



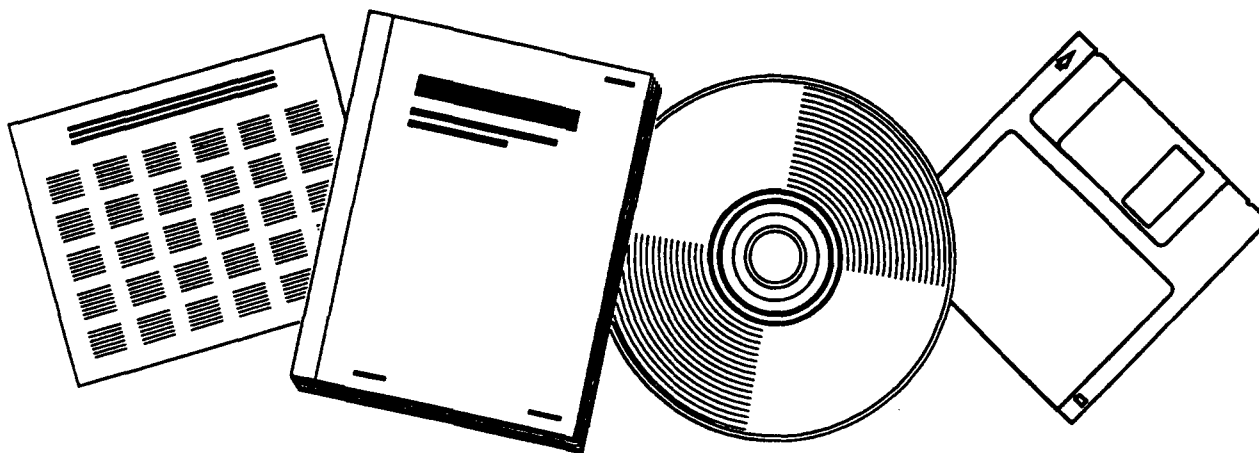
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MINE HOIST ELECTRICAL SYSTEMS STUDY VOLUME I - MINE HOIST ELECTRICAL SYSTEM INSPECTION MANUAL

**COLORADO SCHOOL OF MINES
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MINE HOIST ELECTRICAL SYSTEMS STUDY VOLUME I — MINE HOIST ELECTRICAL SYSTEMS INSPECTION MANUAL

Contract No. J0134006

Mining and Engineering Departments, Colorado School of Mines

Bureau of Mines Open File Report 83-86

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UNITED STATES DEPARTMENT OF THE INTERIOR**



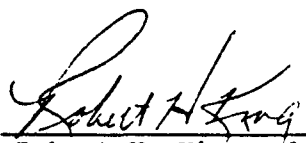
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CERTIFICATION OF THE ABSENCE OF PATENTS AND INVENTIONS

This statement certifies that at the grant report date, no inventions have been developed from phase I of Contract J0134006. Consequently, no patents are pending.



Robert H. King, Phase I
Project Director

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FOREWORD

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1. GENERAL INTRODUCTION TO HOIST ELECTRICAL INSPECTION

1.1 Introduction

This manual is intended to be used as a hoist electrical system inspections guide to prevent an unsafe condition or practice from resulting in an accident. To this end the manual is organized in the following manner.

Section 1 states the purpose of the manual and contains an introduction to hoisting circuits and systems.

Section 2 is a summary of hoist inspection. Checklists are provided for use during daily, weekly, monthly, and annual hoist inspections.

Section 3 lists the pertinent hoisting system requirements from the Code of Federal Regulations (CFR) Title 30, parts 57 and 75 for underground metal/nonmetal mines and coal mines.

Section 4 introduces the reader to ac and dc drives, manual, semi-automatic, and automatic hoist controls. Suggested checklists are included and items with a history of frequent failure or maintenance are highlighted. Applicable regulations are referenced in the checklist for drive systems. This section contains a complete listing of safety circuits required by federal law as well as suggested and commonly installed circuits.

Section 5 of this manual lists suggested maintenance and inspection procedures for circuit breakers, relays, and motor starters found on hoist systems.

Section 6 contains maintenance and inspection procedures for the more common sensors placed on hoist drives, in shafts, and on conveyances to provide information to the hoist controller.

Section 7 of this manual is devoted entirely to the inspection of Lilly¹ Controllers. This is by far the most common hoist controller in the industry worldwide but yet the least understood. Because of the universal acceptance of the Lilly¹ Controller all models are described and recommended inspection practices and checklists are listed.

Section 8 discusses maintenance and inspection procedures for brake cars, commonly found in use with coal mine slope hoists.

Section 9 lists suggested inspection and maintenance procedures for elevators, commonly found in coal mines and on headframes of metal/non metal mines.

Where appropriate, suggestions to improve the safety of a hoist electrical system based on practice in the mining industry and recommendations from manufacturers have been included.

1.2 PURPOSE

This manual has been written with a single purpose in mind; to save human lives. Because of the number of hoists in use at mines throughout the United States it is now more important than ever that all hoist systems be fully inspected and proven safe on a regular basis.

Safety inspections can be performed either by government inspectors or mine personnel, as long as the individual performing the inspection has a complete understanding of the hoist system. This manual provides the background information necessary for mine inspectors or mine personnel to perform an inspection of the hoist electrical system, and be able to recognize an unsafe condition: **IT DOES NOT PROVIDE ALL INFORMATION REQUIRED TO CORRECT POSSIBLE UNSAFE CONDITIONS.**

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

All mine hoists are extremely complex and intricate pieces of machinery. Work performed on any mine hoist should only be performed by personnel thoroughly trained in such procedures. The amount of training required is beyond a publication of this size and detail, but rather the expertise must be gained from wide experience or from formal training. For this reason it is necessary that all repair work be referred to properly trained and qualified personnel.

If an unsafe condition is found, properly trained expertise should always be sought to correct the condition. More often than not, an unqualified person attempting to correct an unsafe condition such as may occur on a hoist electrical system will only aggravate the problem.

Every mine hoist in the world is different in one way or another. This is a general manual that may be applied to many hoists. For this reason, the user may find that some item on a particular hoist is not covered or not applicable. If this case should arise, it is suggested to refer to the manuals supplied by the hoist manufacturer for additional information. If no manuals are available for the hoist, the Technical Support groups of the Mine Safety and Health Administration, (MSHA) located in Denver, Colorado and Pittsburgh, Pennsylvania may be contacted for further information. Their phone numbers are:

Denver Tech Support
303-236-2644

Pittsburgh Tech Support
412-675-6959

The manual contains only the requirements for the hoist electrical control inspection. This should not be construed as an indication that the rest of the hoist is not to be inspected, but rather quite the

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

contrary. The hoist mechanical inspections should be conducted with the same diligence and frequency as the hoist electrical inspections. Many times the two inspections can be conducted at the same time by different personnel to avoid prolonged down time of the hoist. To obtain information on a hoist mechanical inspection refer to "Procedures for Hoist and Shaft inspection and maintenance," published in 1981 as a final report on USBM contract #J0100035.

To obtain the maximum value from this manual, a hoist inspection schedule should be planned and followed. If the inspections occur on a regular basis, they can reveal relative changes that are critical to maintaining a safe hoist.

Device symbols² and numbers³ are standardized throughout the mining industry. Table 1 contains many of the symbols commonly used for one line electrical diagrams. Table 2 lists Institute of Electrical and Electronics Engineers device numbers and functions, while table 3 lists the device numbers commonly found in mining.

Figure 1 shows a full magnetic hoist controller that is quite typical of some older mine hoists. Both are simplified for the purpose of convenient reference.

Figure 2 is a general layout of the mine hoisting system showing shaft limits, drive motors, and various sensing devices.

² "Graphic Symbols for Electrical Diagrams," ANSI Standard Y32.2-1970

³ "Device Numbers," ANSI Standard C37.2-1970

	AIR CIRCUIT BREAKER REMOVEABLE TYPE DH		RECTIFIER BANK
	CIRCUIT BREAKER NON-DRAWOUT TYPE (OIL OR VACUUM)		REACTOR NON-MAGNETIC CORE
	AIR CIRCUIT BREAKER DRAWOUT TYPE		REACTOR MAGNETIC CORE
	AIR CIRCUIT BREAKER NON-DRAWOUT TYPE SERIES TRIP		POWER TRANSFORMER
	MAGNETIC STARTER		3-PHASE POWER TRANSFORMER CONNECTED "DELTA-WYE"
	CURRENT-LIMITING BREAKER DRAWOUT TYPE		Δ DELTA Y WYE
	DISCONNECTING FUSE NON-DRAWOUT		CURRENT TRANSFORMER WITH AMMETER, LETTER INDICATES INSTRUMENT TYPE
	DRAWOUT FUSE		RELAYS CONNECTED TO P.T.S & C.T.S. NUMBER INDICATES RELAY TYPE FUNCTION
	DISCONNECTING SWITCH NON-DRAWOUT		RELAY
	DISCONNECTING SWITCH DRAWOUT TYPE		INDUCTION MOTOR OR GENERAL SOURCE
	CURRENT TRANSFORMER		SYNCHRONOUS MOTOR
	POTENTIAL TRANSFORMER		GROUND
	POTHEAD		OVERCURRENT
	GROUND		DIFFERENTIAL
	SURGE ARRESTER		INSTRUMENT TRANSFER SWITCH LETTER INDICATES TYPE
	SURGE CAPACITOR		DUMMY CIRCUIT BREAKER REMOVEABLE TYPE
	BATTERY		FUTURE BREAKER POSITION REMOVEABLE TYPE
	CABLE TERMINATIONS		RESISTOR

Table 1 - Commonly Used Symbols for One-Line

Electrical Diagrams

(reference 28)

DEVICE NO.	FUNCTION	DEVICE NO.	FUNCTION
1	Master Element	52	AC Circuit Breaker
2	Time-Delay Starting Or Closing Relay	53	Exciter Or DC Generator Relay
3	Checking Or Interlocking Relay	54	High-Speed DC Circuit Breaker
4	Master	55	Power-Factor Relay
5	Stopping Device	56	Field Application Relay
6	Starting Circuit Breaker	57	Short-Circuiting Or Grounding Device
7	Anode Circuit Breaker	58	Power Rectifier Misfire Relay
8	Control Power Disconnecting Device	59	Overvoltage Relay
9	Reversing Device	60	Voltage Balance Relay
10	Unit Sequence Switch	61	Current Balance Relay
11	(Reserved For Future Application)	62	Time Delay Stopping or Opening Relay
12	Overspeed Device	63	Liquid Or Gas Pressure Level Or Flow Relay
13	Synchronous-Speed Device	64	Ground Protective Relay
14	Underspeed Device	65	Governor
15	Speed, Or Frequency Matching Device	66	Notching Or Jogging Device
16	(Reserved For Future Application)	67	AC Directional Overcurrent Relay
17	Shunting Or Discharge-Switch	68	Blocking Relay
18	Accelerating Or	69	Permissive Control Device
19	Starting to Running Transition	70	Electrically Operated Rheostat
20	Electrically Operated Valve	71	(Reserved For Future Application)
21	Distance Relay	72	DC Circuit Breaker
22	Equalizer Circuit Breaker	73	Load Resistor Contactor
23	Temperature Control Device	74	Alarm Relay
24	(Reserved For Future Application)	75	Position Changing Mechanism
25	Synchronizing Or Synchronism Check	76	DC Overcurrent Relay
26	Apparatus Thermal Device	77	Pulse Transmitter
27	Undervoltage Relay	78	Phase-Angle Measuring Or Out-Of-Step Protective Relay
28	(Reserved For Future Application)	79	AC Reclosing Relay
29	Isolating Contactor	80	(Reserved For Future Application)
30	Annunciator Relay	81	Frequency Relay
31	Separate Excitation Device	82	DC Reclosing Relay
32	Directional Power Relay	83	Automatic Selective Control Or Transfer Relay
33	Position Switch	84	Operating Mechanism
34	Motor-Operated Sequence Switch	85	Carrier Or Pilot-Wire Receiver Relay
35	Brush-Operating or Slip-Ring Short-Circuiting Device	86	Locking-Out Relay
36	Polarity Device	87	Differential Protective Relay
37	Undercurrent Or Underpower Relay	88	Auxiliary Motor Or Motor Generator
38	Bearing Protective Device	89	Line Switch
39	(Reserved For Future Application)	90	Regulating Device
40	Field Relay	91	Voltage Directional Relay
41	Field Circuit Breaker	92	Voltage And Power Directional Relay
42	Running Circuit Breaker	93	Field-Changing Contactor
43	Manual Transfer Or Selector Device	94	Triping Or Trip-Free Relay
44	Unit Sequence Starting Relay	95	(Reserved For Special Application)
45	(Reserved For Future Application)	96	
46	Reverse-Phase-Balance Current Relay	97	
47	Phase-Sequence Voltage Relay	98	
48	Incomplete Sequence Relay	99	
49	Machine Or Transformer Thermal Relay		
50	Instantaneous Overcurrent Or Rate-Of-Rise Relay		
51	AC Time Overcurrent Relay		

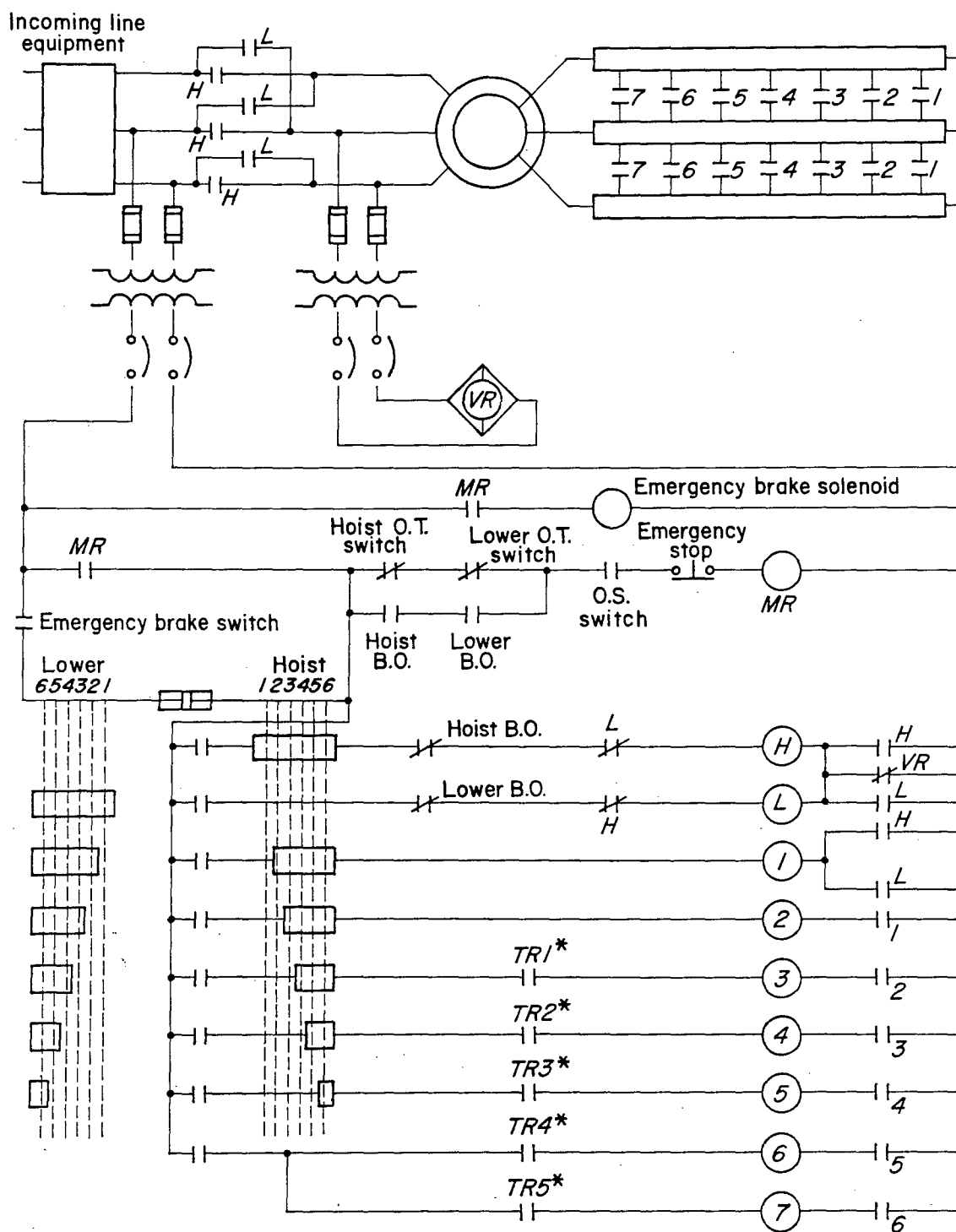
Table 2 - IEEE Device Numbers and Functions

(reference 28)

1	Control switch
3	Plug interlock relay
37	Ground-continuity check undercurrent relay
49 D	Diode thermal relay
49 GR	Grounding resistor thermal relay
49 T	Transformer thermal relay
50	Instantaneous overcurrent relay - a-c
51	Time delay overcurrent relay - a-c
50 G	Instantaneous overcurrent relay - d-c - connected in ground wire
50 N	Instantaneous overcurrent relay - a-c - connected to neutral
51 N	Time-delay overcurrent relay - a-c - connected to neutral
50 Z	Instantaneous current balance relay - a-c - zero sequence
51 Z	Time-delay current-balance relay - a-c - zero sequence
52	a-c circuit breaker
59 GR	Ground protective relay - d-c unbalance relay
72	d-c circuit breaker
76	d-c overcurrent relay
A	Ammeter
D	Demand Meter
GD	Ground Detector
PF	Power Factor
V	Voltmeter
VA	Volt-ammeter
VAR	Varmeter
W	Wattmeter
WH	Watthour meter

Table 3 - Device Numbers Common to Mining

(reference 28)



*For simplification, timing relay operating coils are not shown.

Figure 1

Full Magnetic Hoist Controller

Typical of Some Older Hoists

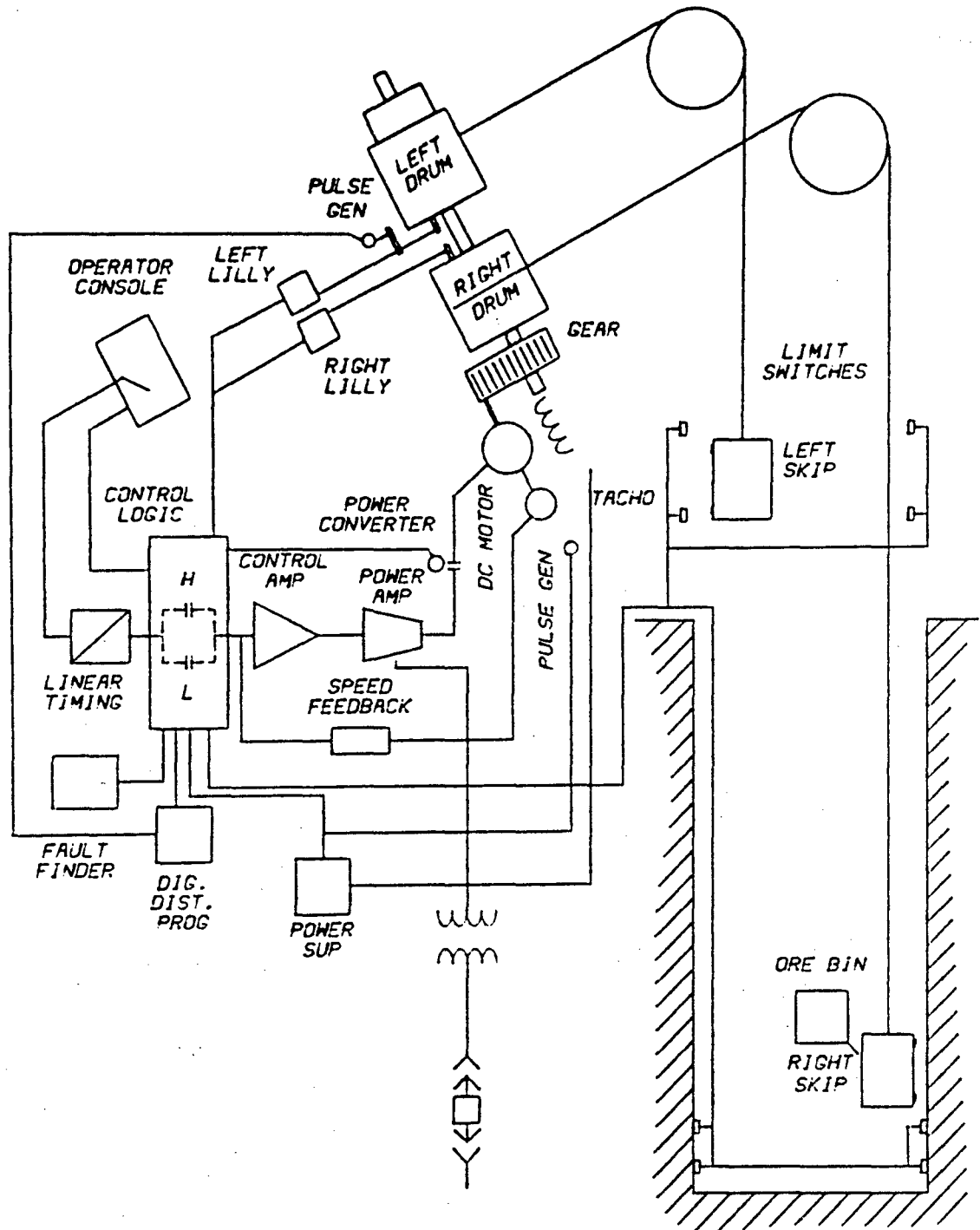


Figure 2

General Mine Hoist Layout

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ASARCO

Texasgulf, Wyoming Potash Operation

Tenneco

Allied Chemical Co.

Bethlehem Mines

U. S. Steel Mining Co.

Peabody Coal Co.

Kitt Energy Co.

2. SUMMARY OF HOIST INSPECTION

Mine hoists are very complex and varied. Control systems can be very simple in the case of single level, manually controlled hoists. In the case of automatic multi-level hoisting, the control and drive systems can be extremely complex computer controlled systems. This manual has been written to include electrical components and sensors found on many of the hoists in use. It is virtually impossible to produce a document that will include every item on every hoist.

Users of this document should have a fairly good understanding of the basic hoist control systems before attempting to apply this section to actual hoist inspection. It is essential that the user read the following, more detailed sections of this document that deal with the regulations, hoist drive systems, electrical switchgear, and sensing devices applicable to mine hoists.

Control systems should be maintained according to the manufacturer's instructions. This may range from simply changing filters on the cabinet ventilation system to routine cleaning of the contactors and relays.

Switches in the hoist control panel are normally maintenance free and are usually replaced when they fail to operate. Likewise, solid state components on programmable controllers or computer controlled hoists are normally replaced with a new or factory repaired unit when they fail to operate correctly.

Cleanliness is the key to effective hoist maintenance. Cabinets should be kept closed, and ventilation filters should be replaced regularly. If dust buildup seems to be excessive within electrical cabinets, there are leaks in the cabinets or the filters are not

effective. Dust, dirt, and water can reduce the effective life of electrical switchgear tremendously.

Overheating may be a problem in warmer climates or in poorly ventilated hoist houses. If frequent tripping of thermal overloads or protection devices is experienced, careful consideration should be given to improving the ventilation system.

All inspection procedures discussed within this manual have deliberately been kept rather simple and straight-forward. As a result very little equipment is necessary to conduct any of the inspections. However, the following items would prove very helpful in conducting a hoist electrical inspection:

- hoist and controller manufacturer manuals
- stopwatch
- flashlight
- stethoscope
- long screwdriver
- multimeter
- rubber or other insulating mat
- lock and tags
- clipboard and note pad
- insulating gloves
- safety glasses
- electrical diagrams of system being inspected
- hammer
- tachometer

2.1 Hoist Motors

The first thing noticed upon entering the hoist house is normally the hoist drum and motor. The inspection of a mine hoist should begin with a visual, audible, and odor inspection of the hoist motor. Detailed instructions for this can be found in section 4 but a brief review is included here.

The motor should not have water or other liquids dripping on it. If the hoist is located underground this may often be a problem. To minimize water damage it is suggested to erect a grounded metal shed of

some type to divert the water, or place a heavy plastic or some type of water proof flame retardant frame over the motor that doesn't restrict cooling air. Care must be taken to maintain adequate ventilation for cooling and drying of the motor. During extended shut-downs in high humidity environments heaters should be placed near the motors and other switchgear and controls to keep them dry.

The physical appearance of the motor should be noted including condition of the brushes and commutator in the case of a dc motor and loose mounting bolts. Grease-packed bearings should always be examined and the presence or lack of grease should be determined. If the bearings appear to be overgreased, this should be noted. Excess grease from lubrication of the motor bearings and drives as well as from the hoist rope should be cleaned up. Good housekeeping habits reflect the attitude of the personnel responsible for the maintenance and inspection of the hoist and reduces fire hazard and personnel slipping hazards.

The motor should be grounded with a separate grounding conductor. When looking for the electrical ground all of the electric ground connections to the motor should be examined and tested with an ohmmeter. ALL POWER SHOULD BE REMOVED FROM THE SYSTEM AND LOCKED OUT BEFORE CONTACTING ANY ENERGIZED ELECTRICAL PART. The connections and splices should be permanent and not temporary. Motor vibration may cause shorting or failure of the connections if not made in a permanent manner. Additionally, all electrical connections should be adequately insulated to prevent arcing to ground conductor and cable entrances to enclosures should be checked for proper bushings.

The sensors placed on the motor to detect vibration, overspeed, overtemperature or other unfavorable condition should be inspected. Detailed instructions for this can be found in Section 6 of this document or in the documentation supplied by the manufacturer of the hoist.

The gear reduction system connecting the motor to the hoist should be inspected next. The drive should be properly lubricated, but not have excess lubricant spilled or overflowing from breather ports. If the hoist is equipped with a sensor to detect the loss of drive train integrity, the sensor should be checked to be certain it is in place and electrically connected to the hoist control system. This will in many cases be a tachogenerator mounted on the hoist drum or Lilly¹ Controller drive connected to a comparator and another tachogenerator mounted on the drive motor. When a difference in the expected speeds is sensed, the hoist will be shut down through the operation of a magnetic starter or loop contactor. Unfortunately the only way to be certain this circuit is working is to disconnect one of the sensors. THIS IS NOT RECOMMENDED FOR ORDINARY INSPECTIONS. This should only be done by properly trained personnel during monthly or annual inspections.

2.2 Hoist Drums

In the area of the hoist drums, several items exist that should be inspected. The first item to be considered is the brake wear indicator switch. This will in many cases consist of a limit switch placed adjacent to the brake application weights that will be operated when the

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

weights travel a predetermined distance indicating excessive brake wear. It may also be a magnetic proximity switch that will sense a difference in the distance to a point on the brake weights. The distance may change as the brakes wear to an unsafe condition.

Limit switches can be operated manually to determine that they are operable. Magnetic proximity switches are somewhat more difficult to inspect and will also exhibit a wider span between the on and off conditions. See sections 6.5 and 6.6 for detailed inspection procedures.

Large hoists will have brakes that are held in the off position with hydraulic or air pressure. Typically, the system will often have a safety circuit that will apply the hoist drums if hydraulic or air pressure is lost. Inspection can be accomplished by shutting off the hydraulic pump or the air supply. Do not perform this inspection with the hoist in a full speed operating condition as it will usually result in an emergency stop.

Continuing, at some point along the route of the wire rope from the hoist drum to the head sheave, there should be a sensor to detect slack rope. This may consist of a photo electric device located below the normal path of the wire rope, a wire stretched below the rope path, or in the case of a slope hoist it may be a roller mounted on a spring and limit switch assembly.

In the case of an infra-red sensor, operation may be assured by passing a stick or other solid item of equal or lesser diameter than the wire rope between the transmitter and receiver. If the hoist is equipped with a wire placed under the path of the rope it may be

inspected by pulling the wire to operate the limit switch. This should cause an emergency stop.

If the hoist is located on a slope instead of a shaft, the rope may become slack when the car is pulled to the surface. For this reason, the slack rope sensor may consist of a roller that is mounted on an adjustable spring and limit switch assembly. The limit switch should be operated by the weight of the rope on the roller. However, if adjustable, the spring should not be set soft enough to cause nuisance tripping of the circuit.

2.3 Power Supply

The power supplies to hoist drive motors are extremely variable depending on whether the hoist motor is ac or dc.

In the case of ac drive motors, the power supply will consist of the incoming voltage being converted to utilization voltage and the protective switchgear associated with this conversion. AC powered systems are thoroughly discussed in section 4.4

Dc motor power supplies will consist of thyristor or motor-generator sets to provide dc power from the incoming ac line voltage. Inspection of thyristor drive systems is discussed in section 4.2, and inspection of motor-generator (M-G) sets is discussed in section 4.3.

2.4 Hoist Control Systems

Hoist control systems are perhaps the most difficult portion of the hoist to inspect. They certainly contain nearly as many variations as there are types of hoists in use.

Hoist control systems can be grouped into three categories; automatic, semi-automatic, and manual. Regardless of how the hoist is

operated, there will nearly always be at least one backup system to control overspeed and overtravel of the conveyance. This may take the form of a mechanical controller such as the Lilly¹ controller, (discussed in section 7), solid state programmable controllers, or a combination of centrifugal switches and limit or proximity switches (discussed in Sections 6.5 and 6.6) in the shaft. Before beginning an inspection of the hoist control system, the nature of the system should be determined.

After determining how the hoist is controlled, the easiest way to determine if the controls are functioning correctly is to operate the hoist through a complete cycle with no load of materials or personnel in the conveyance, and of course be certain no one is working in the shaft or in the hoist area. This should include starting at the uppermost position of travel, accelerating to normal speed, traveling to the intermediate stops, and eventually decelerating to the final stop in the shaft. After reaching the lower stop in the shaft, reverse the cycle and move the conveyance back to the collar. A complete hoisting cycle will have been completed to ensure that the shaft guides and conveyance are all in good order.

MAKE SURE BRAKES ARE IN ADEQUATE CONDITION TO STOP THE CONVEYANCE AT ANY POINT IN THE SHAFT BEFORE ANY TESTS ARE INITIATED THAT REQUIRE MOVEMENT OF THE CONVEYANCE.

Upon completion of one complete hoisting cycle (for the purpose of checking guides and conveyance), begin a second cycle. Conduct this as

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a normal cycle, proceeding to the lower shaft station. At this point the conveyance should be moved at creep speed into the overtravel position. If there is more than one level of overtravel detection, the conveyance should be moved to the most extreme position at creep speed. If the hoist is equipped with alarms to sound at overtravel positions, be certain they function before continuing with the inspection.

While cycling the conveyance from one end of the shaft to the other, the position indicator should be consulted periodically to determine its accuracy. Additionally, the hoist controls should be equipped with an emergency stop switch that will initiate a safe stop of the hoist when it is activated. The emergency stop should sound an alarm or give some indication that it was activated to stop the conveyance. An alarm will aid as a reminder to other personnel in the area that the hoist should be checked out before being operated further. The E-stop (emergency-stop) should always be checked in mid shaft to prevent damage due to overtravel.

Possible overtravel limit schemes can include any or all of the following:

- programmable controller overtravel
- mechanical controller overtravel
- shaft limit or proximity switches.

The control system may use multiple applications of the same method in preventing overtravel. One such application would be the use of limit or proximity switches that will signify normal overtravel and then a second switch to operate as the final overtravel limit.

As the conveyance enters the overtravel zone an alarm may sound, followed by a shutdown of the hoist. If this is not the final

overtravel position, reset the hoist control circuit and move at creep speed to the final overtravel position. When the final overtravel position is reached, the hoist should stop, and the brakes should set.

The final overtravel limit is normally located within 10 to 15 feet of the first level of overtravel. If the conveyance travels farther than this without causing a trip out, stop the test and determine the location of final overtravel. DO NOT LOWER THE CONVEYANCE INTO THE SUMP! If the final overtravel never initiates a trip out isolate the problem and correct it before continuing with the hoist inspection. The brakes should set and the hoist should operate only in the opposite direction of travel.

After making certain the lower overtravel limits operate correctly, the hoist may be started and backed out of overtravel. To perform backout, the overtravel backout switch must be activated. If the hoist will operate without having the backout switch activated, or will operate in the other direction, or the brakes can be released with no holding torque the hoist controls are not functioning correctly. To isolate the problem first check for actual operation of the limits. If they operate physically, check for the correct electrical operation of the limits. Finally, check the wiring diagram to determine where they are connected in the control circuit and see that the circuit is correctly wired. THIS SHOULD ONLY BE DONE BY QUALIFIED PERSONNEL.

The hoist should now be operated in the up direction and moved into the upper overtravel limits. The procedure for determining correct operation of the upper limits is the same as that for the lower

limits. After assuring correct operation of the overtravel limits, the next step is to check the safeties that control the overspeed.

THIS ORDER OF TESTING SHOULD ALWAYS BE FOLLOWED; THAT IS, TEST OVERTRAVEL BEFORE OVERSPEED. IF THE OVERTRAVEL IS NOT CHECKED PRIOR TO THE OVERSPEED SEVERE DAMAGE MAY RESULT IF THE E-STOP OR OVERSPEED SHUT DOWN FAILS TO OPERATE.

Overspeed may be controlled with a mechanical governor, centrifugal overspeed switches on the hoist motors or hoist drums, through the use of a solid state programmable controller that accounts for the time rate of change of the conveyance position, or any combination of above. Before attempting to overspeed a hoist, the hoist operation manuals and trained personnel should be consulted to be certain that overspeed will not damage the hoist drive or control systems.

Overspeed of the conveyance should result in an emergency stop of the hoist. Depending on the particular hoist controller in use, an alarm may sound before the hoist brakes are applied. The rate of deceleration of the conveyance should be within the limits outlined in paragraph 3.1.16 of this document. Due to the damage that would result from an overtravel, the overspeed should be checked out in mid shaft. Because of the possibility for damage and excessive brake wear from performing this test, it is recommended that it be performed no more frequently than annually.

The simplest of inspections have been considered here. Complex automatic hoists may be, and often times are, equipped with fault indicating circuits that will give the location of the last fault in the controller before the hoist was stopped. Simple manually

controlled hoists may have nothing more than the experience of the hoistman or electrician to determine the reason for shutdown.

2.5 Communications

Shaft and station communication with the hoistman must be possible as required in 30 CFR. This can be satisfied in the form of a bell cord that runs the full length of the shaft and is available from the conveyance. Conventional or wireless telephones on the conveyance and at the shaft stations are found in many mines.

If the conveyance is equipped with wired communications to the hoistman or controller, the traveling cable tie off should be inspected during regular shaft inspections. The condition of the jacket of the cable should also be noted, as severe twisting can indicate imminent failure. The electrical condition of the cable can normally be determined by operation of the controls located in the conveyance. If they operate correctly and there do not appear to be unexplained signals, the cable is most likely suitable for continued use. For assistance in locating faults in the trailing cable refer to "Application Notes, Mine Electric Power Systems", a Bureau of Mines Handbook, Part AN 3-80.

Communication with the hoistman or hoist controller on automatic hoists should be checked from each and every station in the shaft. The hoist should be signalled from each station using the bell system or call circuit for automatic hoist controls. If the hoist does not respond as expected when called to the station, the communication system should be checked further, starting at the switch box and checking contacts, wiring, and incoming power.

