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COMPACT SERVICE HOIST SYSTEM FOR UNDERGROUND METAL AND NONMETAL MINES

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Foster-Miller, Inc.

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16. Abstract This report describes the development and limited testing of a semi-automatic, raise climber, Compact Service Hoist System designed for stope access in underground metal and nonmetal mines. Demonstrated capabilities of the system include a 1,000-lb payload capacity, control from the traveling cage and from up to three remote stations, operating in vertical or inclined raises 3 ft in diameter and up to 300 ft in length and a travel speed of 50 ft/min. The system has the capability of operating in crooked raises because the conveyance climbs two stationary wire ropes suspended down the raise. The drive unit is electrically powered with power and control signals supplied to the drive unit through an umbilical cable also suspended down the raise. The system has been designed for portability, ease of installation and minimum raise development. The hoist has been demonstrated successfully in an above ground test tower. This report provides a detailed description of the hoist design and its demonstrated performance to date.			
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FOREWORD

This report was prepared by Foster-Miller, Inc. (FMI) Waltham, MA under USBM Contract No. HO202019. The contract was initiated under the High Speed Mine Development Program. It was administered under the technical direction of the Spokane Mining Research Center with Mr. Al Gooch acting as the Technical Project Officer. Mr. B.G. Horton was the contract administrator for the USBM.

This report is a summary of the work completed as part of the contract during the period of September 1980 to June 1985. This report was submitted by the authors in December 1985.

The technical effort was performed by the engineering systems group at FMI under the supervision of Mr. David A. Monaghan. The Program Manager was Mr. David J. Hoadley. Field operations were directed by Mr. Billy Brunelle. The success of the program is due largely to the significant contributions of Mr. John Healey, Mr. Robert L. Cardenas, Project Engineers, and Mr. Edward Heenan, Senior Electrical Technician.

The cooperation of Ohio Hoist Manufacturing Company in Lisbon, OH throughout the program is gratefully acknowledged. Mr. Dan Grove, Senior Engineer, provided valuable assistance throughout the program.

The cooperation of Mr. Tom Hendricks during the early phases of the program is gratefully acknowledged.

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1. INTRODUCTION

This document is the Final Technical Report prepared by Foster-Miller, Inc. for USBM Contract H0202019, "Compact Service Hoist System for Underground Metal and Nonmetal Mines," summarizing the results of the program efforts in building and testing the compact hoist system.

This program was to be completed in three phases. The last phase was to be an underground test of the system in an active mine. During the design phase, Phase I, a mine was selected as the Phase III test site. An agreement was made with the Hendricks Mining Co. in December 1981 to install the hoist at their Cross Mine in Nederland, CO. The system's site-specific equipment such as the cage and system guidance was then designed based on installation at the Cross Mine.

At the end of Phase II, June, 1982, the hoist was shipped to the Cross Mine for installation. Because of the economic climate in the mining industry at that time, mine management could not commit the funds necessary to complete the raise preparation required for installation of the hoist.

After a long delay the decision was made by the Bureau of Mines to investigate the possibility of another site for the underground testing. During the latter part of 1983 and 1984 a search was conducted for the purpose of finding another test site, however, for various reasons, particularly the continuing depressed condition of the mining industry, none of the mines contacted were able to install the compact hoist.

An attempt was made to make arrangements with the Colorado School of Mines for installation of the hoist system in their experimental mine at Idaho Springs, CO. A combination of budgetary restraints and the actual mine configuration prevented installation of the hoist at the Colorado School of Mines.

In February 1984, at the request of the Bureau, the Compact Hoist was delivered to the Bureau, Denver, CO where it has remained in storage.

1.1 BACKGROUND

Several recent observations and studies have highlighted the need for greatly improved vertical transportation of both men and supplies to stopes in underground metal and nonmetal mines. The AMC Technical Advisory Committee has recommended that the Bureau investigate

development of improved in-mine service hoists. Two Bureau-sponsored studies (1, 2) have identified productivity losses and inadequate safety aspects of present-day stope access hoisting equipment. A recently completed hoist development and test program (3) has demonstrated the practicality and potential benefits of stope access hoisting. In particular, the need for a small, lightweight, low-cost hoist system capable of negotiating changing inclination stope access raises was identified.

1.2 PROGRAM OBJECTIVES

The broad objective of this program was to develop and mine test a compact hoist system suitable for stope access.

Specific program objectives were:

- a. Design a drive unit and control system suitable for universal use
- b. Select an underground test site at a cooperating mine
- c. Design a site-specific conveyance and guidance system
- d. Prepare an engineering and economic analysis
- e. Develop an aboveground test plan
- f. Fabricate the complete system and conduct above-ground testing
- g. Install and field test the system in an underground stope access application.

1.3 SPECIFICATIONS AND REQUIREMENTS

- a. General requirements:
 1. Man-rated at 500 lb net load. 1,000 lb plus maximum net load
 2. 50 ft/min operating speed
 3. Capable of serving a 300 ft raise
 4. Capable of being moved and re-installed quickly and easily at other stopes

b. Control requirements:

1. Controllable from conveyance and three stations; (top, bottom, one intermediate)
2. Suitable lockouts so only one control station functional at a time
3. Primary signal system between hoist and all stations with independent telephone system.

c. Design requirements:

1. The hoist shall fulfill applicable federal and state requirements concerning hoist machinery used in metal and nonmetal underground mines.
2. 3 ft² minimum floor space in man cage
3. Operate from 440 V 3 phase power
4. Functional lifting operation shall be a drive system climbing suspension devices fixed at top of travel, independent of raise compartment structure
5. Structure shall make maximum use of light-weight corrosion resistant materials
6. Hoist shall operate with minimal raise restructure requirements, e.g., smooth-line footwall
7. Readily detachable man conveyance.

1.4 SCOPE OF EFFORT

The program was to be completed in three phases:

Phase I - Design
Phase II - Fabrication and Testing
Phase III - Underground Testing

Phase I requirements included:

- a. Preparation of an updated program plan
- b. Hoist system design and specification
- c. Test site mine selection

- d. Engineering and economic analysis
- e. Test facility design and plan
- f. Phase I report.

Phase II requirements included:

- a. Fabrication and assembly of the nonmine-specific hoist equipment including the drive unit and the electrical power and control system
- b. Fabrication and assembly of the mine-specific equipment including the cage and guide frame
- c. Definition of the mine supplied equipment including raise guides and station hardware specified in a signed working agreement between FMI and the selected test site mine
- d. Comprehensive aboveground testing of the complete system
- e. Phase II report including an Operation and Maintenance manual.

Phase III requirements included:

- a. Installation of the hoist at the selected site
- b. One underground system move and installation with the number of men and man-hours documented by task
- c. Maintenance of an operating log indicating the purpose of all hoist trips
- d. Keeping a system maintenance log
- e. Refinement of inspection procedures to assure safe and effective system operation
- f. Delivery of the system after testing to the Bureau, Spokane, Washington
- g. Preparation of a draft final report.

Details of the Phases I and II were presented in reports submitted October 1981 and July 1982, respectively. A separate system "Operations and Maintenance Manual" submitted in July 1982 is attached as appendix A to this report.

2. TEST SITE SELECTION

2.1 SITE SELECTED

The Cross Mine in Nederland, CO, was selected as the test site. The major considerations used to select this site were:

- a. Small operation
- b. Need
- c. Satisfies program contract specifications
- d. Location is easily accessed
- e. Probable minimum program cost
- f. High level of cooperation anticipated.

The small operation was viewed as an asset to the test program since all mine personnel would eventually use the hoist it would be in their best interest to ensure that the system was properly maintained and not abused. At the time of the site selection the access to the working levels of the Cross Mine was by ladder making the need for a hoist acute. The shaft in which the hoist was to be installed was inclined 60 deg making it a good representation of a typical application for a cable climbing hoist. The area of the test site was accessible from aboveground via a short drift. This would have shortened travel time to and from the site during installation and reinstallation and would have, therefore, reflected a time and money savings to the program.

2.2 MINES VISITED

The final task prior to selecting a demonstration site for the hoist was to visit the mines that had expressed a sincere interest in the program. Five mines were visited:

- a. Hecla Mining Co., Lucky Friday Mine, Mullan, ID
- b. Hendricks Mining Co., Cross Mine, Nederland, CO
- c. Kerr-McGee, Churchrock, NM
- d. Magma Superior Co., Magma Copper, Superior, AZ
- e. West Coast Gas and Oil, Gooseberry Mine, Sparks, NV.

Three of the five mines visited responded in writing, expressing their willingness to participate in the program. In addition to the Cross Mine, the Gooseberry and Kerr-McGee Mines were available as test sites. The Gooseberry and Kerr-McGee Mines were informed that the Cross Mine had been selected as a test site, and asked to be backup sites if the Cross Mine site did not work out.

2.3 MINES CONTACTED

Approximately 20 mines were contacted by telephone initially in the effort to locate a suitable test site. A list of these mines is presented in table 1.

TABLE 1. - List of mines contacted

Mine	Representative
Anaconda Copper Co. Carr Fork Mine Tooele, UT	Gil Knappmiller - Supervisor George McArthur - Chief Engineer
Union Carbide Corp. Bishop Plant Bishop, CA (714) 387-2501	T.W. Scoot - Mine Engineer
Asarco, Inc. Coeur and Galena Mines Wallace, ID (208) 752-1116	M.G. Miskulin - Chief Engineer
Homestake Bulldog Mine Creed, CO (303) 658-2561	R. Boppe - Chief Engineer
Bunker Hill, Inc. Bunker Hill and Crescent Mines Kellogg, ID (208) 784-1261	J. Perrin - Supervisor of Engineering
Heccla Mining Co. Star Mine Burke, ID (208) 752-1251	Walter Paroni - Senior Engineer
Kerr-McGee P.O. Box 28 Churchrock, NM (505) 722-6611	Mike Gibson - Assistant Manager
Sunshine Mine P.O. Box 1080 Kellogg, ID (208) 784-1257	Robert Anderson - General Supervisor Bob Peterson
Helca Mining Co. Lucky Friday Mine Mullan, ID (208) 744-1523	John Marks - Engineer

TABLE 1. - List of mines contacted (Continued)

Mine	Representative
Magma Superior Co. Magma Copper P.O. Box 37 Superior, AZ (602) 689-2444	J. Scheurering - Supervisor
Amax Chemical Corp. Carlsbad, NM (505) 885-3157	-
Asarco, Inc. Ground Hog Mine Vanadium, NM (505) 537-2142	Stephen Hodgson - Supervisor
Sohio Natural Resources Co. P.O. Box 25201 Albuquerque, NM (505) 242-2762	-
Standard Metal Corp. Silverton, CO (303) 387-5533	John Keating
Henricks Mining Co., Inc. Nederland, CO (303) 258-3806	Thomas Hendricks, President
Cotter Corp. Schwartzwalder Mine Golden, CO (303) 642-3605	-
West Coast Gas and Oil Gooseberry Mine Sparks, NV	Dennis LaPairie
New Jersey Zinc Co. Ogdensburg, NJ (201) 827-7121	-

3. COMPACT HOIST SYSTEM DESCRIPTION

The Compact Hoist System has been designed to operate in underground hardrock mines in raises larger than 3 ft in diameter. The system arrangement described in this report was designed for operation at the Cross Mine, Nederland, CO.

3.1 GENERAL DESCRIPTION

The hoist system has been configured to operate in a 60° inclined timbered raise measuring 42 x 48 in. in cross section. The raise includes a ladder and service pipes mounted to the footwall and two guide timbers that have been added to support and guide the hoist.

The moving conveyance of the system is shown in figure 1 and consists of three distinct components:

- a. Cage
- b. Drive unit
- c. Frame.

The cage is mounted below the drive unit and connected to it by means of a simple frame that also serves as the guidance for the complete assembly.

Two 3/8-in diam wire ropes fed through the two wire rope traction climbers of the drive unit support the conveyance and attach through protective load cells to the head frame located at the top level of the hoist travel. The two wire ropes trail beneath the conveyance and attach below the bottom level of the hoist travel by means of swivel connections.

The hoist guidance consists of two 4 x 6 in. high-grade commercial construction-quality wooden rails secured to the existing raise timbers that form the sides of the raise compartment. The wooden rails are 36 in. apart and run the full length of the raise and support the normal component of the hoist weight on their top surfaces. The inner facing surfaces of the wooden rails restrict sideways motion of the hoist conveyance. Limit switches mounted on the moving conveyance, and ramps attached to the guidance rails determine upper and lower travel and overtravel limits.

Control of the conveyance is accomplished through the use of four pushbutton stations located at the top level, bottom level, cage, and one sublevel.

