirement on any self-dumping conveyance used for man transport
75.1403-3(f)	Hoisting procedures	-	Attendant requirement.
75.1403-3(g)	Shafts	4.1/4.2	Precautions to prevent injury to men working in shafts
	Hoisting procedures	-	
75.1403-3(h)	Shafts	4.1/4.2	Men working in or over shaft require safety belts.
75.1403-4(a)	Automatic elevators (cages)	5.2	Cages to be equipped with interlocks.
	Hoisting safety	2.2.2	Door interlocks.

TABLE 8.2 - Coal Regulations - Cross Reference (Continued)

Regulation referenced	Item referenced	Index No.	Comment
75.1403-4(b)	Brakes	2.1.3	Controlled from the conveyance, system should be able to stop the conveyance anywhere in the shaft.
	Hoisting safety	2.2.2	
	Hoist communication	2.2.5	
75.1403-4(c)	Brakes	2.1.3	Interlocked slack cable device to cut power to hoist and apply the brakes.
	Hoisting safety	2.2.2	
	Electrical components	2.3	
75.1403-4(d)	Shaft communications	2.2.5	Communications from cage to surface for calls for assistance.
75.1403-3	Conveyors	-	Not covered in this report.
75.1403-6	Self-propelled personnel carriers	-	Not covered in this report.
75.1403-7(a)	Hoisting procedures	-	Not strictly applicable to slope hoisting, since downgoing conveyances pass at same point in shaft with two conveyances in a double-drum hoist.
75.1403-7(b)	Hoisting procedures	-	Prevention of overcrowding.
75.1403-7(c)	Hoisting procedures	-	Not applicable.
75.1403-7(d)	Rope attachment	6.	Chains, steel rope, or other devices to attach rope to mantrip.
75.1403-7(e)	Hoisting procedures	-	Safety gear for open mantrips (applies to all mantrips including those which are hoist-assisted.
75.1403-7(f)	Hoisting procedures	-	Criteria for determining hoisting speed.
	Shafts	4.2	Shaft conditions govern speed of hoist.
	Overtravel protection	-	Supervision requirements for mantrips.
75.1403-7(h)	Hoisting procedures	-	Orderly loading and unloading of mantrips.
75.1403-7(i)	Hoisting procedures	-	Criteria regarding transport of explosives and detonators, etc.
75.1403-7(j)	Hoisting procedures	-	Operator to have assurance that trip is on a clear road, (slope).

TABLE 8.2 - Coal Regulations - Cross Reference (Continued)

Regulation referenced	Item referenced	Index No.	Comment
75.1403-7(k)	Hoisting procedures	-	Transport of men with equipment, and small hand tools.
75.1403-7(h)	Slope shafts	4.2	Adequate space for access to man-trip and clearance from live electrical circuits.
75.1403-7(m)	-	-	Not applicable.
75.1403-7(n)	Skips	5.1	Drop-bottom cars (normally coal carriers) used for man transport require added locking devices.
75.1403-7(o)	-	-	Not applicable.
75.1403-8(a)	Sloped shafts	4.2	Rails, joints, switches, etc. determine hoisting speed.
75.1403-8(b)	-	-	Not applicable.
75.1403-8(c)	-	-	Not applicable.
75.1403-8(d)	Sloped shafts	4.2	Slopes to be kept clear of debris and other items.
75.1403-8(e)	Vertical shafts Sloped shafts	4.1 4.2	Stops and/or derails on all track near slopes, shafts, surface inclines.
75.1403-9(a)-(d)	-	-	Not applicable.
75.1403-9(e)	Sloped shafts	4.2	Criteria for shelter hole at a slope landing.
75.1403-10(a)	-	-	Not applicable.
75.1403-10(b)	Conveyances	5.	Criteria for pushing conveyances near shafts, slopes or surface inclines.
75.1403-10(c)-(d)	-	-	Not applicable.
75.1403-10(e)	Shafts	4.1	Stop blocks or derails to be used to prevent runaway haulage equipment.
75.1403-10(f)-(m)	-	-	Not applicable.
75.1403-11	Shafts Sloped shafts	4.1 4.2	Self-closing safety gates required at all station and surface entrances to shafts or slopes.
75.1807	Hoists, General	2.	Daily inspection record books.

TABLE 8.3 - Metallic and Nonmetallic Regulations - Cross Reference

Regulation referenced	Item referenced	Index No.	Comment
57.19-1	Hoists	2.1	Rated capacity.
57.19-2	Bearings/Mountings	2.1.6	Anchor securely.
57.19-3	Man-hoist	2.1.5	Drives - no belts, rope or chains.
57.19-4	Brakes	2.1.3	Shall be capable of holding full load at any point in the shaft.
57.19-5	Clutch/brake	2.1.3	Interlock requirement.
57.19-5	Clutch/brake	2.1.4	" "
57.19-6	Brakes, safety device	2.1.3	Apply brakes on power failure.
57.19-7	Overtravel and overspeed	2.2	Requirement for protective devices.
57.19-8	Friction hoist synchr-onizer	2.2	Requirement for synchronizer on friction hoist.
57.19-9	Position Indicator	2.2	Requirement for.
57.19-10	Hoist controls, signals	2.2	Locate controls so hoistman can hear signals.
57.19-11	Drums	2.1.2	Requirement for flanges to extend beyond last wrap of rope.
57.19-12	Drums-grooving	2.1.2	Requirements for grooving.
57.19-13	Diesel powered hoists	2.1.2	Requirement for cutoff.
57.19-14	Tapered guides	4.1	Requirement for use with friction hoists.
57.19-17	Emergency stop switch	2.2	Requirement for.
57.19-18	Overtravel bypass switch	2.2	Requirement for.
57.19-21	Ropes		Static factors of safety.
57.19-22	Rope/drum fastening	6.	Requirement for.
57.19-24	Rope Attachments	6.	Attaching load to rope - requirements.
57.19-26	Safety device attachments to ropes	6.	Shall not damage rope.
57.19-35	Headframes	3.3	Design requirements.
57.19-36	Headframes	3.3	Allowance for overtravel.
57.19-37	Hoist layout	3.3	Fleet angle requirements.
57.19-38	Headsheaves, platforms	3.1	Requirement for toeboards and handrails.