2.6 Checklists

The checklists included in this section are intended to fit a wide variety of hoists. There may be items indicated on the checklist that are not on the hoist being inspected. Conversely, the hoist being inspected may be equipped with safety circuits that are not indicated on the checklists. Consequently, the checklists should be modified by the person performing the inspection on a particular hoist.

For mechanical hoist controllers such as Lilly¹ Controllers, refer to section 7 for detailed inspection instructions. For automatic and semi-automatic hoist controllers refer to the documentation provided with the hoist for detailed inspection instructions.

¹Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

2.7.1 Daily Checklist for Hoist Inspection and Testing

Item:	Description:	Good	Bad	Remarks
1	Lower normal overtravel			
2	Lower final overtravel			
3	Lower overtravel backout			
4	Upper normal overtravel			
5	Upper final overtravel			
6	Upper overtravel backout			
7	Manually operate Hoist and lower overspeed contacts			
8	Operate Emergency stop button conveyance stationary			
9	Brakes hold against 150% torque to lift a fully loaded conveyance.			
10	Hydraulic or air pressure for brake system			
11	Deadman switch			
12	Motor voltage			
13	Shaft communications			
14	General Comments			

2.7.2 Weekly Checklist for Hoist Inspection and Testing

Item:	Description:	Good	Bad	Remarks
1	Repeat all daily checks			
2	Slack rope indicators			
3	Motor full load current			
4	Shaft communications			
5	Motor overspeed sensors			
6	Correct operation of acceleration and deceleration controller			
7	General comments			

2.7.3 Monthly Checklist for Hoist Inspection and Testing

Item:	Description:	Good	Bad	Remarks
1	Repeat all weekly and daily inspections			
2	Vibration sensors on hoist motor			
3	Vibration sensors on hoist drive			
4	Vibration sensors on M-G sets			
5	Main incoming circuit breakers-visual inspection			
6	Hoist motor overcurrent protection-visual inspection			
7	Brake application rate			
8	M-G set overspeed			
9	Loss of drive circuit			
10	Torque proving circuit (cannot release brakes until motor current at least 10% full load)			
11	Brake clutch interlock			
12	Torque proving for overtravel backout			
13	Hoist motor lubrication oil level			
14	Hoist drive lubrication oil level			
15	M-G set lubrication oil level			
16	Hoist motor ventilation			
17	M-G set ventilation			
18	Cabinet ventilation			
19	Temperature sensors, Hoist motor			
20	Temperature sensors, M-G set			
21	Temperature sensors, hoist drive			
22	Shaft station gate open electrical interlocks			
23	Conveyance gate open electrical interlocks			
24	Verify conveyance position indicator			
25	Check conveyance position indicator for automatic hoist controller			
26	Remarks			
27	Components installed in shaft -- such as chairs			
28	Visual inspection of shaft and conveyance			

2.7.4 Annual Checklist for Hoist Inspection and Testing

Item:	Description:	Good	Bad	Remarks
1	Repeat all monthly, weekly and daily inspections	_____	_____	_____
2	Loss of power shutdown and brake application	_____	_____	_____
3	Mechanical controllers	_____	_____	_____
4	Automatic controllers	_____	_____	_____
5	Visually inspect shaft limits and wiring	_____	_____	_____
6	Acceleration rate	_____	_____	_____
7	Deceleration rate	_____	_____	_____
8	Conveyance overspeed	_____	_____	_____

3. MSHA REGULATIONS

This section lists the Federal regulations pertaining to hoist electrical control systems, as well as additional safety features found on some hoists.

3.1 30 CFR Part 57

This section covers all federal regulations governing hoist electrical systems in metal and non-metal mines. Regulations covering mechanical components that are not related to electrical controls are omitted.

3.1.1 Hoist Capacity

57.19-1

"Hoists shall have rated capacities consistent with the loads handled and the recommended safety factors of the ropes used."

Many times the personnel who specified the hoist for a mine are no longer at the mine. This makes it very important that all documentation on a hoist, including designed load be kept at the mine and preferably a copy should be kept in the hoist room to allow the hoist operator to consult the manual when in doubt over hoisting a heavy load.

3.1.2 Drive Train Connection

57.19-3

"Belt, rope, or chains shall not be used to connect driving mechanism to man hoists."

This is primarily a mechanical requirement that is beyond the scope of this report. It is included only because some manufacturers provide devices to sense loss of drive train integrity such as opposing tachogenerators and a signal comparator on newer hoists.

3.1.3 Brake Requirements

57.19-4

"Any hoist used to hoist men shall be equipped with a brake or brakes which shall be capable of holding its fully loaded cage, skip, or bucket at any point in the shaft."

See reference 8 by V. B. Cook for a detailed description of hoist brakes. Some hoists are equipped with a circuit to stop the hoist if brake wear is excessive. This is most normally in the form of a limit switch that is operated when the brake application weights travel an excessive distance, as shown in figure 3.

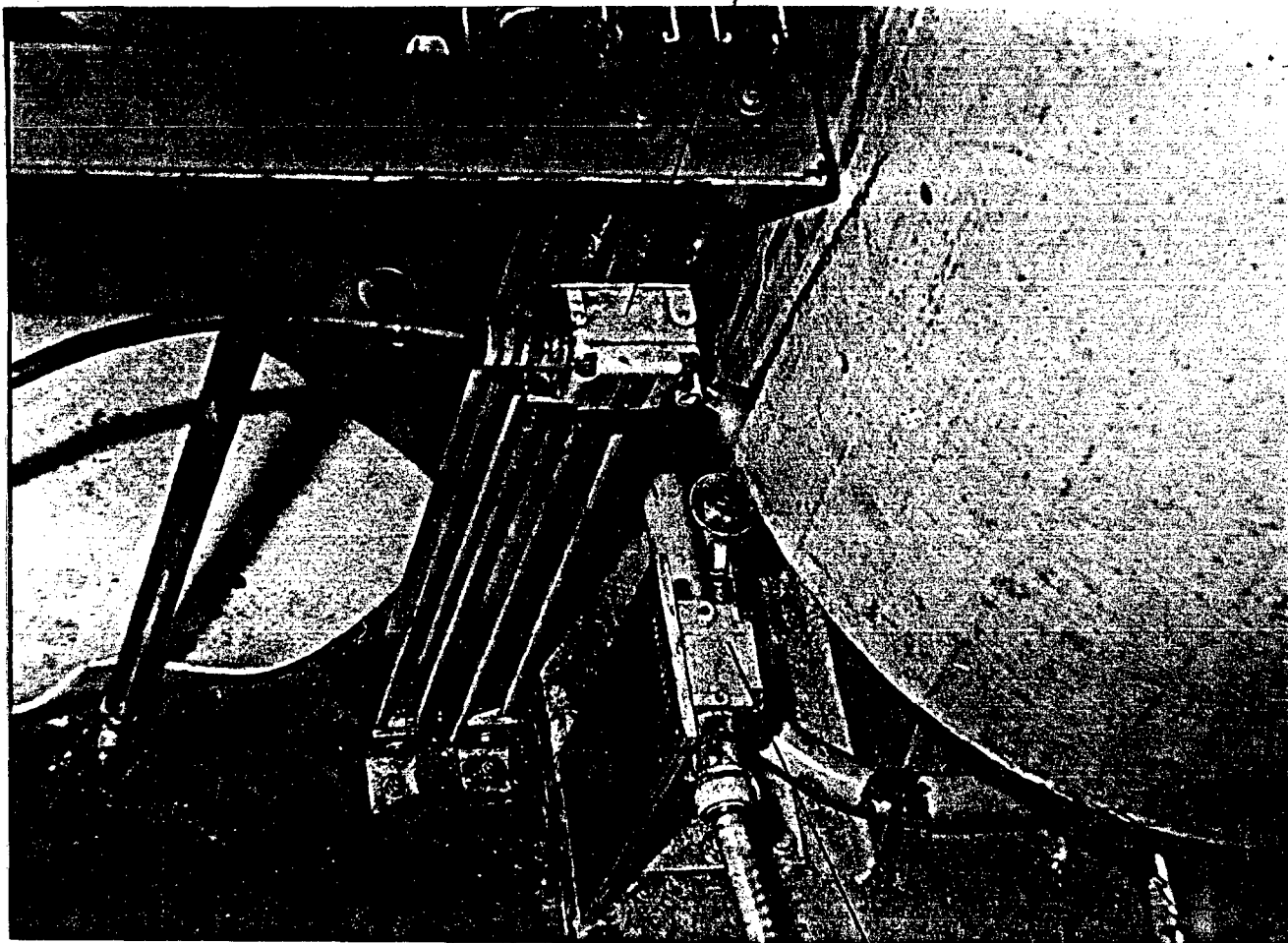
One particular incident at a mine involved a case of the brakes not being able to hold the loaded conveyance midway in the shaft. As the conveyance was being loaded the hoistman noticed the hoist was beginning to move, and tried unsuccessfully to stop the hoist from rotating. As the hoist gained speed the operator panicked, hit the emergency shut off and no longer had any power for dynamic braking to assist the mechanical brakes. As one conveyance struck the bottom of the shaft the other came through the heads sheave in the headframe. Fortunately, no one was fatally injured as no men were on the conveyance and none were in the shaft.

3.1.4 Clutch-Brake Interlock

57.19-5

"The operating mechanism of the clutch of every man hoist drum shall be provided with a locking mechanism, or interlocked electrically or mechanically with the brake to prevent accidental withdrawal of the clutch."

Brake Set Switch



Brake Wear Limit Switch

Figure 3

Brake Wear and

"Brake Set" Limit Switches

This can be accomplished through the use of mechanical interlocks, electric lockout relays, or limit switches.

If this were not the case, and the hoistman could clutch out the driven drum without first setting the brake and the conveyance would be allowed to fall to the bottom of the shaft.

3.1.5 Loss of Power

57.19-6

"Automatic hoists shall be provided with devices that automatically apply the brakes in the event of power failure."

This requirement has led to the implementation of fail safe gravity applied brakes on automatic hoists. This can show up in a number of ways with one of the most common being an electrically operated spring loaded or counter weighted valve that releases the brakes when dc energized. In other words in the deenergized state or when power is removed from the drive motor, the brakes automatically apply. If this were not the case, and the power failed, an upward moving loaded conveyance would coast to a stop and begin to free fall. This should be a controlled stop. Otherwise it can be a suicide stop that can injure personnel or damage equipment.

3.1.6 Overtravel and Overspeed Requirements

57.19-7

"All man hoists shall be provided with devices to prevent overtravel. When utilized in shafts exceeding 100 feet in depth, such hoists shall also be provided with overspeed devices."

Overtravel protection is necessary to protect from hoisting a conveyance into the headframe or lowering a conveyance into the sump. As shaft depth increases, hoist speed normally increases and therefore

the hoistman must begin to slow the conveyance at an earlier point in the operating cycle. The overtravel device is required to stop the conveyance before any damage is done.

The overtravel device can be a mechanical limit switch or magnetic proximity switch located in the shaft. It may also be an overtravel cam located on a mechanical programmable hoist controller. Overspeed devices range from mechanical flyball governors to sophisticated comparator circuits on solid state hoist controls. Figure 4 shows the centrifugal governor of a Lilly¹ Model C controller used to sense and limit conveyance overspeed.

3.1.7 Slip Calibration

57.19-8

"Where creep or slip may alter the effective position of safety devices, friction hoists shall be equipped with synchronizing mechanisms that recalibrate the overtravel devices and position indicators."

This can be performed with a mechanical linkage to adjust the Lilly¹ controller at a set point (usually at the collar) or through an electrical circuit. If the recalibration circuit fails, frequent overtravel or improper spotting of the conveyance at the station occurs. Modern friction hoists are equipped with a comparator that includes electronic counters to assure that calibration is maintained.

¹Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

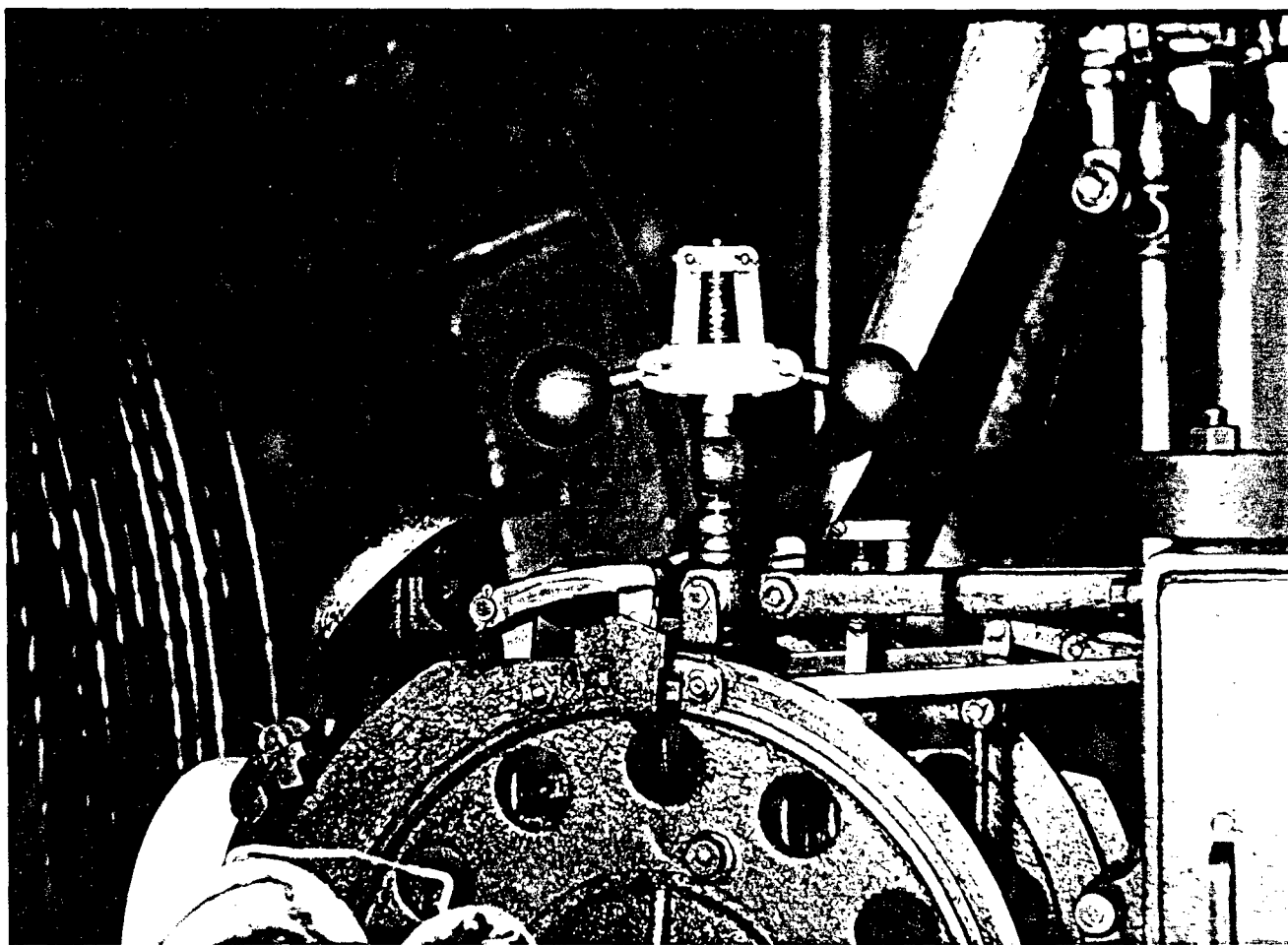


Figure 4
Centrifugal Governor Used to
Limit Conveyance Speed

3.1.8 Position Indicator

57.19-9

"An accurate and reliable indicator of the position of the cage, skip, bucket, or cars in the shaft shall be provided."

This is most commonly done with a drum or a large dial connected to the mechanical hoist controller drive as shown in Figure 5. The drum or dial like a Lilly¹ controller have been set up to indicate depth for a particular application and should be recalibrated if moved from one shaft to another or if the shaft is driven deeper. The importance of having an accurate indication of the conveyance position in the shaft is related to spotting at the stations and to indicate to the hoistman when to begin deceleration to avoid overtravel.

Newer, more modern hoists are being equipped with electronic counters and tachogenerators that indicate depth based on a measured speed for the hoist and a counted time span.

3.1.9 Location of Controls

57.19-10

"Hoist controls shall be placed or housed so that the noise from machinery or other sources will not prevent hoistmen from hearing signals."

The hoistman must be able to hear and understand the signals being sent. If there is sufficient noise to prevent the hoistman from hearing the signals clearly, the result will be to move the conveyance when it should not be moved, or something similar. This housing can

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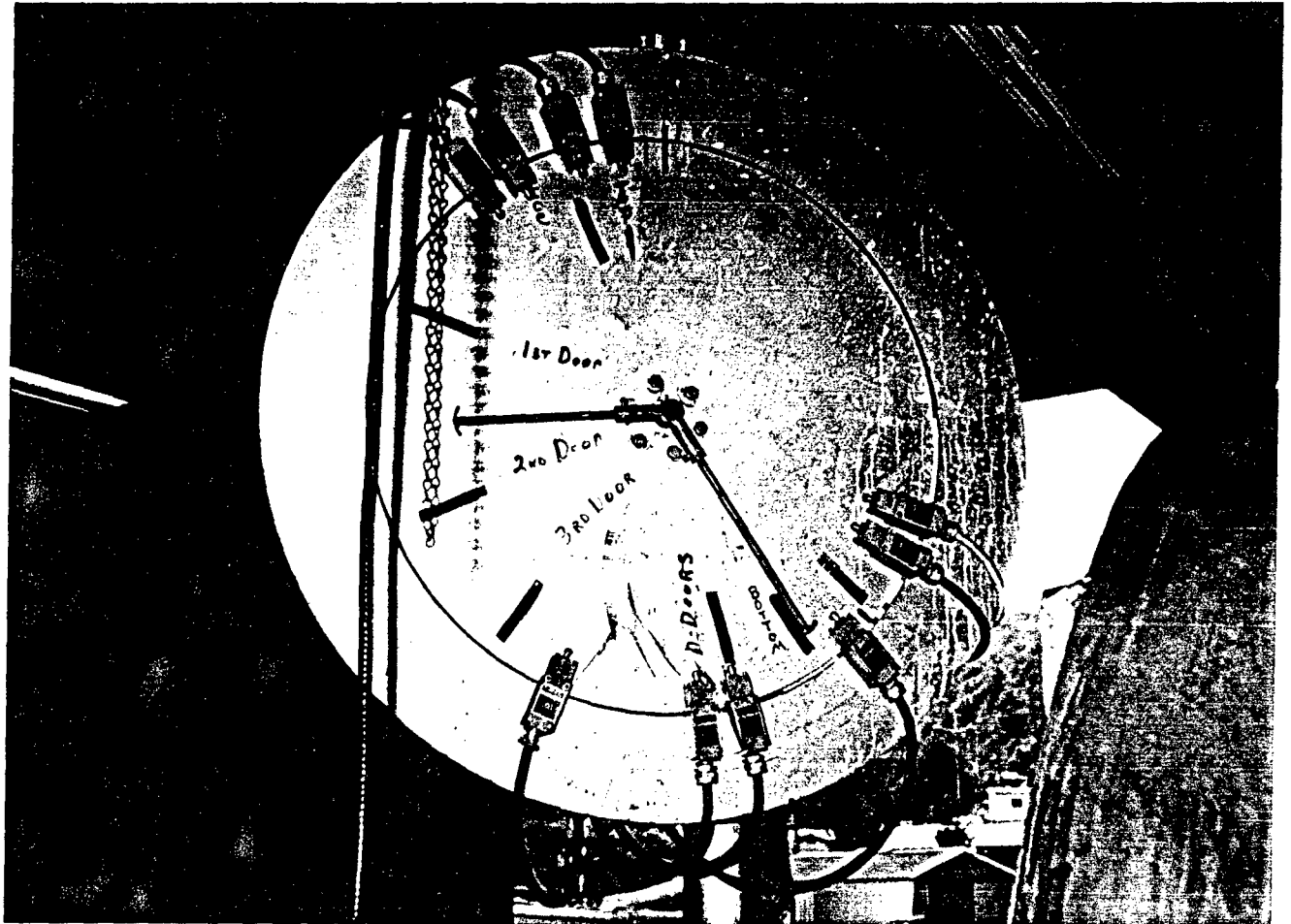


Figure 5

Conveyance Position Indicator Dial

also serve to provide some environmental protection to the control panel.

3.1.10 Overtravel Backup

57.19-14

"In a friction hoist installation, tapered guides or other approved devices shall be installed above and below the limits of regular travel of the conveyance and arranged to prevent overtravel in the event of failure of other devices."

The possibility of slip on friction hoists brings this requirement into existence. If a large amount of slip were to occur during a hoisting cycle before recalibration could occur, and the shaft limit switches did not function properly, the conveyance would overtravel.

3.1.11 Emergency Stop

57.19-17

"Each electric hoist shall be equipped with a manually operable switch that will initiate emergency braking action to bring the conveyance safely to rest. This switch shall be located within reach of the hoistman in case the manual controls of the hoist fail."

Normally this is referred to as the emergency or E-Stop. It is usually a brightly colored (red) "mushroom head" button on the control panel. This should be a controlled stop to avoid injuring personnel and damaging equipment. In the case of dc electric drives with regenerative braking, the braking current can be applied to the drive motor as the brakes are set. This varies considerably from one hoist to another; therefore, the circuit diagrams for the particular hoist being inspected must be consulted.

The E-Stop circuit should not remove all control power and especially not the dynamic braking exciter current. If the controls fail to respond on manually controlled hoists, the normal course of action is to remove all power from the system and set the brakes. Unfortunately this can cause problems if the hoist requires dynamic braking to assist the mechanical brakes in stopping the hoist. Once the control power has been removed, the only way to bring the hoist under control is to set the mechanical brakes.

3.1.12 Overtravel by-pass Switch

57.19-18

"When an overtravel by-pass switch is installed, the switch shall function so as to allow the conveyance to be moved through the overtravel position when the switch is held in the closed position by the hoistman. The overtravel by-pass switch shall return automatically to the open position when released by the hoistman."

Invoking the overtravel bypass function in some cases limits the hoist speed to something near creep or the lowest speed. Furthermore, electrical interlocks are something used to prevent the hoist from being operated in the direction of the overtravel condition. On some of the newer hoists, the distance the conveyance can be moved in this mode is also limited.

The overtravel bypass switch must be hand-held and automatically returned to its normal position. If the overtravel by-pass switch did not automatically return to the open position when released by the hoistman, the overtravel protection would be defeated. This would allow the conveyance to be put in the condition of overtravel at any time. The control circuit should be checked to make sure that overspeed protection is not bypassed when this switch is operated.

3.1.3 Brake Requirements

57.19-4

"Any hoist used to hoist men shall be equipped with a brake or brakes which shall be capable of holding its fully loaded cage, skip, or bucket at any point in the shaft."

See reference 8 by V. B. Cook for a detailed description of hoist brakes. Some hoists are equipped with a circuit to stop the hoist if brake wear is excessive. This is most normally in the form of a limit switch that is operated when the brake application weights travel an excessive distance, as shown in figure 3.

One particular incident at a mine involved a case of the brakes not being able to hold the loaded conveyance midway in the shaft. As the conveyance was being loaded the hoistman noticed the hoist was beginning to move, and tried unsuccessfully to stop the hoist from rotating. As the hoist gained speed the operator panicked, hit the emergency shut off and no longer had any power for dynamic braking to assist the mechanical brakes. As one conveyance struck the bottom of the shaft the other came through the heads sheave in the headframe. Fortunately, no one was fatally injured as no men were on the conveyance and none were in the shaft.

3.1.4 Clutch-Brake Interlock

57.19-5

"The operating mechanism of the clutch of every man hoist drum shall be provided with a locking mechanism, or interlocked electrically or mechanically with the brake to prevent accidental withdrawal of the clutch."

3.1.16 Acceleration and Deceleration Limits

57.19-62

"Maximum normal operating acceleration and deceleration shall not exceed 6 feet per second per second. During emergency braking, the deceleration shall not exceed 16 feet per second per second."

If the hoist has a Lilly¹ controller, the profile of the deceleration cams on the can control the rate at which the brakes are applied. If an automatic or semi-automatic hoist control is installed, this function is controlled electronically. Some circuits control the rate of release of the fluid (hydraulic oil or air) that actuates the brake release cylinders.

3.1.17 Lowering Loads Using Only the Hoist Brakes

57.19-65

"Conveyances shall not be lowered by the brakes alone except in the case of emergencies."

The drive mechanism should not be disengaged, or "clutched-out", when lowering a load. The only way that a load can safely be lowered down a shaft is by using the hoist motor(s) to turn to drum. If the overhauling load is allowed to turn the drum, the service brakes could possibly overheat and fade to failure. If this occurs and the hoist motor is not operating, the end result is a conveyance running out of control to the bottom of the shaft.

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3.1.18 Cage Doors Must be Closed

57.19-70

"Cage doors or gates shall be closed while men are being hoisted; they shall not be opened until the cage has come to a complete stop."

If the cage doors or gates are not closed during hoisting it is obvious that the persons being hoisted could fall from the cage.

Nearly all of the automatic hoists in operation have electrical interlocks that will prevent the hoist from operating until the cage door is closed and locked. This interlock is not required by law, however, it is a very safe and practical requirement with the draw back that it necessitates the implementation of a traveling cable. A technique that is preferred over a traveling cable is a radio control.

3.1.19 Man Safety Equipment

57.19-72

"When combinations of cages and skips are used in the same compartment, the cages shall be enclosed to protect personnel from flying material and the hoist speed reduced to man-speed as defined in standard 57.19-61, but not to exceed 1000 feet per minute. Muck shall not be hoisted with personnel during shift changes."

"Man safety" devices can be attached to mechanical controllers. When changing from hoisting ore to men the hoist operator readjusts the limits of travel and maximum speed of the conveyance. Man safety devices are accessories to Lilly¹ models C and D.

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3.1.20 Maximum Speed When Hoisting Men in Buckets

57.19-76

"When men are hoisted in buckets, speeds shall not exceed 500 feet per minute and shall not exceed 200 feet per minute within 100 feet of the intended station."

This requires specific settings for whatever speed controller is in use at operations where men are hoisted in buckets.

3.1.21 Overtravel Backout

57.19-83

"A manually operated device shall be installed on each electric hoist that will allow the conveyance or counterbalance to be removed from an overtravel position. Such device shall not release the brake, or brakes, holding the overtravelled conveyance or counterbalance until sufficient drive motor torque has been developed to assure movement of the conveyance in the correct direction only."

This paragraph states a torque proving requirement. In other words, the brakes are not released until voltage and current to the drive motor have reached some predetermined values. The "Brake Set" limit switch prevents the brakes from being released before the drive motor has developed sufficient torque.

3.1.22 Signalling From Shaft Stations

57.19-90

"There shall be at least two effective approved methods of signalling between each of the shaft stations and the hoist room, one of which shall be a telephone or speaking tube."

This is normally fulfilled by the installation of a telephone and pull bottle to signal the hoist at each station. On automatic hoists

the pull bottle is usually replaced with a "call" button that signals the hoist and rings a bell in the hoist room. The possibility of failure of the communications system in the shaft is very real. Ice may form on the conveyance in the winter and damage the communications systems. In addition, protruding loads may catch and damage the communications system. If two means of communication are available, the chances of maintaining communication are greater. Furthermore, there may not always be a bell signal to cover a particular situation which makes voice communication necessary.

3.1.23 Signalling From Mid-shaft

57.19-92

"A method shall be provided to signal the hoist operator from cages or other conveyances at any point in the shaft."

The installation of a telephone on the cage with a traveling cable satisfies this requirement. More recent developments have led to the installation of radio frequency signals that are transmitted on the hoist rope. A pull line that runs the entire length of the shaft may also be used.

The most common reason for having communications from any point in the shaft is for shaft inspection. Also it is very convenient to have mid-shaft communications in emergency situations such as when dislodging a conveyance that is hung up between stations.

3.1.24 Gates at Shaft Landings

57.19-100

"Shaft landings shall be equipped with substantial safety gates so constructed that materials will not go through or under them; gates shall be closed except when loading or unloading shaft conveyances."

This requirement is intended to prevent loose material, rail cars, or people from falling down the shaft when the conveyance is not at the station. On some systems there may even be electrical interlocks to prevent the conveyance from moving when the station gate is open. Please note that this is different from the cage door interlocks mentioned in the discussion of 57.19-70 and this does not require a traveling cable on the cage.

3.1.25 Inspection Requirement

57.19-120

"A systematic procedure of inspection, testing, and maintenance of shaft and hoisting equipment shall be developed and followed. If it is found or suspected that any part is not functioning properly, the hoist shall not be used until the malfunction has been located and repaired or adjustments have been made."

Not only is it a safe practice to maintain a hoist inspection and maintenance program but as can be seen here, it is required by law. If a hoist is not inspected on a regular basis it becomes very difficult to determine when and if something is actually wrong. Furthermore if something is suspected to be incorrect with the hoist it should always be corrected before the hoist is operated except in the case of an emergency.

3.1.26 Recording of Inspections

57.19-121

"Complete records shall be kept for one year of inspections, tests, and maintenance of shafts and hoisting equipment."

The keeping of records of inspections is extremely important. If no record exists of previous inspections and corrective procedures,

there is virtually no way to determine what has been a common failure item or even what has failed in the past on the hoist system.

3.1.27 Replacement Parts

57.19-122

"Parts used to repair hoists shall have properties that will insure the proper and safe function of the hoist."

This regulation is one of the most often abused and most difficult to detect. When a jumper wire is installed to continue hoist operation (because of the failure of some component), this regulation has been violated. Unfortunately this can result in fatal accidents because the jumper is then forgotten or intentionally left in place. An important safety feature, that is relied on in emergencies, may have been defeated.

The violation of this requirement may not be obvious. If the correct replacement spring on the governor of a Lilly¹ controller is not used, the action of the controller has been defeated. Although this may seem somewhat trivial it is a very important point to remember and should always be strictly enforced.

3.1.28 Pre-shift Inspection

57.19-129

"Hoistmen shall examine their hoists and shall test overtravel, deadman controls, position indicators, and braking mechanisms at the beginning of each shift."

¹Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

To determine if the limits in the shaft and on the hoist controller are working, it is necessary to perform this test. Normally the test consists of running the conveyance from one end of the shaft to the other with no load before the start of shift. The conveyance should be moved at creep speed into the overtravel limits to determine that they are operating correctly. Any abnormal reactions should be noted and corrected before hoisting commences or the hoist is placed in service.

3.1.29 Special Inspection Requirements

57.19-130

"Before hoisting persons and to assure that the hoisting compartments are clear of obstructions, empty hoist conveyances shall be operated at least one round trip after

(a) Any hoist or shaft repairs or related equipment repairs that might restrict or obstruct conveyance clearance;

(b) Any oversize or overweight material or equipment trips that might restrict or obstruct conveyance clearance;

(c) Blasting in or near the shaft that might restrict or obstruct conveyance clearance; or

(d) Remaining idle for one shift or longer."

Supplemental to 57.19-129, this requirement is self explanatory. If anything has taken place in or near the shaft that could obstruct the travelway, it is more than likely that the shaft guides, limits, or hoist communications installed in the shaft have been damaged. A common hazard in colder climates is the forming of ice on the shaft guides during periods when the hoist is idle. This can be a tremendous hazard to both personnel in the mine and all equipment installed in the shaft.

One accident investigated involved the conveyance hanging up on ice covered shaft guides midway down the shaft. The slack rope detector on the hoist did not operate before enough rope had reeled onto the top of the conveyance to force it loose. As the conveyance was forced loose it fell some distance before hitting the end of the rope. When it did finally reach the end of the rope the velocity was great enough to snap the rope allowing the conveyance to fall to the bottom of the shaft. Luckily no one was on the cage at this time.

3.2 30 CFR Part 75

This section covers all regulations applying to the operation of hoists in coal mines.

3.2.1 Position Indicator

75.1401

"Hoists shall have rated capacities consistent with the loads handled and the recommended safety factors of the ropes used. An accurate and reliable indicator of the position of the cage, platform, skip, bucket, or cars shall be provided."

An indicator such as that connected to a Lilly¹ Controller, or other mechanical hoist controller is required.

3.2.2 Position Indicator Location and Inspection

75.1401-3

"The indicator required by 17.1401 of this chapter shall be placed so that it is in clear view of the hoisting engineer and shall be checked daily to determine its accuracy."

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

This is normally connected to some part of the hoist controller, it is very easy to check the other functions of the controller at the same time, such as overspeed, overtravel, etc.. However, this inspection should be made by a qualified electrician or mechanic. The hoisting engineer is not always qualified.

The importance of a daily inspection of the hoist controls cannot be emphasized enough. The controllers are easy to check at the same time as the hoist is being run through the pre-shift inspection. The suggested checklists included in the section on Lilly¹ controllers can be used to perform this inspection.

3.2.3 Communication and Signalling

75.1402

"Communication between shaft stations and hoist room."

This paragraph is the same as 57.19-90 in the metal/non metal regulations and is normally satisfied by the installation of a telephone and bell system. However, 75.1402-2 requires that the system be tested daily.

3.2.4 Other Safeguards for Hoist Brakes

75.1403-2

"Hoists and elevators used to transport materials should be equipped with brakes capable of stopping and holding the fully loaded platform at any point in the shaft, slope, or incline."

If the power fails when hoisting a fully loaded conveyance it is essential that the brakes be able to stop and hold a full load. As was

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

stated earlier, the result can be the conveyance colliding with the headgear.

3.2.5 Brake-Clutch Interlock

75.1403-3(a)

"The clutch of free drums on man hoists should be provided with a locking mechanism or interlocked with the brake to prevent the accidental withdrawal of the clutch."

In addition to mechanical interlocks on manually controlled hoists, this can be accomplished through the use of lockout relays or limit switches.

If this was not the case, and the hoistman clutched out the driven drum without first setting the brake, the conveyance would be allowed to fall to the bottom of the shaft.

3.2.6 Requirements for Elevators

75.1403-4

"(a) The doors of automatic elevators should be equipped with interlocking switches so arranged that the elevator car will be immovable while any door is opened or unlocked, and arranged so that such door or doors cannot be inadvertently opened when the elevator car is not at a landing.

(b) A "Stop" switch should be provided in the automatic elevator compartment that will permit the elevator to be stopped at any location in the shaft.

(c) A slack cable device should be used where appropriate on automatic elevators which will automatically shut-off the power and apply the brakes in the event the elevator is obstructed while descending.

(d) Each automatic elevator should be provided with a telephone or other effective communication system by which aid or assistance can be obtained promptly."

Even though there are a large number of elevators in the coal industry, it is still very common for the operating company to maintain a service contract with the manufacturer of the elevator. Elevator inspection is discussed in detail in section 9. Since elevator doors might open any time, a controlled stop should occur automatically if the doors are opened.

4.0 HOIST DRIVE INSPECTION

This portion of the manual is divided into four parts. The first division will cover the inspection of dc electric motors. Part two will cover the inspection of SCR units and associated switch gear. The third part will cover the general inspection of motor generator sets. Finally, the fourth part will discuss ac electric motors.