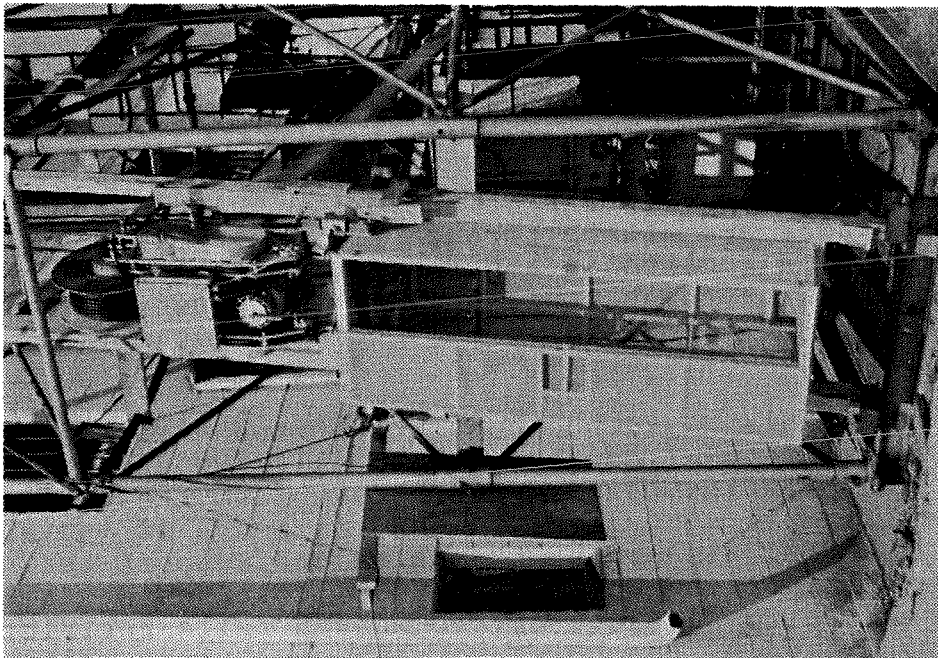
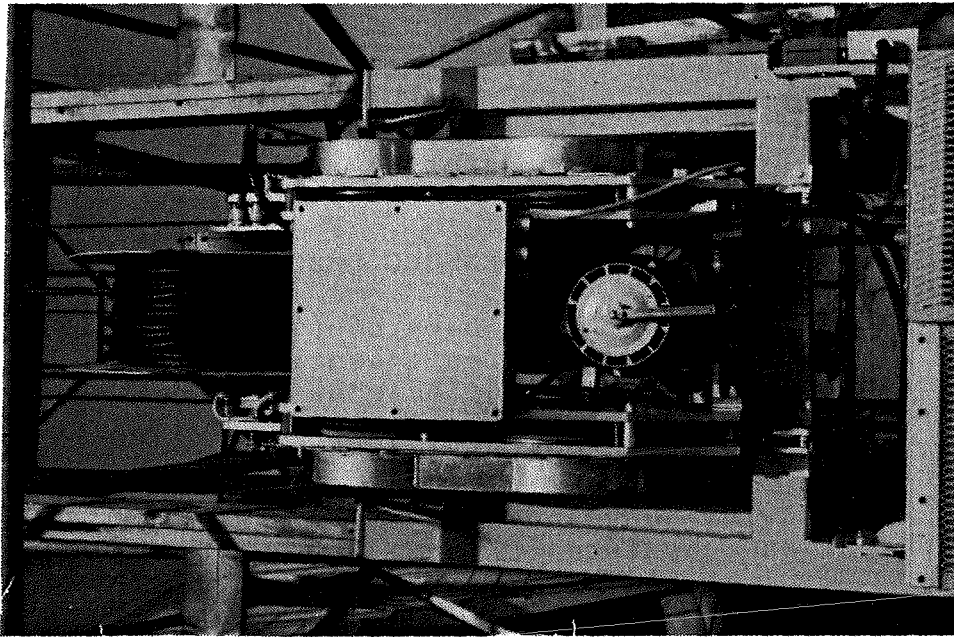


FIGURE 1. - General arrangement of Compact Hoist System.

In the following subsections are brief descriptions of the major subsystems. These are presented under two headings: universal equipment and site-specific equipment.

3.2 UNIVERSAL EQUIPMENT

The equipment that is common to all applications of the Compact Hoist includes:

- a. Drive Unit
- b. Electrical System
- c. Rope Load Cells
- d. Head Support Beam.

3.2.1 Drive Unit

The drive unit for the Compact hoist has been developed by Ohio Hoist Manufacturing Company of Lisbon, OH, under subcontract to FMI. The general arrangement of the unit is shown in figure 2. The unit is electrically powered, measures 48 x 29 x 24.5 in., and is completely self-contained. The drive system is designed to climb two stationary wire ropes which are anchored at the top of the raise and suspended down the full depth of the raise. Electrical power is supplied to the drive unit from above through a stationary power cable. This cable is stored on the drive unit on a powered collection drum.

Drive Train

The general arrangement of the drive train is shown in figure 3. The drive motor is a 480V ac three-phase single-speed unit developing 5 hp at 1,725 rpm. The primary system brake is attached to the rear end of the motor. This unit is a Powerbloc 28 ft-lb spring-set, power-released, single-disc brake which sets when power is removed from the electric motor. The electric motor is C-face mounted to a special lightweight dual output gear reducer. The gear reduction is 5.9:1 achieved through two helical gear pairs. The three gear shafts are each supported by pairs of taper roller bearings. The gearbox housing is a two-piece arrangement using cast high-strength aluminum alloy. The two output shafts from this gearbox are co-axial. The primary output shaft supplies power to the drive differential unit. The secondary output shaft provides the power source to drive the power cable collector drum.

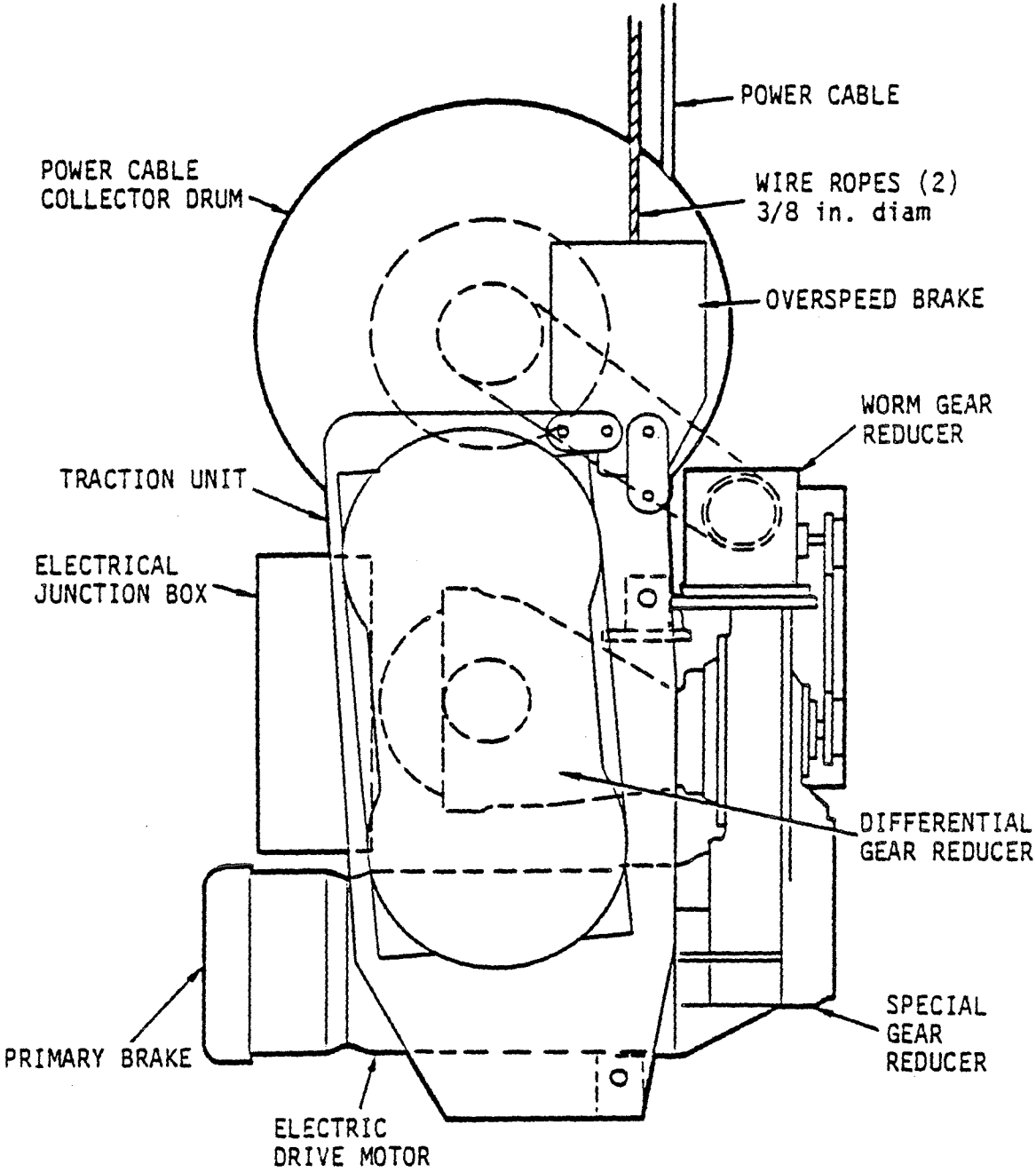


FIGURE 2. - General arrangement of compact hoist drive unit.

The differential unit is a commercially available item manufactured by Spicer Heavy Axle Division. The unit weighs 80 lb and provides a 5.89:1 reduction between the single input shaft and the dual output shafts. The unit selected is a Model 44-1C rated at 1,250 ft-lb continuous output torque.

The two differential output shafts are coupled directly to the two traction unit assemblies. Each shaft connects to a gear pinion located near the center of the

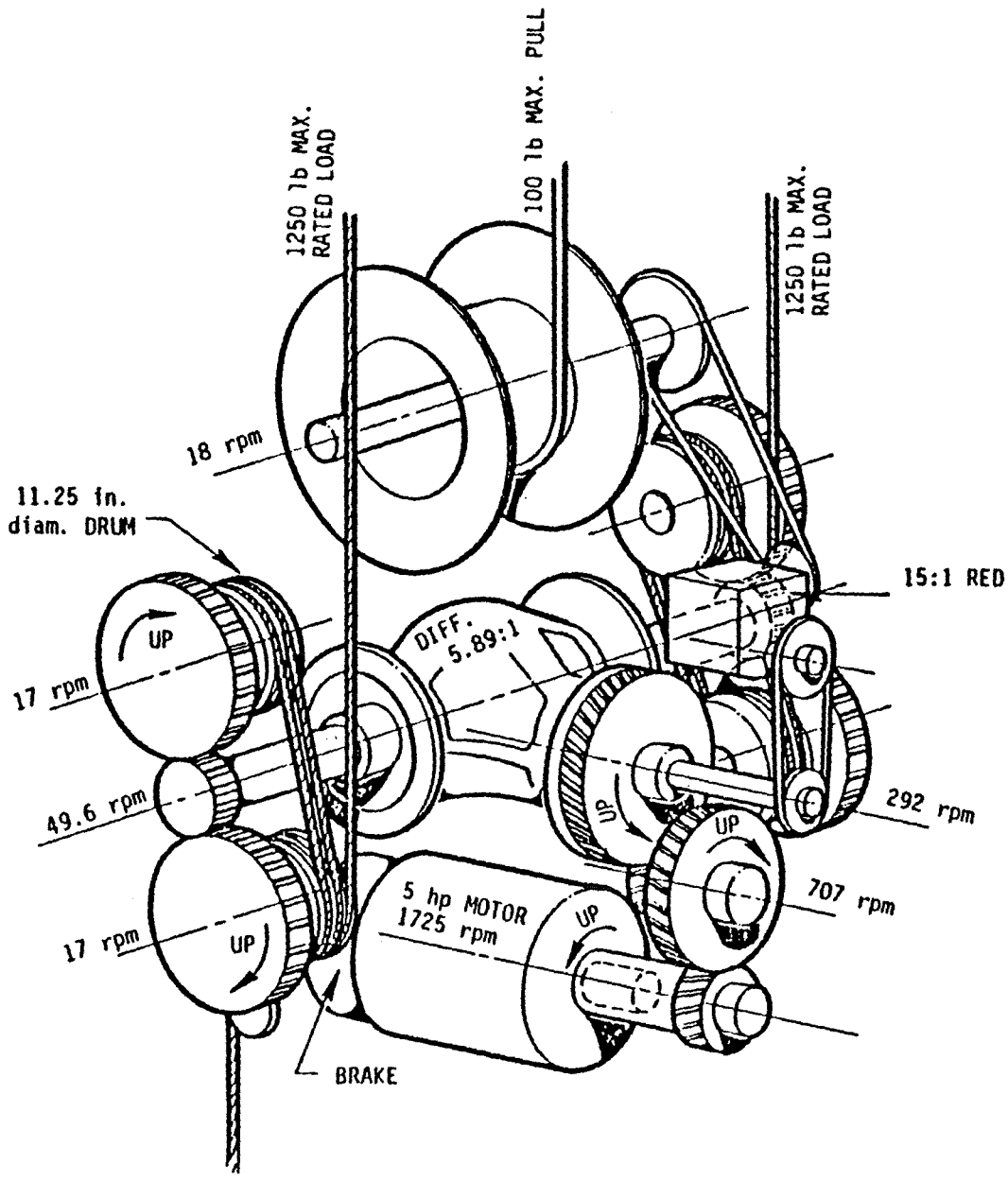


FIGURE 3. - Drive system arrangement.

traction unit. This pinion meshes directly with two bull-gears which are mounted to the two traction drum shafts. This arrangement provides a 2.92:1 reduction.

The secondary output shaft from the special gear reducer is connected via a 1:1 silent chain drive to a one-way clutch which connects to the input side of a 15:1 single worm gear reducer. The output from this reducer connects to the power cable collector drum through a cog-belt drive with a 1.1:1 reduction. This arrangement turns the cable drum in the up-travel direction at approximately 18 rpm.

Traction Unit

The drive unit includes two traction units which attach directly to mating flanges on the differential unit. The traction units include two traction drums, one of which doubles as a transfer drum. Both traction drums are driven through identical bull-gears through a common pinion to give a peripheral velocity of 50 ft/min. The effective diameter of each traction drum is 11.25 in. This gives a drum diameter (D) to rope diameter (d) ratio (D/d) of 30. The lower traction drum has three grooves and the upper drum has two grooves. The suspension wire rope is reeved to pass around the lower traction drum in the inner groove for 175° and then up and over the upper drum and down to the lower drum. The rope is reeved twice in this manner. It is then routed out of the bottom of the traction assembly.