TABLE 8.3 - Metallic and Nonmetallic Regulations - Cross Reference (Continued)

Regulation referenced	Item referenced	Index No.	Comment
57.19-39	Hoist drums	2.2.2	Diameter requirement.
	Sheaves	3.1	
57.19-40	Sheaves	3.1	Groove requirement.
"	"	3.2	
57.19-45	Conveyances	5.	Requirement for metal bonnet.
57.19-49	Buckets	-	When used.
57.19-50	Buckets	-	Requirements for use.
57.19-53	Sinking platform	-	Rope requirement.
57.19-54	Rope guides	4.1	Requirement for locked coil construction.
57.19-55	Hoist procedures		
57.19-58			
57.19-61	Hoisting speed		Determination of maximum speed for man hoisting.
57.19-62	Hoist acceleration and deceleration	2.2	Limits for
57.19-63	Hoist rooms		Procedure
57.19-65	Hoisting procedure		Lowering conveyances by brakes alone.
57.19-66	Hoisting procedure		Maximum men in a conveyance.
57.19-67 -71	Hoisting procedure		Man hoisting procedures.
57.19-72	Skip/cage conveyance	5.3	Cage requirements and limit to man speed.
57.19-73	Shaft compartment	4.1/4.2	Hoisting men in men/rock shaft.
	Hoisting procedure	-	
57.19-74	Shaft inspection	4.1/4.2	Procedures
	Hoisting procedure	-	
57.19-75	Open hooks	6.	Shall not be used to hoist buckets or other conveyances.
57.19-76	Buckets	-	Speed limits, hoist procedure.
57.19-77 -78	Buckets	-	Procedure when hoisting.
57.19-79	Mine cars cages, skips	4.1/4.2 5.1/5.2	Requirements for blocking mine cars.

TABLE 8.3 - Metallic and Nonmetallic Regulations - Cross Reference (Continued)

Regulation referenced	Item referenced	Index No.	Comment
57.19-80	Hoisting tools		Proper procedure.
57.19-81	Hoising procedure		Conveyance not in use.
57.19-83	Overtravel switch	2.2	Requirement for device to allow hoistman to remove conveyances form overtravel position.
57.19-90	Signals	2.2.5	Requirement for two systems.
57.19-91	Signals	2.2.5	Procedure
57.19-92	Signals	2.2.5	Method to signal hoist operator from conveyance at any point in shaft.
57.19-93	Signals	2.2.5	Requirement for standard signal code.
57.19-94	Signals	2.2.5	Requirement to post code.
57.19-95	Signals	2.2.5	Location of signalling device.
57.19-96	Signals	-	Procedure
57.19-100	Shaft landing gates	4.1/4.2	Requirements
57.19-101	Stop blocks		Requirement for
57.19-102	Shaft guides	4.1/4.2	Requirement for
57.19-103	Dump facility	4.1/4.2	Requirement to minimize spillage into shaft.
57.19-104	Shaft stations	4.1/4.2	Requirement for clearance
57.19-105	Shaft station	4.1/4.2	Design requirement
57.19-106	Shaft sets	4.1/4.2	Maintenance requirement.
57.19-107 -108	Shaft repair and maintenance	4.1/4.2	Procedure.
57.19-109	Shaft inspection and maintenance	4.1/4.2	Work platform requirements.
57.19-110	Shaft bulkhead	-	For deepening shafts
57.19-111	Shaft ladders/escape hoist	4.1/4.2	Requirement during shaft sinking.
57.19-120	Inspection, testing, and maintenance procedure	-	Requirement for
57.19-121	Records	-	Required records for inspection testing and maintenance.

TABLE 8.3 - Metallic and Nonmetallic Regulations - Cross Reference (Continued)

Regulation referenced	Item referenced	Index No.	Comment
57.19-122	Hoist parts	-	Requirement.
57-19-123	Wire ropes	-	Inspection, testing and maintenance.
57.19-124	" "	-	" " "
57.19-125	" "	-	" " "
57.19-126	" "	-	" " "
57.19-127	" "	-	" " "
57.19-128	" "	-	" " "
57.19-129	Hoistman tests	7.	Test overtravel, deadman controls, position indicators and braking mechanisms at the beginning of each shift.
57.19-130	Hoisting		Procedure
57.19-131	Conveyance connections	6.	Requirement for inspection.
57.19-132	Safety catches	5.8	Requirement for inspection and testing.
57.19-133	Shafts		Requirement for inspection.
57.19-134	Sheaves	4.1/4.2 3.1/3.2	Requirement for inspection and lubrication.
57.19-135	Rollers	4.2	Requirement for lubrication and repair.

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