Drive systems installed on mine hoists consist of two basic types, ac and dc driven electric motors. The inspection procedures for both types are very similar but will be considered separately. DC drives are normally found on hoists requiring over about 300 horsepower. AC drives are normally found installed on the lower horsepower hoists.

Direct current drives installed on mine hoists consist of two types; SCR (rectifier) and M-G (motor-generator) powered drives. In both cases the prime mover on the hoist is a dc electric motor, with the primary difference being the method that is used to convert ac electricity to dc.

The SCR units are basically an ac to dc power converter. The process is accomplished through the use of solid state power converters. This will normally be a unit such as the General Electric¹ "Silcomatic Plus" Thyristor (SCR) unit.

The motor generator type systems will have an ac motor turning a large dc generator. This type of system is somewhat older and, therefore, will normally only be seen on hoists installed before about 1970. The relative age of the two systems has no influence on fitness

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

to perform the task of converting ac to dc and the authors do not endorse or advocate a particular type or manufacturer of system.

4.1 Direct Current Electric Motors

4.1.1 Operating Principles and Explanation

DC motors consist of two parts, one stationary and one rotating. The stationary part contains the field poles, field windings, bearings, and brush holders. The rotating part contains the armature winding which carries the load current, and a commutator. The commutator consists of several copper sectors insulated from each other and from the motor shaft. The ends of the armature coils are tied to the copper segments. Carbon brushes mounted in brush holders transfer current to and from the armature winding through contact with the commutator. Torque is produced by the interaction of current flowing through the armature coils and the fixed dc field. The purpose of the commutator is to keep the current flowing in the armature winding in the same direction relative to the field so that the torque produced in all armature windings is additive, that is, contributes to the mechanical power output to the machine.

Essentially, the dc motor is a variable speed motor. The speed can be varied by changing the applied armature voltage or the field strength. Generally, armature voltage control gives a speed range from zero to fullspeed, while varying field strength is used for a narrower band such as plus or minus 10% of speed range. The direction of rotation can be changed by either reversing the polarity of applied armature voltage or by reversing the direction of the fixed field. Also, given the direction of rotation and a fixed field, armature

current will flow one direction when the machine is acting as a motor and the opposite direction when it is acting as a generator.

As a result of these characteristics, different configurations of equipment are used to obtain speed and torque control.

4.1.2 DC Motor Control

DC mine hoists utilize closed loop control. Speed and torque can be controlled very closely. Older closed loop control schemes utilize rotating controllers such as the Rototrol (Westinghouse)¹ or Amplidyne (General Electric)¹. At various stages other control systems were used, for example, tube and transistor amplifiers. Magnetic amplifiers have also been used. The magnetic amplifier consists of a saturable reactor combined with diodes. These amplifiers have been used by themselves or in conjunction with rotating controllers.

New control systems normally use operational amplifiers. Operational amplifiers permit very accurate control of the current ramps. The system response is easily modified by changing small components such as resistors and capacitors. It is also possible to easily produce current ramps to control acceleration and deceleration. Current is limited to required rating and is easily adjusted. Essentially, the solid state control performs the same functions as the rotating controllers but is smaller, consumes less power, requires less maintenance and is easily tuned. Normally, plug-in spares are available. The operational amplifier control schemes are used on both M-G sets and thyristor (SCR) units. The control amplifiers usually

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form part of a larger overall control system incorporating logic functions, mechanical safety devices, etc. Originally operational amplifiers were made up of discrete components. Now they usually come in the form of an integrated circuit.

Automatic speed control of hoists relies upon a tachometer generator to provide input to the hoist controls on the speed of the motor at any point in time. The tachogenerator is a small dc generator which produces a voltage that is proportional to speed.

Tachogenerators are driven by the main hoist motor or by an auxiliary gear. They can also be driven by idler sheaves turned by friction hoist ropes for the purpose of rope slip detection.

A motor overspeed sensor is normally a centrifugal switch mounted on the end of the motor shaft. As the motor overspeeds, the switch opens and shuts down the system.

Motor and bearing temperature sensors are normally thermocouples or thermal switches mounted on the armature of the motor and will alarm, but not interrupt the power if the motor has reached an unsafe operating temperature.

Vibration sensors may be located most anywhere on the unit. If the motor vibrates excessively, the switch will stop the motor.

4.1.3 DC Motor Braking

DC motors on hoisting systems normally utilize regenerative braking. In an automatic regulated system in which speed is the reference variable, the motor terminal voltage is varied to obtain desired speed. The motor current is dictated by the load and, essentially, the current drawn is sufficient to meet load torque requirements at the particular speed. If the required load torque changes, as it

does in a hoisting cycle, the output voltage is changed by the control system to maintain speed. If the load torque becomes overhauling, the hoist motor acts as a generator and the conveyance slows.

In the case of an M-G set with an overhauling load, the energy flows into the generators from the hoist motor, driving the M-G set. The M-G set drive motor acts as a generator. The generator fields are adjusted by the control system so that the hoist motor speed is kept at the reference speed. The terminal voltage is manipulated by the controls to maintain the speed regardless of the load torque or current direction.

In the case of a dual converter thyristor drive, the drive controls must sense a zero current or crossover condition. The forward bridges switch off, and the reverse bridges turn on as the hoist goes from motoring to overhauling. This is necessary because the bridges can only conduct in one direction. When the reverse bridge is on, power is being transferred from the hoist system to the incoming power or a series of resistors.

4.1.4 Suggested Inspection Schedule

4.1.4.1 Bearings

Make sure that grease or oil is not leaking out of the bearing housings. If any leakage is present, correct the condition before continuing to operate.

In the case of ball and roller bearings, listen to a few bearings on a sampling basis using a stethoscope if available. If one is not available, a screwdriver placed against the housing will conduct sounds and vibrations to the human ear. Bearings that get progressively

noisier might require replacement at next shutdown. The temperature of noisy bearings should also be checked.

For sleeve bearings check the oil level. Check the oil color through the sight gage. Slightly cloudy is acceptable. Black oil is a danger sign. All bearings should be checked at least on a monthly basis.

4.1.4.2 Brushes

Before checking any electrical component the power must be removed and locked out.

Check the brush length. (Replace when the rivet or clip will rub the commutator before next inspection.) Inspect for worn or shiny brush clips, loose pigtails, and chipped or broken brushes. Remove a few brushes to check the brush-commutator contact face. Burned areas indicate commutation troubles. Loosen each brush in its holder. Clean out the area of the brush holder and brush holder stud insulation. The brushes and commutators should be inspected and maintained monthly.

4.1.4.3 Commutators

Check the commutator for roughness by carefully feeling the brushes with a fiber stick. Jumping brushes give advance warning of a commutator going rough. Observe the commutator for signs of threading or the presence of fine lines. If the threading appears to be getting progressively worse refer to table 4 and the factory supplied motor maintenance manual for the recommended corrective action. If the threading appears to be healing over, this is acceptable.

The commutator should be checked for an excessive wear rate, streaking, copper drag, pitch bar marking and heavy slot bar marking.

4.1.4.4 Insulation

Visual inspection is recommended as the quickest means of finding insulation system troubles. Visual inspection may not sound like a test method but if carefully done by a competent person it is one of the most valuable means of judging insulation condition.

In addition to collecting contaminants, insulation shrinks, cracks, discolors, and becomes brittle with heat and age. These changes allow movement of coils, loose filler strips, loose ties, chafing and abrasion, all of which can be picked up by visual inspection.

The aforementioned inspections should be conducted on at least a monthly basis. The following insulation inspections should be conducted every six months.

Experience and judgement can be gained by careful observation and comparing with the results of insulation resistance and polarization index measurements. Contact the motor manufacturer for instructions on the latter two tests.

Wipe and brush deposits from brush holder stud insulation and commutator creepage path. Remove heavy deposits from around field coil connections where grounding might occur. Brush and vacuum deposits out of commutator riser area. Blow out any blocked ventilation openings in windings. Make a visual inspection for any signs of overheating (dry, cracked, "roasted-out" insulation and varnish).

4.1.4.5 Mechanical

Air filters on the cooling blowers for the motors should be inspected monthly and replaced when dirty. If the filters are excessively dirty every month this is an indication of severe working

conditions, and the filters should be checked more often, perhaps semi-monthly. This also indicates that the rest of the motor should be cleaned more often and checked more frequently than normal. All screens and louvres on the machines should be checked at least once monthly to insure that none are in any way obstructed.

The entire motor should be checked for loose bolts, loose parts, or loose electrical connections. While checking for loose bolts and parts, check for any unusual noise or vibration that may be different from previous observations. Electric motors are intended to run very smoothly and should not operate with any excessive vibrations or noises.

All mechanical inspections and observations should be performed at least once each month except for taped electric connections. Any problems detected during this inspection should be noted and corrected at once.

The following mechanical inspections should be performed every six months:

Remove and lockout all electrical power to the system and visually check all uninsulated electrical connections to be certain they are tight. Look for signs of poor connections such as discoloration. Do not remove insulation, especially from high-voltage connections.

Most newer hoists are equipped with vibration sensors to alarm, but not interrupt the power, when the vibration rises above a specified value. To determine if the vibration sensors on the equipment are in fact functioning properly, consult the documentation or operating manual for the hoist or vibration sensors. There are several different types of sensors on the market, and adjustment procedures may be different for each type. Vibration sensors are discussed in more detail in Section 6.

4.1.5 Trouble Shooting Guide for DC Motors

This section is intended to be used to supplement documentation of dc hoist motors. This should not be used in place of a complete set of trouble shooting instructions for a hoist motor, as supplied by the manufacturer. The section is organized by trouble type. Under the headings are an assortment of problems with the recommended determination procedures for each.

4.1.5.1 Motor Will Not Start

Disconnect the motor from the driven machine if possible to be certain the problem is in the motor.

Open circuit in control. Check control for open in starting circuit, open contacts, fuse, or breaker.

Low terminal voltage. Check voltage with nameplate rating. Check splices and other connections. Check incoming power and conductor size or resistance.

Bearing frozen. Recondition shaft and replace bearing.

Overload. Check terminal voltage. Check bearings. Check motor conditions. Check motor current. Try to reduce load.

Excessive friction and bearing temperature. Check lubrication in bearings to make sure that the lubricant has been replaced after installation of the motor or changing of the lubricant.

4.1.5.2 Motor Stops After Running Short Time

Motor is not getting power. Check the voltage at the motor terminals. Also check the fuses and the overload relays.

4.1.5.3 Motor Attempts to Start but Overload Relays Operate

Motor is started with weak or no field. If adjustable speed motor, check regulator for correct setting. If correct, check condition of the regulator.

The field coils should also be checked for an open winding. Check wiring for loose or broken connection.

Motor torque insufficient to drive load. Check line voltage with name plate rating. Check to determine if the load being hoisted is larger than the system is designed to handle or if there is an obstruction.

4.1.5.4 Motor Runs too Slow Under Load

Line voltage too low. Check and remove any excess resistance in supply line, connections, or control.

Brushes ahead of neutral. Set brushes to neutral.

Overload. Check to see that load does not exceed allowable load on the motor.

4.1.5.5 Motor Runs too Fast Under Load

Weak field. Check for resistance in shunt field circuits. Check for ground faults.

Line voltage too high. Correct high voltage condition (refer to documentation on power supply).

Brushes behind neutral. Set brushes back to neutral.

4.1.5.6 Sparking at Brushes

Commutator in bad condition. Clean and reset brushes.

Eccentric or rough commutator. Grind and true commutator, also undercut mica.

Excessive vibration. Check alignment. Check for and clean out any excessive foreign material. Balance armature. Check brushes to make sure they ride freely in the holders.

Broke or sluggish acting brush-holder spring. Replace spring and adjust pressure to manufacturer's recommendations.

Brushes too short. Replace brushes.

Machine overloaded. Reduce load. If this happens frequently, or reevaluate loading of hoist. Hoist overloading can damage the entire hoist and should be avoided.

Short circuit in armature. Check commutator and remove any metallic particles between segments. Check for short between adjacent commutator risers. Test for internal shorts in armature and repair.

4.1.5.7 Brush Chatter or Hissing Noise

Excessive clearance of brush holders. Adjust holders.

Incorrect angle of brushes. Adjust to recommended angle.

Incorrect brushes for the service. Solicit manufacturer's recommendations.

High mica. Undercut mica.

Incorrect brush spring pressure. Check height of commutator bar. Adjust to the correct value.

4.1.5.8 Selective Commutation

Insufficient brush spring measure. Adjust to correct pressure, making sure brushes ride free in holders.

Unbalanced circuits in armature. Eliminate high resistance in defective joints by inserting armature or equalizer circuit commutator risers. Check for poor contacts between bus and bus rings.

4.1.5.9 Excessive Sparking

Brushes off neutral. Adjust brushes back to neutral.

Poor brush fit on commutator. Sand in brushes and polish commutator surface.

Brushes riding in the brush holder. Remove and clean holders and brushes with an approved cleaning agent. Remove any irregularities on surfaces of brush holders or rough spots on the brushes.

4.1.5.10 Sparking at Light Loads

Foreign material on commutator. Clean commutator, and provide protection against foreign matter. Adjust brushes back to neutral. If necessary, install an enclosed motor designed for the application.

4.1.5.11 Field Coils Overheat

Short circuit between turns or layers. Replace defective coil.

4.1.5.12 Commutator Overheats

Brushes off neutral. Adjust brushes back to the neutral point.

Excessive spring pressure on brushes. Decrease brush-spring pressure but not to the point where sparking is introduced.

4.1.5.13 Grooving of Commutator

Brushes not properly staggered. Stagger the brushes according to the manufacturer's recommendations.

4.1.5.14 Brushes Wear Rapidly

Rough commutator. Resurface commutator and undercut mica.

Excessive sparking. Make sure brushes are in line with commutating fields.

Improper brushes. Check brush grade for correct environment and application.

4.1.5.15 Armature Overheats

Motor overloaded. Reduce load to correspond to allowable load.

Motor installed in location where ventilation is restricted.

Arrange for free circulation of air around the motor and to air louvres.

Armature winding shorted. Check commutator and remove any metallic particles between segments. Test for internal shorts in armature and repair.

4.2 Thyristor Convertors

The application of thyristor converters to mining hoists and other equipment is relatively recent. For this reason, most mines with hoists powered by thyristor drives have maintenance personnel that are well trained in the inspection and maintenance of these units. The information presented here should only be considered as an outline to supplement or be used in conjunction with established programs.

4.2.1 Introduction to Thyristor Convertors

A thyristor converter is, simply put, a device to convert ac line current to dc current for use in driving a dc motor or other machine. The thyristor converter is somewhat more efficient, more reliable, and considerably quieter than a motor generator unit. Until the early 1970's the motor-generator set was the primary means of converting ac to dc power.

The thyristor converter will nearly always be equipped with the following protective gear on the ac side of the unit:

AC power circuit breaker

Filters and voltage surge suppressors

Converter transformer.

The side of the thyristor converter that is connected to the ac line power is referred to as the primary of the converter. The dc side of the converter is referred to as the secondary. Figure 6 shows some basic rectifier circuits, or circuits used to convert ac to dc. Figure 7 shows a non-reversing converter schematic, and figure 8 shows a more common reversing dual converter schematic.

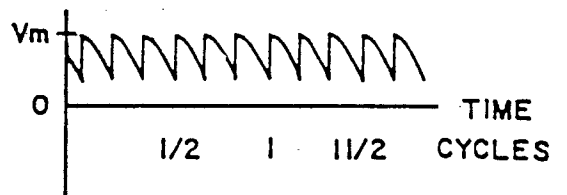
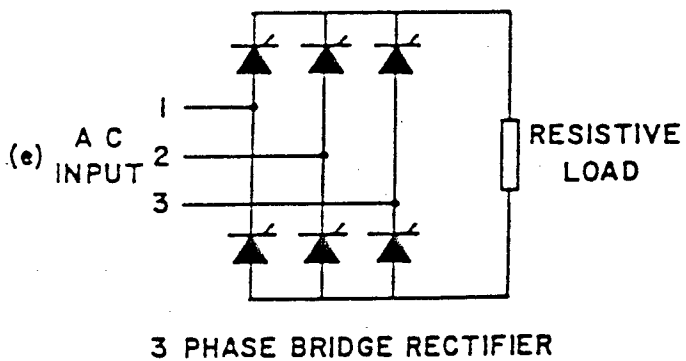
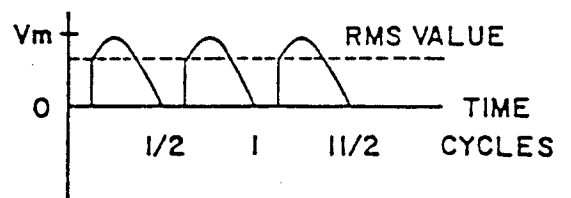
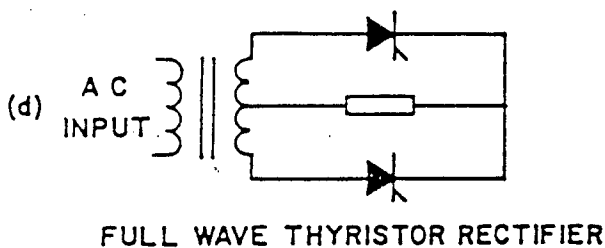
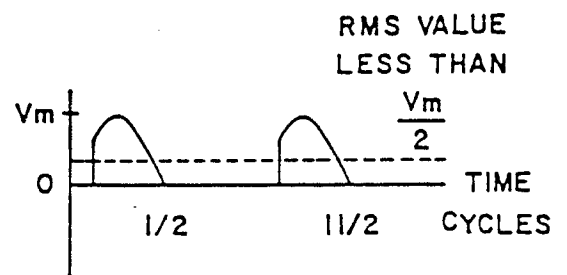
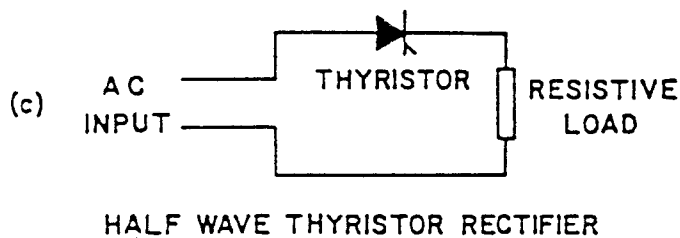
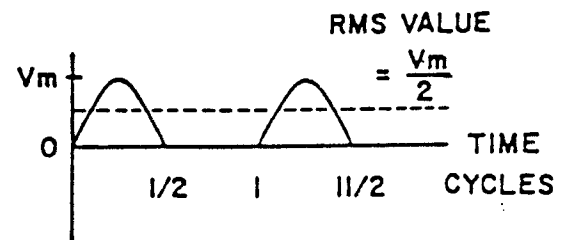
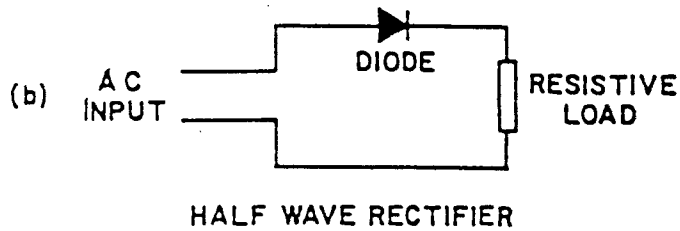
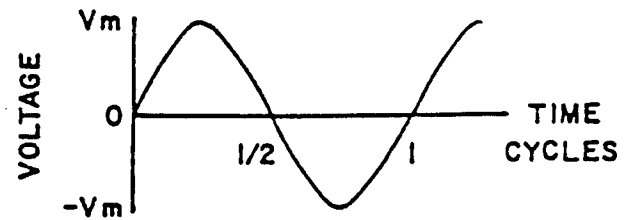
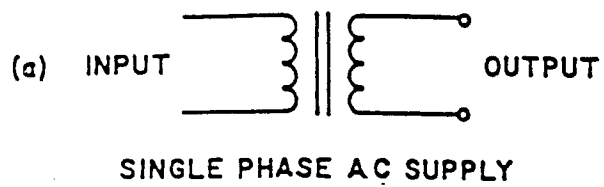


Figure 6
Rectifier Circuits
(reference 8)

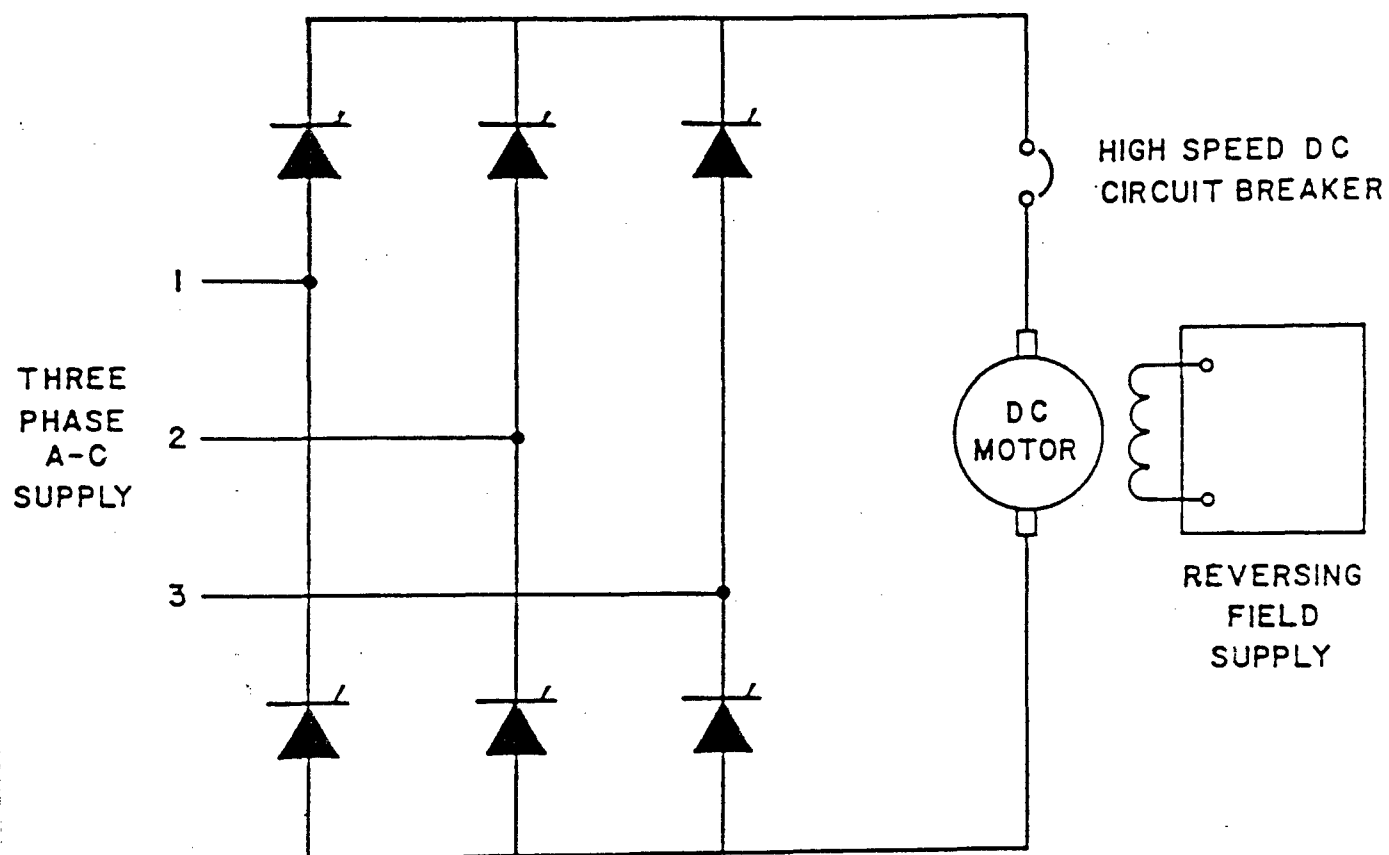
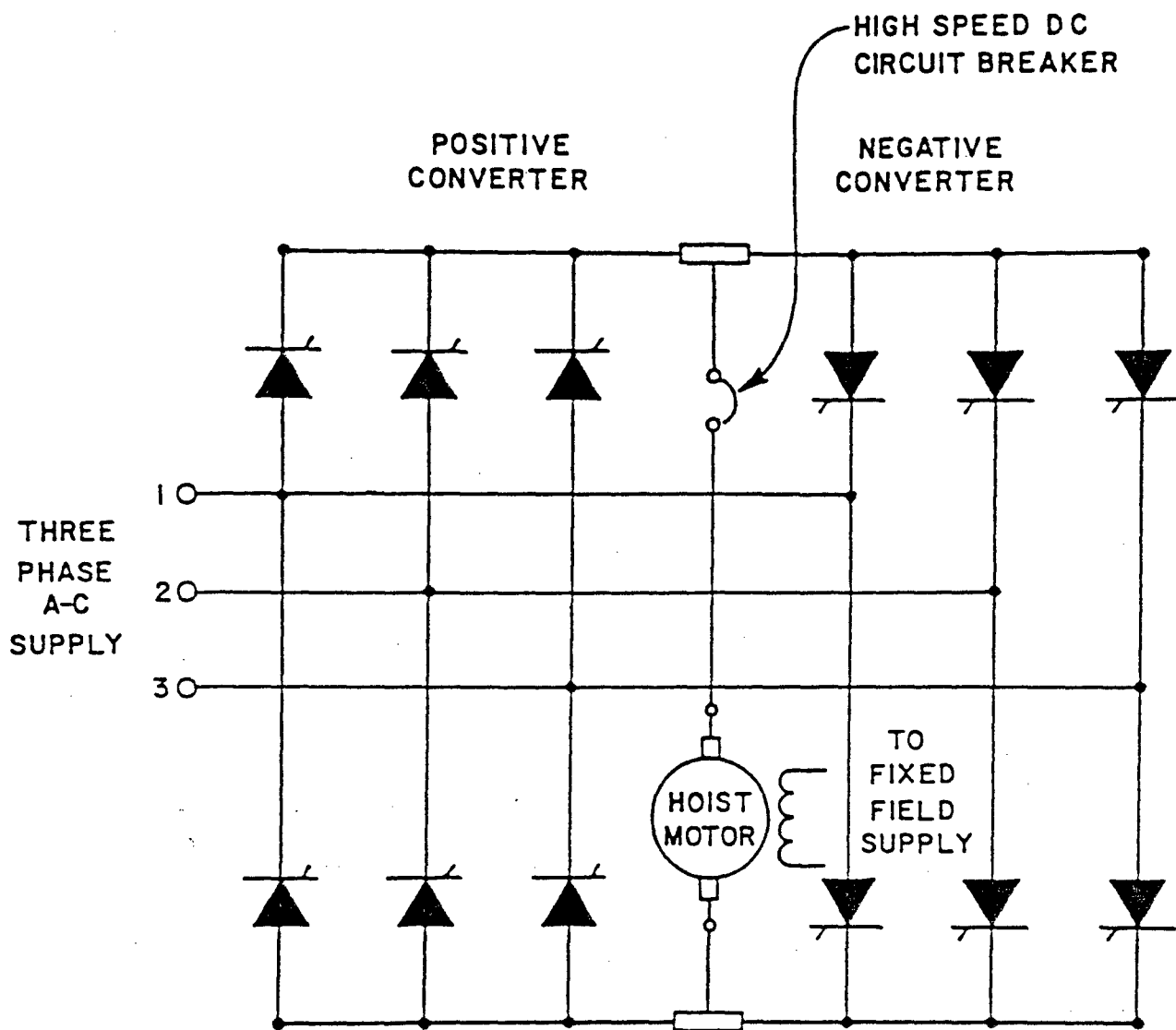


Figure 7

Nonreversing Converter Schematic

(reference 8)



NOTE: CONTROL CIRCUITS NOT SHOWN.

Figure 8
Dual Converter Schematic
(reference 8)

4.2.1.1 Converter Transformer

An isolating-type converter transformer is nearly always used in the power supply line above the converter. This transformer is especially designed to coordinate with the converter for proper circuit and regulation characteristics and to limit available fault currents within the converter capability. These transformers are normally wound delta-ye for six pulse converters. For twelve pulse converters, the transformers are wound delta-delta.

For drives of a large KW rating (above 1000 KW), a self cooled liquid filled transformer will normally be used. This may be either close-connected with the converter lineup or separate with bus duct connections between the transformer and converter. This type of transformer will usually be equipped with liquid temperature, pressure, and level indicators with switch contacts. A pressure relief valve and a sudden pressure device will normally be in place as well.

For smaller drives, a dry type transformer is normally provided and mounted within the converter lineup. A thermal switch for overtemperature detection may be imbedded in each winding during manufacture. Access to the transformer is generally made through bolted panels but is not necessary for routine inspection and maintenance.

4.2.1.2 Voltage Surge Protection

Voltage surge protection devices are applied to the ac secondary buss (below the isolation transformers) at the point of entry into the converter. Line to frame capacitors may be applied to suppress voltage spikes due to switching surges by providing a path between secondary windings of the delta-usage isolation transformer and ground.

For higher voltage ratings (greater than 600 volts) a diode bridge and surge suppressor unit may be applied. This provides a completely static function designed to clip line to line surges at a value between peak voltage level of the circuit and the primary rated voltage of the thyristors. A loading resistor maintains the circuit in conductive or "ready" condition. The suppressor triggers or "discharges" at a preset level to clip even the highest rate of rise spikes, and then extinguishes the follow-up arc after the surge has passed. These devices are fused and may have indicating lamps to monitor the condition of the fuses.

As stated previously, the function of converting ac power to adjustable dc power is performed by the converter. This is made possible by the ability of the thyristor to block voltage in both directions, while the current flow in one direction is controlled by "gating" the thyristors at adjustable times on the ac voltage wave. The converter is normally of modular design in both the arrangement of the basic power circuits and the gating control circuits.

The converter assembly will normally consist of a six or more power leg modules that contain at least the following components:

Current limiting fuse and thyristor in series

Pulse amplifier

Reactor shunt network

Transformer module

Reactor

Heat sink.

For converters fed from a low voltage substation source, a power circuit breaker may be mounted either in the converter lineup or

remotely and may be either manually or electrically operated. It is normally equipped with series overcurrent trips, shunts, and/or undervoltage trip devices. The breakers will have some labeling on the bodies to aid in determining what optional equipment is installed within the unit.

In addition to isolation, the ac power circuit breaker provides protection for primary faults, and is not tripped by converter protective functions other than ac undervoltage or when ac current is greater than dc current. It may also have time-overcurrent protection.

Primary protection for converters on ac sources above 600 volts is normally provided by close coupled or remote metal-clad switchgear, with a control or permissive switch at the converter. The functions are essentially the same as on low voltage primaries.

The switch-gear on the dc side or secondary of the converter will normally consist of dc breakers with undervoltage and overvoltage protection for the field and armature. In addition, a large magnetically operated loop contactor to close the motor circuit will be installed in the system.

4.2.2 Inspection and Maintenance

Before starting any electrical inspection it is required by law that all power be removed from the system being inspected and locked out. Then, when conducting the inspection, the authors recommend that insulated mats be placed to stand on, and insulated gloves be worn.

A periodic routine of cleaning and inspection should be established to prevent corrosion and accumulation of dust. All maintenance or replacements should be recorded in the logbook for the unit. This will

help to identify frequent maintenance items and aid in locating faults in the future.

Inspections should be more frequent when the demands on the equipment are exacting as in the case of hoist controls. It is possible under normal operating conditions for the protective devices not to operate; therefore, when the conditions are less than favorable or even very poor, maintenance and inspection become crucial to the continued safe operation of the hoist.

Thyristor converters are very reliable and are usually maintained through the use of visual inspections and component replacement. Thyristor converters have no moving parts and consist of solid state electrical components. For this reason failed components are usually returned to the manufacturer where experienced, trained personnel make the repairs. However, there are several common items that may be inspected to prevent serious safety problems. These are listed in the following paragraphs.

4.2.2.1 Visual Inspection of Cabinets

Ventilating blowers, filters and louvres, circuit breakers, relay contacts, and general cabinet condition can be very easily inspected and corrective action taken to prevent continual nuisances. The actual converters, logic circuits, and control transformers should not be inspected or tampered with unless persons are thoroughly trained for this task. Modern converters are of the modular design. If a component fails, the printed circuit card on which it is located is normally replaced with a new or factory repaired card.

Most of the printed circuit cards are equipped with indicating lights to indicate operable or inoperable condition. If a card displays

a fault signal, other than a burned-out light, a problem exists on the card and the hoist should not be operated until the condition is corrected.

4.2.2.2 Inspection of the Converter Transformer

Transformers will continue to operate until they are overheated to the point of insulation failure. When this occurs, two or more windings will come in contact or the winding will go to ground and cause a short that fails the transformer. It is necessary only to check the temperature to be certain it is within operating range. Normally this is well below 70 degrees C.

On liquid cooled transformers, the oil level must be maintained, and the pressure must be kept at an acceptable operating level. To determine this value, consult the available documentation or the manufacturer of the transformer.

4.2.2.3 Surge Suppressor Inspection

To inspect surge suppressors, it is necessary to see that the indicating lights, where used, show the fuses ready. All connections should be tight and clean with no corrosion or other accumulations that could increase resistance of the connection. Insulators should not be cracked or discolored.

No adjustments for these devices is provided or intended. Their values have been calculated and fixed at a certain point to maintain balance within the system.

4.2.2.4 Thyristor Power Module

Six power legs are combined to create full wave rectification, or the creation of perfect dc power. Additional bridges may be paralleled to increase the load current rating of the converter.

The first cell failure of a leg will normally be indicated by an indicating light on the power module door. If the second cell of the same power leg fails, another indicating light will glow, and gate pulses to the thyristors will be prevented and the dc breaker or contactor will trip. This will generally have initiated a process fault stop.

4.2.2.5 D-C Power Switchgear

Before inspecting any of the dc power switchgear, the power must be removed from the circuit and locked out.

Loop contactors are normally large copper bars that are closed magnetically to start the motor. These are subjected to very high currents at a substantial voltage and, therefore, tend to pit and corrode. Note: Do not watch the loop contactor when switching under load as the arc can cause eye damage. The condition of the contactor points or mating surfaces should be observed periodically when the power is off to insure that they are not pitted severely. If the points are severely pitted it is possible for the points to stick together when switching and prevent the drive motor from being stopped.

On occasion the loop contactor may vibrate loose from the mounting bolts inside the cabinet. For this reason it is suggested that the mounting bolts of the contactor be checked for tightness when the hoist controls are inspected.

4.3 Motor-Generator Sets

Motor-generator (M-G) sets are normally found on older hoists. They tend to have a somewhat higher frequency of maintenance than thyristor units, but will still perform the same function of converting ac to dc power.

The motor-generator sets consist of an ac electric motor turning a dc generator. Because there are moving parts in the unit several safety circuits are normally found on M-G sets that are not found on thyristor converters. These will be listed here but inspection of the sensors for each circuit are found in section 6.

Switchgear found on M-G sets will consist of ac breakers and switches to control the ac motor and the same dc switchgear found on thyristor driven dc hoist motors. For inspection and maintenance procedures on ac breakers and switches, refer to section 5.

Figure 9 shows a typical Ward-Leonard system used for controlling dc motors supplied by an M-G set.

DC switchgear, such as the loop contactors, were discussed thoroughly under thyristor drives.

4.3.1 Generator Inspection

A dc generator is a dc motor being driven by mechanical energy rather than electrical energy. For this reason, generator units on M-G sets should be inspected in the same manner as a dc motor which was explained thoroughly in section 4.1.