A series of tension rollers is positioned to bear on the outer surface of the rope spooled around the traction drums. During reeving, when the rope is not under tension, these rollers hold the rope firmly against the traction drums to prevent rope slippage. Once tension is applied to the rope, a positive grip is achieved through the capstan effect produced between rope and drum.

The traction drums and final drive gearing are supported by two machined 1/2-in thick aluminum side plates. One traction unit includes a footage counter mechanism and the electrical system plugging switch. As the wire rope exits from the traction assembly, it is routed to pass over a guide sheave. The sheave is sized to rotate one revolution for each foot of rope. The sheave rotation of one traction unit is sensed through a single lobe cam by an electrical switch. Signals from this switch, together with direction logic circuitry, drive the system position indicators located at each control station. The plugging switch is driven off the input drive pinion through two transfer gears. The switch is turned at a speed of 100 rpm at a hoist speed of 50 ft/min.

Overspeed Brake

The drive unit assembly is fitted with two overspeed brake assemblies. One assembly is mounted above each traction unit. The wire rope to each traction unit passes through the overspeed brake assembly prior to entering the traction unit. Wire rope speed through the brake assembly is monitored by a centrifugal device which initiates brake setting at a rope speed of 65 ft/min. Braking action is achieved through use of a steel wedge assembly which firmly grips the rope and locks it to the brake structure.

Power Cable Collector

The power cable collector mounts to the top of the drive unit. The assembly includes a driven drum on which up to 300 ft of power cable can be stored, and an electrical slip-ring assembly which transfers the electrical power and control signals from the rotating drum-mounted cable to the rotatively stationary drive unit.

The cable collector drum measures 8 in. wide by 25 in. in diameter, and has a barrel diameter of 12 in. The drum is fabricated from light-gauge sheet steel. The drum is power driven at 18 rpm in the up-travel direction from off the main drive. The drum rotative speed is slightly greater than that required. The speed difference is taken up through an adjustable tension slip clutch. In the down-travel direction, the input drive is free-wheeled through a one-way clutch and locked through the non-rotating 15:1 worm gear drive. The drive rotates against the adjustable tension slip clutch.

The power cable stored on the drum is terminated inside the drum barrel at a 10-conductor, 50A capacity slip-ring assembly. Each slip-ring rotates with the drum. Two stationary carbon brushes contact each ring and transfer the electrical power and control signals to the drive unit electrical junction box.

The drive unit electrical system comprises a small junction box which connects the following drive unit and cage-mounted equipment.

- a. Slip-ring assembly (10 active circuits)
- b. Drive motor and primary brake
- c. Overspeed brake solenoids (two)
- d. Overspeed brake limit switches (two)
- e. Footage counter switch

- f. Plugging switch
- g. Cage control box, including:
 - 1. Cage door interlocks (two)
 - 2. Travel limit switches (two)
 - 3. Overtravel limit switches (two).

The junction box mounts above the primary brake and measures approximately 12 x 8 x 6 in. The box contains:

- a. Terminal strip
- b. 480/24V ac transformer
- c. Reversing motor starter.

3.2.2 Electrical System

The electrical power and control system is made up of the following subsystems:

- a. Main control box
- b. Remote pushbutton stations
- c. Cage pushbutton station
- d. Moving conveyance junction box
- e. Power and interconnecting station cables
- f. System interlocks.

The power and control system provides mine-supplied 480V ac at 20A three-phase 60 Hz electrical power to the downhole drive unit. The system monitors the supply and provides control of the moving conveyance from three remote control stations positioned along the raise and from a control station within the traveling cage. A typical system deployment is shown in figure 4.

Mine-supplied power connects to the power and control box (PCB) situated at the service level. The PCB connects electrically to each remote control station through a single six-conductor cable. Power to the moving conveyance is supplied by the PCB through a 10-conductor "umbilical" cable. Detailed subsystem descriptions are presented in the following paragraphs.

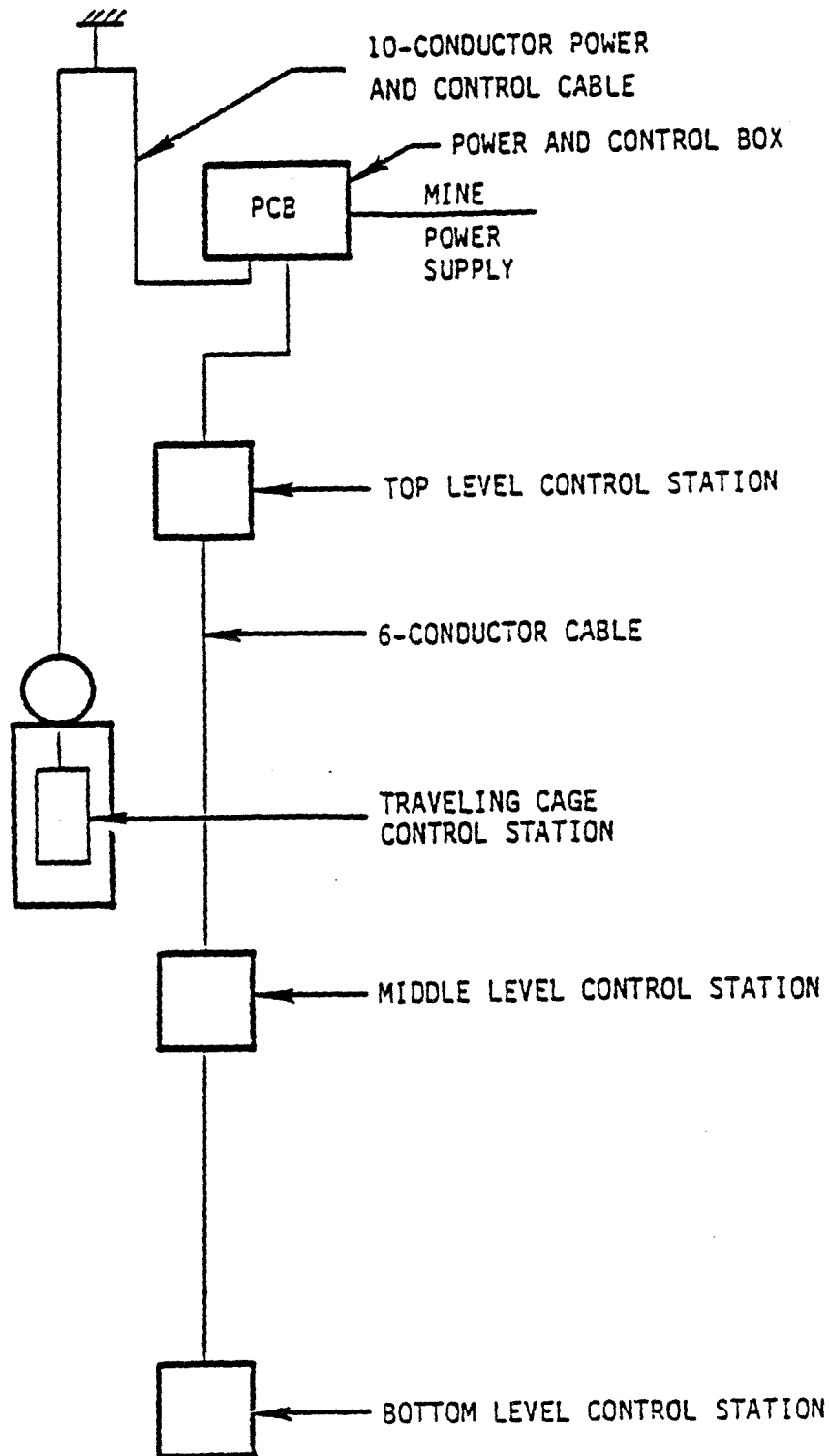


FIGURE 4. - Typical electrical system deployment.

Main Control Box

The main control box houses a hybrid system of relays and solid-state components:

- a. Main circuit breaker, fuses and a "ground break" detection system
- b. Cycle counter and hour meter
- c. dc power supply and stepdown transformer.

The main circuit breaker provides 20A, three-phase short-circuit protection to the system. The ground break detection system senses low-level currents in the equipment ground and automatically shuts the power off if fault currents occur.

The cycle counter registers the number of times the cage is moved in the down direction and the hour meter accumulates the moving time that the system operates. This information will help estimate the wear and fatigue behavior of the wire rope.

The dc power supply provides control power to the main control box, the remote pushbutton stations, and the cage. The stepdown transformer interfaces the 480V ac mine power with the 120V ac input required for the dc supply. Housing the power supply in the main control box provides weight and space savings on the moving conveyance and in the remote pushbutton stations.

Remote Pushbutton Station

Each of the three remote control stations are identical. The unit measures 16 x 12 x 8 in. and has a face arrangement as shown in figure 5. They provide for:

- a. Unique control from that station
- b. Indication of control from another station
- c. Direction control
- d. Position readout
- e. Interstation call communications
- f. Interstation phone communications
- g. Station gate interlock.

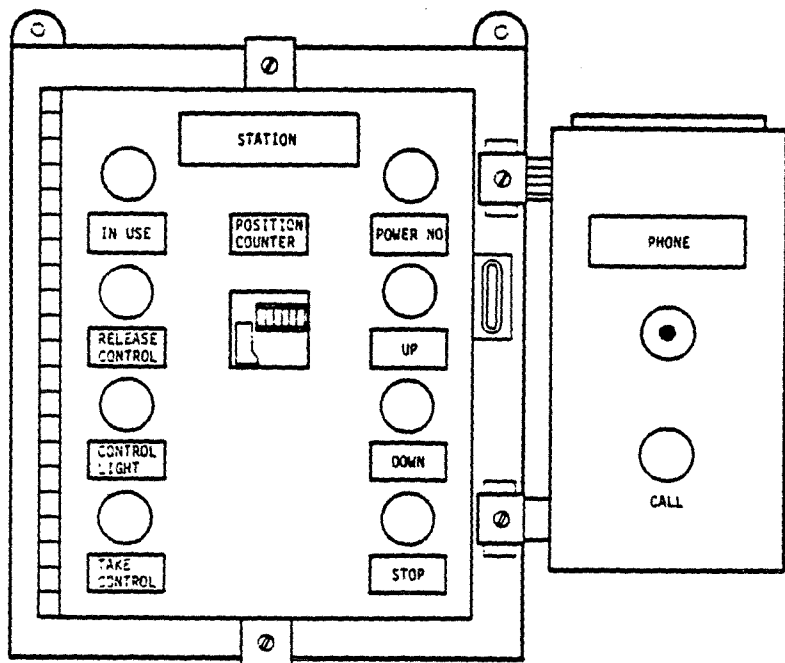


FIGURE 5. - Pushbutton face arrangement.

The remote stations include a printed circuit logic board to accomplish position readout and phone communications. All logic boards utilize CMOS integrated circuits which have excellent noise immunity and tolerate wide variations in source power. The logic boards are chemically coated to resist corrosion and moisture.

Cage Pushbutton Station

The cage pushbutton station provides all the functions that the remote stations provide. Additional functions provided by the cage pushbutton station include:

- a. Footage counter-circuit
- b. Travel and overtravel logic
- c. Cage door interlocks
- d. Overspeed interlock.

The physical dimensions of the cage pushbutton station are the same as the remote stations even though these additional functions are provided.

3.2.3 Drive Unit Junction Box

The drive unit junction box interconnects the following downhole components:

- a. Cage pushbutton station
- b. Slip-ring outputs
- c. Main motor and brake
- d. Footage counter pulse switch
- e. Overspeed brakes
- f. Travel and overtravel switches
- g. Plugging switch
- h. Reversing motor starter
- i. Overspeed brake relay
- j. Stepdown transformer and rectifier circuit.

The physical volume of the junction box is approximately 1 ft³, which is adequate to house the necessary terminals to accomplish the above interconnections plus the motor starter, relay and transformer.

Umbilical and Interconnecting Cables

The umbilical cable is a 10-conductor No. 12 wire which connects the PCB to the moving conveyance through rotating slip-rings. The cable selected for this purpose is a catalog item stocked by Anixter Bros. Inc. The cable is 5/8 in. in outside diameter and weighs 0.31 lb/ft.

The remaining interconnecting cables are six-conductor, catalog item, common, heavy-duty extension cord type cables.

System Interlocks

The system interlocks are:

- a. Travel and overtravel
- b. Cage and station doors
- c. Overspeed brakes

d. Rope/overload detectors

e. Slack rope detectors.

Travel limit occurs only at the top and bottom of the shaft and provides automatic stopping if the moving conveyance is unattended. Overtravel stops provide for system shutdown in the event of a travel limit failure.

The cage door and station interlocks automatically stop the moving conveyance in the event that any door is open. The system must be manually restarted after the door has been closed.

The overspeed electrical interlock automatically trips the second overspeed brake once one of the brakes has tripped. It also prevents the moving conveyance from traveling downward until the overspeed brakes have been manually reset.

Circuit Description

The circuit configuration is a low voltage relay logic circuit. The final or output components of the electrical system are the 5 hp motor and the reversing motor starter. They provide the mechanical power and direction logic to the hoist which cause the hoist to "go up," "go down," or "stop." Two low voltage (12V dc) relays signal the motor starter, one to go up and the second to go down. (Stop is no signal from either relay.) The up and down relays are electrically interlocked to prevent the possibility of both signaling at the same time. In addition, the motor starter is electrically and mechanically interlocked to prevent up and down signals from occurring simultaneously. The up and down relays are located in the cage pushbutton station. An additional relay is located in each of the remote and the cage pushbutton stations. They provide the "take" function which allows operation of the system from only one location at a time. The take relays are interlocked such that only one can be energized at a time and the up and down signals are fed through the "take" relay at each station.

The cage position is displayed by a counter on each pushbutton station. Each pushbutton station includes a solid state circuit that activates the add coil in the counter when the system is moving up and a count signal occurs. The count signal is generated by a switch on the main drive that is closed by a cam which rotates once per foot of cage motion. The switch output signal is fed to the input of a "one-shot" integrated circuit which is triggered by only the leading edge of the switch signal and puts out a constant width pulse of approximately

0.5 sec time duration. When the system is moving down, the solid state logic activates the subtract coil on the counter while everything else works the same as it did in the up mode. The same solid state logic activates the call and phone circuit when the system is not moving. Thus, the count signal line is shared between phone system and the position readout system.

All the functions described above are accomplished by four signal lines between the pushbutton station. An additional two lines provide dc power to the stations.

The four signal lines are utilized as follows:

- a. In use/not in use
- b. Up/stop
- c. Down/stop
- d. Count/phone and call.

When the system is not in use, the "in use" line is held positive through a 50 ohm resistor. When a station takes control, the "in use" line is shorted to ground by the "in use" relay at the station in control. All other take control relays located in the other pushbutton stations utilize the "in use" line positive signal to energize and therefore cannot activate. The up and down relays are also held on through another 50 ohm resistor. Thus, to generate a stop signal, both the up and down signal lines are shorted to ground which causes the up or down relay to de-energize. This circuit is separate from the take circuit; therefore, any station will stop the system, yet system control will remain where it originated.

Additional system safety interlocks are:

- a. Rope overload
- b. Travel and overtravel limits
- c. Cage door and station gates
- d. Emergency brakes.

When any one of these interlocks activate they simply generate a stop signal, with the exception of the over-speed brake, which only allows the system to move up.

3.2.4 Rope Load Cells

Two identical rope load cell assemblies are used to monitor the tension in the two 3/8-in diam wire ropes which support the compact hoist system. The cell assemblies are mounted to the head beam at the top of the raise. The wire ropes attach to the cell assemblies. Each assembly includes two electrical switches. One switch signals a rope overload condition, the other a slack rope condition. Rope overload is defined as a load in excess of 1,500 lb and slack rope, a rope tension of less than 500 lb. The load cells are connected electrically to the PCB on the main service level. Abnormal rope load conditions in either rope will cause automatic shutdown of the hoist.

3.2.5 Head Support Structure

The head support structure assembly is of welded fabrication and comprises two spaced flange-to-flange 6-in channels capped and boxed by 1/4-in steel plate. The assembly weighs 85 lb and is 3 ft long. Mounting holes are provided for load cell and umbilical cable attachment together with a variety of holes for mounting the structure in the raise. The unit can be mounted with eight lateral rock bolts in shear, or it may be placed to bear on suitable mounting structing and bolted at either end to that structure. For all the available methods of mounting, the assembly has been sized to accept a total load in excess of the combined rope breaking strengths, a load of 12.2 tons.

3.3 SITE-SPECIFIC EQUIPMENT

Unlike the drive unit, which is nonsite-specific to the degree that it can be used in any raise having a minimum 36-in diam cross-section, certain components of the system are site-specific in that they were designed based on the size and configuration of the raise in which the system was to be installed. These components are described in the following subsections and include:

- a. Cage
- b. Hoist frame and guidance
- c. Travel limit control
- d. Lower rope guidance
- e. Raise preparation.

3.3.1 Cage

The cage measures 27 in. deep by 32-1/2 in. wide by 84 in. high, giving a useable floor space of 5.3 ft². Cage construction consists of a lightweight welded frame of 1-in. square structural tubing covered on four sides with expanded metal mesh. The floor is solid, using lightweight aluminum diamond plate, and the roof has a sheet metal bonnet to prevent possible injuries from falling stones, debris, etc.

The cage has two doors; the main access door slides in tracks top and bottom and is interlocked to prevent movement of the hoist while open. The second door is the emergency door, which is located opposite the main access door and provides access to the emergency escape ladder. The emergency door is removable from inside the cage by means of quick-release pins.

3.3.2 Hoist Frame and Guidance

The joist frame provides both structural support for the cage and drive unit and system guidance. The hoist frame utilizes two 4 x 3-1/2-in structural steel angles as the main frame support and means of guidance. These angles are flared at both ends and the outer contact surfaces are lined with ultra-high molecular weight polyethylene to form low friction runners that will allow the complete system to slide up and down timber rails.

When nested into the timber rails, one surface of each angle will carry half the hoist weight component normal to the guide while the surface perpendicular to it on each angle will serve as guidance preventing side-to-side motion.

The angle rails, or runners, are tied together in a ladder configuration with one cross-member at each point directly below and above the cage, the latter serving also as the bottom attachment point of the drive unit. In addition, the top end of the drive unit is attached in a similar manner. The frame is of welded construction and measures 40 in. wide by 132 in. long.

3.3.3 Travel Limit Control

The system includes automatic travel and overtravel limit control. The ramps are mounted to the timber guide rail, one each at the top and bottom limits of travel. These ramps operate two switches which are mounted to the hoist guide frame. These switches provide both travel and overtravel control. The travel control arrangement stops the system automatically and will only allow travel in the

reverse direction. Should the travel limit system fail, the overtravel system will stop the system automatically and prevent operation in either direction.

3.3.4 Lower Rope Guidance

The two suspension wire ropes are routed along the full raise length. At the lower end, the two wire ropes are routed over two sheaves to maintain the proper center to center distance between ropes. A weight is attached to the end of each rope to provide a minimum trailing cable tension of 100 lb.

3.3.5 Raise Preparation

Raise preparation would consist primarily of the removal or relocation of any obstructions which might interfere with the movement of the hoist, installation of the head support structure and wooden guide rails, and the construction of station gates at levels as required.

4. FEATURE TESTING

A series of feature tests were conducted by the drive unit subcontractor, Ohio Hoist, to establish rope life parameters associated with the compact hoist drive unit configuration. The configuration selected is unique in that within each traction unit assembly *two* traction drums are used with one also acting as a transfer drum. Both drums have been sized to achieve a drum diameter (D) to rope diameter (d) ratio (D/d) of 30 using 3/8-in. diam wire rope. Testing has been conducted on this arrangement to establish the following:

- a. Wire rope life at rated load of 1,250 lb
- b. Wire rope construction for best rope life
- c. Effect of lubrication on rope life.

The test arrangement used was as follows: two traction drums each 11.25 in. in diameter were driven at the same speed by a single pinion meshing with two bull gears connected to the traction drum shafts. The upper traction drum has two grooves and the lower drum has three grooves. The wire rope to be tested was reeved around the lower drum to the top drum twice. The traction unit was anchored to the ground and the wire rope was passed over two sheaves 25 ft above ground level and down to a 1,250 lb weight. The drive was cycled through 18 ft of wire rope.

The results achieved are summarized in table 2. These results demonstrate a significant improvement over previous traction hoist systems with a D/d of 18 and single traction drums and cycle lives of 1,500 to 1,750 cycles. The final test of the series showed a dramatic improvement resulting from the use of rope lubricants.

TABLE 2. - Summary of rope cycle life test results

Rope manufacturer	Rope construction	Lubrication	Rope load (lb)	Number of cycles to retirement
MacWhyte	6 x 19G PFC	None	1,000	2,600
MacWhyte	6 x 26G PFC	None	1,000	4,950
MacWhyte	7 Flex	None	1,000	2,200
MacWhyte	6 x 31G PFC	None	1,000	2,500
MacWhyte	8 x 19F PFC	None	1,250	2,500
MacWhyte	6 x 19 PFC	None	1,250	2,800
MacWhyte	6 x 19 PFC	SR-12X	1,250	6,000+

Rope diameter = 3/8 in.

D/d = 30

5. SHOP TESTING

The complete compact hoist system was tested at the Ohio Hoist Manufacturing facility in Lisbon, Ohio. Over a three week period, the entire system was thoroughly checked out and debugged.

5.1 DESCRIPTION OF TEST FACILITY

For the complete system test, a 50-ft test tower at the Ohio Hoist facility was modified to enable the Compact Hoist to operate at an incline of approximately 80 deg from horizontal. The drive unit cage and guide frame were supported by two 3/8 in. wire ropes attached to a head support beam installed at the top of the tower. In addition to load cells at each wire rope termination, dynamometers were added in line to monitor individual wire rope loads at all times. Specification mine rails, complete with travel and overtravel limit switch ramps, were installed in the tower to simulate actual mine interfacing.

The complete electrical system, including the power and control box and three pushbutton stations, was interconnected with the cage pushbutton station through the umbilical cable and drum.

5.2 INSTALLATION PROCEDURE

The completely assembled compact hoist was installed in the test tower using the systems climbing capability to hoist itself from a horizontal carrying position to an inclined operation position.

The leading or upper flared ends of the hoist guide frame were nested in the wooden guide rails installed in the test tower. Two approximately 60 ft long, 3/8 in. diam wire ropes attached to the head support structure at the top of the tower and suspended the length of the test tower were reeved through the hoist traction unit and the system was raised under its own power to its operating position.

Once in position, the remaining electrical and mechanical connections were made and a complete system check was performed.

5.3 SYSTEM TESTING

During system testing all aspects of the compact hoist operation were checked. These items included:

- a. Operation of drive unit and umbilical winder
- b. Main brake
- c. Overspeed brakes
- d. Plugging switch
- e. Travel and overtravel limits
- f. Station and cage pushbutton stations
- g. Phones
- h. Footage counters
- i. Complete electrical system.

Numerous drop tests were conducted to simulate a drive train failure. For each test both the free-fall drop distance from the initial stationary position to the overspeed brake arrested position and the resulting wire rope loads were measured and recorded. The results of these tests are summarized in table 3.

5.4 DROP TEST RESULT ANALYSIS

A total of 20 drop tests were conducted to verify all operation of the two overspeed brake assemblies. Both brakes operated correctly on every test. Detailed test results and conclusions are discussed below.

5.4.1 System Test Weights

Two weight configurations were tested. The selected configurations represent the minimum and maximum system operating weights.

- a. Minimum configuration: 1,650 lb (150 lb operator)
- b. Maximum configuration: 2,500 lb
(1,000 lb payload)
- c. 12 tests were conducted at 1,650 lb
- d. 8 tests were conducted at 2,500 lb.

5.4.2 Electrical Power Status

Two electrical power conditions were tested: power on and power off. Operation of the two overspeed brakes in unison is achieved through use of an electrical interconnect. Both brakes have centrifugally operated

TABLE 3. - Compact hoist drop test results

Test No.	Suspended weight overspeed brakes no set		Peak dynamic load during overspeed braking		Static load overspeed brakes set		Distance to overspeed stop (in.)	Comments
	Rope No. 1	Rope No. 2	Rope No. 1	Rope No. 2	Rope No. 1	Rope No. 2		
1	1,400	1,225	-	-	750	1,800	16	1,000 lb load in cage, solenoid assist, both brakes trip.
2	1,300	1,250	-	-	1,700	990	17	Same as Test No. 1.
3	1,375	1,225	-	-	1,650	1,025	17	Same as Test No. 2.
4	1,275	1,275	-	-	900	1,775	15	Same as Test No. 3.
5	950	825	-	-	550	1,175	58	150 lb load in cage, solenoid assist, both brakes trip.
6	900	860	-	-	500	1,225	68	Same as Test No. 5.
7	910	815	-	-	500	1,275	58	Same as Test No. 6.
8	900	850	-	-	400	1,375	59	Same as Test No. 7.
9	900	900	-	-	-	475	42	150 lb load in cage, no solenoid assist, both brakes trip.
10	850	825	-	-	650	1,125	30	Same as Test No. 9.
11	875	800	-	2,500	0	1,700	61	New dynamometer rope No. 1, 150 lb load in cage, no solenoid assist, both brakes trip.
12	900	750	1,800	1,600	975	800	59	150 lb load in cage, no solenoid assist, both brakes trip.

Test No.	Suspended weight overspeed brakes no set		Peak dynamic load during overspeed braking		Static load overspeed brakes set		Distance to overspeed stop (in.)	Comments
	Rope No. 1	Rope No.2	Rope No. 1	Rope No. 2	Rope No. 1	Rope No. 2		
13	1,350	1,250	2,725	1,800	1,800	850	14	1,000 lb load in cage, no solenoid assist, both brakes trip.
14	1,325	1,250	1,850	2,800	975	1,700	12	Same as Test No. 13.
15	1,350	1,250	2,650	1,600	1,800	900	13	1,000 lb load in cage, solenoid assist, both brakes trip.
16	1,550	1,250	1,750	3,000	1,075	1,650	13	Same as Test No. 15.
17	950	850	2,200	1,100	1,450	350	37	150 lb load in cage, no solenoid assist, both brakes trip.
18	850	900	1,050	2,100	500	1,325	40	Same as Test No. 17.
19	900	850	1,100	2,200	475	1,350	42	150 lb load in cage, solenoid assist, both brakes trip.
20	900	900	950	2,300	300	1,500	40	Same as Test No. 19.