4.3.2 AC Motor Inspection

AC motor inspection and maintenance is discussed at length in section 4.4 titled "AC MOTORS" and, therefore, will not be discussed at length here.

4.3.3 General M-G Set Inspection

All components discussed in the following section will normally appear on the motor and the generator of the M-G set.

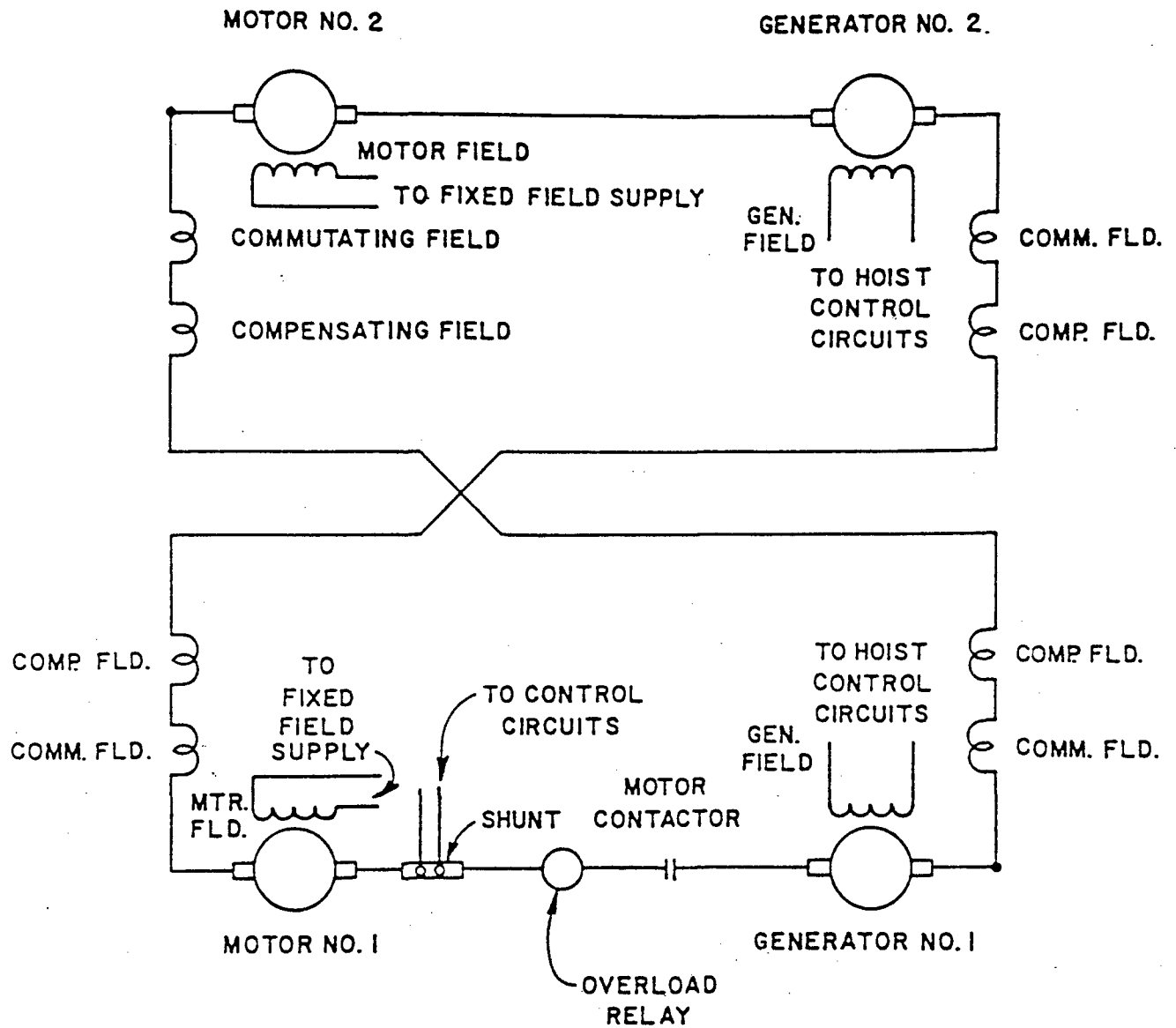


Figure 9
 Typical Ward-Leonard System
 (after V.B. Cook)

4.3.3.1 Ventilation System

Ventilation systems for M-G sets will normally consist of a blower and a series of filters. The air intake for the system will likely be the location of the filters.

Filters should be inspected and normally replaced at least every six months. If during periodic weekly or monthly inspections the filters appear to be dirty and restricting the free flow of air, they may need to be replaced more often. Climate and operating conditions will have a great affect on the life of filters; if operating in a dry dusty environment, the frequency of changes will be much greater than if operating in a wet or clean environment.

Blower motors should be lubricated normally when filters are changed. The lubrication will normally consist of applying a light oil or grease to bearings if they are not of the sealed type. Additionally, the air intake for the blower motor should not be obstructed in any way.

4.3.3.2 Bearings

Bearings will normally need to be lubricated on larger units such as are found on mine hoists, with a multi purpose grease. Records should be kept to show what type of grease is being used to avoid mixing greases.

Greasing should not be done more often than is recommended by the manufacturer of the equipment. This is normally once per year for most applications found in mining. If the environment is very dirty and hot with a large degree of vibration, this may be increased to once every 4 months.

Motors and generators should be greased while not operating. Lubrication fittings should be clean and free from dirt before an

attemp is made to apply more grease. Remove the lower grease relief plug. When grease begins to appear at the lower grease relief hole, the bearing is properly lubricated. Allow the machine to operate about ten minutes before replacing the grease relief plug to allow excess grease to drain.

Bearings will normally be equipped with overtemperature sensors. These may be either of the infra-red type that changes colors to indicate temperature or, they may be of the electrical type that will cause a warning possible followed by a shutdown if the bearing reaches a predetermined temperature. Additionally, bearings on large units will often be equipped with vibration sensors to stop the unit when vibration becomes excessive.

When inspecting operating equipment unusual noises and vibrations should be noted and checked out. If the noise or vibration tends to increase from one inspection to the next, it may indicate a bearing failure about to occur. This is another reason for maintaining inspection logs.

4.3.3.3 Electrical Connections

All power must be removed and locked out before conducting the following inspections.

All electrical connections in junction boxes on or at the machine should be adequately insulated to prevent short circuiting. If insulation shows signs of overheating, fuses and circuit breakers should be checked to be sure they are operable.

Uninsulated, bolted connections at the machine should be checked for tightness. If not tight, tighten before proceeding. Vibration during normal operation will very often cause the connections at the

machine to become loose. Loose connections should be noted during each inspection to prevent them from being overlooked during future inspections.

4.3.3.4 Generator Brushes

Pigtails on the brushes can be marked with some type of wear indicator. This may consist of a ring clamped around the pigtail above the top of the brushholder. When this ring reaches the top of the brushholder, brush replacement should be reconsidered. Continuing to use worn out brushes will result in commutator damage and therefore should not be practiced.

4.3.3.5 Commutator

The commutator on the generator should be kept clean and free from oily dirt or other contaminants. Normally this can be accomplished by wiping the commutator of a stationary generator with canvas or some other type of lint free material. For service procedures on the commutator refer to section 4.1.4.3.

4.3.4 Sensors Normally Found on M-G Sets

The discussion included here includes only the sensors commonly found and their location on M-G sets. See Section 6 for more information.

1. **Bearing Temperature** - This will normally be found on the end bearings of shafts of the motors and generators. Electrical sensors will be connected into the hoist control circuits to provide a warning when bearing temperature is becoming dangerous.

Infra-red indicators will consist of a multi colored strip attached to the bearing. As the bearing changes temperature, the strip will change colors.

2. **Vibration Sensor** - Vibration sensors are commonly located at bearings, in close proximity to the bearing temperature sensors.
3. **Overspeed Switches** - Overspeed switches will normally be centrifugal switches mounted on the shaft ends of motors and generators.

4.4 AC Motors

AC drive systems are perhaps the simplest drive system available for mine hoists. The motor is usually driven from ac line voltage reduced to 480 volts from the incoming 4160 or 2300 volts. Because of the simplicity of the system, inspection consists primarily of checking contacts, electrical connections, and mounting bolts on timing relays, starters, and circuit breakers.

4.4.1 AC Motor Control

Speed control of an ac wound rotor motor consists of changing the effective secondary resistance of the wound rotor. This is done through the use of relays that allow the hoist controller to add or remove resistance from the wound rotor secondary circuit. The resistors will normally be assembled in a series of banks somewhere in the hoist room.

The time at which the relays operate to change the resistance of the rotor will normally be controlled with the use of time delay relays or a manual controller.

4.4.2 AC Motor Inspection

Mechanically an ac motor should be inspected just as a dc motor or generator. This includes condition of the bearings and condition of the cooling air passages. The motor may very well be equipped with the same sensors outlined for dc hoist drives.

Refer to section 4.1 for a listing of commonly found sensors located on hoist motors such as the squirrel cage induction motor.

4.4.3 Timing Relays, Motor Starters, and Contactors

Timing relays should actually be timed with a stopwatch to be certain they are operating to keep acceleration below the limits set forth in 30 CFR. The original design criteria from the manufacturer of the hoist will have to be available to determine that the timing of the relays has not changed from the designed values. If the timing of the relays has changed considerably, then the relay should be adjusted. If the relay cannot be adjusted, then it or the timing element will have to be replaced.

Except when electronic timers are used, time delay relays consist of a relay with the addition of a plunger and cylinder. The plunger must force air out of the cylinder to allow the relay to close. The rate at which the air escapes from the cylinder is controlled by the size of the exit orifice. The timing of the relays should be such that the hoist can not accelerate faster than the rates allowed by law.

After the timing of the relays is checked, the condition of the contacts and electrical connections should be checked as outlined in section 5.2. The motor starters should be checked as outlined in section 5.3. Figure 10 is a schematic for a wound rotor motor starter circuit, showing the timing relays and major components.

All circuit breakers should be inspected. Instructions for this are contained in section 5.1.

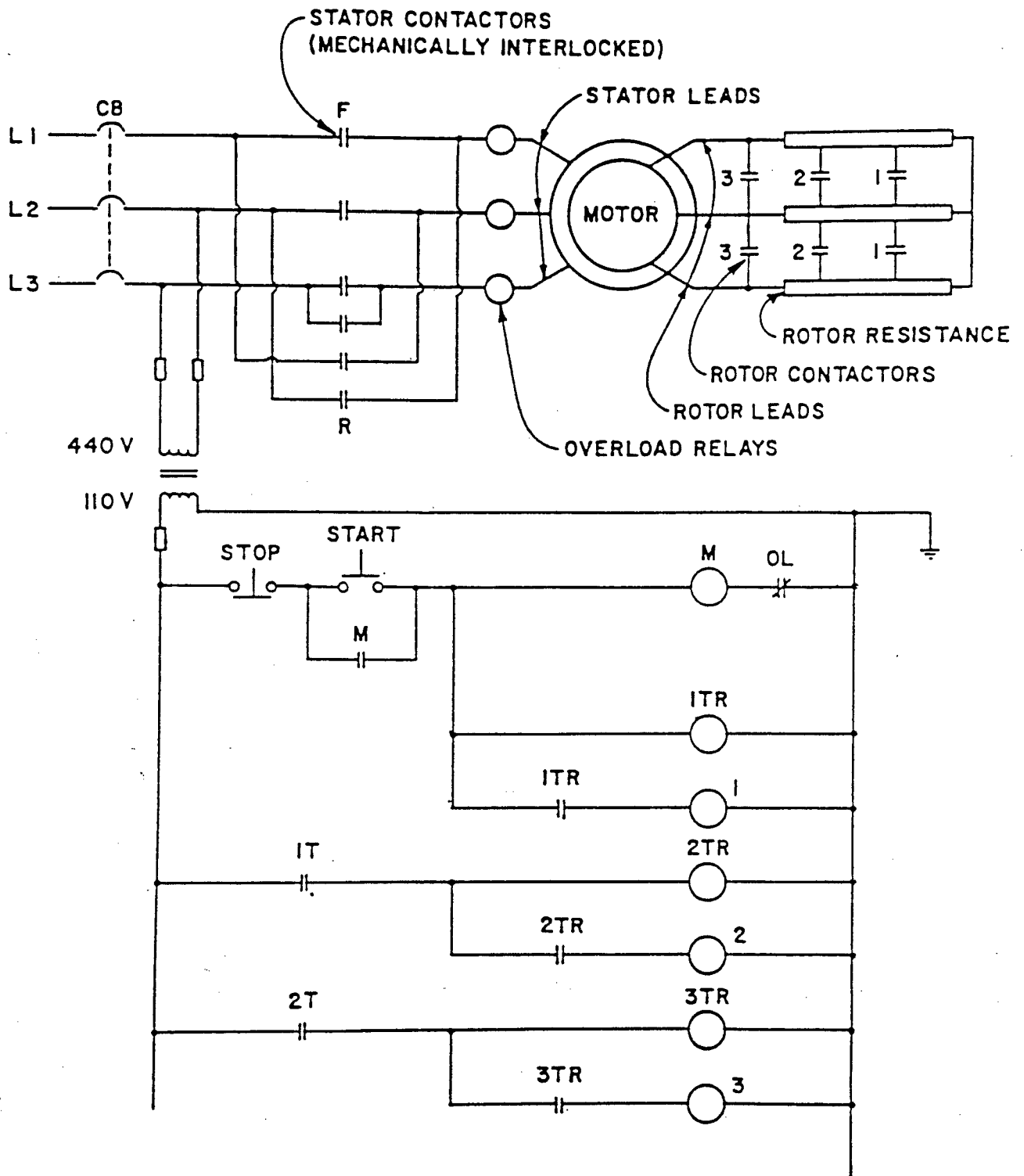


Figure 10

Wound Rotor Starter Schematic

(reference 13)

Contactors should be inspected to detect loose electrical connections or mounting bolts. The condition of the contactor mating surfaces must be noted. Burned or damaged contactors as shown in figure 11 should be replaced.

4.4.4 Resistors

Inspection of the resistors will normally consist of the following routine.

Remove and lockout all electrical power from the hoist before continuing with the inspection.

Using compressed air or some other means, blow all dirt off of the resistors to allow inspection of the resistors for cracks and discoloration. If any resistors are found to be cracked or discolored they should be replaced.

All electrical connections and mounting bolts for the resistors should be checked for tightness. Loose connections should be tightened.

4.4.5 DC Power Supply

The dc power supply can consist of anything from a dc welder to a sophisticated rectifier unit. However, they should all produce the specified voltage needed for dynamic braking if the hoist is so equipped. This value should be obtained from the hoist documentation and checked at the power supply. If the value is lower than stated, the power supply should be checked out according to the manufacturer's instructions, by trained, authorized personnel.

The dc power supply will normally be equipped with an ac circuit breaker to control the incoming power. This should be inspected as outlined in section 5.1. The dc power will also normally be equipped



Figure 11

Burned Electrical Contactor

with a circuit breaker or fuse. This should be checked. Fuses should be checked for continuity, and circuit breakers should be inspected as set forth in section 5.1.

5. CIRCUIT BREAKERS, CONTACTORS, AND STARTERS

This section covers some of the more common power switchgear found on mine hoists. Maintenance for all of the switchgear will normally be the same for ac and dc power.

5.1 AC Circuit Breakers

A wide variety of ac circuit breakers may be used. Therefore, in addition to the general procedures described here, it is suggested that the manufacturer be contacted for specific maintenance requirements. A reference that explains how to maintain and inspect circuit breakers is the following:

Breaker Basics

A Working Manual on Molded Case Circuit Breakers

by Westinghouse Electric Corporation

Low Voltage Breaker Division

Beaver, Pennsylvania 15009

Rather than repeat existing published material, the more important points will be summarized here.

Before any breaker is inspected all power must be removed and locked out.

5.1.1 Inspection

All circuit breakers should occasionally be tripped manually to insure that they are free to operate. This applies to the dc circuit breakers as well as the ac circuit breakers. If the system is equipped to simulate a ground fault and cause the breaker to trip in this manner, it is preferable to simply "pulling the handle".

For lower voltages, normally less than 1000 volts, molded case circuit breakers may be applied. The most important point to maintaining reliability of the breaker is the proper application and installation of the breaker.

To insure that proper breaker life is attained, it is essential that all terminal connections and trip units be tightened to the proper torque value as recommended by the manufacturer. Dirty or corroded terminals, improper terminal size, and loose terminations are all faulty conditions which may cause heating and deterioration. Any routine maintenance inspection should involve a check for tightness of all terminal connections and trip units with the power off.

Unless the breaker is equipped for electrical field testing where sufficient test instructions are provided, all testing should be done through a reliable service organization.

5.1.2 Trouble Shooting

If a breaker is continually tripping thermally the following should be considered.

1. **Excessive current.** The breaker may be operating properly and clearing an overload. Check to see if the current is in excess of the thermal trip rating.
2. **Terminals not torqued properly to base of breaker.** Visually inspect terminal area for any discoloring that would indicate loose connections. With the power off, check looseness.
3. **Cable improperly torqued in terminal.** Visually inspect for discoloring. Cables can become loose during service due to various reasons, such as vibrations and cold flow.

4. **Improper wire size.** To avoid fire and insulation damage, the proper size of current carrying conductors should be used. Cable Ampacity tables in the National Electrical Code should be checked.

5. **Ambient temperature too high.** This can become a problem on hot summer days. If the temperature fluctuates and sometimes exceeds 104 degrees F, an ambient temperature compensating breaker should be installed. If the temperature is consistently above this, a specially calibrated, high-temperature breaker should be installed.

6. **Trip unit damaged.** If all the above items check out OK, the trip unit should be removed from the breaker and inspected for discoloring.

If a breaker has experienced repeated mechanical and electrical malfunctions, high humidity and a corrosive environment may be to blame especially if the hoist is underground.

1. **High humidity.** High humidity contributes to corrosion, tracking, and dielectric failure. Forced ventilation or space heaters may be installed within the enclosure to reduce humidity.

2. **Corrosive environment.** The breaker should be removed from the corrosive environment if possible. Specially treated breakers are available to resist corrosive environments.

5.2 DC Mill Type Contactors

These will be found on all older dc powered hoists that are not thyristor driven. This is a single pole, dc operated contactor or relay, as shown in figure 12. DC mill type contactors may be found in place either with or without blowout protection.

Forms of the contactor without blowout coils should only be installed in the dynamic braking circuit. These have only make and

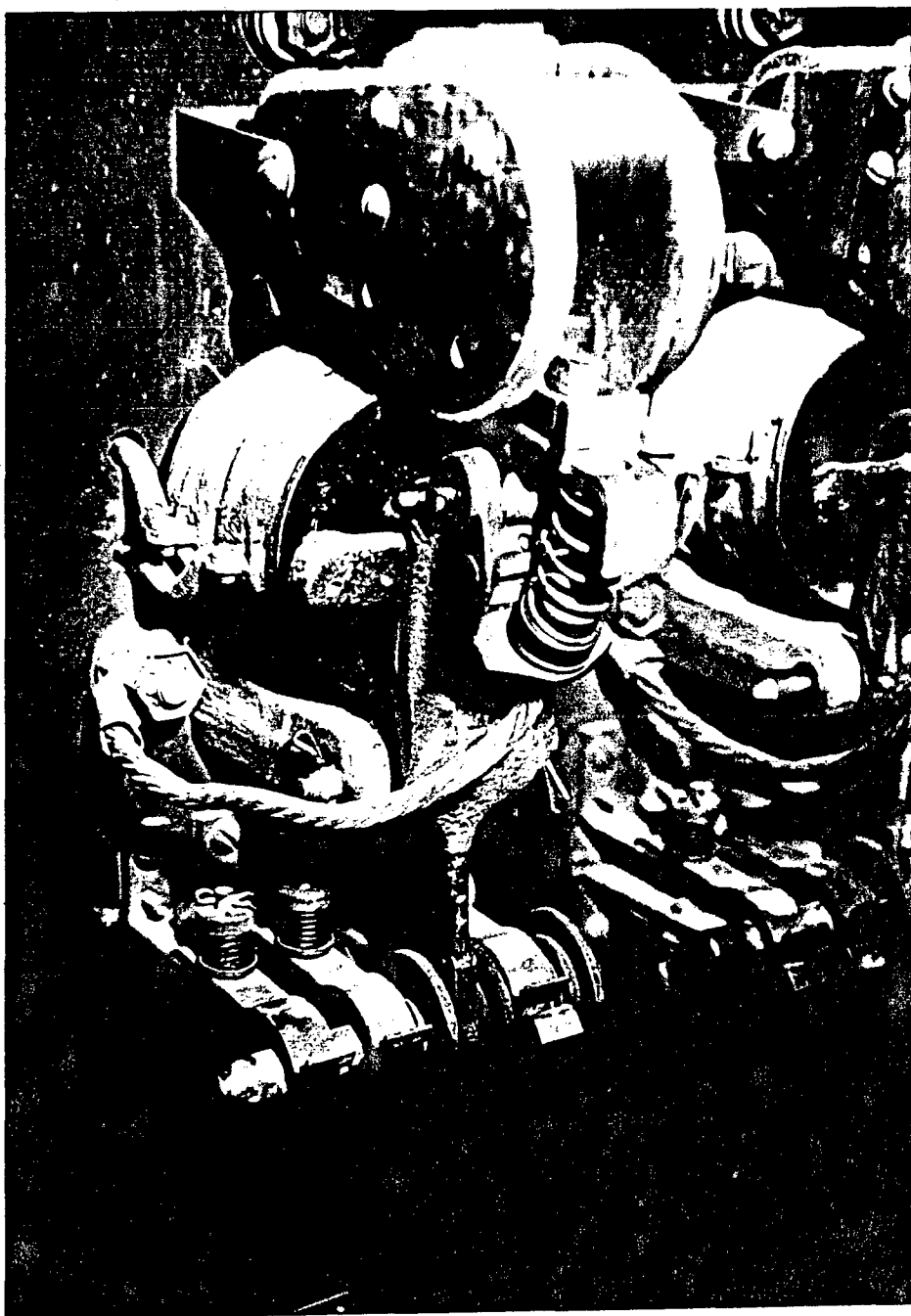


Figure 12

DC Mill Type Contactor

carry ratings and are not intended to be used to interrupt circuits under load.

If the contactor is installed with the purpose of interrupting a loaded circuit, the rating must be consistent with the load to be interrupted.

5.2.1 Maintenance

Before any contactor is inspected all power must be removed and locked out.

Maintenance of the mill type contactor will consist normally of the following:

1. Periodically tighten the electrical connections and the mounting bolts of the unit. The contactor is normally bolted to a large nonconducting surface. Because of the vibration from normal operation, this type of contactor may be vibrated completely away from the mounting surface. The vibration is also responsible for causing the electrical connections to work loose. This may cause loss of an intermediate hoist speed.
2. The contacts of the unit will tend to corrode and pit after normal use. When the contacts become excessively oxidized it may be necessary to dress the contact surfaces. Care should be taken here to avoid gouging the surface and to maintain parallel surfaces. When the contacts have been dressed several times, they should be replaced as per the manufacturer's instructions.
3. Occasionally the compression springs behind the moveable contact will loose strength and cause the contactor to open sluggishly. This will normally happen only after many years of service.

When the contactor is open, the spring will not appear to be tight against the supports at each end. When this is the case, the spring will need to be replaced.

4. If the contactor fails to operate, there are two possible reasons: either the coil is not energized, or the coil is shorted out electrically. If it is determined that power is being applied to the coil, then the coil should be replaced.

Early indications of a failing coil are such things as: occasional loss of a motor speed and slow or sluggish closing of the contactor. When these are noticed, the contactor is likely in need of a new coil and compression spring.

Because of the several different suppliers of this contactor, specific adjustment and repair procedures should be obtained for the unit being serviced.

5.3 Magnetic Starters

Magnetic starters are found on three-phase ac electric motors. These take the place of the loop contactor used on dc motors and, in addition, provide overload protection for the motor.

5.3.1 Maintenance

Before any starter is inspected all power must be removed and locked out.

Maintenance of the magnetic motor starters is normally very limited as they are an extremely reliable piece of electrical equipment. The following are some good rules to follow for all magnetic motor starters:

1. The magnet mating surfaces should be kept free of any dirt or dust. If the operating environment is extremely harsh, this may require the frequent disassembly of the unit for cleaning.

The starter can be disassembled normally by the removal of two to four screws from the front of the unit. This will then allow the magnet assembly to be removed, and the mating surfaces can be wiped clean. These surfaces should never be filed, oiled, or greased.

2. The silver-cadmium oxide contacts of the starter should never be filed to clean them. Instead, they should be wiped clean with a mild solvent. When the tip material is nearly all gone or the contacts are pitted very badly, they should be replaced.

To replace the contacts, first remove the magnet assembly and the coil. The contacts are normally mounted under the magnet assembly on a sliding plate. In some cases this is actually part of the magnet assembly.

3. All electrical connections to the unit should be tightened and checked as outlined for ac circuit breakers. All mounting bolts should also be checked and tightened. If experience and records show frequent occurrence of loose mounting bolts or connections the bolts and connections should be checked for tightness every month.

4. The overload units installed in a starter should be sized according to the load and voltage applied to the starter. Because this is different for every size and manufacture of starter, tables for sizing overloads should be obtained from the manufacturer. Frequently, they will be applied to the inside of the enclosure housing the starter.

If frequent starter dropout is experienced, the overloads are very likely undersized for the application. Conversely, if frequent overheating of the motor is experienced, the overloads are likely oversized and not providing protection to the motor.

6. SENSING DEVICES

Along with the items already mentioned, there are many other components on mine hoists that should be inspected. Because the location, design, and manufacture of each component can vary tremendously, only the more common items will be mentioned here.

Locations of the sensors have been discussed previously in this manual. If in doubt about the location of a unit, refer to the hoist documentation provided by the manufacturer. Figure 13 shows the typical location for tachogenerators, vibration sensors, and centrifugal overspeed switches.

6.1 Tachogenerator

The tachogenerator is quite similar to dc generators used to supply power to hoist motors in dc drive systems, except that it is much smaller. The output of the tachogenerator is proportional to the speed at which it is turned. Therefore, the output from the unit can be used to indicate speed (in revolutions per minute) of the machine rotating it.

If accessible, the brushes of the tachogenerator should be checked regularly. When performing this inspection, the hoist motor must be shut down and all power to the unit locked out. Badly worn or arcing brushes need to be replaced. The signal output from the tachogenerator is dependent on the condition of the commutator and brushes of the unit. If the brushes are worn, the signal from tacho will be inconsistent and often meaningless.

If the brushes can't be checked, check the tachogenerator output and replace the unit if the output is incorrect.

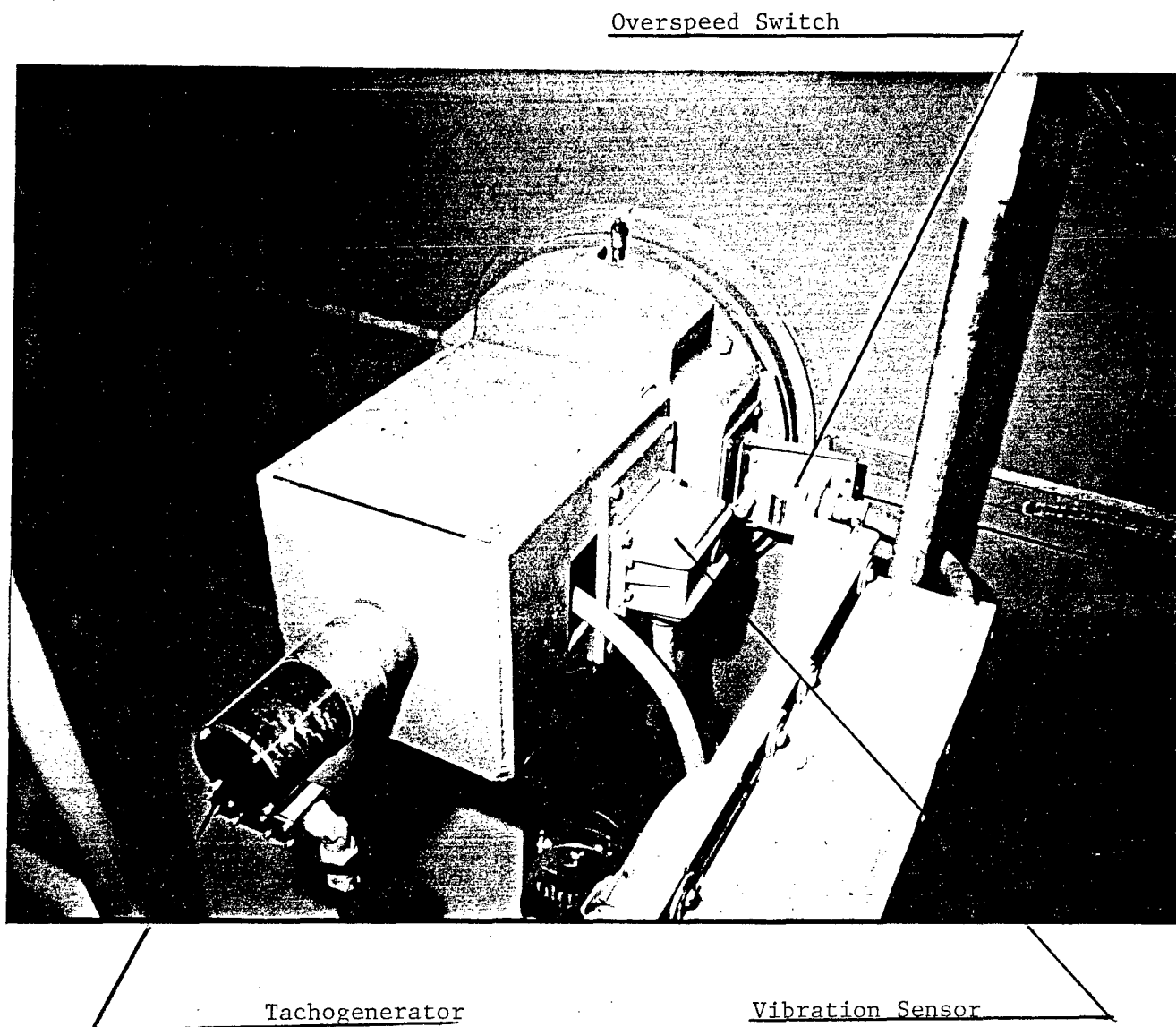


Figure 13
Tachogenerator, Vibration Sensor,
and Centrifugal Overspeed Switch

The tachogenerator is most normally found on the hoist motors and on the output side of the gear reducer for the hoist drums. When located on the drive motor, it is usually direct coupled to the motor shaft. When found on the hoist drive, it indicates drive speed and/or senses gear train faults by comparing speeds from one drum to the other or by comparing the relative speeds of the motor and the drum, after reduction. The output from one of the tachogenerators can be used to cause a deflection on a meter in the operators' control panel that will indicate rope speed.

An example to determine the correct tachogenerator output is:

Drum diameter = 10 feet

Drum RPM = 45 (determined with a stopwatch)

Rope speed = $45 \times 10 \times 3.14$ Feet per minute

Rope speed = 1413 feet per minute.

The tacho system should indicate approximately 1400 feet per minute. If a discrepancy of over 10% or over the manufacturers specifications is noted, the exercise should be repeated. If the same results are obtained again, the speed indicator circuit should be checked starting at the tachogenerator.

If documentaion on the tachogenerator is available, the output from the tacho can be checked using a multimeter. Consult the documentation supplied by the manufacturer and determine what the voltage ouput from the tacho should be for a given speed. Measure the voltage ouput of the tacho and compare it to the expected ouput. If there is a difference greater than a few percent, the tacho is in need of service.

The condition of the tachogenerator should be determined, starting with the brushes and commutator. If this part of the unit is in good

condition, the inspection should continue to cover the drive connection of the tacho and the wiring of the unit.

Loose or faulty connections can often be the source of inaccurate indications from the tacho. All electrical connections on the unit should be permanent and well insulated.

If the above have been conducted and the signal received is still not as expected, there is a good possibility that the panel meter is faulty. Replace the existing meter with a new meter and run the system. All of the above checks should only be performed by fully trained and authorized personnel.

6.2 Overspeed Sensors

Overspeed sensors will normally consist of one of two types. The first type will consist of a tachogenerator connected to a governor circuit that will sound an alarm and possibly shut the hoist down when the output exceeds a predetermined limit. Inspection and maintenance of tachogenerators has been discussed in section 6.1; however, the safety circuit will be considered briefly here.

If overspeed protection is continually tripping, the cause will lie in the tacho or in the adjustment of the governor circuit. The system should be inspected starting at the tacho and conducted as outlined in section 6.1. If the problem still exists, the the governor circuit is out of adjustment. If the governor is adjustable, it should be reset to the hoist control manufacturer's specifications. If the governor is not adjustable, it will likely have to be replaced.

Overspeed sensors of the centrifugal switch variety should be regularly inspected to determine that they will operate and close the required contacts if an overspeed condition is encountered. This is

normally accomplished by operating the switch manually. Figure 14 is a centrifugal overspeed switch located on a large motor.

If the power is interrupted and the switch cover is opened, several internal components can be checked. The electrical contacts on the switch should be in good condition with no deterioration or corrosion. The contacts are normally not lubricated or greased. Electrical connections on and to the switch should be permanent and well insulated. Unexplained tripping of the overspeed circuit may be corrected by reinsulating the connections to be certain they are not arcing from one to the other or from the energized circuit to ground.

6.3 Temperature Sensors

Temperature sensors consist primarily of two types, both of which are acceptable for mine hoist application. The first type discussed here will be the heat sensitive chemical unit. This type of temperature sensor has no electrical function and cannot shut down the hoist when an overtemperature condition is encountered. The heat sensitive chemical device consists of a multi-colored strip that changes color with corresponding temperature changes. These are adhesive backed and can be attached to any portion of the hoist. The one disadvantage of this type is that it requires visual inspection by a non-color-blind individual. As was previously mentioned, there is no way to relay the indication of the unit to an electrical indicator or safety circuit. However, they are inexpensive and can be replaced simply by applying a new unit to the location to be sensed. Often times this type of temperature sensor will be used during commissioning of a new hoist to indicate temperature of bearings and gear housings as well as drive motors. This is a very useful and inexpensive aid in maintaining hoist safety.