TABLE 3. - Compact hoist drop test results (Continued)

overspeed sensing devices. Tripping of either brake causes solenoids in both brakes to operate. These solenoids trip the brakes and ensure that both brakes operate essentially in unison. Operating the system with no electrical power simulated a double failure - a broken transmission and an electrical power failure. Under these circumstances the two overspeed brakes operate independently. Coordinated operation occurs because the centrifugal overspeed sensors are sensitive to both rotational and vertical inertia loading. The setting of one brake provides sufficient decelerating load to trip the second brake.

- a. 12 tests were conducted with power on.
- b. 8 tests were conducted with power off.
- c. Both brakes engaged in all tests.

5.4.3 Rope Load Sharing

Rope loads were monitored through use of two Dillon beam-type dynamometers equipped with maximum indicators. These dynamometers were mounted at the rope suspension points.

Rope loads were recorded both before and after each drop test. During hoist operation rope load sharing occurs through the operation of the differential gear reducer. The degree of rope load sharing is indicated by the "before" rope load readings in table 1. Results indicate satisfactory rope sharing of approximately ± 5 percent of nominal.

The "after" rope loads are somewhat more complex. The higher of the two loads probably indicates which of the two brakes set first. Unequal rope tension will cause the conveyance to cock until diagonal points of the guide frame contact the fixed timber guides or until rope load sharing occurs. The situation is further complicated by rope stretch which will compensate to alleviate unequal loading. These tower test results represent a worst-case condition in that rope lengths were short (~30 ft). Under these circumstances test results indicate satisfactory rope load sharing after engagement of the two safety brakes.

5.4.4 Dynamic Rope Loading

Dynamic rope loads were measured during 10 of the 20 drop tests conducted through use of maximum indicators on the dynamometers. Dynamic loads recorded represent a worst case condition because of the short rope lengths

used (30 ft). The maximum rope load recorded (3,000 lb) was 2.4 times the nominal static rope load (1,250 lb). This load is 25 percent of the rated ultimate strength of the rope.

5.4.5 Rope Condition

The 20 drop tests were conducted on the same two lengths of rope. The safety brakes engaged the rope in the same region. No visible signs of damage to the rope could be found at the conclusion of the 20 drop tests.

5.5 SYSTEM WEIGHTS

During the initial stages of the compact hoist design, based on the use of a 5-hp motor, a maximum payload of 1,000 lb and a conveyance speed of 50 fpm, the maximum system weight including payload was determined to be 2,500 lb. This yielded a net maximum system weight excluding payload of 1,500 lb and was budgeted for design purposes as follows:

- a. Complete drive unit assembly including 300 ft of umbilical cable - 1,000 lb
- b. Complete cage and guide frame assembly - 500 lb.

At the completion of system assembly and tower testing and in preparation for shipment to the cooperating mine, the complete system as removed from the test tower was weighed as a unit. The final system weight was determined to be 1,487 lb.

Table 4 is a detailed breakdown of the system component weights with the major components being the drive unit, frame, and cage.

TABLE 4. - Compact hoist system weights

Component	Quantity at weight (lb)	Total weight (lb)
1. Drive Unit		
a. Motor and main brake	1 at 110	110
b. 5:1 gear reducer	1 at 70	70
c. Differential	1 at 83	83
d. Differential adaptor	1 at 3 2 at 2.5	3 5
e. Traction unit	2 at 185	370
f. Overspeed brake	2 at 25	50
g. 15:1 gear reducer	1 at 20	20
h. Umbilical reel	1 at 50	50
i. Electrical junction box	1 at 35	35
j. 375 ft umbilical cable	300 at 0.33 lb/ft	100
k. Plugging switch	1 at 6	6
l. Miscellaneous hardware brackets, etc.	80	80
Total drive unit weight		982
2. Frame	1 at 212	212
a. Limit switch bracket	1 at 6	6
b. Drive unit attachment brackets	2 at 5 2 at 3	10 6
c. Plastic wear strips, miscellaneous hardware	16	16
Total frame weight		250
3. Cage		
a. Cage with bonnet and floor	1 at 165	165
b. Front door	1 at 27	27
c. Front door brackets	2 at 2	4

TABLE 4. - Compact hoist system weights (Continued)

Component	Quantity at weight (lb)	Total weight (lb)
d. Front door latch	1 at 1	1
e. Emergency door	1 at 25	25
f. Plastic wear strips and hardware	4	4
g. Go switch	2 at 2	4
h. Cage pushbutton station	1 at 15	15
i. Phone	1 at 10	10
Total cage weight		255
4. Drive unit and frame combination		
a. Drive unit	1 at 982	982
b. Frame	1 at 250	250
c. Cage	1 at 255	255
Total system weight		1,487

6. UNDERGROUND DATA COLLECTION AND PERFORMANCE EVALUATION TEST PLAN

The hoist system was to be tested for 4 months at the Cross Mine in Nederland, CO with FMI field engineers monitoring system operation on a full time basis for the first 3 weeks of operation. Thereafter, one FMI engineer was to visit the installation on a 2-days-a-month basis.

During transportation of the system underground, handling procedures and difficulties would be noted, timed, and recorded. The system would then be installed at the test site. Again, procedures and difficulties would be recorded and tasks timed. Once the system was installed, each facet of its operation would have been verified. Drop tests would have been conducted and recorded.

While monitoring system operation, FMI engineers would record trip cycles and their purpose using the daily trip log (fig. 6). Once an established pattern of system use was known, we felt that the hour meter in conjunction with the cycle meter would record this data automatically. In addition, we would solicit the cooperation of the miners in particular the shift bosses to record any abnormal use of the system. We feel that this approach is preferable from a program cost standpoint to full-time system monitoring.

A maintenance log would be maintained and inspection procedures refined to assure safe and effective system operation.

At the conclusion of the underground test period, a final report was to be prepared containing the results of phase III work, including a complete system evaluation and recommendations for improvements.

Figure 6 is a sample of the daily data sheet prepared for the purpose of gathering information of the compact hoist usage.

FIGURE 6. - Sample of compact hoist daily trip log.

COMPACT HOIST DAILY TRIP LOG

DATE: _____

TRIP NO.	TRIP PURPOSE (CHECK ONE)						TRAVEL BETWEEN STATIONS						REMARKS
	MEN ONLY			MEN & MAT'LS	MAT'LS ONLY	EMPTY	2	3	2	2	3	2	
	1	2	3				3	4	4	4	4	4		3

7. ECONOMIC ANALYSIS

7.1 INTRODUCTION

An economic comparison was made between the compact hoist system and other hoist systems commonly used. The hoist systems considered were:

- a. Nipper-Material-Hoist and Ladder-Manway (NH/LM)
- b. Nipper-Man-and-Material-Hoist (NMMH)
- c. Compact man-and-supply-hoist
- d. Alimak U-500 man-and-supply-hoist.

For the analysis, a typical mine application was defined. The typical mine's parameters were varied to determine their effect on the hoist selection economics. The varied parameters were:

- a. Frequency of hoist movement to different work areas
- b. Raise length
- c. Rope life of the compact hoist
- d. Hoist usage
- e. Capital cost of the compact hoist
- f. Miner labor costs.

For each condition a before tax rate of return analysis was used to compare the four hoist systems.

7.2 SUMMARY OF RESULTS

The compact hoist proved to be very competitive for all the combinations of parameters studied. It gave the highest rate of return for the invested dollar when compared to the other hoisting systems. The economics of the compact hoist was least affected by rope life. The Alimak hoisting system may become economically competitive with the compact hoist for raise lengths greater than 200 ft and with high use. The Alimak hoist's high initial and installation costs, which made it economically unfavorable in most of the cases considered, were offset by its faster traveling speeds at longer raise lengths and more frequent use. Nipper hoisting systems were economically unfavorable because a full-time nipper is required

for each shift. For ten out of the eleven cases reviewed, the material-hoist and man-ladder-manway system, the most commonly used system was the least economically attractive. The analysis calculations are given in appendix B.

7.3 SYSTEM DESCRIPTION

Each system assumes miners use the system at the start and end of each shift. During the shift, one miner uses the hoist to get supplies. When supplies are being moved, two miners are involved, one loading and one unloading.

7.3.1 Nipper-Material-Hoist and Ladder-Manway System

This system (which is the most common in the mining industry) uses a nipper air hoist to move materials only. The miners use ladders to get to the stope areas. The hoist cage, which is not man-rated, travels on timber rails or slides on the shaft lining; in either case, no special shaft guides are required. The obvious drawback to this system is the need for a full-time nipper who is needed only part of the work day.

7.3.2 Nipper Man-and-Material-Hoist System

This system uses a nipper air hoist to move men and materials to the stope area.

The two-man cage requires steel channel guides to be put into the shaft in addition to the shaftlining. Again, a full-time nipper is required for only part-time work.

7.3.3 Compact Hoist System

As described in previous sections, this man and supplies system is miner-controlled from the cage, and does not require a nipper. The cage can be custom made to ride on any shaft lining system and, therefore, does not require any special shaft preparation. The compact hoist system is the slowest of the four systems considered.

7.3.4 Alimak U-500 System

This hoist system is a miner-controlled men and supplies system. The two man cage rides a rack and pinion track system and requires extra shaft work to install the rack guide. This system does eliminate the cost of a full-time nipper; however, it is the most expensive of the four systems.

7.4 THE TYPICAL MINE

To identify a baseline working environment, a typical mine was identified.

Several mines were reviewed either by FMI interviews or by reviewing a 1975 report done for the Bureau by Theodore Barry and Associates entitled "Analysis of Men Materials and Supplies Handling Systems in Underground Metal and Nonmetal Mines."

The parameters which define the typical mine conditions are:

- a. Labor rates (includes wages and benefits):
Maintenance men - \$14.13/h
Miners - 21.75/h
- b. Inspection time per hoist:
2.5 manhours/week
- c. Raise length:
Average - 123 ft
Range - 50 to 200 ft.
- d. Production area life:
Average - 1.2 yr
Range - 0.5 to 2 yr.
- e. 30 active stopes at two stopes per raise:
Potentially 15 hoists per mine
- f. Stope crew size:
Three men
- g. Number of crews per stope per shift:
One crew
- h. Active stopes per raise:
Two stopes
- i. Shifts worked per stope per week:
10 shifts/week
- j. Days worked per year - 225
- k. One-way mantrips per shift:
Average 12 one-man trips per shift
- l. One-way supply trips for moving materials per shift:
Average 11 trips per shift

- m. One-way supply mantrips per shift:
Average 4 trips per shift
- n. Travel times:
Nipper hoist - 150 ft/min
Climb ladder - 36 ft/min
Alimak hoist - 90 ft/min
Compact hoist - 50 ft/min.
- o. Study period - 10 yr
- p. Annual inflation rate - 11%
- q. Mantrips per year - 6,120
- r. Supply trips per year - 5,610
(Two mines waiting on supplies for loading and unloading)
- s. Mantrips for supply per year - 2,040
- t. Lost time - 8,160 mantrips per year
(Does not include 5,610 supply trips)
- u.. Nipper man and material hoist:
Capital cost - \$7,500
Guide cost - \$35/ft
Rope cost - \$0.81/ft
2 man cage
- v. Nipper material hoist and ladder manway:
Capital cost - \$6,500
Rope cost - \$0.81/ft
Cage not man rated
Guides part of shaft lining.
- w. Alimak U-500 hoist cost:
Capital cost - \$59,200
Guide cost - \$130/ft
2 man cage
- x. Compact hoist cost:
Capital cost - \$22,500
Rope cost - \$0.81/ft
2 man cage
Guides part of shaft lining method.

7.5 RATE OF RETURN

The purpose of any engineering economic analysis is to determine the economic attractiveness of investment opportunities by analyzing the prospective differences

between technically feasible alternatives. There are several different analyses which can be applied to any given set of investment opportunities. Any of these methods should determine the most economically attractive alternative. A description of these methods can be found in any engineering economy text book.

The method of analysis presented here is the "Rate of Return Method," which is also known as the "Discounted Cash Flow Method" and the "Investor's Method." This method determines the rate at which a prospective investment will be paid back, and is, therefore, a number which is compared to the minimum interest rate, or the Minimum Attractive Rate of Return (MARR) which an investment must realize in order to be considered an economically attractive investment. The interest rate calculated by the rate of return method is known as the "Profitability Index," the "Interest Rate of Return," the "Solving Rate of Return" or the "Internal Rate of Return (IRR)."

The rate of return method determines an interest rate (IRR) from the conditions and assumptions outlined for a given investment opportunity. This interest rate is then compared to the MARR which is determined by a company and its overall investment opportunities. If the IRR is greater than the MARR, then the investment is economically attractive. If the IRR is less than the MARR, then the investment is rejected since the dollars invested will realize a higher rate of return by investing in the MARR opportunity. Finally, if the IRR is equal to the MARR, then the investment can be accepted or rejected without penalty.

It is possible to have several projects which all have an IRR greater than the MARR and the question is then: which of these projects shall receive funding? This question is answered by determining the incremental IRR for a pair of projects. The incremental IRR is the rate of return realized by incremental increases in dollar investments. The incremental IRR for each pair of projects is again compared to the MARR and, if it is greater than the MARR, the additional dollar investment is justified. In general, the project selected is the one with the largest dollar investment where both the gross rate of return and the incremental rate of return exceed the MARR.

The hoist analysis is another situation where the incremental IRR comes into play. In this case, one of several alternatives must be selected; however, none of the alternatives has a sufficient positive income to produce a rate of return on the invested capital. An example of this would be the use of hand labor as opposed to the use of machines to perform a needed task, in which

case the question is, can the additional dollar investment be justified?