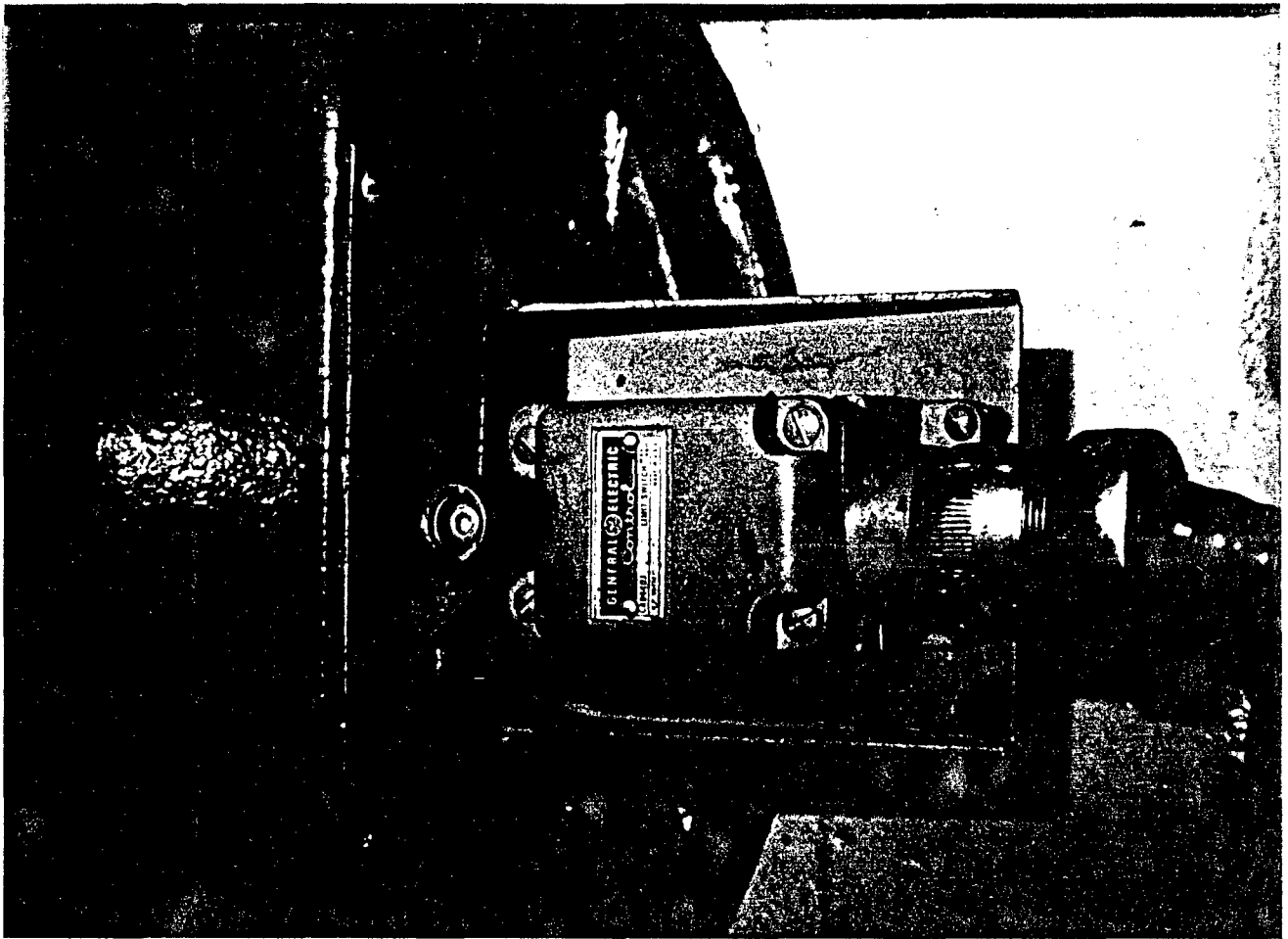


Figure 14

Centrifugal Overspeed Switch

Electrical temperature sensors normally consist of a thermistor connected to the component of interest. When the temperature changes, the electrical resistance within the thermistor changes and a voltage change is noticed by the control. This can be relayed to a panel meter that will give a reading of the temperature, and/or it can be connected to a control relay that will give an alarm when a predetermined temperature is reached.

If the temperature sensor causes tripping of the hoist control safety, it should be checked to determine if it is accurate. This can be done by placing a magnetic thermometer on the component or by application of a heat sensitive chemical thermal strip. If the component has overheated, the trouble should be corrected before continuing to operate the hoist. If the component has not overheated, the sensor is faulty and an inspection should be initiated that starts with the electrical connections. If all electrical connections are found to be solid and well insulated, the power supply to the sensor should be checked. If the incoming power to the sensor is as specified by the manufacturer, the sensor will likely have to be replaced.

6.4 Vibration Sensors

Vibration sensors have recently become widely applied in the mining industry. They can now often be found on large ventilation fans, compressors, and hoist drive motors. They are useful for picking up early signs of bearing failure, loose motor mounts, or bent shafts as indicated by increased vibration.

Increase vibration can mean either that bearing wear is becoming unacceptable or that the rotating piece of machinery is becoming out of balance. Both of these conditions are cause for inspection of the

equipment. Therefore, vibration sensors are normally connected to the hoist control circuit to give an alarm and/or stop the hoist when vibration becomes unacceptable.

Vibration sensors found installed on mine hoists are reasonably new and well documented in hoist operation and maintenance manuals from the standpoint of inspection and maintenance. The greatest problem is determining an acceptable level of vibration and where the unit should be set to give an alarm. The first method employed to overcome this problem is to consult the supplier of the unit being monitored or the supplier of the sensor. From this point it becomes somewhat of a trial and error approach.

The sensor should be adjusted down to where it will not trip during normal operation. As the machinery wears, the sensor may begin to cause trip-outs of the safety circuit. These should be carefully evaluated, and if the equipment is in good condition, then the sensor should be readjusted. This should be done with extreme care so as not to make the sensor inoperative. The sensor should be set to operate before the vibration becomes unacceptable.

Inspection of the sensor will consist primarily of determining that all electrical connections are solid and well insulated. The power supply to the unit should be as specified by the supplier. As previously noted, the sensor may be connected to cause an alarm and/or a shut down of the hoist.

Safety circuits discussed up to this point can be inspected by injecting a signal. This involves the careful application of a signal that imitates the output of the sensor to the safety circuit. This will cause the system to recognize an unsafe condition and give the

appropriate alarm or initiate a shut down of the hoist. THIS SHOULD ONLY BE DONE BY FULLY TRAINED AND AUTHORIZED PERSONNEL. However it is a preferable method to overspeeding or emergency stopping the hoist, because extreme care must be taken to avoid damage to the hoist controls or the hoist. Full speed shutdowns and overspeeding should be avoided as they cause unnecessary stresses to the hoisting equipment.

6.5 Proximity Switches

Magnetic proximity switches are normally found located in the shaft to indicate the actual position of the conveyance. Proximity switches operate by generating a magnetic field in front of the face of the switch. When this field is broken by the conveyance or a magnet located on the conveyance, a signal is produced. This will then be relayed to the hoist control to indicate the position of the conveyance. Switch maintenance is limited as there are no moving parts. Inspection consists of making certain that the buildup of dirt or other contaminants is not excessive enough to cause malfunction of the switch. If the switch cover appears to be damaged the switch may have been hit and may be unreliable.

The electrical connections to the unit should be solid, well supported, and thoroughly insulated. The power supply to the unit should be as specified by the supplier. Because of the location in the shaft or headframe, corrosion may be a problem. This will eventually result in failure of the switch and results in a possible unsensed overtravel. The correct operation of the switch is normally determined by moving the conveyance into an overtravel position at creep speed. During the movement into overtravel the conveyance should be visually observed by personnel in contact with the hoist operator.

As with other electrical equipment, care should be taken not to contact energized circuits. Proximity and mechanical limit switches however have an additional inherent danger in inspection because of the hazard of falling down the shaft. Inspection of shaft limits is normally conducted during regular shaft inspection, and should be conducted only by personnel familiar both with the electrical precautions and also with the normal precautions such as wearing safety belts and being securely tied off.

6.6 Mechanical Limit Switches

Mechanical limit switches are normally located in the shaft in conjunction with or in lieu of proximity switches. They are used to indicate conveyance position. Mechanical limit switches are somewhat more maintenance intensive as they have moving parts that can and do wear out.

Mechanical limit switches consist of an arm and roller assembly connected to a switch that is opened or closed when the conveyance passes. The switch may be either normally open or normally closed, but this should be determined before inspection from the hoist control circuit diagrams.

Inspection will consist primarily of determining that the switch is still physically in place, that the arm is not bent or broken and that the roller is not damaged. The hoist controls should respond correctly when the switch is activated. Mechanical limit switches may be operated manually during shaft inspections. Electrical connections should be inspected as for proximity switches, and the incoming power to the switch should be compared to the manufacturer specified value.

7. LILLY¹ CONTROLLERS

7.1 Introduction

The purpose of this section of the manual is to provide mine operators and safety inspectors with an easy to understand, complete reference on the operation of Lilly¹ controllers. It has been divided into three sections. The first section provides an introduction to the Lilly¹ controller, including a brief history. The second section describes the operation of major controller components. Finally, the third section contains a suggested inspection and maintenance schedule. Also included in the third section are some minor adjustments and corrective measures based on the outcome of inspections.

Lilly¹ controllers were first introduced in the early 1900's when mine operators began to realize the need for a device to assist in preventing hoisting accidents. In 1913 Mr. Lilly entered the field and produced two Model A controllers, which were not placed on the market. Around 1919 Mr. Henry Logan entered the field of controllers and the Model C controller was produced. The Model C produced today is virtually the same as was produced in 1923.

Lilly controllers are installed on nearly every metal/nonmetal mine hoist and many coal mine slope and shaft hoists in the U.S. today. Even so, there is very often confusion over what it is capable of doing. Briefly, the Lilly¹ will sense and control overspeed and overtravel, and initiate a stop. The Lilly¹ Controller will NOT indicate or control slack rope, brake wear, etc..

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

Additionally the Lilly¹ will perform the following functions:

1. Sound an alarm when normal speed has been exceeded, and initiate stopping the hoist if prompt action is not taken to slow the conveyance.
2. Indicate when it is time to begin retarding the hoist.
3. Limit the maximum speed during retarding.
4. Prevent the conveyance from being hoisted or lowered into an overtravel position without the hoistman performing some type of manual override.
5. With accessory devices, prevent the hoist from being started in the wrong direction when the conveyance is at the end of travel.
6. Initiate an emergency stop if at any time an alarm or warning is ignored or overlooked by the hoistman.
7. Regulate the rate at which the brakes are applied.
8. Indicate the position of the conveyance within the shaft (simplex only).

It must always be remembered that the Lilly¹ controller will only sense and indicate overtravel at the extreme ends of the hoisting cycles unless equipped with "variable depth" equipment, in which case all functions are repositioned. In other words, the overtravel limits merely prevent the conveyance from being pulled into the headframe or lowered into the sump.

A Lilly¹ controller will provide many safeguards provided it is properly installed, adjusted, and maintained. The importance of the inspection and maintenance procedures described herein can be better understood when one considers the following facts.

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

From 1971 to 1979 at least six men were killed as a result of improperly installed or maintained hoist controllers. In addition to this, at least ten nonfatal hoisting accidents occurred in the same time period which caused several million dollars' worth of damage and loss of production. These figures reflect only United States accidents that were investigated and reported by MSHA. Specific component or inspection/ maintenance failures which resulted in accidents are included in part 7.3 to explain why certain inspection and maintenance techniques should be used.

The following describes how the Lilly¹ functions in the basic hoisting cycle. Figure 15 diagrams a typical man hoisting cycle. The origin represents the conveyance at the upper station of the shaft, and not moving. The line from point 1 to point 2 represents the acceleration of the conveyance from rest to normal operating speed. The distance from point 2 to 3 represents the conveyance traveling in the shaft at normal speed, while the distance between points 3 and 4 represents the conveyance slowing to a stop at the landing. Typically the cycle will appear the same for hoisting and for lowering. The flat portions at the ends of the cycle represent what is commonly known as the "creep" speed, or the period of very slow movement just before coming into a station or just after leaving a station. This is normally 8% of full speed for a Model C controller and 22% for Simplex and Model D controllers. A Lilly¹ controller forms a protective envelope above the normal operating curve. As shown in figure 19, any time the hoist speed exceeds the envelope or retarding is not started

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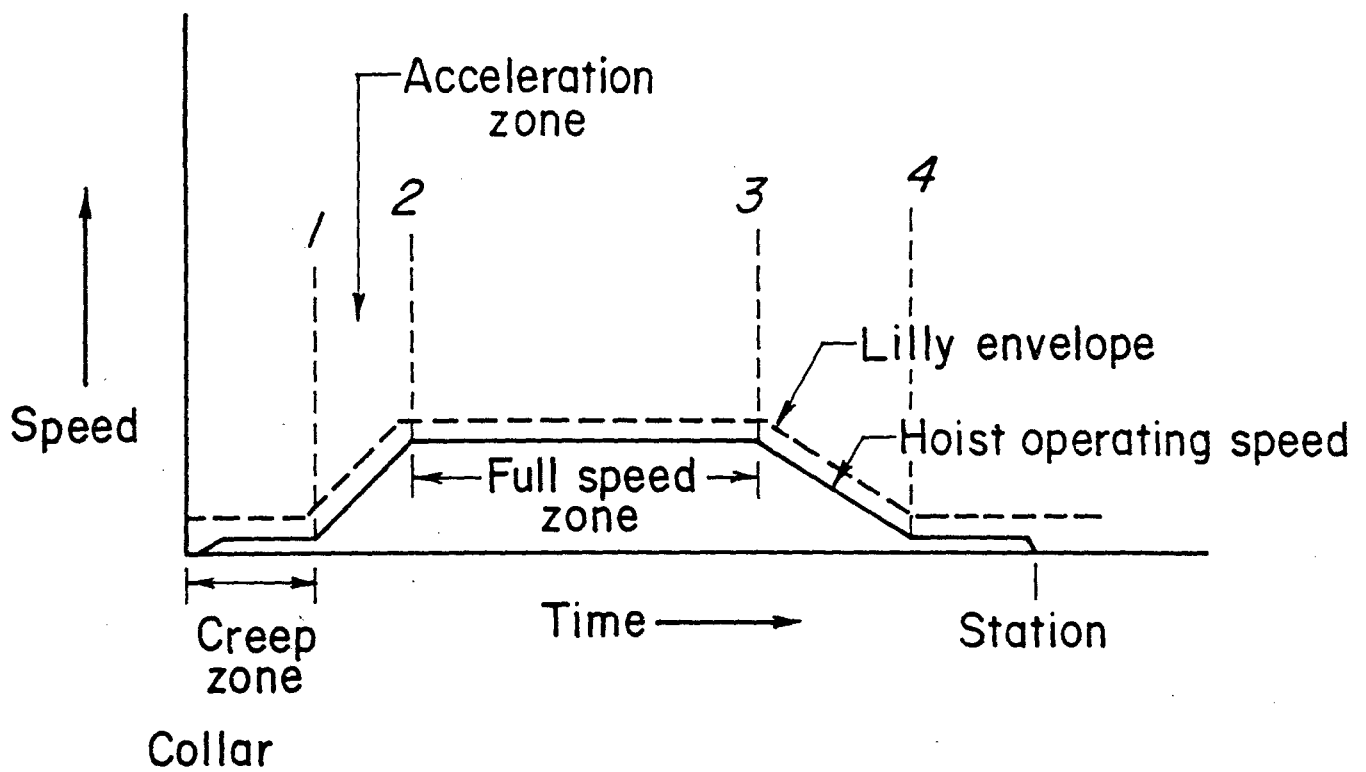


Figure 15

Typical Hoist Speed Time Operating Diagram

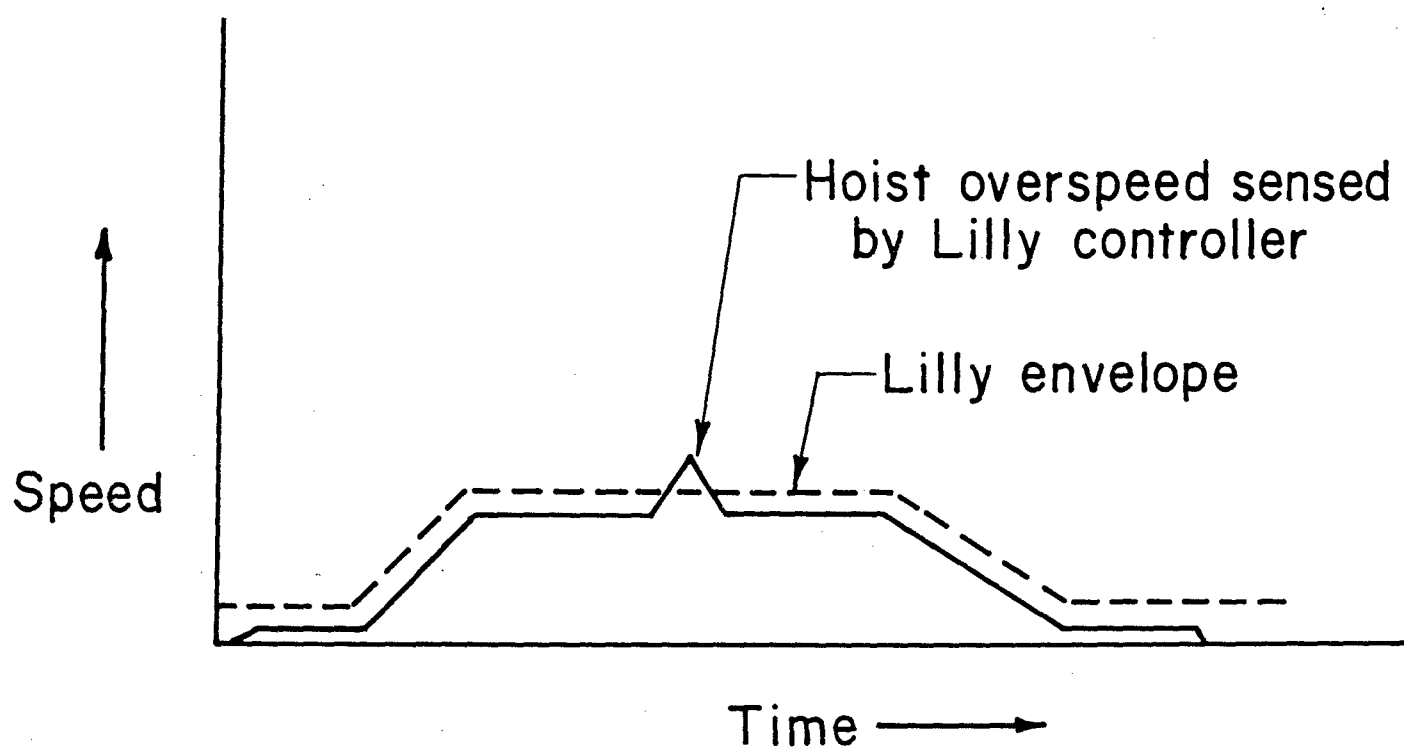


Figure 16

Hoist Overspeed Sensed by Lilly Controller

soon enough, the Lilly¹ can give a warning and/or initiate an emergency stop. To simplify the drawings, acceleration and deceleration rates were shown to be about the same. This is not always true in actual practice.

7.2 Principles of operation of the Lilly Controller

The fundamental principle of operation of the Lilly Controller is based upon the co-ordinated movements of the governor and cams with the governor following the hoist speed and the cams following the relative position of the conveyance providing a pattern for the correct speeds at all points of travel including retardation.

The Lilly¹ controllers do not interfere with the normal operation of the hoist within the predetermined bounds of speed and travel and the hoist may be stopped at any place and started with full torque in either direction except at the limits of travel where it may be operated only in the return direction.

The Simplex controller is the most basic of all of the Lilly¹ controllers as it is intended to be applied to simple hoisting operations. As such, the controlling ability of the Simplex is somewhat limited when compared to the Model C and Model D controllers. It will, however, still control overspeed, overtravel, and retardation. A large dial can also be used as a depth indicator. It is equipped with a flyball governor that is enclosed in a housing behind the depth indicator. For this reason it may be necessary to open the hinged housing cover to inspect the governor. This should only be done by qualified personnel.

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

The operation of the Simplex controller is based upon the coordinated movements of a centrifugal governor and a pair of cams mounted on a rotating cam dial driven from the hoist drum. The movements of the governor and cams are synchronized with the hoist drum and will, therefore, represent at any time the speed of the conveyance in the shaft and the position of the conveyance in the shaft respectively. The combined operation of the governor and the cams manipulates an electric switch that will cut off the power to the hoist motor and apply the brakes in an overspeed or overtravel situation.

The only cams on the Simplex are retarding cams, one for each end of travel in a shaft. NOTE: All cams for Lilly¹ controllers are shipped from the factory with an unfinished profile and must be profiled for each application.

The cams are mounted on a rotary dial and may be moved to any position on the dial through the use of clamping bolts moving in a "T" slot in the back of the dial. These bolts must be tight enough to prevent the cams from slipping.

Each cam provides overspeed and overtravel protection for each end of travel in the shaft. Therefore, the two cams are mounted to come in contact with the respective roller at the end of travel controlled.

The length of the taper on the cam should correspond to the distance the rim of the cam dial moves during retardation and acceleration. The profile should be such that the cam operated arm of the switch will follow as closely as possible the movement of the governor operated arm during retardation when the hoist is operated in a normal manner.

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

The full speed adjustment of the Simplex is obtained by means of a screw extending through the top of the casing. The more it is screwed in, the faster the hoist can run without causing a trip-out. The screw should be locked in final position by a locknut provided for the purpose.

The Model D and Model C controllers are very similar in operation. The primary difference is that the Model D controller is equipped with only one cam dial to control both the hoisting and lowering cycle. The controller will still control overtravel and overspeed in both directions as well as provide an alarm when entering the retarding zone. Additionally, the Model D will only have one governor to control speed during the entire hoisting cycle.

The Model D controller has two separate cams to provide overtravel protection at each end of the hoisting cycle. They are fastened to the cam dial in a manner that allows them to be positioned anywhere on the dial, as required by the individual installation. The two limits are offset so that they operate separate switches. The Model D is more fully explained in part 7.3. However, the manual supplied by the manufacturer should also be consulted.

The primary components of a Lilly¹ Model C controller are shown in figure 17. The cam dial rotates as the conveyance moves in the shaft and changes direction of rotation as the conveyance changes direction of travel. The cams are securely connected to the cam dial and, therefore, rotate with the dial. However, the rollers and switches are rigidly mounted on the frame of the controller.

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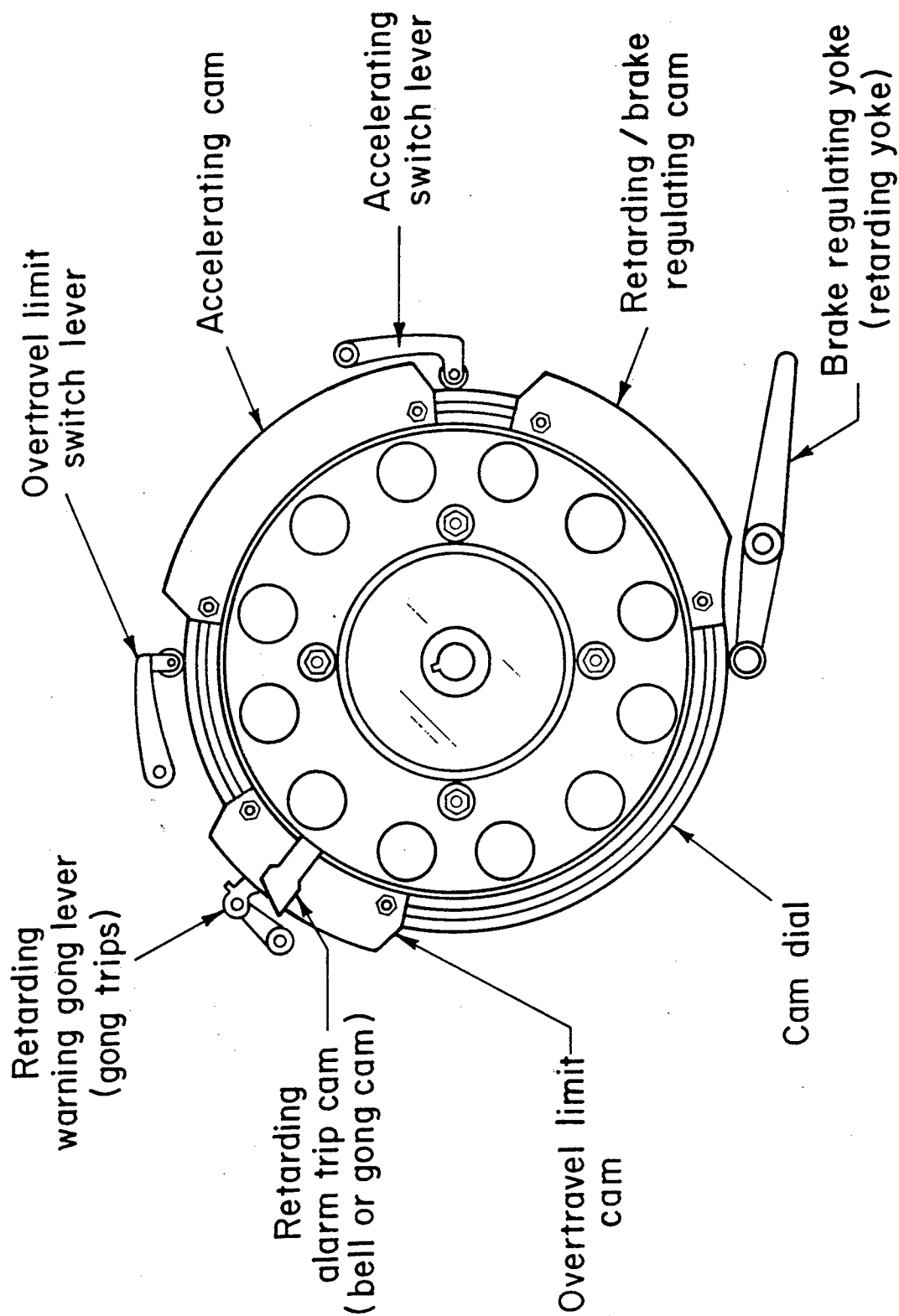


Figure 17

Lilly Controller Cam Dial Components

If the Model C controller is equipped with a long range dial drive, the cam dials rotate only near the ends of the hoisting cycle. This allows the controller to maintain more precise control over the speed and limits of the hoist.

If the cam dial moved throughout the hoisting cycle on a deep shaft, it would be necessary to gear down the controller a considerable amount to get the entire cycle in less than one revolution of the cam dial. For this reason with deep shafts, usually in excess of 3000 feet it is essential to equip the controller with a long-range dial drive. This will enable the controller to be geared at a reasonable value and still control all of the functions of the hoist in somewhat less than one full revolution of the cam dial.

As the cam dial rotates (clockwise in Figure 19) near the end of travel, the retarding warning gong is sounded by the retarding alarm trip to indicate that the conveyance is entering the retarding zone. Also at this point, the accelerating switch is engaged to allow a fast acceleration out of the station in the opposite direction of travel. The retarding/brake regulating cam contacts the brake regulating yoke roller to control the rate at which the brakes are applied. Finally, the overtravel cam will contact the overtravel limit if the conveyance passes the limits of safe travel.

Because of the necessity for protection at both extremes of travel, all of the aforementioned features are required for the hoisting as well as the lowering portion of the cycle. To provide this, a Model C controller is equipped with two cam dials. One for hoisting, and one for lowering. The figures shown herein relate to the cam dial controlling movement within the lower portion of travel. The

other dial located on the opposite side of the controller functions in exactly the same manner.

Two basic types of governors are provided on Lilly¹ controllers. These are the single governor and the duplex governor. Both are flyball governors, connected by a complex linking mechanism to the internal components and switches of the controller. The duplex type is normally installed on hoists operating at a high rate of speed (normally in excess of 1500 feet per minute). The combination of two governors allows for two separate and distinct speed ranges to be controlled. One governor will control speed up to half of the normal operating speed, whereupon the second governor begins to take over the control of overspeed. This combination provides for a speed control range of nearly twice that of a single governor.

When the hoist speed has slightly exceeded (about 10% to 14%) the predetermined maximum speed or if it is not decreased in conformity with the profile of the retarding cam when approaching the end of travel, an electrical contact closes a circuit to ring a bell or buzzer to warn the hoistman of the condition. If he fails to respond promptly and permits a slight further increase in speed or if a retarding cam engages the cam roller without the hoist being retarded, the overspeed switch in the Lilly¹ controller will open the safety circuit, thereby cutting off the power by opening the motor start or circuit and initiate setting the brake.

Now, a round trip will be taken to explain the operation of the Lilly¹ controller. It will begin with the conveyance reaching the

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lower position or station in the shaft as shown in figure 18. Just before the hoist comes to a stop during lowering, the retarding alarm gong (figure 18) signals an alarm to indicate to the hoistman that the retarding zone (point 3 of figure 15) is being entered. As this occurs the accelerating cam causes the accelerating switch to close. The retarding cam requires the hoistman to properly slow down until the hoist has come to complete stop (slightly past point 4 in figure 15). After the retarding zone has been entered (figure 19), and the hoist speed has been reduced to creep speed, the Lilly¹ controller still has control. If the hoist speed was to exceed creep speed before stopping, an alarm would normally be triggered followed by a "trip-out". A "trip-out" means an emergency stop occurs by interrupting power to the hoist motor and setting the brakes immediately.

If a stop is not made before the overtravel cam contacts the overtravel limit, an alarm and a trip-out will occur. Figure 20 shows a normal stop, figure 21 shows an overtravel condition.

After the conveyance has been brought to a normal stop and conveyance direction reversed, the accelerating cam engages a roller activated switch (figure 22). It energizes the accelerating solenoid through directional contacts in the master controller only when leaving the limit of travel. This solenoid then causes the overspeed alarm contacts to open slightly more than normal. Furthermore, the action of the flyball governor is overridden until

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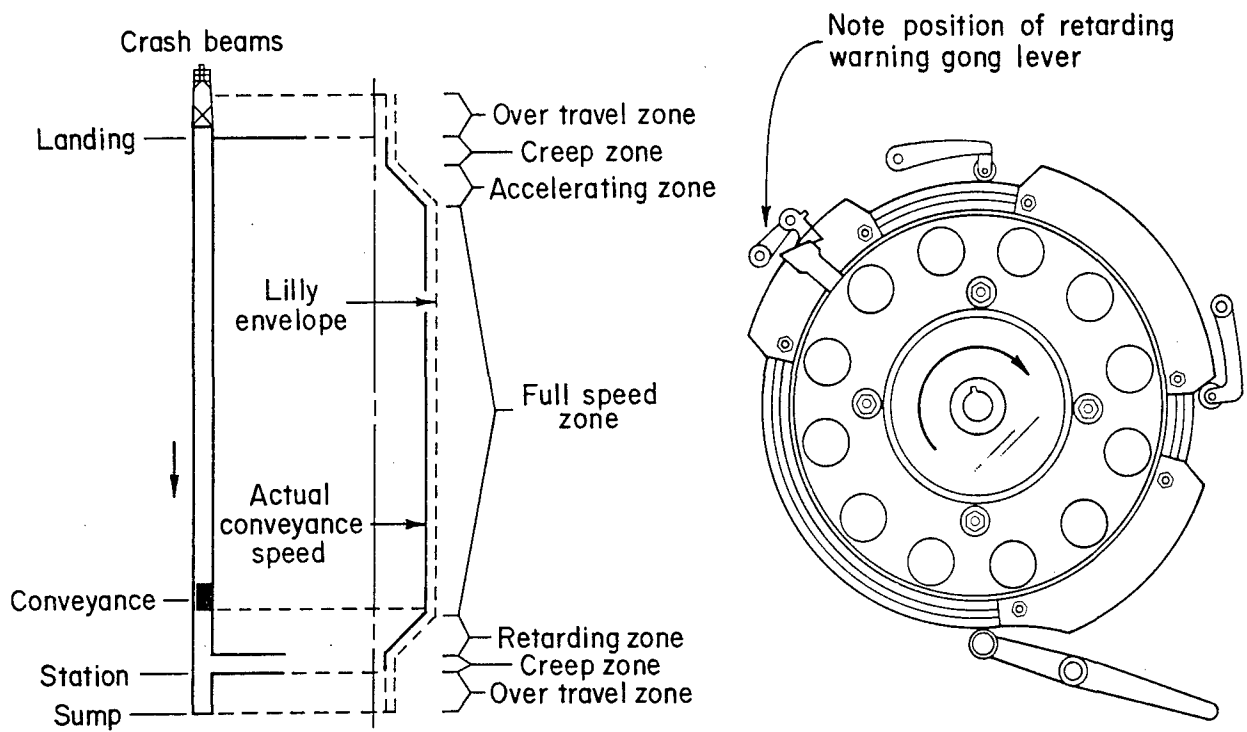


Figure 18
Cam Dial Position as
Hoist Enters Retarding Zone

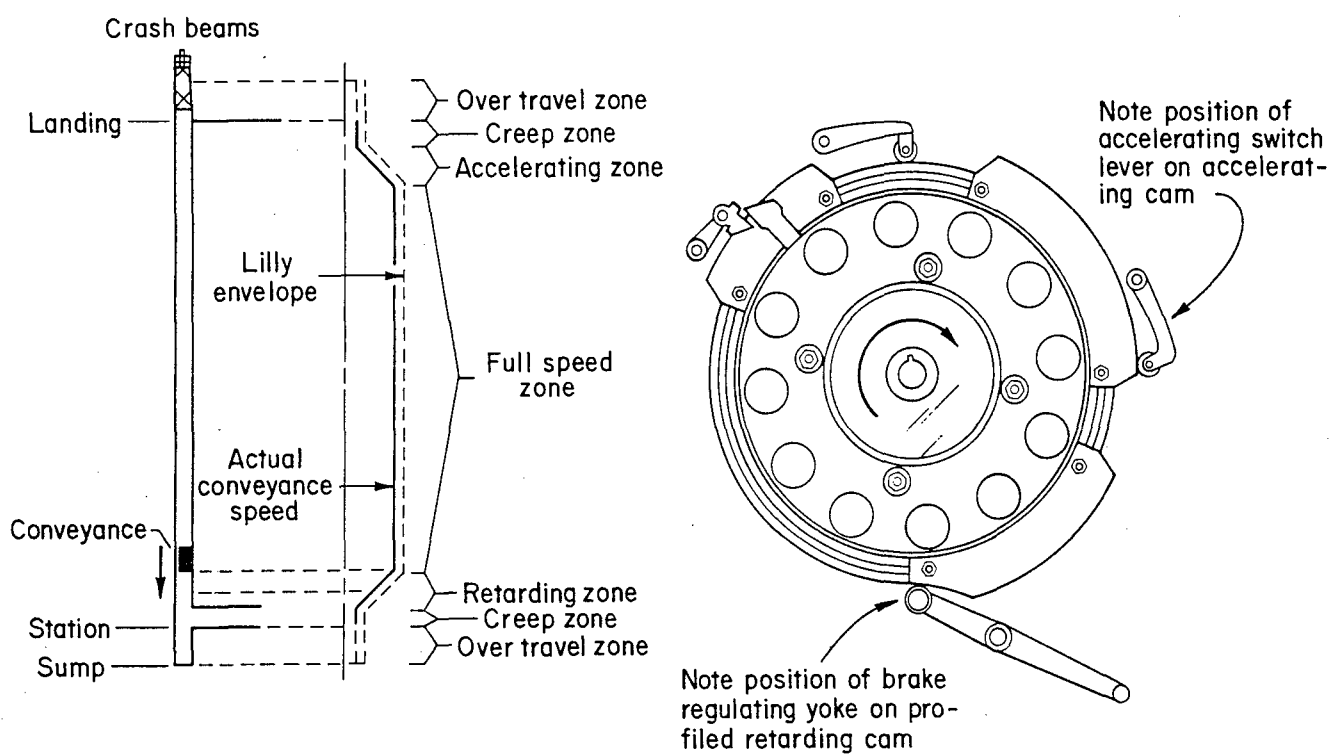


Figure 19
Cam Dial Position with
Hoist in Retarding Zone

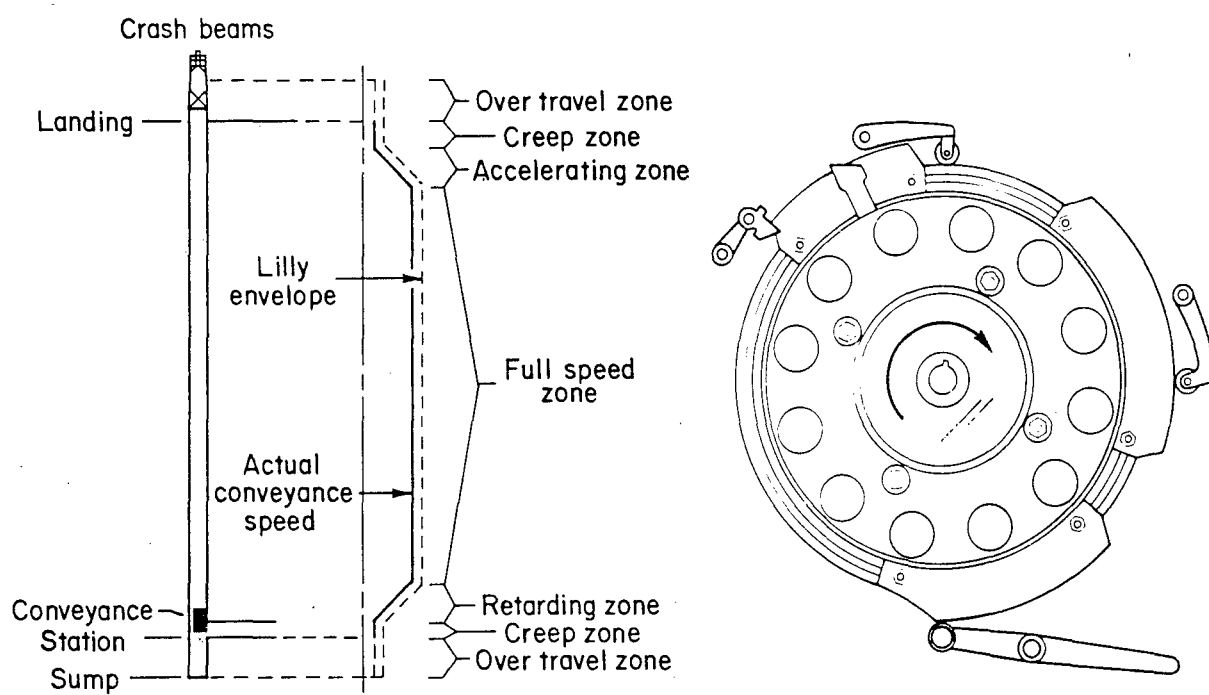


Figure 20
Cam Dial Position for
Normal Hoist Stop at End of Travel

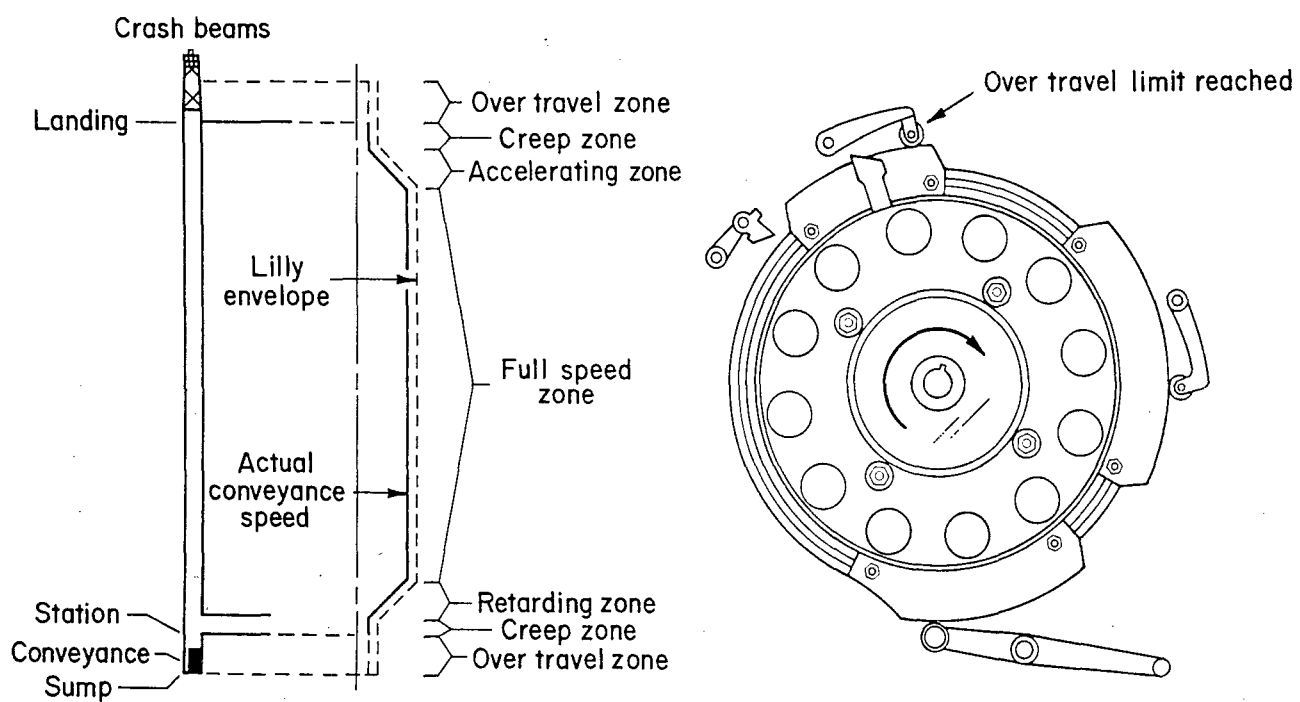


Figure 21

Cam Dial Position with
Hoist in Over Travel Condition

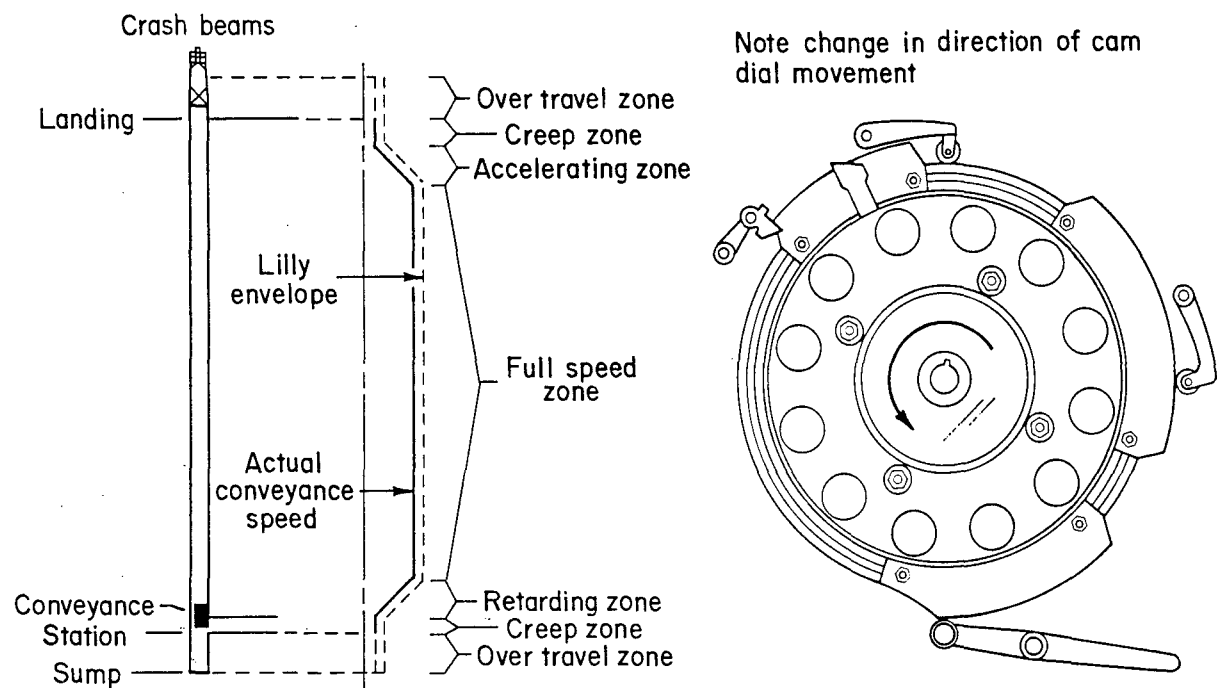


Figure 22

Cam Dial Position

When Hoist is Accelerating

full speed is reached. This allows for a faster cycle time by increasing the acceleration of the hoist and reducing the creep time while not sacrificing safety.

As the hoist is operating in the full speed part of the cycle (between points 2 and 3 in figure 15), the flyball governor monitors the hoist speed (see figure 23 and 24). During normal operating the flyballs should be below the horizontal slave in the case of a single governor to allow room for them to move upwards if an overspeed were to occur. Normally the overspeed control is set to operate when normal speed has been exceeded by 8 to 10%. When an overspeed is encountered the flyballs raise above their normal operating position and open the overspeed contacts which in turn initiates a trip-out.

The Model C controller can be equipped with many optional features: reversing switch, double overspeed contacts, resynchronizing switches, friction dial drive, man safety equipment, and variable depth equipment. This manual does not include detailed instructions for all of the possible combinations of equipment of controllers, but rather the more common optional features. If the controller being inspected is equipped with features not included here, it is suggested that the controller manual supplied by Logan Actuator Company¹ be referenced for further information. If the manual is needed contact:

Logan Actuator Co.
4956 Elston Avenue
Chicago, Illinois 60630
(303) 736-7500

for replacements or information.

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

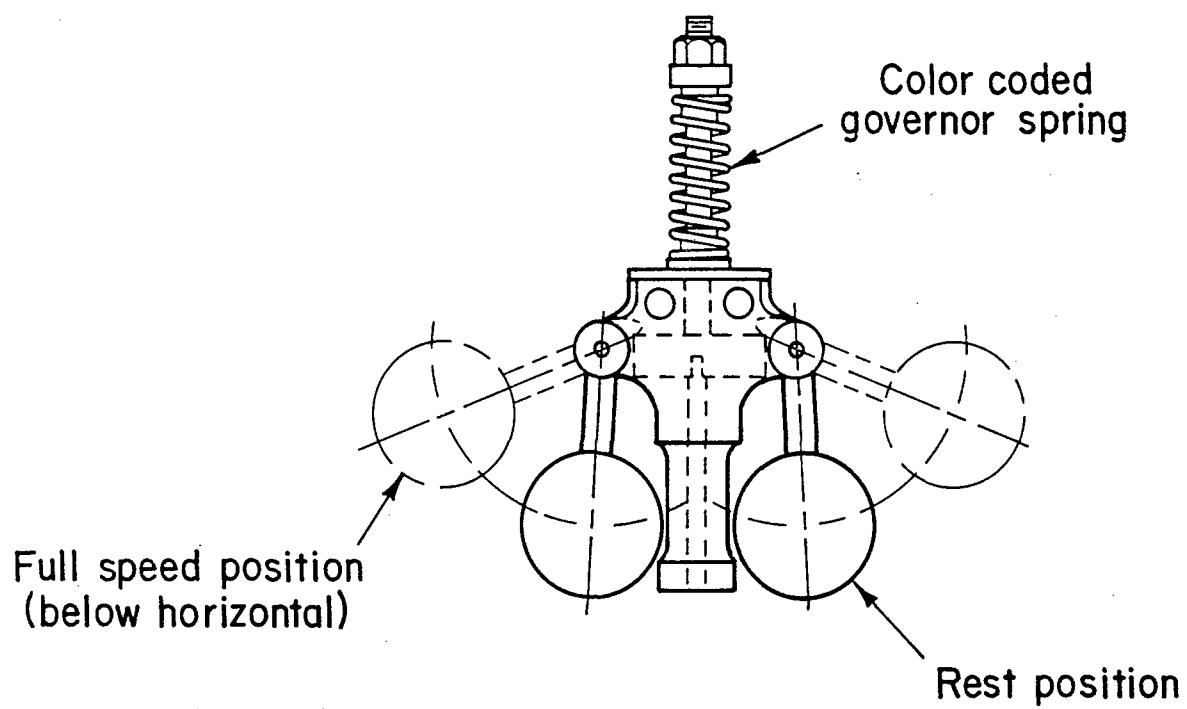


Figure 23

Lilly Controller Fly Ball Positions

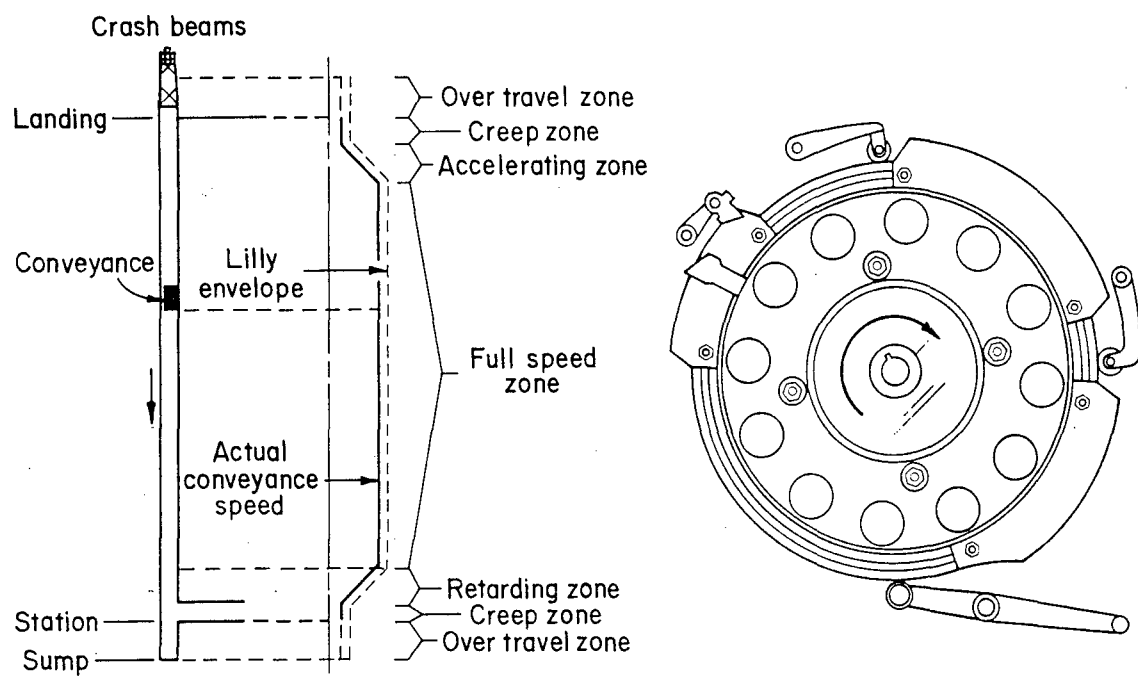


Figure 24

Cam Dial Position with Hoist
in Full Speed Operation

7.3 Lilly Controller¹ Inspection

7.3.1 Introduction to Inspection

The Lilly Controller¹ is a very intricate and complicated piece of machinery. For this reason help from experienced personnel should be sought out before adjusting or repairing the controller. This manual is intended to assist the user to recognize when adjustment and repair is necessary. MSHA Technical Support located in Denver, Colorado can assist in locating a qualified person.

This portion of the manual contains a list of items to be checked when performing periodic inspections. The items on the checklist and inspection procedures are explained in the following pages. The checklist appears at the end of the section. If this manual is followed carefully, the Lilly¹ controller should never cause an unsafe condition. The following accident description will demonstrate the importance of thorough inspection!

At the end of the shift, during the normal hoisting of men the Lilly¹ controller tripped out and shut down the hoist after only two turns of the drum. As the hoistman left his console to reset the controls, he noticed the hoist drum turning and rushed back to the console to tighten the manually applied brake. Before he could stop it, the cage hit bottom with a full load of men. Luckily, this was a nonfatal accident but two employees had to spend the night in the hospital.

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The cause of the accident was the failure to properly apply the hoist brakes, due to neglect of the maintenance of the Lilly¹ controller.

Problems found during the accident investigation:

1. The overspeed warning bell was inoperable.
2. The drive linkage for the Model D controller was installed backwards.
3. The roller on the brake regulating yoke was badly worn.
4. The overspeed contacts on the controller had been filed to clean them.
5. The hoisting deceleration cam was improperly profiled.
6. The Lilly¹ drive chain was slack.
7. The keyway was loose and worn on the input shaft to the Lilly controller.
8. The input shaft bearing for the controller was misaligned.
9. The Lilly¹ controller gears were dirty, indicating the lack of a systematic maintenance program.
10. The brake linkage wear was excessive.

This accident involved nearly every possible thing that could be wrong with a Lilly¹ controller. The reason as was stated, was the lack of a systematic inspection and maintenance program. The miners were lucky. A multiple fatality could have occurred. In the following paragraphs an inspection procedure that could have prevented this accident and others like it will be explained. The Lilly¹ controller must be carefully installed, inspected, and maintained to be effective in maintaining hoist safety.

7.3.2 Controller Identification and Application

7.3.2.1 Simplex Controller

Simplex controllers are usually installed on hoists having a small drum diameter (from 3 - 5 feet) and with speeds ranging from 300 to 750 feet per minute (FPM). The safety features of the simplex controller are

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

Overspeed protection

Upper overtravel protection

Lower overtravel protection.

The simplex controller is a combination safety controller and depth indicator. To determine the minimum speed at which this controller provides overspeed protection, divide operating speed by 4.5.

Example: If the hoist operates at 450 FPM the controller provides protection to 100 FPM.

7.3.2.2 Model D Lilly Controller

The Model D controller is normally installed on hoists operating at speeds up to 1500 FPM. The safety features of the Model D controller are:

Overspeed warning and tripout

Upper overtravel protection

Lower overtravel protection

Retardation warning and control

Man safety equipment.

To determine the lowest speed sensed divide the operating speed by 4.5.

7.3.2.3 Model C Controller, Single Governor

The Model C controller with single governor is normally found installed on hoists operating at speeds up to 1500 FPM and shaft depths no more than 3000 feet. The safety features commonly found on this controller are:

Overspeed warning and tripout

Upper overtravel protection

Lower overtravel protection

Retardation warning and control

Accelerating solenoid

Man safety equipment

Loss of motion warning

Level depth selector.

To determine the lower limit of overspeed protection divide operating speed by 5, and if specially equipped, divide by 6. The manufacturer's documentation supplied with the controller must be consulted.

7.3.2.4 Model C Controller - Duplex Governor - Standard Dial

This controller is normally found installed on hoists with drums 8 feet in diameter and greater, operating at speeds upto 3300 FPM, and shafts up to 4000 feet deep. This controller may also be used on friction hoists where the shaft depth is less than 2500 feet. The safety features found on this controller are the same as those found on the Model C - single governor controller. To determine the lower limit of overspeed protection, divide the operating speed by 12 or 16. This can be determined by consulting the manual supplied with the controller by the manufacturer.

7.3.2.5 Model C Controller - Duplex Governor - Long Range Dial

This controller is normally installed on hoists with drums over 8 feet in diameter, and operating at speeds up to 3300 FPM; however federal regulations limit man hoisting speeds to 2500 fpm. It may also be used on friction hoists with no limit on shaft depth. The safety features are the same as for the Model C single governor with standard dial. To determine the lower limit of overspeed protection, divide operating speed by 12 or 16.

7.3.3 Drive

The Lilly¹ controller must be connected to the hoist drum in a manner that provides for the Lilly¹ to be driven in a secure manner. This should be done very carefully as this is likely the single most important component in the Lilly¹ circuit. If the Lilly¹ drive fails it does not matter how well the Lilly¹ is adjusted or maintained, it is no longer providing any protection. The Lilly¹ drive systems can be grouped into two general types: gear drives, and chain drives. Figure 25 shows a properly installed gear drive system.

7.3.3.1 Gear Drives

If the Lilly¹ controller is equipped with a gear drive system, the item of greatest importance is the condition of gears. All of the gears should be in good condition with little visible wear and play. If any of the gears have chipped or broken teeth, it may be possible for the Lilly¹ to creep out of calibration due to slippage. Furthermore, it indicates that at some point in time the drive system has been subjected to a severe shock and, therefore, may be in need of further inspection.

7.3.3.2 Chain Drives

Just as the condition of the gears is important to the gear driven controllers, the condition of the sprockets and roller chain is critical to the performance of the chain drive system. All of the sprockets in the drive train must be of the cut type, not cast. The chain must be a good quality roller chain, preferably of the sealed roller type.

The chain drive systems should be checked for excessive play and wear. If the chain or sprockets are worn, the chain may slip and allow

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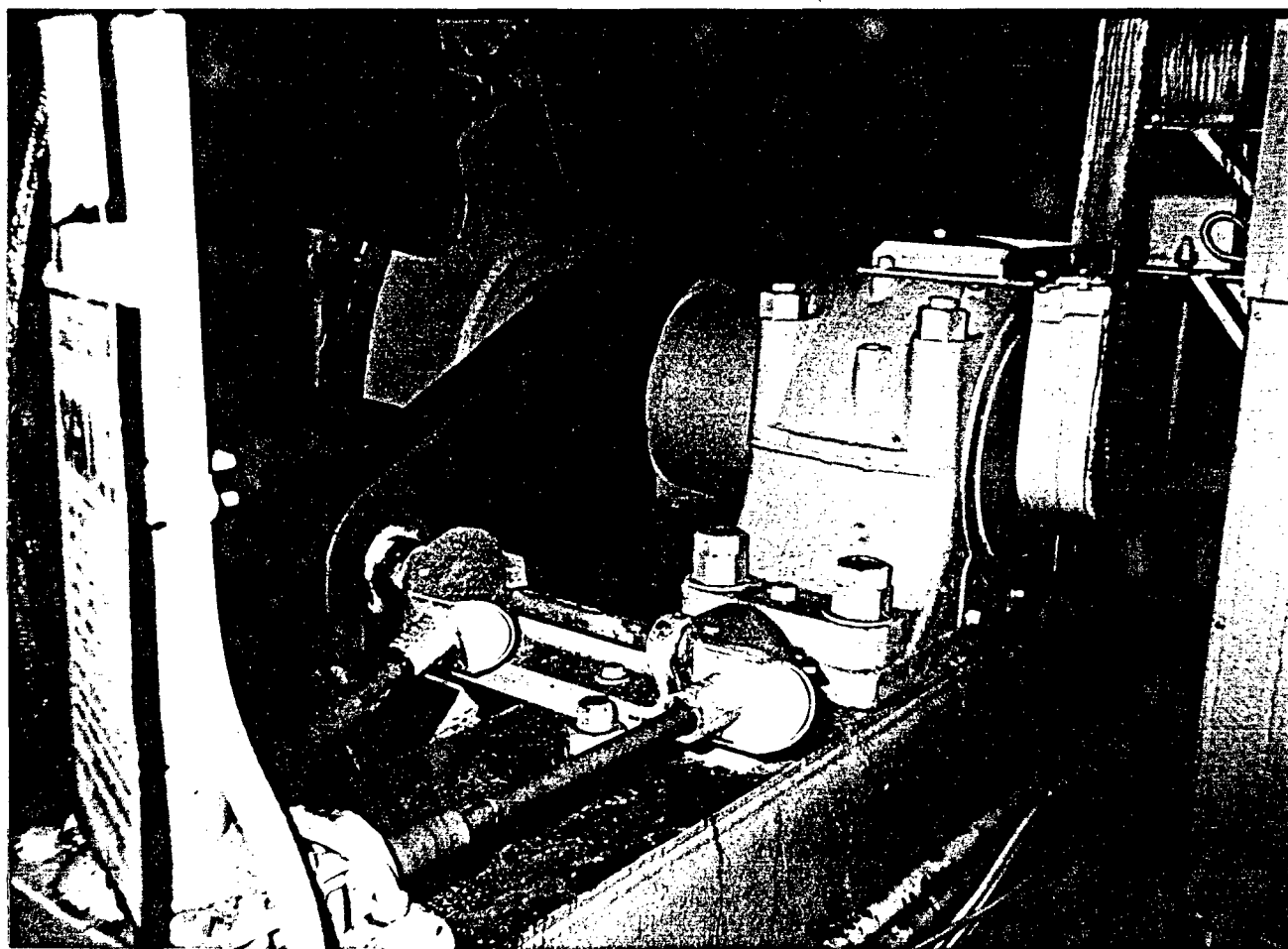


Figure 25

Properly Installed Lilly Drive

the controller to operate in an unsynchronized manner. The same situation may occur if the chain becomes too loose. An excellent feature, but not a necessity, is a spring-loaded take-up idler that maintains constant tension. This type of arrangement is very amenable to the installation of a limit switch that would indicate excessive wear in the drive system.

7.3.3.3 General Drive Train

All moving parts should be guarded in a manner that permits easy inspection but provides adequate protection to all personnel working in the area. Expanded steel or plexiglass makes an excellent guard.

Drive shafts longer than about three feet should be provided with an intermediate support along the length of the shaft. Normally, a pillow block bearing is used. This helps to maintain true and proper alignment as well as relieves bending stresses in the shaft. Any bearings should be well maintained, clean, and adequately lubricated. If a drive shaft shows any signs of deformation by wobbling, the drive system might have been subjected to a large and potentially damaging stress and further examination is warranted.

Gears and chains must be kept free of dirt and other abrasive contaminants. Over-lubricated chains and gears tend to collect excessive amounts of dirt. Therefore, it is essential that the drive systems be lightly but adequately lubricated.

Couplings, gears, and sprockets must be securely fastened to the shaft with set screws and keys and keyways. This can normally be determined through inspection. If this is not possible perform the following inspection.

Before hoisting, scribe a straight line with a grease pencil from the gear or sprocket to the shaft. If this line appears to be broken as the hoist begins to rotate, it indicates the connection is slipping and should be inspected further. It may need to be tightened or replaced.

Because this is an intricate piece of equipment, excessive wear, overtightening of nuts, or metal shavings anywhere on the controller are an indication that something is wrong. However, at the same time, nuts and linkages should not be loose to the point of sloppiness.

7.3.4 Electrical components

The electrical components associated with the Lilly¹ controller may be broken down into two general classifications: wiring and switching.

7.3.4.1 Wiring

Consider the following from a safety inspector's report:

"When we entered the hoist house, the Lilly¹ appeared to be operating correctly. As the hoist slowed so did the Lilly¹. As the conveyance reached the end of travel the cams seemed to be in the proper places. However, after further inspection it was found that at no place on the Lilly¹ switchgear was there any power."

In other words, the Lilly¹ was functioning correctly in a mechanical sense but was serving no purpose at all as it was not wired into the system at any point.

All wiring should be installed in a manner that complies with all applicable codes and standards. These standards will normally insure

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

that the wire is capable of handling the expected current. Wiring should be protected from physical damage by moving machinery in and around the hoist. All wiring should be installed in a professional manner and give the appearance of a very neat and clean installation. This serves many purposes, the most important of all being that it will help to establish the attitude that the hoist area must be kept neat and clean. In addition, well-installed wiring normally tends to last much longer as it is less apt to be damaged during normal activities in the hoist area and allows for an easier inspection. Another practice that helps inspection is marking all conductors and having an up-to-date wiring diagram available.

Finally, all wiring should have a specific purpose. In other words if a conductor is not being used it should be removed, as it is nearly impossible to tell the extent of damage possible if the line were to become accidentally energized. This is also a detraction from the "neat and clean" attitude that is essential in the hoist area.

When inspecting the wiring, signs of trouble include such things as discoloration of insulation, apparent melting or overheating of insulation, or other physical damage to the insulation. Also, be aware of any loose terminals or connections as well as any uninsulated in-line connections. Dust and dirt should also be removed from the wiring to aid in detecting insulation damage. Any jumper wires that appear to be temporary or are fastened in with alligator clips should be investigated and removed permanently or replaced by the correct, properly installed wire.

7.3.4.2 Switches and Contacts

A large metal box mounted on the front of the controller houses many of the switches to be inspected. To open it, unscrew the wing nut on the front of the cover. The entire cover is then free to slide away from the controller and lift out of the way. This will allow the inspection of the man safety, accelerating, and limit switches. Any contacts showing an excessive amount of wear or pitting from arcing should be replaced.

All contacts of switches mounted on the Lilly¹ controller are silver or, on older controllers, bronze buttons. Perhaps the greatest source of damage to these has been from personnel attempting to clean them with files or emery paper; this should NEVER be done. The proper method of cleaning the switch contacts is:

- a. Deenergize and LOCKOUT the switch and adjacent electrical hardware,
- b. Moisten a clean rag with an approved contact cleaning solvent,
- c. Wipe the carbon off the contacts with the rag, being careful not to contact other electrical gear.

The acceleration and overtravel switches are operated by levers with cam rollers on them. The connection of the levers or roller arms to the switches should be secure to ensure that the switches operate properly and as needed. If excessive slack or looseness is noted, it must be corrected immediately, normally by inserting a tighter fitting pin or washer or even by replacing the roller arm.

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

Normal operation of the Lilly¹ controller may cause slight amounts of play to develop in the rest of the switch operating mechanism. This can be an unsafe condition and should be corrected as soon as possible.

There must be no obstructions to prevent the free operation of any of the switches. Inspect the switch housing for tools or blocks that may have been placed in the controller during installation, service, or a previous inspection.

While inspecting the switches and operating mechanisms it is a good idea to inspect the dashpot located between the Lilly¹ main body and the switch housing. This dampens the action of the mechanical activators and is essential to smooth operation of the Lilly¹. The dashpot should be filled with a CLEAN, light machine oil. Extreme care must be taken not to confuse this with the acceleration solenoid dashpot which is dry. The breather hole on the side of the dashpot must also be inspected to make certain it is clean and unobstructed.

After making the previous inspections it is necessary to run the hoist to the end of travel and stop. In this position the overspeed alarm contacts should be .015" to .032" apart. Then, with the hoist stopped, raise the governor balls slightly and the overspeed alarm should sound. Now start the hoist and move the conveyance to a point midway in the shaft and bring the hoist to a stop. At this point the flyballs should have to be raised higher than before to make the overspeed alarm sound.

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

Start the hoist and move the conveyance to a point near the end of travel. With the hoist moving slowly, raise the linkage and the brakes should set immediately. Reset the system and start the hoist again to creep speed. Open the overtravel switch. The brakes should again set immediately. DO NOT CONDUCT THIS TEST AT FULL SPEED!

If during any of the above tests the outcome is not as predicted, obscure the difference and record what was obscured. It is suggested that help be requested from either the manufacturer or someone skilled in the maintenance and adjustment of the Lilly controller.

7.3.5 Governors

As the hoist moves so does the governor. For this reason it is of primary importance that the governor not be restricted in its required movement. If the flyballs are not free to move upwards as the hoist accelerates, the action of the governor is being overridden and, therefore, it is useless as a speed controlling device. Many times the obstructions that may prevent the flyballs from operating are not visible and the only way to determine this is as follows:

Remove the switchbox cover from the front of the controller. With the hoist at rest raise the flyballs by grasping one firmly in each hand and pull them out from the axis of rotation and upward. As they are raised, the overspeed alarm should sound and then the overspeed contacts should open. All of this should occur before the flyballs reach the horizontal position.

As the flyballs are raised, care should be taken to notice any abnormal play or wear in the mechanism. The nut on top of the flyball spindle should be snug against the flyball harness and no more than 1 or

2 threads should be visible above the nut. If more threads are showing than this, the spring in use is probably incorrect and the governor is improperly adjusted. The governor springs to be used are color coded and are always one of the following colors: black, blue, yellow, green, or red. The operator will normally have a record of what springs were delivered with the controller, as this is necessary to reorder spares.

If the nut on top of the spindle is not snug with 1 to 2 threads showing, the spring is likely to go solid and the governor will never be allowed to open the overspeed switch, thereby resulting in no speed control.

With the hoist running at normal speed, the flyballs should be well below the horizontal. If this is not the case and the flyballs are very near to or at the horizontal, they do not have enough movement left to allow them to operate the overspeed switch. This again results in an unsafe condition.

The only way to ensure that the overspeed switch is properly functioning is to allow the switch to be opened during the normal operation of the hoist.

With the hoist operating under normal speed in the middle of travel, well away from the limits and with no load or men in the conveyance, open the overspeed switch. This should result first in the sounding of the overspeed warning alarm followed by an emergency stop. Then step up the speed, continuing the tests under the same conditions until the governor stops the hoist. CAUTION: This should only be done by qualified personnel and with the conveyance in the middle of travel. If not performed properly, this test can result in damage to the hoist, conveyance, and personnel.

7.3.6 Cams

The following fatal accident illustrates what can happen if the cams are improperly adjusted on the Lilly¹ controller:

During normal hoisting, the shift foreman noticed the skip come out of the collar of the shaft at a very high rate of speed followed by crashing noises as the conveyance was pulled into the head sheave. As this happened the hoist rope broke and allowed the conveyance to fall to the bottom of the shaft killing one of three men working in the shaft bottom. When the conveyance reached the location where the hoist would normally stop, the decelerating/brake regulating roller had only climbed to 50% of the profile. The hoist was traveling AT LEAST twice as fast as it should have been because the cam had been set back on the cam dial to prevent it from slowing down the hoisting cycle. Also, since this cam regulates the rate that the brakes are applied, the brakes could not have been set in time to stop the conveyance from hitting the head gear.

If the following systematic inspected system had been in use, this accident probably never would have occurred. Or, in other words, one man would still be alive.

Model D and Model C Lilly¹ controllers are equipped with cams securely fastened to a rotating cam dial to operate limit switches at the ends of travel as is shown in part 7.2 of this manual. Because the cam arrangement is slightly different between the Model D and Model C controllers they will be discussed separately. Therefore, before proceeding any further, it must first be determined if the controller being inspected is a Model D or Model C. The Model C will be discussed first.

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

7.3.6.1 Model C Lilly¹ controller

The Model C controller is equipped with two separate cam dials. One for the hoisting and one for the lowering part of the cycle. This is true for all installations of Model C controllers.

As was stated in part 7.2, the Model C is equipped with the following cams to control the operation of the hoist:

- a. overtravel limit cam,
- b. accelerating cam,
- c. decelerating/brake regulating cam, and
- d. retarding zone indicator.

The overtravel limit cam functions to ensure that the conveyance is never allowed to move outside of the limits of safe travel. If the hoist is not stopped at the correct location, the cam dial continues to rotate until the limit cam engages the overtravel limit roller arm. At this time the power will be removed from the hoist motor, an alarm may sound, and the brakes should set. The overtravel cam should be located so as to stop the hoist before any damage is done to the conveyance or personnel are placed in a hazardous situation as a result of overtravel.

To ensure that this is the correct location of the overtravel limit cam, the conveyance should be moved at creep speed into an overtravel position. CAUTION: It is best that the operator be very skilled on the hoist being tested and that the conveyance not be moved to a point that damage will occur. It is also necessary to have an observer in phone or bell contact with the hoist operator, who is located to see the position of the conveyance. If the overtravel limit

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

does not engage before this point, the limit cam is located too far back and should be advanced in a clockwise direction. To determine the correct location move the conveyance to the point of overtravel and stop the hoist. Now loosen the limit cam and advance it in a clockwise direction until it contacts the overtravel limit and the overtravel switch is opened, giving the overtravel trip. Tighten the bolts, back the conveyance out of the overtravel position and stop the hoist. Start the hoist and ease the conveyance into the overtravel position again. Repeat the above procedure until the hoist stops at the correct position.