Mathematically, the IRR is that interest rate at which the present worth of the net cash flow is zero.

$$NPW = \sum_{n=0}^j FV_n \frac{1}{(1+i)^n} = 0 \quad (1)$$

where

NPW = net present worth

FV_n = future value in year n

i = interest rate at which the investment will be paid back. For the special case shown in equation 1, where the net present worth is equal to zero, i is defined as the IRR

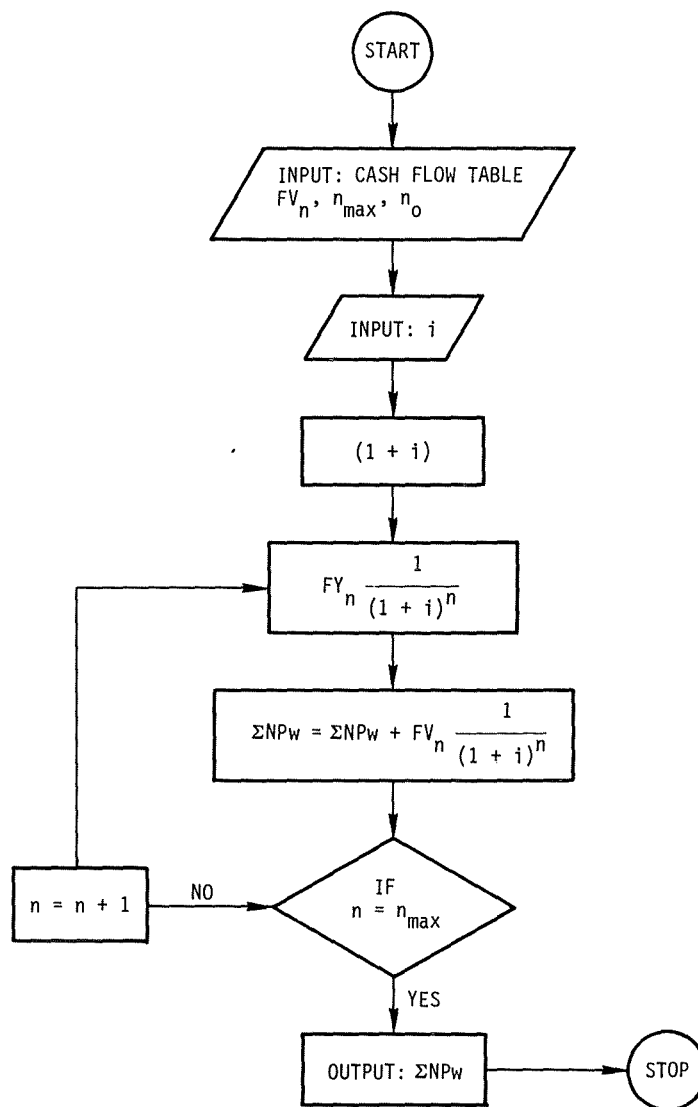
j = study period or expected system life in years

n = year of payment period

The net present worth calculation can be made using an HP34C calculator as shown in Figure 7. Equation 1 requires a trial and error solution which involves guessing a value for i , calculating a value for NPW and repeating the process until a negative and a positive value for NPW has been found, at which time a value for IRR can be found by linear interpolation.

The present worth and future value are tied together by the $1/(1+i)^n$ factor, known as the single-payment, present worth factor, which is a function of time and interest rate. This factor allows dollar amounts to be converted into equivalent amounts from a future date to a present date for a given interest rate. For example, at 10% interest, receiving \$1.10 one yr from today is the same as receiving \$1.00 today. The \$1.10 is known as the future value and the \$1.00 is known as the present worth.

Not only must the equivalent value of money be considered, but also the equivalent purchasing power. This is accounted for by considering the effects of inflation and deflation. These effects are usually accounted for by the use of Index Numbers for appropriate years. However, predicting inflation is highly uncertain at best, and may require a sensitivity analysis to determine a project's reaction to different inflation rates.



HP-34C CALCULATOR PROGRAM

```

LABEL B
R/S - INPUT i (DECIMAL)
1
+
STORE .1 - STORE (i + 1)
CLX
LABEL 1
RCL .1 - RCL (i + 1)
RCL I - RCL n
x
y
1/x
RCL (.i) - RCL FVn
x
RCL .3 - RCL ΣNPW OLD
+
STORE .3 - STORE ΣNPW NEW
RCL I - RCL n
RCL .2 - RCL nmax
x = y
GO TO 2
RCL I - RCL n
1
+
STORE I - STORE n + 1
GO TO 1
RTN
LABEL 2
0
STORE I - STORE n = 0
RCL .3 - RCL ΣNPW
R/S - OUTPUT: ΣNPW
0
STORE .3 - STORE ΣNPW = 0
RTN

```

PROGRAM OPERATION

```

STORE 0
1
2
3
4
5
6
7
8
9
.0
} CASH FLOW TABLE YEARS
  0 TO 10
  WHERE STORAGE 0 = YEAR 0
  AND STORAGE .0 = YEAR 10

STORE 1 - n = 0 (WILL BE UPDATED
              BY PROGRAM)

STORE .2 - nmax = 10 YEARS

STORE .3 - ΣNPW = 0 (WILL BE UPDATED
              BY PROGRAM)

[B] INPUT: i (DECIMAL)

[R/S] OUTPUT: ΣNPW
      SETS n = 0

[R/S] SETS ΣNPW = 0

FOR NEW TRIAL i
[B] AND RERUN PROGRAM

```

FIGURE 7. - Net present worth calculation.

The rate of return which a project will realize will be influenced by income taxes. Therefore, it is possible to talk about before and after tax rates of return. For an after tax analysis, there are two major tax considerations: one is depreciation and the other is tax credit.

Depreciation reduces taxes by reducing taxable income, whereas tax credits reduce taxes directly. At present, an Accelerated Cost Recovery System is being accepted for determination of depreciation by the Internal Revenue Service. There are other methods available and these are described in detail in any engineering economy textbook. The Hoist analysis did not consider the tax factors and is a before tax analysis.

As stated earlier, an engineering economic analysis evaluates the prospective differences between technically feasible alternatives. The easiest way to determine these differences is to establish the costs and then construct a cash flow table. This should be the first step in doing any engineering economic analysis, regardless of the method applied.

For this discussion, the term costs refers to any receipts, savings and disbursements which a project might realize throughout its life. These costs are usually assembled in a cash flow table as annual costs for each year of the project life. Costs which are common to all projects studied can be eliminated from the analysis since only the differences need to be considered.

7.6 SYSTEMS COSTS AND CASH FLOW TABLES

The costs for each system are defined by the following categories:

- a. Capital cost
- b. Installation cost
- c. Operating cost
- d. Maintenance cost
- e. Ownership cost
- f. Miners' lost productive time cost.

The capital costs will include all the costs associated with the initial capital investment, such as purchase, freight from the factory to the job site, and off-loading at the job site.

The installation costs will include all the costs associated with transporting the hoisting system underground, installing the system, and troubleshooting to make the system operational.

The operating cost will include all materials, fuel, power, and labor costs directly related to the hoist operation.

The maintenance costs will include all materials and labor costs directly related to routine maintenance and minor repairs. Major overhauls were considered.

The ownership cost will include all taxes, insurance, and general overhead costs.

The miners' lost productive time costs, for the purposes of this analysis, is taken to mean the cost of having the miners using the hoist system as opposed to being at their work station performing productive tasks. No attempt is made to relate this lost time to potential tons produced.

Costs and cash flow tables were established for each of the test conditions given in table 5. For all cases inflation was 11 % and the project study life was 10 yr. The costs and cash flow tables are in appendix B.

7.7 DISCUSSION OF THE ANALYSIS

The scheme of an incremental analysis is use the lowest first cost alternative as the baseline alternative. The next lowest first cost alternative is compared to the baseline condition to determine if the additional first cost can be justified by increased revenues or savings in future years.

Following this scheme the lowest cost system the Nipper-material-hoist and ladder manway was compared to the next lowest cost system the Nipper-man-and-material hoist. For ten of the eleven conditions tested the additional cost of the NMMH system was paid back within 1 to 2 yr with an incremental rate of return greater than 50%. Condition eight which required the hoists to be moved twice a year favored the NH/LM system. This was due to the added cost of the shaft guides required for the NMMH system.

The NH/LM - NMMH comparison defined a new baseline system to which the third lowest cost system, the compact hoist system, was compared. For each of the eleven

TABLE 5. - Summary of parameters for cash flow conditions

Condition No.	Parameters	Condition Varied
1.	Frequency of movement - 1/yr Raise length - 123/ft Rope life - 6 months Hoist usage - 1 x base	Base
2.	Frequency of movement - 1/yr Raise length - 123 ft Rope life - 3 months Hoist usage - 1 x base	Compact hoist rope life
3.	Frequency of movement - 1/yr Raise length - 123 ft Rope life - 15 months Usage - 1 x base	Compact hoist rope life
4.	Frequency of movement - 1/yr Raise length - 50 ft Rope life - 6 months Usage - 1 x base	Raise length
5.	Frequency on movement - 1/yr Raise length - 200 ft Rope life - 6 months Usage - 1 x base	Raise length
6.	Frequency of movement - 1/yr Raise length - 123 ft Rope life - 6 months Usage - 2 x base	Usage
7.	Frequency of movement - 1/yr Raise length - 123 ft Rope life - 6 months Usage - 3 x base	Usage
8.	Frequency of movement - 2/yr Raise length - 123 fr Rope life - 6 months Usage - 1 x base	Shaft life
9.	Frequency of movement - 1/2/yr Raise length - 123 ft Rope life - 6 months Usage - 1 x base	Shaft life
10.	Base condition Compact hoist cost	Capital cost of compact hoist 1.5 x base
11.	Base condition Labor rates	Labor rates of all systems 1.25 x base

conditions the additional cost of the compact hoist was paid back within 1 yr with an incremental-rate-of-return greater than 200%. The big cost savings was the elimination of the full-time nipper.

The compact hoist economics was least affected by rope life, increased with shaft length, decreased with usage, decreased with a shaft life less than 1 yr, decreased with increased compact hoist cost and increased with labor costs. These trends indicate that the compact hoist's higher cost and slower travel speeds are justified by the elimination of the full-time nipper.

The compact hoist was then used as the baseline system to be compared with the highest cost Alimak hoist system. Only in two of the eleven conditions was the additional cost of the Alimak system paid back within the 10-yr study period. These two conditions were the increased usage conditions. Under these conditions the Alimaks faster travel speed become a factor. It is possible that the Alimak system could be economically competitive in long life, high usage shafts greater than 200 ft deep.

The economic analysis of the compact hoist system showed that it is clearly the most economic alternative for a service shaft hoisting system. The baseline test condition, condition one, had an average annual cost savings of \$3,000, if, as the typical mine parameters suggests, there are 15 hoists per mine, a mine could potentially save \$120,000/yr by installing compact hoist systems.

8. CONCLUSIONS AND RECOMMENDATIONS

This report has presented a design for an economical, effective and safe man and supply hoisting system for servicing working stopes in metal and nonmetal mine applications.

8.1 CONCLUSIONS

The design presented in this report is the culmination of both a previous hoist development program (3) and the design and test efforts of this program.

8.1.1 System Performance

All performance requirements specified by the contract and listed in subsection 1.3 were met or exceeded.

8.1.2 System Cost

The system cost for a three station hoisting system would be \$25,000 each for a production quantity of five. This price would reduce for increased production quantities.

8.1.3 Economic Factor

The Compact Hoist System developed compares favorably on an economic basis with competitive men and material supply systems. When compared against the closest competitive system for a typical stope access situation, \$3,000/year savings are projected.

8.1.4 Wire Rope Life

Dramatic improvements in rope life were demonstrated during feature testing. Rope life was increased by at least a factor of four. This would be sufficient for one year of typical operation.

8.2 RECOMMENDATION

It is recommended that the Compact Hoist System be installed and demonstrated in an underground application at the first available opportunity.

9. BIBLIOGRAPHY

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2. "Analysis of Large Scale Underground Mining Methods," Dravo Corporation, Pittsburgh, USBM Contract Report S0122059.
3. "Development of a Man and Supply Hoisting System for Underground Metal and Nonmetal Mines," Foster-Miller, Inc., USBM Contract Report H0252068, April 1981.

APPENDIX A

COMPACT HOIST SYSTEM
OPERATION AND
MAINTENANCE MANUAL

BM-8035

by

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John Healey

Prepared for:

United States Department of the Interior
Bureau of Mines

USBM Contract Report (USBM H0202019)

July 1985

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A1. INTRODUCTION

This manual is the preliminary operation and maintenance manual for the Compact Hoist System developed by Foster-Miller, Inc. (FMI) under Bureau of Mines Contract No. H0202019.

The configuration to which this manual applies is a specific one designed to operate in a 60° inclined, timbered raise measuring 48 in. x 42 in. Conveyance guidance is provided by two 4 in. x 6 in. wooden rails mounted to the sides of the raise. The moving conveyance main frame is constructed from two 3-1/2 in. x 4 in. steel angles which slide on the wooden rails.

Section A2 of this report covers installation of the hoist. Section A3 lists initial checkout procedures, to be performed before the hoist goes into operation. Section A4 covers system operation and regular inspection procedures necessary for safe operation. Section A5 contains detailed descriptions of the operation sequences of the important subsystems, for use in troubleshooting. In the appendix, considerable manufacturer's information on the more complicated of the components is given.

A complete system description is given in the Final report for this program.

A2. INSTALLATION

A2.1 PRELIMINARY CHECK

On a preliminary trip underground, check that the minimal dimensions shown in table A2-1 are available. The dimensions are determined either by operational necessity or by safety requirements, and must be met or exceeded. Provisions should also be made for the equipment required for assembly, as listed in tables A2-2, A2-3 and A2-4.

A2.2 TRANSPORTATION

The route to be used for bringing the component parts of the system to the raise must be checked out carefully in advance for clearances and tight places. Problems at transfer points should be anticipated.

A2.3 RAISE PREPARATION

First, the minimum dimensions of table A2-1 must be met. The top of the raise must be large enough for the 36 in. long headbeam, and should be prepared for any easy, fairly level installation flush up to where the rock bolts will attach. Staging will be required for this installation.

TABLE A2-1. - Raise and station preparation

Item	Description
1	Establish clearance at top of raise of 20 ft above highest landing, for installation of head support.
2	Establish clearance at bottom of raise of 6 ft below lowest landing. (This may depend on system configuration.)
3	Provide necessary decking at all landings.
4	Provide sufficient clearance at all landings for materials handling.
55	Determine optimum route for bringing system component parts to the raise. Adequate clearances and proper conveyance must be provided.
6	Assemble tools, staging, etc. (table A2-4)

TABLE A2-2. - System parts and spare parts

The following unit items comprise the complete system. All items should be assembled at the site prior to installation of hoist.

Item	Description
1	Drive Unit Assembly
2	Umbilical Drum and Cable Assembly 375 ft
3	Guide Frame Assembly
4	Cage Assembly
5	Load Cell Assembly (2)
6	Head Support Beam
7	Travel Limit Ramps (2)
8	Power and Control Box
9	Station Control Box (3)
10	Interstation Cable (Type SO 6-conductor, Number 14)
11	Wire Rope - 360 ft 3/8 in. diam with thimble and 4 clips (2)
12	Guide Frame Attachment Hardware
13	Load Cell Attachment Hardware
14	Load Cell/PCB Cable
15	Umbilical Attachment Clamp
16	Bottom Rope Anchorage Assembly

TABLE A2-3. - System parts and spare parts

The following items should be available as replacement spares.

Item	Description
1	Load Cell Assembly
2	Drive Traction Unit (2)
3	Overspeed Brake Assembly (2)
4	Drive Differential Unit
5	360 ft 3/8 in. diam rope with thimble and 4 clips (2 complete sets)
6	Full set of electrical components
7	Guide Frame Attachment Hardware
8	Load Cell Attachment Hardware
9	Miscellaneous Hardware
10	Power and Control Cable (350 ft)
11	Main Drive Motor, 5 hp
12	Slip Ring Assembly, 50 A, 10 Circuits
13	Motor Brake, 28 ft-lb

TABLE A2-4. - Tools necessary for installation

Quantity	Description
	2500 lb "tugger"
	Staging to erect headbeam
4	4 ft or longer resin roof bolts
1	Torque Wrench (45 ft-lb)
1	Side Cutters
1	Pliers
1	Wire Brush
1	Micrometer (1 in.)
1	Adjustable Wrench (18 in.)
1	Pipe Wrench (12 in.)
1	Adjustable Wrench (6 in.)
1	Vise Grips (10 in.)
1	Channel Locks
1	Level
1	Set of Allen Wrenches
1	Set of Screwdrivers
1	Hammer
1	File
1	Wire Stripper
1	Wire Crimpers
1	"Simpson" Volt-Ohm Meter
1	Ammeter
1	Axe
1	Timber Saw
1	Wrecking Bar

Tools as needed:

Chain

Sheaves

Pry Bars

A2.4 STATION PREPARATION

Adequate access to the cage door and to the raise ladder must be provided at each station. Decking to the lip and the raise is generally necessary for safe footing entering or leaving the cage. Safety gates to prevent men and materials from falling down the raise are also required.

At this time, location and cabling of the pushbutton stations should be planned.

A2.5 SYSTEM ASSEMBLY AND INSTALLATION

The first step in assembly is to set a 2,500 lb capacity tugger at the raise. Pick points should be chosen and placed capable of supporting 1-1/2 tons (3000 lb). A sheave is then placed at the top of the raise in a location which will not interfere with the headbeam.

The sequence of assembly is given in table A2-5. This is then followed by reeving of the wire rope, covered in table A2-6, complete electrical checkout in table A3-1, subsystem checkout in table A3-2, an overspeed brake checkout procedure in table A3-3, and overspeed brake reset procedure in table A3-4. After these have been completed, the system is ready for operation.

TABLE A2-5. - Hoist assembly sequence

Step	Description
1	Attach headbeam at top of raise as shown in figure A2-1
2	Attach load cells to headbeam using attachment bolts
3	Route 50 ft cables from load cells to the selected location of the Power and Control Box (PCB)
4	Install PCB at desired location: • Attach PCB enclosure to the wall • Attach load cell electrical cable • Attach drive unit umbilical cable to PCB and route umbilical cable to center area of the headbeam and tie off using umbilical clamp • Provide PCB with 480 Vac power (20A source - leave circuit breaker off).
5	Install Station 1 in selected area convenient to raise (assuming PCB is at top of raise - if PCB is at bottom of raise use Station 3)
6	Temporarily install an electrical jumper across load cell switches (for reeving and drive installation only)
7	Position guide frame on wooden guide rails and hold in position with chairs such that the top one-third of the frame is above the raise collar
8	Reeve wire ropes through the drive unit as outlined in table A2-6
9	Attach wire ropes to load cells, using thimble and 4 clips on 3 in. centers, and tighten to 45 ft-lb
10	Position drive unit over raise (raise covered) and slowly jog drive in up direction to lift drive unit into position on main frame (a come-along may be necessary to keep drive away from the main frame until the drive unit is at the appropriate height)
11	Attach the drive unit to the main frame using spacers and 3/4 in. hardware
12	Move hoist to just below top station
13	Install travel limit ramps to guide rail as shown in figure A2-2

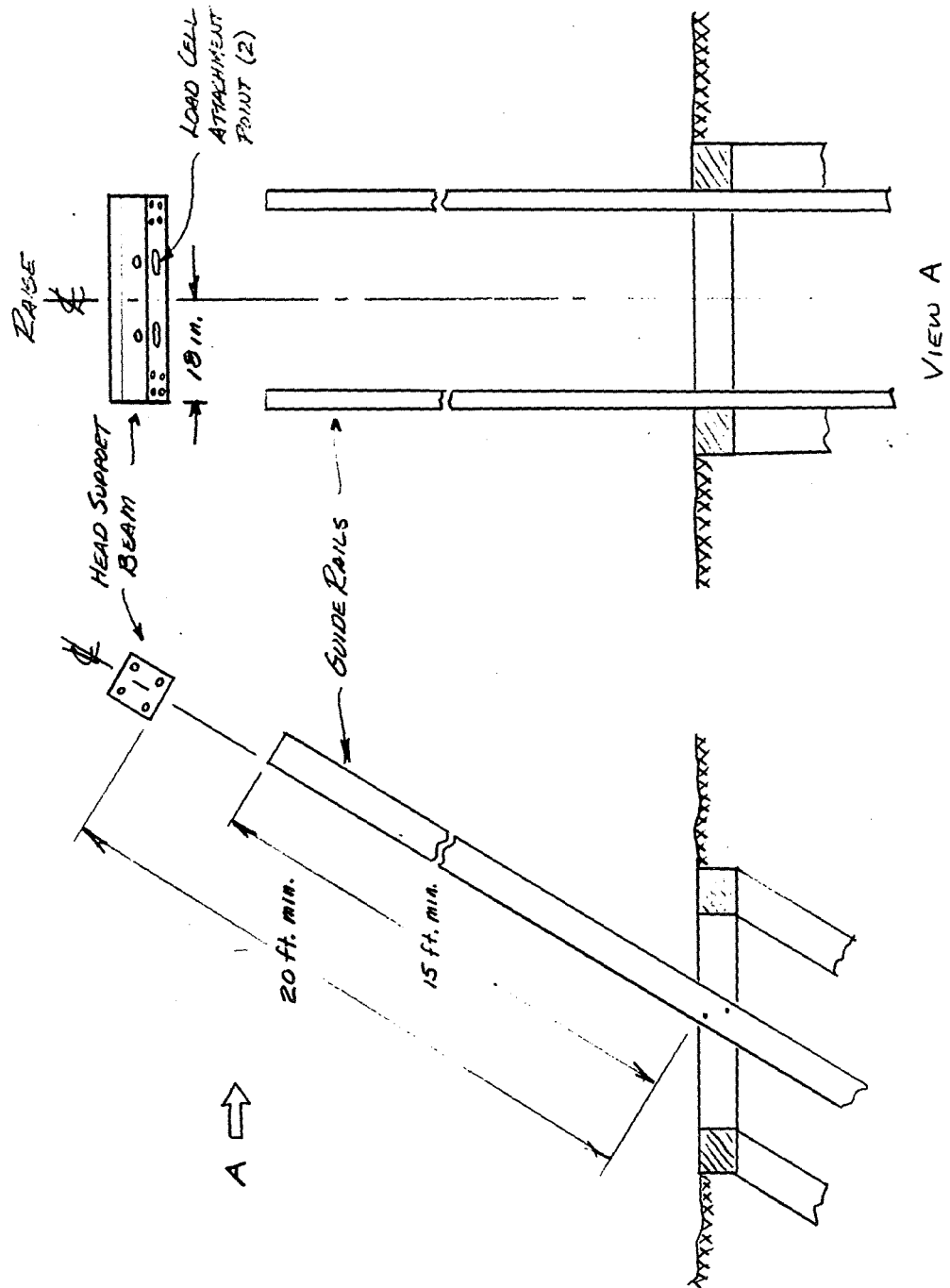


FIGURE A2-1. - Head support beam location.

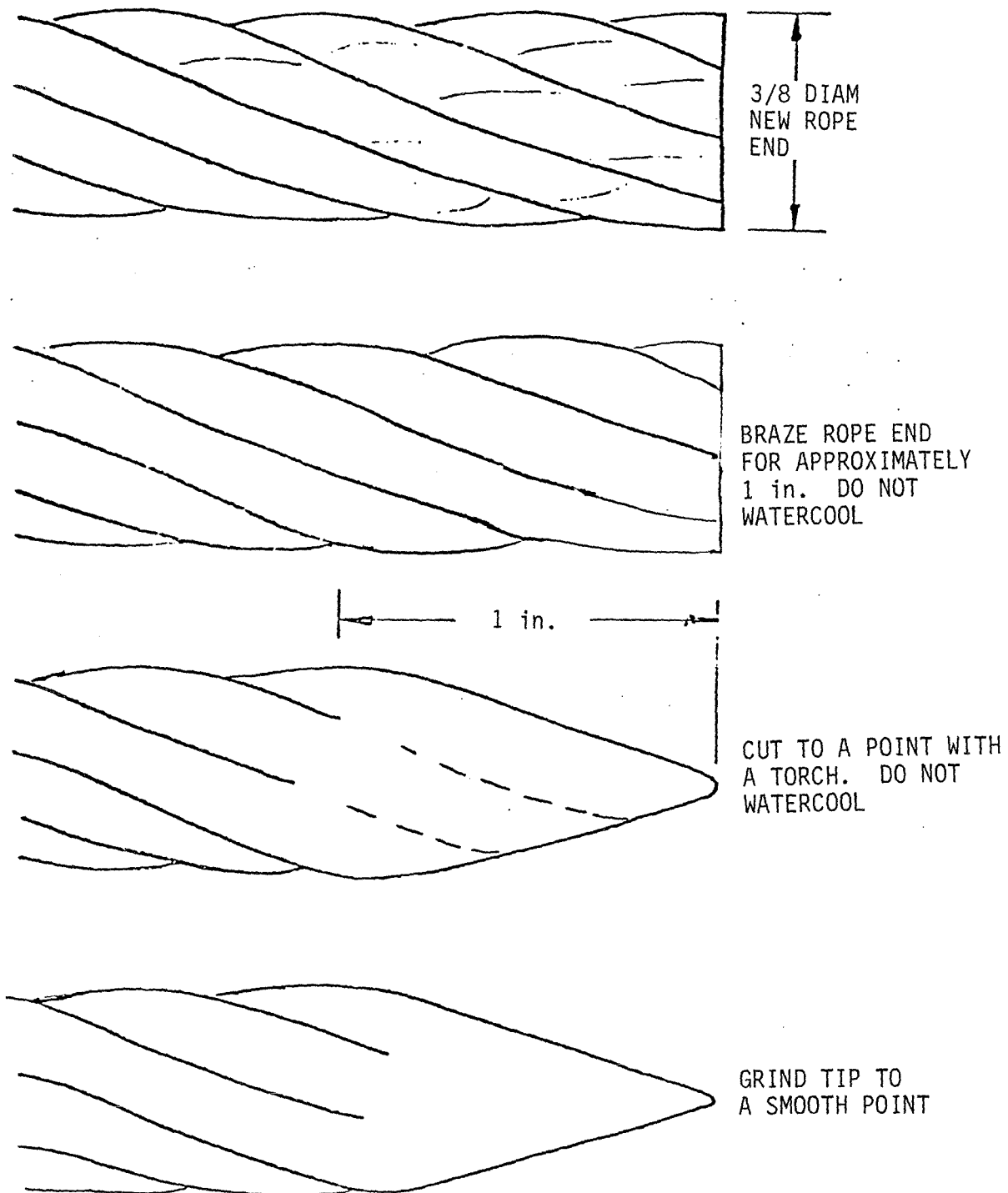


FIGURE A2-2. - Wire rope end preparation.