Finally, (and this applies to all of the cams) make certain that the cam is tapered gently enough on both sides to allow the roller to climb from either side, as shown in figure 26. In the event of something unforeseen happening, this will prevent the roller arms from being broken or bent should the cam dial travel to an extreme position.

2. The accelerating cam should be located to contact the accelerating roller arm at the same time the decelerating or brake regulating cam contacts its roller (see figure 27). Furthermore it should be long enough to stay in contact with the roller for the entire length of the decelerating period.

The cam is too short if the roller moves down the back side before the hoist comes to a stop as shown in figure 28.

As was stated in part 7.2 of this manual, the accelerating cam overrides the effect of the decelerating cam when hoisting out of a station or away from the deceleration cam and must not be active at any other point in the hoisting cycle.

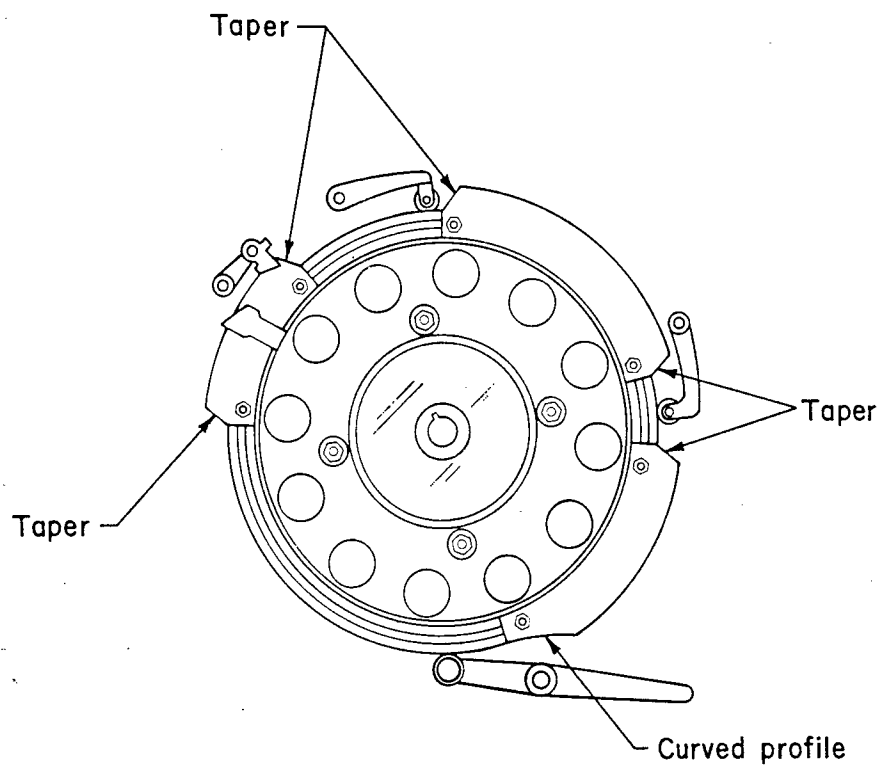


Figure 26

Location of Cam Tapers and Profile

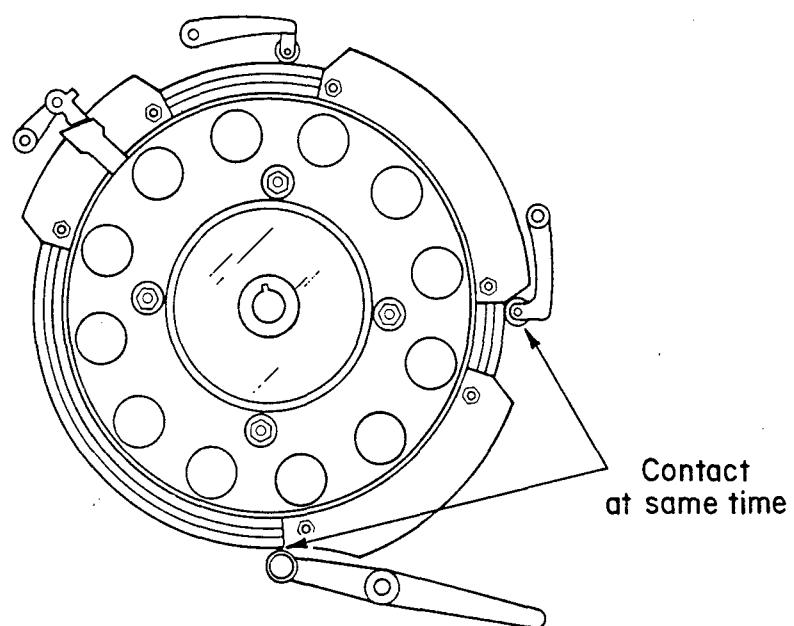


Figure 27

Cam Dial Position

at Beginning of Retarding Zone

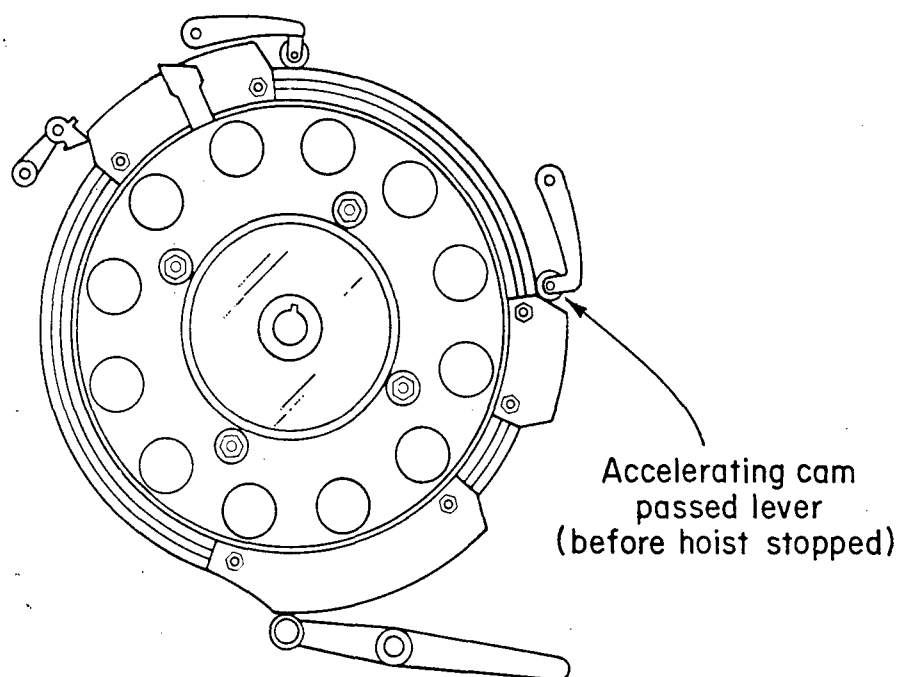


Figure 28

A Short Accelerating Cam

3. The decelerating/brake regulating cam is a two function cam. The profile of the cam determines the maximum speed during the deceleration portion of the cycle. In addition, it determines the rate at which the brakes are applied.

Hoist brakes are normally gravity applied by a weight that is held up by a cylinder operating either on compressed air or hydraulic fluid. By controlling the rate at which the air or fluid leaves the cylinder, the rate of fall of the weight is controlled. This controls the rate at which the brakes are applied.

As the hoist slows down near the end of travel, the distance available for stopping the hoist is reduced. For this reason it becomes necessary to stop the hoist more rapidly. However in the middle of travel the hoist is moving at a higher rate of speed and cannot be stopped as rapidly without injuring persons riding in the cage, nor is it necessary to stop the hoist as rapidly.

The deceleration brake regulating cam is only active during deceleration at the ends of the cycle. The hoist should stop at the upper or lowermost station with the roller at or near the upper end of the deceleration slope. If this cam is moved, it may also be necessary to move the accelerating cam until the configuration described under accelerating cam adjustment is achieved.

4. Deceleration Zone Indicator is usually a gong that sounds as a trip moves past a hammer and allows it to strike the gong. However, it may also operate a switch to sound an electric alarm. The latter is a good idea in noisy installations, as the gong may not always be heard easily.

The deceleration zone indicator should operate just before the hoist enters the zone of deceleration. At this point the decelerating/

brake regulating cam should begin to come in contact with its roller. On manually controlled hoists it provides the operator with a warning to begin slowing the hoist before an overspeed alarm and emergency stop occurs.

The features just discussed will be present on all Model C controllers regardless of optional equipment. Furthermore, it will always operate in the same manner whether equipped with man safety, long range drive, or two governors.

7.3.6.2 Model D Lilly¹ Controller

The Model D controller operates in much the same manner as the Model C. Except it has only one cam dial to control both the hoisting and lowering parts of the cycle. On this dial are arranged the following cams:

- a. upper overtravel limit cam,
- b. hoist deceleration/brake regulating cam,
- c. lower overtravel limit cam,
- d. lower deceleration/brake regulating cam, and
- e. retardation warning cam.

1. The upper overtravel limit cam should be positioned to stop the conveyance before it passes the upper limit of travel.
2. The hoist deceleration/brake regulating cam should come in contact with the roller as, or maybe just before, the deceleration zone warning is sounded. It should be profiled to allow the hoist to come to a stop with the roller on top of the cam, at the very end of the slope or profile.

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

3. The lower overtravel limit cam should be positioned to stop the hoist before the conveyance passes the lower limit of travel.
4. The lower deceleration/brake regulating cam should operate as the hoist deceleration/brake regulating cam at the lower end of travel.

For detailed inspection and adjustment procedures see the discussion on Model C Lilly¹ controllers. The methods used for each controller are the same, except for the fact that a Model C has two dials instead of one.

7.3.6.3 General Considerations

Several points are shared between the two controllers as far as cams are concerned.

- a. All cams should have smooth profiles.
- b. All cams should have a smooth taper on the back side to allow the roller to climb if the dial is advanced to an extreme position.
- c. All cams should be firmly affixed to the cam dial, with no signs of slippage relative to the cam dial.
- d. All cams should approach their rollers or trips from a clockwise direction. Except for Model D and Simplex Controllers
- e. All cams should be in the same vertical plane as their respective rollers or trips.
- f. No obstructions should be present to interfere with the free movement of the cam dial.
- g. The cam dial should not have an excessive amount of wear relative to the rest of the Lilly¹ controller.
- h. The cam dial should not be warped, dented, or marred.

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

7.3.7 Man Safety Equipment, Model C Controller

If the Lilly¹ controller is equipped with the man safety feature, it becomes somewhat more complex; however, it is still very effective if properly maintained. In general, there are two items to be considered when inspecting the man safety features the electrical system and the mechanical system.

7.3.7.1 Electrical System

The electrical system will normally consist of an indicator of some type to signify that man safety has been engaged and a mechanism to readjust the limits of travel and the maximum speed before overspeed is indicated.

To inspect this portion of the system, first engage the man safety and observe the indicator and the indexing of the cam dial. If this occurs as expected, operate the hoist and check out all of the functions previously mentioned. The limits will normally be readjusted to stop the conveyance at the personnel stations in the shaft instead of some other extreme position. As a safety factor in the hoisting of men, the maximum speed may be reduced somewhat to comply with regulations. Additionally the profile of the decelerating/brake regulating cam may be different.

When the man safety equipment is activated the overspeed contacts should still remain approximately 1/32 inches apart. Additionally, all other contacts should remain as previously stated. In other words, the man safety equipment basically readjusts the travel limits and speed of safe travel.

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

7.3.7.2 Mechanical

In general, the mechanical inspection of the man safety equipment consists of checking for smooth operation of the equipment. When shifted to engage man safety, the operation should be smooth. There should be no lost motion in the form of overstressing of rods or looseness in the system.

As previously stated, when engaged, the cam dial on the Model C controller should rotate to readjust the limits of safe travel within the shaft. This should be a single smooth motion, with no jerkiness or play in the action.

The man safety should not have to be held in the engaged position but rather the system should be well enough balanced and lubricated to stay in the engaged position.

7.3.8 Brake Control

This section pertains to all Lilly¹ controlled brakes.

The mechanism by which the brake application rate is controlled has already been discussed. However, further details are necessary here.

The brake application rate is normally controlled by a long metal rod connected from the regulating yoke on the Lilly¹ to an adjustable valve in the brake application circuit. This rod should not be extremely heavy as the Lilly¹ may not be able to move it. This will cause an undue stress and possible damage to the controller. To determine if the mechanism is operating properly, run the hoist through a complete cycle watching the rod as the deceleration/brake regulating

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cam contacts the roller. At this time, the rod should move upward a slight amount and continue until the hoist has come to a complete stop and the brakes have been applied. If this does not happen, further investigation beyond the scope of this manual is required, and it is suggested that experienced help be sought.

The weights that apply the brakes must have no obstructions to prevent them from falling freely to the extent necessary to set the brakes. If this is not the case, the hoist may be noted to creep when stopped and during loading or unloading. The weights must be heavy enough to set the brakes securely. NOTE: If the hoist creeps under these conditions, the situation is very dangerous and may indicate excessive brake wear. This must be thoroughly investigated and corrected before continuing the inspection.

If the hoist is equipped with hand operated brakes, the distance pulled to engage them should be noted. If this is at or near the extreme travel allowed by the design of the hoist, the brake shoes and linkages should be inspected to locate any serious deformations, strains, or wear.

7.3.9 Long Range Dial Drive

For hoisting depths greater than 3500 feet, the movement of the cam dial on a standard controller would be so slight that effective control of the hoist would not be possible. This is when it becomes necessary to apply a long range dial drive.

The long range dial drive is simply a modification that allows the cam dial to be in motion only during the ends of travel, thereby

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allowing the action of the cams to be more closely controlled. This in turn increases the accuracy of the controller.

The cam dials are mounted loosely on a shaft that is driven as a normal cam drive shaft. At each end of this shaft is a clutch wheel mounted so that it is slideable on the shaft and keyed to the shaft to prevent rotary slippage. As the hoist backs out of one end of travel weights cause a reverse rotation of the cam dial to a position of rest where it will remain until picked up by the clutch when the conveyance returns to that end of travel.

During the full speed operation of the hoist, the cam dials remain at rest and do not control the hoist, but the flyballs are still in operation. As the hoist continues to run, the drive screw is turning into the clutch wheel on the cam dial that controls the approaching end of travel. Immediately prior to approaching the deceleration zone, the cam dial engages a tab or stop on the clutch wheel and starts turning as on a standard drive cam dial. From this point all functions are the same as for a standard Model C controller.

When inspecting the long range dial drive, it should first be observed for all of the previously mentioned points. After confirming or correcting the proper operation of the controller, inspect the long range dial drive for signs of wear. The clutch wheel should be examined to determine the condition of the drive thread. This is a square-shouldered thread and should not have rounded or tapered edges. If these are present, it could indicate that the drive thread is well worn. If the clutch wheel still fits securely on the screw and does not wobble, there is no reason to be concerned; however, it should be noted for future reference when considering repair of the controller.

The clutch wheel and cam dial should also be inspected to determine the condition of the cam dial drive tabs. If these show deformation, cracks, or wear, they should be observed during operation to note any slippage after the cam dial has been picked up by the clutch wheel. If slippage exists, the hoist controller may be operating out of adjustment. The drive screw should be clean with a light coating of lubricant. If the drive becomes excessively dirty, this will cause an undue amount of wear on the threads and clutch mechanism and reduce the life of both.

After thoroughly inspecting the cam dials and clutch wheels, the weights and suspension chains should be checked. The weights should be free to fall far enough to rotate the cam dials in a counter-clockwise direction until they engage the dial stops. Otherwise, the dials are not disengaging far enough. This must be corrected. The chains suspending the weights should be inspected to determine that they are in good enough condition to continue supporting the counterweights. If they show cracks or any signs of stretching or deformation they should be replaced.

Lilly¹ Controller Inspection Checklist

Mine I. D. _____

Location of controller _____

Controller Model (circle one): C D Simplex

Man Safety: yes no

Long Range Dial Drive: yes no

Governor type: Single Duplex

Hoist Speed (feet per minute): _____

Condition	Good	Bad	Remarks
-----------	------	-----	---------

I. DRIVE

A. Gear Drive

1. Gear condition	_____	_____	_____
2. Gear lash	_____	_____	_____

B. Chain Driven

1. Sprockets	_____	_____	_____
2. Chain	_____	_____	_____

C. General

1. Lubrication	_____	_____	_____
2. Cleanliness	_____	_____	_____
3. Keys & Pins	_____	_____	_____
4. Couplings	_____	_____	_____
5. Shafts	_____	_____	_____
6. Guards	_____	_____	_____
7. Bearings	_____	_____	_____
8. Wear	_____	_____	_____

D. Comments on the drive system: _____

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II. Electrical components

A. Wiring	Good	Bad	Remarks
1. Neatness of installation	_____	_____	_____
2. Wires going to nowhere	_____	_____	_____
3. Wire in conduit	_____	_____	_____
4. Covers in place	_____	_____	_____
5. All wire out of harm's way	_____	_____	_____
6. All wiring clean	_____	_____	_____
 B. Switching			
1. Contacts clean	_____	_____	_____
2. Contacts not filed or pitted	_____	_____	_____
3. Operating harness tight	_____	_____	_____
4. Switches have operating room	_____	_____	_____
5. Specified voltage on terminals	_____	_____	_____
6. No jumpers present	_____	_____	_____
7. Overspeed alarm contacts gap 0.1" to .032" at end of travel.	_____	_____	_____
8. Raising flyballs slightly opens overspeed contacts	_____	_____	_____
9. Flyballs rise further to open o.s. contacts in middle of travel	_____	_____	_____
10. Freedom of movement of overspeed alarm contacts.	_____	_____	_____
11. Opening overspeed switch causes brakes to set	_____	_____	_____
C. General comments on the electrical inspection_____			

III. Governor(s)

A. Flyballs	Good	Bad	Remarks
1. No obstructions to movement present	_____	_____	_____
2. Well below the horizontal at full speed	_____	_____	_____
3. Overspeed alarm sounds prior to setting of brakes (raise flyballs by hand with hoist at rest)	_____	_____	_____
4. Flyballs not damaged	_____	_____	_____
B. Harness and spindle			
1. No play in harness	_____	_____	_____
2. All pins in place	_____	_____	_____
3. No nuts over or undertightened	_____	_____	_____
4. No bent linkages	_____	_____	_____
5. Flyball spindle does not appear to wobble during operation	_____	_____	_____
C. General comments on the flyballs	_____		

IV. Cams

A. Model C controller	Good	Bad	Remarks
1. Overtravel limit cam			
a. stops hoist before overtravel condition occurs	_____	_____	_____
b. when engaged, causes an emergency stop	_____	_____	_____
c. mounting bolts tight	_____	_____	_____

	Good	Bad	Remarks
2. Accelerating cam			
a. contacts the roller at the same time as the brake regulating cam			
contacts the roller	_____	_____	_____
b. stays in contact with roller until hoist stops	_____	_____	_____
c. mounting bolts tight	_____	_____	_____
d. roller never goes down back side of cam	_____	_____	_____
3. Decelerating/Brake regulating cam			
a. roller stops at top of profile at end of hoist travel	_____	_____	_____
b. smooth profile	_____	_____	_____
c. mounting bolts tight	_____	_____	_____
4. Deceleration zone indicator			
a. sounds the deceleration alarm prior to the brake regulating cam and roller making contact	_____	_____	_____
B. Model D controller			
1. Upper limit cam			
a. stops the hoist before the conveyance hits the overtravel limits	_____	_____	_____
b. locking bolts tight	_____	_____	_____
2. Hoist deceleration cam			
a. contacts the roller as the deceleration zone alarm is sounded	_____	_____	_____
3. Lower limit cam			
a. stops the hoist before the conveyance reaches the lower limit of safe travel	_____	_____	_____
b. locking bolts tight	_____	_____	_____

4. Lower deceleration cam			
a. contact the roller as the deceleration alarm is sounded	Good	Bad	Remarks
b. roller stops at top of profile for normal hoist movement	_____	_____	_____
C. General cam considerations			
1. All cams have smooth profiles	_____	_____	_____
2. Smooth taper on both ends of cams	_____	_____	_____
3. All mounting and clamping bolts tight	_____	_____	_____
4. All cams approach rollers from a clockwise direction	_____	_____	_____
5. All cams line up vertically with proper roller	_____	_____	_____
6. No signs of looseness or slippage on cam dial	_____	_____	_____
7. No obstructions to normal movement of cam dial	_____	_____	_____
D. General comments on cams	_____		

V. Man safety equipment	Good	Bad	Remarks
A. Electrical			
1. Indicator shows correct status	_____	_____	_____
2. Overspeed and overtravel limits are readjusted	_____	_____	_____
3. At man speed, o.s. alarm contacts remain 1/32 inches apart	_____	_____	_____

B. Mechanical	Good	Bad	Remarks
1. Smooth operation	_____	_____	_____
2. No lost motion in linkages	_____	_____	_____
3. Cam dial rotates smoothly when shifted on Model C	_____	_____	_____
4. Man safety is self holding	_____	_____	_____

VI. Brake control

A. Brake regulating mechanisms

1. Cam operates brake regulating roller and yoke at correct time	_____	_____	_____
2. Brake regulating yoke has no play	_____	_____	_____
3. Brake regulating yoke is not bound or otherwise restricted in movement	_____	_____	_____
4. Brake regulating linkage firmly connected to yoke with no lost motion	_____	_____	_____
5. Linkage is not bent or otherwise deformed	_____	_____	_____
6. Linkage is not oversized to cause overstressing of regulating yoke	_____	_____	_____

B. Brake operating mechanism (except Simplex)

1. Hand operated brakes			
a. not pulled to extreme to set firmly	_____	_____	_____
b. frame and lever not deformed or damaged	_____	_____	_____
2. Mechanically applied brakes			
a. free to travel to full extent to set firmly. Must not "bottom out".	_____	_____	_____
b. set at varied rates (set slow in middle of cycle, fast at end of cycle)	_____	_____	_____

C. General comments on the brake regulating mechanism _____

VII. Long range dial drive

A. Drive Screw	Good	Bad	Remarks
1. Threads not damaged	_____	_____	_____
2. Clutching tabs in tact	_____	_____	_____
3. Keying in place on clutch wheel	_____	_____	_____
4. Properly engages limits (if all inspections to this point have been positive, the long range dial drive is likely in adjustment; i.e. the dial advances approximately 120 degrees)	_____	_____	_____

B. General comments on the long range dial drive _____

VII. General comments on the Lilly¹ Controller _____

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

8. SLOPE HOIST BRAKE CARS

This section is divided into three parts. The first part is intended to familiarize the reader with brake cars and their application. The second deals with the procedure of placing them in service. Finally, the third gives suggested inspection schedules. The information contained herein was obtained from "Operating Instructions for Brakeman Cars", by the Sanford-Day division of Marmon Transmotive¹.

8.1 Introduction to Brake Cars

Brake cars are normally intended to operate on a slope at a rope speed previously specified by personnel from the mine and manufacturer. The braking action is obtained from multiple magnetic track brakes with renewable wear bars, as shown in figure 32. The actual braking force will depend upon condition of the rails, brakes, batteries, and car speed.

Power to set the brakes is supplied normally from lead-acid batteries at a potential of approximately 48 volts. Fully charged batteries will in most cases last for 1 1/4 hours of continuous braking action. Because the brakes are held off of the rail with springs, the batteries are required to energize the braking action. For this reason it is very important that the brakes are not used unnecessarily to avoid discharging the batteries.

There are three lights on the control panel inside the brake car. When the disconnect switch is closed and the car is ready for operation, a red light will normally glow. A green light shows the rollback circuit is closed. A white light indicates that the brakes are energized.

¹ Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

Brake cars are normally equipped with a circuit to apply the brakes in the event the car moves in the direction other than intended, by pushing the up or down buttons. This is commonly called the rollback circuit.

Brakes may be applied manually by pushing the on pushbutton, by operation of the overspeed or rollback centrifugal switches, or by action of the fail safe circuit. The brakes can be released by the OFF switch except when they have been applied by action of the fail-safe circuit, in which case it is necessary to open the disconnect switch.

A normally closed contactor connects the battery to the track brakes. If the control circuit fuse fails, or a circuit breaker (with overload relay) should open the brakes set automatically. There is a breaker for each brake in most cases. A short on any brake causes the appropriate breaker to trip. This action opens the normally closed contactor and applies the remaining non-shortened brakes. A white light will indicate that the brakes are on. They can be released by opening the disconnect switch below the hinged cover on the control panel. If the brakes apply by the action of this normally closed contactor, and the fuse is not blown or a circuit breaker tripped, the battery may be discharged. Figure 29 shows a typical brake car electrical diagram.

Overspeed protection in the inby direction is obtained by two centrifugal switches connected in parallel, driven from the car wheels, and set to actuate the brakes at about 15% above normal rope speed. Rollback protection when moving outby is obtained from a third centrifugal switch. Pushbuttons marked UP and DOWN control the rollback circuit. When this circuit is closed (by pushing the UP button),

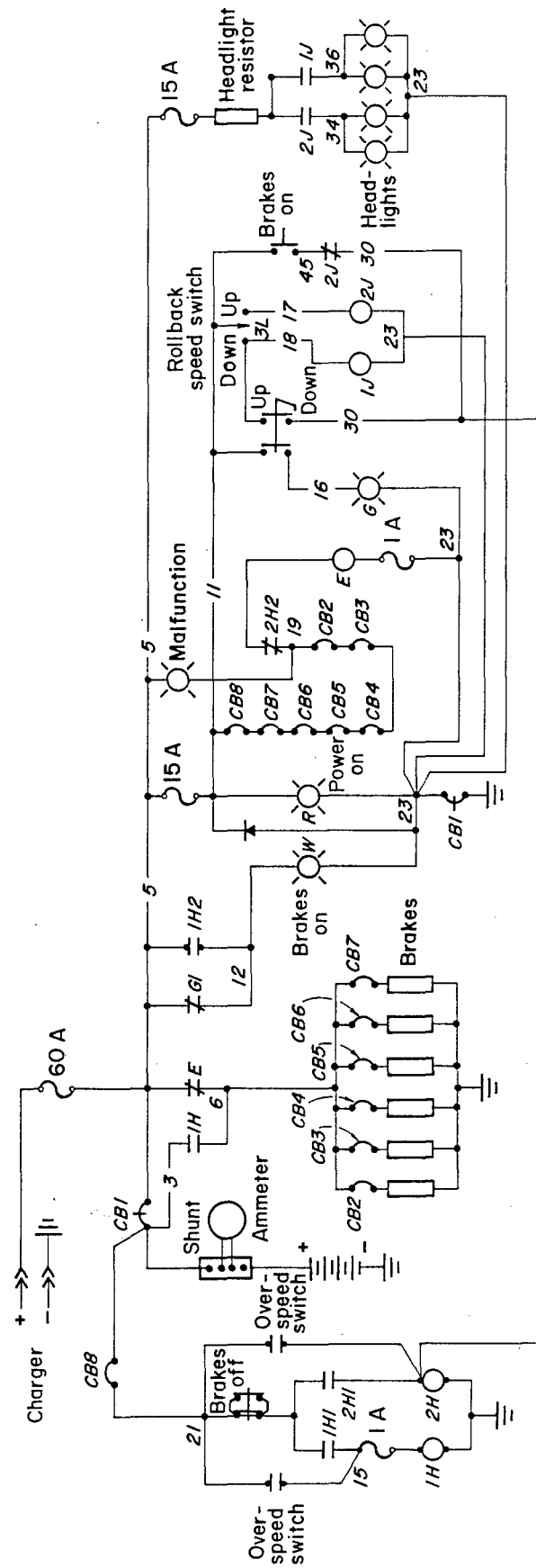


Figure 29

Typical Brake Car Electrical Diagram
(courtesy Marmon Transmotive)

movement of the car inby at approximately 50 feet per minute will cause the brakes to be applied.

When the brakes are applied with the car on the slope, do not, under any circumstances, release the brakes unless the hoist rope is tight or the car is held securely by other means.

Communication between the brake car and the hoist operator is essential. This is most normally accomplished through the use of a low frequency radio system that may use the hoist rope as a carrier for the radio signal.

When the brake car has come to the top of the slope, it may be possible for the hoist rope to trip the slackrope indicator. Many times the car will come to rest in a flat area at the portal of the slope, and there will be no tension on the rope. This will allow the rope to sag enough to trip the slack rope indicator. Limit switches can be installed to disarm the slack rope indicator when the brake car is on the surface.

8.2 Placing the Brake Car in Operation

Put the car on the track and protect it from rolling. Connect the hoist rope, rope clamps, and safety chains leaving enough slack in the chains for the car to go around curves without either of the chains becoming tight. Adjust the brakes so that they are suspended approximately 1/4 inch above the top of the rail. Open the cover of the control panel enclosure and close the circuit breaker disconnect switch. The red light will go on. If the white light burns without pressing the ON button, it is a signal that the fail-safe circuit has applied the brakes. This means that there is a problem somewhere in the system that is causing a circuit breaker to trip and set the other

brakes. Open the disconnect circuit breaker, then open the control enclosure, and see if the circuit breakers mounted horizontally on the panel are closed (these breakers provide the short circuit protection). Check the condition of the fuses; if burned, replace them before proceeding. Again, close the disconnect breaker.

If the white light is off, press the ON button to apply the brakes. If they don't apply, check to be certain the main disconnect is on. If this is on, check the specific gravity of fully charged batteries. It should be between 1.225 and 1.260. The ammeter should show 85-90 amperes discharge. If it does not see that all of the brakes are on the rail. If they are not, deenergize the brake system and remove any obstructions, and check the surfaces of the brake shoes for high spots, or places that are not in the same profile as the rest of the brake shoe.

If they are all on the rail, press the OFF button to release the brakes. Check to see that all brakes are released before proceeding. If all of the brakes are not releasing, check the failsafe circuit to see that it is not energizing the brakes. If the failsafe circuit is not energizing the brakes, an obstruction in the guides or a weak return spring is preventing the brake from releasing.

With the car at the top of the slope ready for operation, press the UP button and move the car in the inby direction; the brakes should set at a slow speed. If the brakes don't set, the rollback circuit is not operating correctly. Release the brakes by pressing the OFF button. Press the DOWN button. Check to see that the track is clear and allow the car to overspeed down the slope with no load or men on the car. The overspeed relay should set the brakes. If the hoist can

not be run overspeed, relay operation can be checked by pulling it with a locomotive on level track.

To determine if braking force will hold the loads expected to be placed on the brake car, prevent other activities on the slope and continue with the following procedure. Connect a loaded car to the brake car and see if the brakes hold it stationary. Then, let the car run down the slope and apply the brakes by the ON button or by action of the overspeed relay. On the first trial a light load is suggested, with the load gradually being increased until the maximum load or the braking limit is reached. When making these tests, slack hoist rope may develop. Always take up slack rope before releasing the brakes. This test is not recommended unless an adequately sized, well maintained and inspected rope is used.

It should be noted that there is a considerable difference in the amount of braking obtained at rope speed and the amount that would be available under run-away conditions. The man-carrying loads should be sized to the run-away capacity. This varies depending on the size and manufacturer of the car; refer to the documentation supplied by the manufacturer of the brake car.

8.3 Inspection and Maintenance

This section contains daily, weekly, and periodic checklists to aid in inspecting the brake car.

8.3.1 Daily

1. Check brakes to see that they are 1/4 inch to 3/8 inch above the rail and move freely on their supports.
2. Check the battery charge with an hygrometer. The specific gravity of a fully charged battery will be between 1.225 and 1.260 except at

high altitudes. While checking the batteries, note the water level in each cell. There is normally a ring in each cell as in an automobile battery to indicate proper water level. Make sure each cell is filled with clean, distilled water.

The connections at each battery terminal should be clean with no corrosion. If corrosion exists, it should be cleaned up. This is one of the most important checks that is made. If no power is available from the batteries, the brakes will not set regardless of the condition of all other components on the car.

3. Check the condition and tension of the V-belts driving the centrifugal switches. The belt tightener should move freely. If the belts appear to be cracking from age, they should be replaced before the brake car is put into operation.

If misalignment is appearing it is indicative of looseness developing or the result of extreme impact on the sheaves. This should also be corrected before allowing the car to be placed in service.

4. The circuit breaker mounted vertically on the control panel provides short circuit protection. This should be left closed at all times.

5. Close the circuit breaker next to the ammeter. The red light should go on signalling that the car is ready for operation. This switch should be opened if the car is not in use for a period of time greater than one shift, but it must be closed when charging the batteries.

6. Push the ON button to apply the brakes. All brakes should be on the rail and the ammeter should indicate 85-90 amps discharge. The white light should be on.

7. Push the OFF button to release the brakes.

8. Push the UP button to establish the roll-back circuit. The green light will go on. Move the car inby and see that the brakes are applied.
9. Push the OFF and DOWN buttons to release the brakes and cut out the roll-back circuit.
10. Once the car has been put in service at the start of the shift the only attention needed is to push the UP button before starting up the slope; the DOWN button before going down.
11. If the control circuit fuse blows or panel mounted circuit breaker opens, the brakes will be applied automatically through the fail-safe circuit. The white light will go on and the ammeter will show discharge. Correct the fault, then open the circuit breaker next to the ammeter to release the brakes.
12. When the brakes are applied with the brake car on the slope, do not release the brakes unless the hoist rope is tight or the brake car is held by another means. Do not remove the other means unless the brake car brakes are applied.

8.3.2 Weekly

The overspeed centrifugal switch contacts should be checked manually. Move the car in the inby direction a short distance so that relay directional contacts will be in correct position. Remove the relay cover. Close the circuit breaker to put power on the control and brake circuit. Grasp one of the relay fly weights with thumb and forefinger and swing it out so that the moveable contacts touch the stationary contacts. The brakes should now go on. Release the brakes and repeat this procedure for the other overspeed switch.

Two contactors are used to apply the brakes to provide a level of redundancy. Check to be sure both are operating properly. Normally, when the OFF pushbutton is pushed, one contactor will draw an arc on opening, and the other will not.

8.3.3 Monthly

The brake car should be allowed to overspeed down the slope with no load or men on it once a month. The application of the brakes should take place at about 15% over normal operating speed.

The relay fly weight assembly is to be lubricated with light oil through the holes provided. The shaft should be kept free from dirt buildup and other gumming substances where the shaft bearings slide.

Contact operating speed has normally been set at the factory to operating speed plus 15%. Do not adjust this unless properly trained and the equipment is available to accurately measure the contact operating speed.

In most cases the relays should be returned to the factory for service or recalibration.

All of the brake shoes should be checked for wear. There is often a tendency for the surfaces of the brakes in contact with the rail to wear more towards the ends. This produces gaps at the ends of the shoes and drastically reduces the amount of braking force available. Worn shoes should be machined to as near the original profile as possible as soon as this wear becomes noticeable. However, this does not include wear to the contour of the top the rail as this type of wear allows the brake to sit in better contact with the rail and provide more braking force.

8.3.4 Semi-annual

The braking force of the brake car should be checked every six months in most cases. If large decreases in braking force are noted in this time period, the test should be conducted more often.

8.4 Checklists for Use During Inspection

8.4.1 Daily

Description	Good	Bad	Comments
1. Brake shoes			
a. position above rail	_____	_____	_____
b. freedom of movement	_____	_____	_____
2. Batteries			
a. water level	_____	_____	_____
b. specific gravity	_____	_____	_____
3. V-belts			
a. alignment	_____	_____	_____
b. condition	_____	_____	_____
4. Circuit breaker			
number 1 closed	_____	_____	_____
5. Close breaker number 2			
a. red light comes on	_____	_____	_____
6. Push "On" button			
a. ammeter reads			
85-90 amps	_____	_____	_____
b. all brakes on the rail	_____	_____	_____
c. white light comes on	_____	_____	_____
7. Push "Off" button			
a. all brakes release	_____	_____	_____
8. Push "Up" button			
a. roll-back circuit sets			
brakes when moved in by	_____	_____	_____
9. Push "Off" and "Down"			
buttons			
a. brakes release	_____	_____	_____
b. roll-back circuit			
is cut out	_____	_____	_____
10. Open circuit breaker			
number 1			
a. brakes set	_____	_____	_____
b. white light comes on	_____	_____	_____

8.4.2 Weekly

Description	Good	Bad	Comments
1. Repeat daily inspection	_____	_____	_____
2. Overspeed centrifugal switch			
a. move the car in by			
lift a fly weight and			
the brakes should go on	_____	_____	_____
3. Redundancy circuit for			
brake application	_____	_____	_____
a. one contactor draws			
an arc when opening	_____	_____	_____

8.4.3 Monthly

Description	Good	Bad	Comments
1. Repeat daily inspection	_____	_____	_____
2. Repeat weekly inspections	_____	_____	_____
3. Overspeed brake car			
a. brakes apply at 15%			
above normal speed	_____	_____	_____
4. Suspension system			
a. pin and spring lube	_____	_____	_____
b. take-up arm pivot bearings	_____	_____	_____
5. Wheel bearings show grease	_____	_____	_____
6. Relay fly weight lubrication	_____	_____	_____
7. Brake shoe wear	_____	_____	_____

8.4.4 Semi-annual

Description	Good	Bad	Comments
1. Repeat daily inspection	_____	_____	_____
2. Repeat weekly inspections	_____	_____	_____
3. Repeat monthly inspections	_____	_____	_____
4. Braking force of the car	_____	_____	_____
5. Lubricate king pins	_____	_____	_____

9. ELEVATOR INSPECTION

Elevators are special types of hoists. An elevator is defined as an automatic piece of equipment, primarily used for vertical movement of people with an overspeed sensing device located on the conveyance that is electrically or mechanically interlocked with the controller. An elevator does not require a hoistman to be present for operation of hoisting men. Elevators are most commonly found in coal mines, but are occasionally found in metal/non-metal mines, primarily in the form of rack and pinion raise climbers. Section 3.2.4 of this manual contains the requirements of 30 CFR part 75.1403-3 for elevators in coal mines. Because elevators in metal/non-metal mines are somewhat less common there are no specific regulations dealing with them. Elevators in metal/nonmetal mines will normally be located in headframes, processing facilities, or on construction projects.

9.1 Introduction to Elevator Inspection

An elevator inspection checklist can be found at the end of this section. The checklist is general in nature and components found at individual sites may vary from those listed here. Consequently, the list may have to be modified for individual conditions. Furthermore, not all check list items are discussed in detail here to avoid repetition of ANSI/ASME Standard A17.1-1981 which should be studied prior to conducting an elevator inspection.

Elevators are a very complicated piece of equipment and only properly trained and certified personnel should be allowed to inspect them. Often service contracts with elevator manufacturers prohibit mine personnel from servicing an elevator. In other instances, mine personnel do not have the required certification and must rely on the manufacturer or a consultant.

Nearly all elevators found in coal mines in the United States are maintained by the manufacturer. Inspections are performed by MSHA personnel and occasionally, by mine personnel.

An excellent reference for the inspection of elevators can be found in ANSI/ASME A17.1-1981 PART X. This is only suggested as a reference and is not intended by the authors to be used in place of existing 30 CFR regulations. Pertinent portions will be discussed here.

Elevators consist of three primary types: electric or rope elevators, hydraulic elevators, and rack and pinion elevators. Each one will be discussed separately as inspection is somewhat different for each type.

9.2 Electric Elevators

Electric elevators include all elevators in which the car is suspended on ropes. Inspections of this type of elevator should involve the following locations:

Inside of the Car

Outside Hoistway

Top of the Car

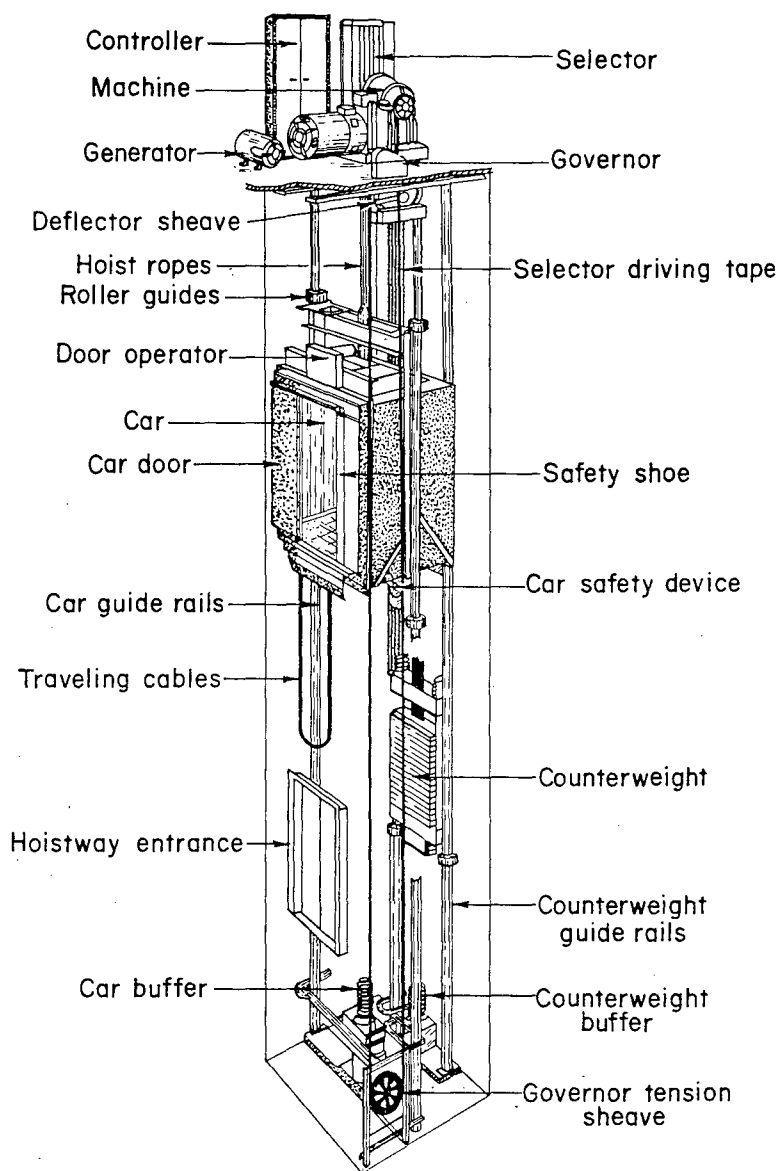
Machinery Room

Elevator Pit.

Figure 30 diagrams a typical electric elevator and shows all the previously mentioned items.

9.2.1 Inside of the Car

30 CFR part 75.1403-4 requires that an emergency stop switch and means of communication, such as a phone, be located within the car. In addition to the requirements of part 75.1403-4, there are some other items that are recommended to be in place or checked.



Typical Elevator Installation-Geared Machine

Figure 30

(reference 30)

The emergency signals for the car should be posted inside of the car in a conspicuous place where they will be readily observed in the case of an emergency. Elevator cars used for materials, personnel, or both should have a rated, certificated capacity posted where it is easily noted. The certificate should be consistent with the manufacturer's design criteria as posted on the hoisting equipment.

If the elevator is equipped with self closing doors there should be a door opening device located somewhere in the car. The door opening device should be operable in the event of full power failure.

One item that is unique to elevators is that lighting is required in the car. Lighting is not a specifically stated requirement in 30 CFR, but is an ANSI requirement.

9.2.2 Outside of Hoistway

The outside of the hoistway, or the shaft station should have several items in place that are necessary for safe operation.

Unlike a common mine hoist, elevators are normally equipped with power closing shaft doors at each station. The doors should be checked for proper and correct operation. There should be a way to lock the doors or install an electrical interlock so that they should not open unless the car is stopped at the station. All power closing doors must not close with an obstruction in the doorway. Furthermore, the doors should not close with excessive force. ANSI/ASME A17.1-1981, Rule 112.3 suggests that the force required to keep a power operated door from closing should not exceed 30 pounds. This is not required for mines, but is only a recommendation.

A control should be in place to allow the elevator car to be parked from the outside of the hoistway, or from the station. The control will normally consist of a "Call" button that will park the car at the station. When operated, the parking device should signal the controller to start the elevator, move the car to the station, and open the doors after the car is stopped within 12 inches of the landing.

The bottom station in a multiple station shaft should provide access to the pit. The contents and inspection of the pit will be discussed at a later point. Persons should not enter the pit until power to the elevator is interrupted by the pit stop switch.

9.2.3 Top of Car

The top of the car should always be inspected to insure safety in emergencies and during shaft inspections.

When the car is at the full up position in the shaft or hoistway, there should be a space between obstructions at the top of the shaft and the top of the car of about 30 inches.

First and foremost, a car operating control or signalling device to a remote operator and a stop switch should be located on top of the car. The controls should all be inspected to be certain they are operational.

Most elevators have an additional slack rope detector connected to the top of the car. The slack rope sensor functions also as an overspeed sensor and is connected to a governor sheave in the machinery room. When the car reaches an overspeed condition, the governor which is electrically interlocked with the hoisting machinery, causes the hoist and sheave to stop. This will, in turn, apply the brakes on the car.

When the car is run to the full up position, the normal and final overtravel limits should be checked. The normal overtravel should stop the car within 12 inches of the landing. The final overtravel should allow a refuge space between the top of the car and the bottom of the machinery room or other obstruction at the top of the hoistway as previously mentioned.

9.2.4 Machinery Room

The machinery room will contain the controller, the governor, the hoisting gear, and the motor generator set or thyristor convertor, as most elevators are driven with direct current. An item of primary importance in the machinery room is cleanliness. Before conducting an electrical inspection in the machinery room, the elevator car must be parked and all electrical power removed and locked out.

Electrical cabinets should be pressurized, or have forced ventilation. The only way to be certain the ventilation is always working is to open the cabinets and check for the accumulation of dust. In a coal mine this cannot be overemphasized because of the explosive nature of coal dust.

When the cabinets are open, the presence of electrical "jumpers" should be noted. If they are found, they should be removed and a permanent repair made by properly trained personnel.

All wiring must conform to the applicable wiring codes when the elevator was installed. If these are not known, the 1968 National Electrical Code may be referenced. In general all conduit entering cabinets must be equipped with insulating bushings, conductor sizes should be sufficient for the load carried, motor starters must be capable of handling the motor connected, and fuses must be sized to

National Electrical Code requirements, and hazardous environment equipment installed where applicable. All equipment must be grounded according to the appropriate regulations, depending on the location of the installation.

The governor is normally located on the floor of the machinery room in close proximity to the hoisting mechanism. The governor rated speed should be checked to be certain it is consistent with the speeds indicated on the elevator documentation the speed governor marking plate, and car crosshead data plate in place on the car. Figure 31 depicts a typical elevator governor.

9.2.5 Elevator Pit

The pit will be located at the bottom of the shaft and will normally contain the lower final overtravel switches and the buffer for the car. Buffers will be either oil filled, a spring, or a solid bumper. In any case, they will be in place to cushion an overtravel. The following items may appear as mechanical items to be inspected but may be electrically interlocked with the elevator master controller. For this reason the condition of the buffers should be noted.

Oil filled buffers should be checked for oil level and condition. The plunger should also return and not stay in the compressed position as this will cause a failure of the buffer to operate correctly and provide a cushion effect. If the plunger fails to return to the full extended position within 90 seconds, it is probably in need of service or replacement.

Spring buffers should be inspected for physical damage and a data plate should be present to indicate correct application. If the spring

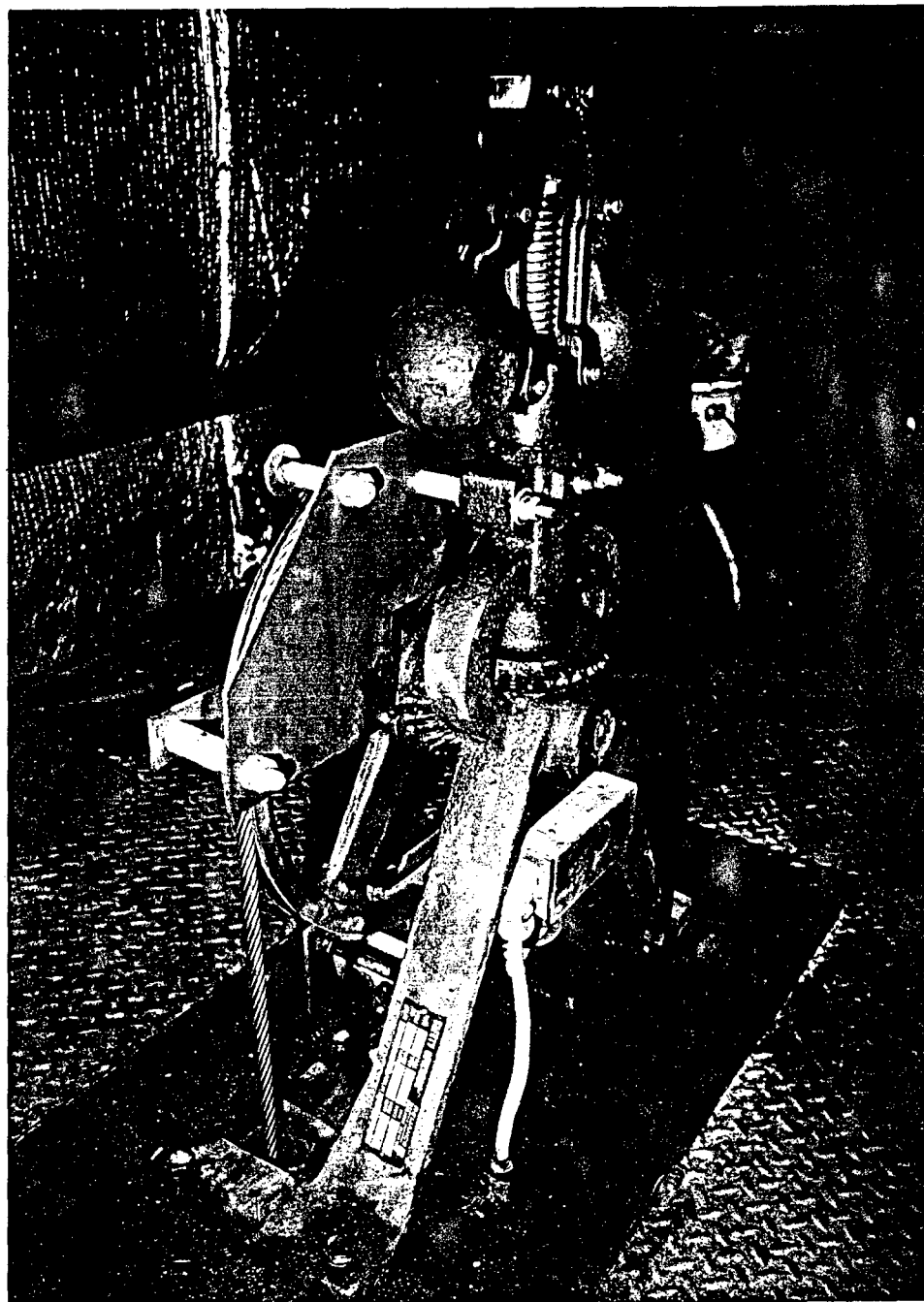


Figure 31

Typical Elevator Overspeed Governor

(Courtesy Marmon Transmotive)

buffer appears to be compressed it will be ineffective in the event of an overtravel and should be serviced or replaced.

Any wiring found in the pit should comply with any applicable regulations found in Title 30 CFR. Normally there will be wiring for lighting and a sump pump. Normal and final overtravel devices should be checked for proper operation by noting that the car stops when the limits are operated.

Electric elevators are equipped with a counterweight that will have normal and final overtravel limits at each end of travel. These should be checked for correct operation to see that they stop the elevator when activated. The counterweight will also be equipped with guides and a buffer, all of which should be inspected.

9.3 Hydraulic Elevators

Hydraulic elevators differ from electric elevators in that they accomplish movement of the car through the use hydraulic cylinders rather than through the use of winding machinery.

Hydraulic elevators are not especially common at present in mines. When inspecting hydraulic elevators they will be nearly the same as electric elevators except that the pit will be somewhat more complex. In addition, leveling switches will normally be in place on the top of the car to prevent it from becoming jammed due to the force being applied to the bottom of the car and by an uneven load distribution within the car.

The machinery room, normally located at the bottom of travel will contain hydraulic pumps and hoses in addition to the controller and switchgear. The electrical inspection here should be the same as outlined in section 9.2.4. Leaks in the hydraulic system should be

1

corrected, with drip pans placed under trouble spots. Oil should not be allowed to accumulate and drip pans should be emptied regularly to prevent fire hazards.

The pit on hydraulic elevators will contain valving, hoses, and cylinders in addition to the buffers found on other elevators. Leakage from the hydraulic system should be at a minimum with ruptured hoses being replaced immediately. Hydraulic plumbing and electrical wiring should be neat and permanently installed with support as needed.

Normal and final stopping devices or limit switches should be checked for correct operation by operating the car from one end of travel to the other end. This normally can be done only by operating the elevator from outside of the pit and should not be attempted from the pit area.

9.4 Rack and Pinion Elevators

Rack and pinion elevators normally are found installed in metal mines, on coal storage silas, in processing plants, or on building construction on the surface at any mine. The primary difference between other elevators and rack and pinion elevators is that the occupants must be able to let themselves down in the event of a power failures.

Governors installed on certain types of rack and pinion elevators are stamped and sealed with a mandatory replacement date. After this date, the governor must be replaced with a freshly sealed and stamped governor available from the manufacturer. If the seal has been broken this could indicate tampering with the setting of the governor and it must be replaced.

Rack and pinion elevators are normally driven by electric motors connected to a gear box that drives the pinion gear. The lubricating oil in the gear box can become extremely heavy and viscous in cold weather . This can cause overheating of the drive motors which, in turn, can cause nuisance tripping of the overloads. For this reason it is suggested that in cold weather applications of a rack and pinion elevator a lighter weight oil be used.

9.5 General Considerations

Elevators are normally not designed for applications as severe as are found in underground applications at most mines. This causes some rather high maintenance effort that can become a nuisance.

Elevators may be equipped with traveling cables that are not intended for mine duty. These should always be replaced with mine duty cables because of possible freezing and other hazards in the shaft. Ice may form on the cable and cause it to stretch and eventually break. For this reason, the traveling cable tie off to the shaft and to the elevator car should be checked regularly. If inconsistent operation of the car is noted, it may indicate short circuits in the cable, in which case the cable should be replaced.

Controls located in the elevator car are being improved continually but can still become inoperative in cold weather. If the shaft is wet, this can cause additional problems for the switching. Switching problems can often be corrected by the installation of small cabinet heaters that keep the switchgear dry.

Problems associated with cold weather operation of an elevator are very difficult to solve. Normally they can be overcome by installing heavy duty cables and waterproof enclosures for switchgear or by

installing a heater at the shaft collar. This last alternative is often more expensive than the problems it is intended to correct and is applied only in extreme cases.

9.6 Checklists

The checklists included here are intended only as a guide to aid in inspection of an elevator and should not be considered appropriate for all cases. Elevator installations may vary from one to another and may or may not have all of the items listed here. These checklists should be revised for each specific application.

Elevator inspections should progress in a logical manner. First, run the elevator through a full cycle. Start by having the elevator called from the different stations while watching the hoisting equipment and switchgear for rough or abnormal operation. Only after the elevator is shown to be operating properly should the individual components be inspected.

If this procedure is followed, the checklists included here may be used to assist in the location of troubles as well as in a normal inspection.

9.6.1 Checklist for Inspection and Test of Electrical Control Circuits of Electric Elevators

Mine

Name _____

I. D. No. _____ Test Date _____

Rated Capacity _____ Rated Speed _____

Classification _____ Manufacturer _____

Type of Operation _____

New Installation _____ Modernization _____

Additional Information:

Item:	Description	Condition		
		Good	Bad	Comments
	INSIDE THE CAR			
1	Emergency Stop Switch	_____	_____	_____
2	Car Emergency Signals	_____	_____	_____
3	Rated Load-Platform Area	_____	_____	_____
4	Capacity and Data Plates	_____	_____	_____
5	Signs in Freight Elevator	_____	_____	_____
6	Car Enclosure	_____	_____	_____
7	Ventilation of Passenger Elevator	_____	_____	_____
8	Ventilation of Materials Elevator	_____	_____	_____
9	Side Emergency Exits	_____	_____	_____
10	Car Door or Gate	_____	_____	_____
11	Car Door or Gate Electric Contacts	_____	_____	_____
12	Closed Position of Car Door or gate	_____	_____	_____
13	Power Opening of Doors or Gates	_____	_____	_____
14	Power Closing of Doors or Gates	_____	_____	_____
15	Door Closing Force	_____	_____	_____
16	Closing Speed of Power Doors	_____	_____	_____
17	Door Re-Opening Device	_____	_____	_____
18	Floating Platform	_____	_____	_____
19	Collapsible Gate, Passenger Elevator	_____	_____	_____
20	Collapsible Gate, Materials Elevator	_____	_____	_____
21	Car Lighting	_____	_____	_____
22	Car Emergency Lighting	_____	_____	_____
23	Station Numbers	_____	_____	_____

Item:	Description	Condition		
	OUTSIDE OF HOISTWAY	Good	Bad	Comments
24	Car Platform Guard	_____	_____	_____
25	Power Closing of Hoistway Doors	_____	_____	_____
26	Sequence Operation	_____	_____	_____
27	Hoistway Enclosure	_____	_____	_____
28	Types of Entrance	_____	_____	_____
29	Vision Panels	_____	_____	_____
30	Hoistway Door Locking Device	_____	_____	_____
31	Elevator Parking Device	_____	_____	_____
32	Access to Hoistway	_____	_____	_____
33	Emergency Power System	_____	_____	_____
34	Access to Pit	_____	_____	_____
	TOP OF CAR			
35	Traveling Cables	_____	_____	_____
36	Speed Limiting Switches	_____	_____	_____
37	Windows in Hoistway	_____	_____	_____
38	Governor Rope	_____	_____	_____
39	Car and Counterweight Top Clearance	_____	_____	_____
40	Hoistway Dimensions and Clearance	_____	_____	_____
41	Normal Terminal Stopping Device	_____	_____	_____
42	Final Terminal Stopping Device	_____	_____	_____
43	Stop Switch on Car Top	_____	_____	_____
44	Top of Car Operating Device	_____	_____	_____
45	Top Emergency Exit and Refuge Space	_____	_____	_____
46	Counterweight	_____	_____	_____
47	Counterweight Safeties	_____	_____	_____
48	Car Top Light and Outlet	_____	_____	_____
49	Crosshead Data Plate	_____	_____	_____
50	Multiple Hoistway	_____	_____	_____
51	Construction of Hoistway	_____	_____	_____
52	Floor Over Hoistway	_____	_____	_____
53	Venting of Hoistway	_____	_____	_____
54	Guide Rails and Fastenings	_____	_____	_____
55	Raceway and Wiring in Hoistway	_____	_____	_____
56	Pipes and Duct in Hoistway	_____	_____	_____
57	Landing Sill Guards	_____	_____	_____
58	Suspension Rope Hitch Plate	_____	_____	_____
59	Wire Rope Data Plate, Crosshead	_____	_____	_____
60	Wire Rope Data Tag, Suspension Rope	_____	_____	_____
61	Rope Sockets	_____	_____	_____
	MACHINERY SPACES AND MACHINE ROOM			
62	Governor Tripping Speed	_____	_____	_____
63	Governor Overspeed Switch	_____	_____	_____
64	Governor Seal	_____	_____	_____
65	Enclosure of Machine Room Spaces	_____	_____	_____
66	Access to Machinery Spaces	_____	_____	_____

Item:	Description	Condition		
		Good	Bad	Comments
67	Access Doors	_____	_____	_____
68	Head Room in Machinery Spaces	_____	_____	_____
69	Lighting	_____	_____	_____
70	Ventilation of Machinery Spaces	_____	_____	_____
71	Ventilation of Control Cabinets	_____	_____	_____
72	Guards for Exposed Equipment	_____	_____	_____
73	Visual Check of Gears and Bearings	_____	_____	_____
74	Type of Driving Machine	_____	_____	_____
75	Numbering of Machines and Disconnect Switches	_____	_____	_____
76	Electrical Ground	_____	_____	_____
77	Mainline Disconnects	_____	_____	_____
PIT				
78	Bottom Clearance for Car and Counterweight, and Runby	_____	_____	_____
79	Construction of Oil Buffers	_____	_____	_____
80	Oil Buffer Plunger Return	_____	_____	_____
81	Oil Level Gage	_____	_____	_____
82	Oil Buffer Data Plate	_____	_____	_____
83	Spring Buffer Data Plate	_____	_____	_____
84	Solid Bumpers	_____	_____	_____
85	Construction of Solid Bumpers	_____	_____	_____
86	Construction of Spring Buffers	_____	_____	_____
87	Buffer Switches	_____	_____	_____
88	Car Safeties Required	_____	_____	_____
89	Type of Safeties Identified	_____	_____	_____
90	Marking Plate for Safeties	_____	_____	_____
91	Counterweight Guard	_____	_____	_____
92	Protection of Space Below Pit	_____	_____	_____
93	Normal Terminal Stopping Devices	_____	_____	_____
94	Final Terminal Stopping Devices	_____	_____	_____
95	Guard Between Pits	_____	_____	_____
96	Access	_____	_____	_____
97	Illumination	_____	_____	_____
98	Stop Switch	_____	_____	_____
99	Compensating Sheave Switch	_____	_____	_____
100	Minimum Pit Depth	_____	_____	_____
101	Floor of Pit, Level	_____	_____	_____

Test		Result		
		Good	Bad	Comments
TESTS				
1	Speed Load	_____	_____	_____
2	Car and Counterweight Safeties	_____	_____	_____
3	Governor	_____	_____	_____
4	Governor Overspeed Switch and Car-Safety Mechanism Switch	_____	_____	_____
5	Level of Car Platform	_____	_____	_____
6	Oil Buffer	_____	_____	_____
7	Normal Terminal Stopping Device	_____	_____	_____
8	Final Terminal Stopping Device	_____	_____	_____
9	Operation Under Fire or Other Emergency Conditions	_____	_____	_____
10	Brake	_____	_____	_____
11	Operation on Emergency Power	_____	_____	_____

9.6.2 Checklist for Inspection and Test of Electrical Control Circuits of Hydraulic Elevators

Mine Name _____

I. D. No. _____ Test Date _____

Rated Capacity _____ Rated Speed _____

Classification _____ Manufacturer _____

Type of Operation _____

New Installation _____ Modernization _____

Additional Information:

Item:	Description	Condition		
		Good	Bad	Comments
	INSIDE THE CAR			
1	Emergency Stop Switch	_____	_____	_____
2	Car Emergency Signals	_____	_____	_____
3	Rated Load-Platform Area	_____	_____	_____
4	Capacity and Data Plates	_____	_____	_____
5	Signs in Materials Elevator	_____	_____	_____
6	Car Enclosure	_____	_____	_____
7	Ventilation of Passenger Elevator	_____	_____	_____
8	Ventilation of Materials Elevator	_____	_____	_____
9	Side Emergency Exits	_____	_____	_____
10	Car Door or Gate	_____	_____	_____
11	Car Door or Gate Electric Contacts	_____	_____	_____
12	Closed Position of Car Doors/ Gates	_____	_____	_____
13	Power Opening of Doors or Gates	_____	_____	_____
14	Power Closing of Doors or Gates	_____	_____	_____
15	Door Closing Force	_____	_____	_____
16	Closing Speed of Power Doors	_____	_____	_____
17	Door Re-Opening Device	_____	_____	_____
18	Floating Platform	_____	_____	_____
19	Collapsible Gate Passenger Elevator	_____	_____	_____
20	Collapsible Gate Materials Elevator	_____	_____	_____
21	Car Lighting	_____	_____	_____
22	Car Emergency Lighting	_____	_____	_____
23	Station Numbers	_____	_____	_____

Item:	Description	Condition		
	OUTSIDE OF HOISTWAY	Good	Bad	Comments
24	Car Platform Guard	_____	_____	_____
25	Power Closing of Hoistway Doors	_____	_____	_____
26	Sequence Operation	_____	_____	_____
27	Hoistway Enclosure	_____	_____	_____
28	Types of Entrance	_____	_____	_____
29	Vision Panels	_____	_____	_____
30	Hoistway Door Locking Device	_____	_____	_____
31	Elevator Parking Device	_____	_____	_____
32	Access to Hoistway	_____	_____	_____
33	Emergency Power System	_____	_____	_____
34	Access to Pit	_____	_____	_____
	TOP OF CAR			
35	Traveling Cables	_____	_____	_____
36	Speed Limiting Switches	_____	_____	_____
37	Windows in Hoistway	_____	_____	_____
38	Governor Rope	_____	_____	_____
39	Car and Counterweight Top Clearance	_____	_____	_____
40	Hoistway Dimensions and Clearance	_____	_____	_____
41	Normal Terminal Stopping Device	_____	_____	_____
42	Final Terminal Stopping Device	_____	_____	_____
43	Stop Switch on Car Top	_____	_____	_____
44	Top of Car Operating Device	_____	_____	_____
45	Top Emergency Exit and Refuge Space	_____	_____	_____
46	Counterweight	_____	_____	_____
47	Counterweight Safeties	_____	_____	_____
48	Car Top Light and Outlet	_____	_____	_____
49	Crosshead Data Plate	_____	_____	_____
50	Multiple Hoistway	_____	_____	_____
51	Construction of Hoistway	_____	_____	_____
52	Floor Over Hoistway	_____	_____	_____
53	Venting of Hoistway	_____	_____	_____
54	Guide Rails and Fastenings	_____	_____	_____
55	Raceway and Wiring in Hoistway	_____	_____	_____
56	Pipes and Ducts in Hoistway	_____	_____	_____
57	Landing Sill Guards	_____	_____	_____
58	Wire Rope Hitch Plate	_____	_____	_____
59	Wire Rope Data Plate, Crosshead	_____	_____	_____
60	Wire Rope Data Tag	_____	_____	_____
61	Rope Sockets	_____	_____	_____
62	Leveling Switches	_____	_____	_____
	MACHINERY SPACES AND MACHINE ROOM			
63	Access	_____	_____	_____
64	Machinery Space	_____	_____	_____
65	Enclosure of Machine Room Spaces	_____	_____	_____
66	Electrical Ground	_____	_____	_____
67	Power Supply	_____	_____	_____

Item:	Description	Condition		
		Good	Bad	Comments
68	Lighting and Ventilation			
69	Ventilation of Control Cabinets			
70	Mainline Disconnect			
71	Numbering of Machines and Disconnect Switches			
72	Pumps			
73	Drives			
74	Relief and Check Valves			
75	Flexible Hose and Fittings			
76	Tanks and Oil Level			
77	Drip Pans			
78	Piping and Supports			
79	Control Valves			
80	Pressure Tanks or Accumulators			
81	Guards for Exposed Equipment			
82	Visual Checks of Gears and Bearings			
PIT				
83	Clearance and Runby			
84	Construction of Oil Buffers			
85	Oil Buffer Plunger Return			
86	Oil Buffer Oil Level Gage			
87	Oil Buffer Data Plate			
88	Spring Buffer Data Plate			
89	Solid Bumpers			
90	Construction of Solid Bumpers			
91	Construction of Spring Buffers			
92	Car Safeties Required			
93	Type of Safeties Identified			
94	Marking Plate for Safeties			
95	Protection of Space Below Pit			
96	Normal Terminal Stopping Devices			
97	Final Terminal Stopping Devices			
98	Guard Between Pits			
99	Access			
100	Illumination			
101	Stop Switch			
102	Minimum Pit Depth			
103	Floor of Pit, Level			
104	Cylinder Air Relief			
105	Counterweight Guard			
106	Cylinder Oil Collection			
107	Pipes Valves and Fittings			
108	Piping and Supports			
109	Plunger			
110	Plunger Fastening			
111	Cylinder			

Item:	Description	Condition		
		Good	Bad	Comments
	TESTS			
1	Speed Load	_____	_____	_____
2	Car Safeties	_____	_____	_____
3	Oil Buffer	_____	_____	_____
4	Normal Terminal Stopping Device	_____	_____	_____
5	Final Terminal Stopping Device	_____	_____	_____
6	Operation Under Fire or Other Emergency Conditions	_____	_____	_____
7	Operating on Emergency Power	_____	_____	_____
8	Relief Valves	_____	_____	_____
9	Static Load	_____	_____	_____
10	Stop Ring	_____	_____	_____

9.6.3 Checklist for Inspection and Test of Electrical Control Circuits of Rack and Pinion Elevators

Location _____

Type _____ Serial No. _____

Capacity _____ Speed _____

Year Manufactured _____ Date of Installation _____

Lifting Height _____ Number of Landings _____

Configuration _____ Control _____

Power Feed _____ Communication System _____

Lower Device _____

Expiration Date of Safety Device _____

Serial Number of Safety Device _____

Item:	Description	Condition		
		Good	Bad	Comments
INSPECTIONS				
1	Check alignment of cable guides and functions of the spring blades	_____	_____	_____
2	Function of the power cable trolley	_____	_____	_____
3	Inspect and adjust motor brake to minimum gap	_____	_____	_____
4	Rack is well greased	_____	_____	_____
5	Alignment of guide rollers	_____	_____	_____
6	Lubrication of guide rollers	_____	_____	_____
7	Oil leakage from gear box	_____	_____	_____
8	Mast bolts tight	_____	_____	_____
9	Roller bolts tight	_____	_____	_____
TESTS				
1	Overspeed safety device with full load	_____	_____	_____
2	Upper final limit switches	_____	_____	_____
3	Upper normal limit switches	_____	_____	_____
4	Lower final limit switches	_____	_____	_____
5	Lower normal limit switches	_____	_____	_____
6	Mechanical function of the car doors	_____	_____	_____
7	Electrical interlocks on car doors	_____	_____	_____
8	Mechanical function of the landing doors	_____	_____	_____

Item:	Description	Condition		
INSPECTIONS		Good	Bad	Comments
9	Electrical Interlocks on the Landing Doors	_____	_____	_____
10	Emergency Stop Buttons	_____	_____	_____
11	Function of the Centrifugal Brake	_____	_____	_____
12	Stop Next Landing Function	_____	_____	_____
13	Function of all Control Stations Including Top of Car Station	_____	_____	_____

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