TABLE A2-6. - Wire rope reeving sequence

Item	Description
1	Take conveyance and set guide frame on chairs, and maintain control
2	Prepare rope ends as shown in figure A2-3. The wire may be reeved directly from a spool or from a coil. If rope is coiled, precautions should be taken to avoid tangling or damaging rope. During the following steps, refer to figure A2-4
3	Install an electrical jumper bypassing the slack rope detector switches
4	Set both overspeed brakes on reset position
5	Loosen the four tension rollers on the last wrap of each traction drive, by <u>tightening</u> tension nuts
6	On one traction unit, feed one rope end through top roller assembly, overspeed brake shoes, past rope guide, as far as it will go
7	After 8 to 10 ft are passed through, release UP button
8	If rope is not in the outside groove of the traction drum, push DOWN to unreeve the rope, and repeat items 7 and 8
9	Feed rope manually through outside groove on transfer drum, past guides, until it exits at the bottom of the traction drum. Ensure rope is tight
10	Repeat Item 10 for the next two grooves, again ensuring that rope is tight
11	On last wrap, feed rope over transfer drum until it engages the guide wheel and tension roller on the last wrap of the traction drum
12	Press UP button and keep hand tension on incoming rope until rope exits traction unit and all rope slack is removed from each and all wraps
13	Retighten tension rollers by loosening their tension nuts, until 1/8 in. gap is between nut and roller block
14	Push UP, keep tension on incoming rope, feed rest of rope through traction unit
15	Repeat items 6 through 14 on second traction unit
16	Feed ropes through until ropes tighten and pick up conveyance
17	Remove electrical jumper cable to activate slack rope protection
18	Remove temporary supports.

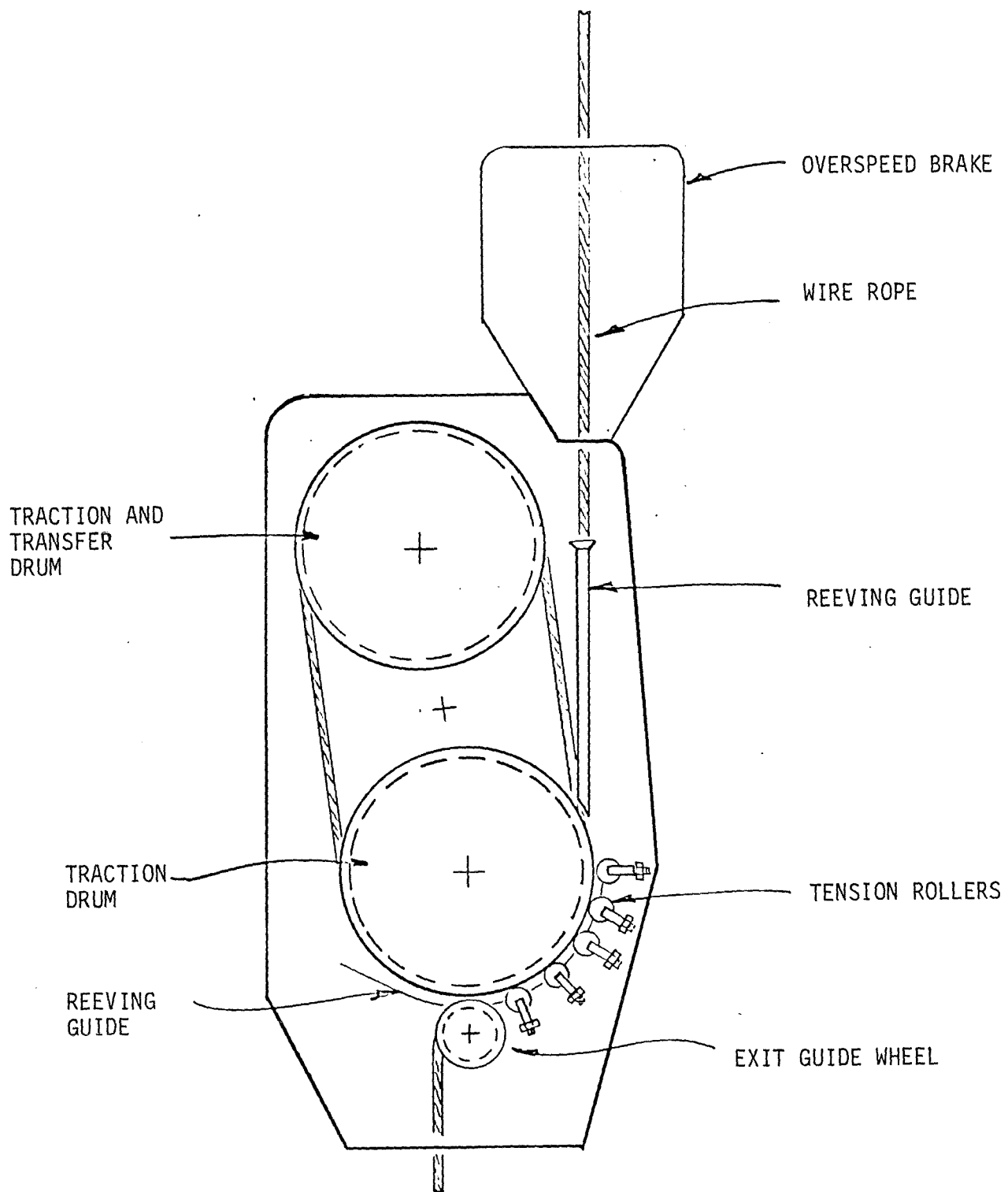


FIGURE A2-3. - Drive assembly arrangement.

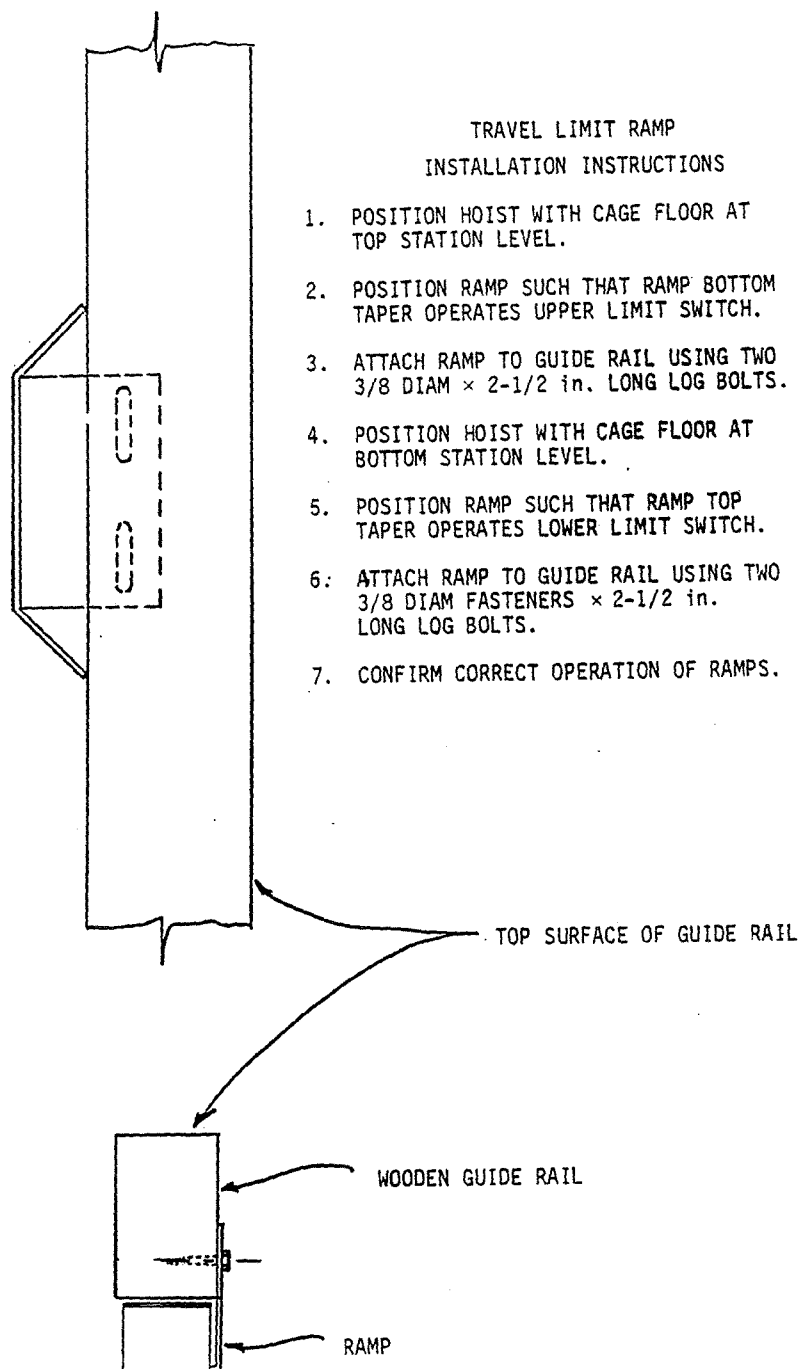


FIGURE A2-4. - Attachment of travel limit ramp.

A3. PRELIMINARY INSPECTIONS

This section contains three inspection checklists:

- a. The initial electrical inspection (table A3-1) - to be performed as soon as installation is complete
- b. The initial system checkout (table A3-2) - to be performed after the electrical inspection
- c. Overspeed brake checkout procedure (table A3-3).

TABLE A3-1. - Initial electrical inspection

Instructions:

In addition to all items listed, check all connections for physical damage and loose wiring.

System Items	Inspection Items
<u>Drive Unit Wiring</u>	
1. Umbilical cable	1. No physical damage 2. Properly installed 3. Properly connected to the power control panel
2. Slip ring assembly	1. All wires to brushes are connected and have Loctite applied to lockscrews 2. Brushes and springs are in good condition
3. Footage counter limit switch	1. Properly positioned 2. After power is turned on, works properly
4. Overspeed brake assemblies which contain overspeed solenoids and overspeed limit switches	1. After power is on, solenoid tripping 2. Check up only circuit

TABLE A3-1. - Initial electrical inspection (continued)

System Items	Inspection Items
5. Plugging switch	1. Check for contact closure at 15 fpm in down direction
<u>Cage Wiring</u>	
1. Door limit switches	1. Properly connected to cage pushbutton station
<u>Guide Frame Wiring</u>	
1. Travel limit switches (2)	1. Properly connected to cage pushbutton station
<u>Load Cells Wiring</u>	
	1. Limit switches are in good condition
	2. Cables are properly connected to the PCB
<u>Incoming Power</u>	
	1. Properly installed
Station Control Boxes Wiring	
	1. Pushbuttons operate properly
	2. Lights operate
	3. Horn operates
	4. Phone operates
	5. Landing interlocks properly connected
<u>Main Power Control Box</u>	
which contains:	

TABLE A3-1. - Initial electrical inspection (continued)

System Items	Inspection Items
1. Contactor	1. Relay contacts
2. Phase detector	2. Running time-meter operates
3. Main 20 amp circuit breaker CB-1	3. Phase detector operates
4. Running time-meter	
5. Ground break monitor	
<u>Inspection List for Push-button Stations</u>	
1. Pushbuttons	1. Electrical wiring
2. Indicator lights	2. Physical damage
3. Printed circuit board	3. Cables are in good condition
4. Footage counter	4. Securely mounted to mine wall
5. Call and phone system	5. Installed in an accessible but safe area
	6. Electrical cable properly connected

TABLE A3-2. System checkout

Item	Description
1	Check that POWER ON light is ON at the PCB. Also check call lights, horns, and phones
2	Send cage to bottom station
3	Zero all position footage meters
4	Verify main and rear door safety interlocks; hoist should not move with either door open
5	Check entire length of raise to see if guide rail location provides required hoist clearance
6	Position system such that travel limit switch is just above the travel limit ramp. Verify that the overtravel limit switch will be engaged by the ramp in the event of a travel limit failure. Manually activate the overtravel limit switch and verify that this switch does shut the system down. Repeat this procedure with cage positioned just below the travel limit ramp at the top of the raise
7	Verify operation of load cells
8	Lower cage onto temporary supports. Slack rope cells should prevent system from operating
9	Electrically disconnect load cells and add jumper to get hoist off temporary supports, then remove jumper and reconnect load cells
10	Verify operation of umbilical drive.

TABLE A3-3. - Overspeed brake checkout procedure

Item	Description
1	With the hoist at the top level, set safety supports such that the system can be lowered into the raise to within 2 or 3 in. of resting on the supports and leave only the drive unit above the raise collar
2	With electrical power off, remove the six bolts which attach the two overspeed brakes to the main drive unit
3	With electrical power on, move one of the two brakes down the wire rope at a rate sufficient to mechanically trip the brake. Check that the second brake was electrically tripped. Reset both brakes and repeat this procedure for the second brake
4	When it is determined that both overspeed brakes are functioning properly, with the electrical power off, reinstall both brakes on the drive unit
5	Hoist the system out of the raise and remove the safety supports.

A4. SYSTEM OPERATION

A4.1 MAIN ELECTRICAL POWER SYSTEM

After installation, the main circuit breaker (CB1, 20 amp, 3 pole) located inside the PCB is switched to the "ON" position and remains on. When CB1 is in the ON position the presence of 480V ac power is indicated by the red "Power On" light.

CB2 supplies 120V ac power to the main PCB and the D.C. power supply. Energizing (pulling) the system start button provides control power to the system; "ON" is indicated by a green light. Pushing the system start button de-energizes the system control power.

A4.2 HOIST OPERATION

Both cage doors must be closed and latched for the hoist to move. In addition, when station gate electrical interlocks are used all station gates must also be closed. The main cage access door is opened by lifting the latch and sliding the door sideways. The rear egress door opens by removing four pins and lifting the door into the cage. If the hoist is at the lower extreme of travel it will only travel up, if it is at the upper travel extreme it will only travel down.

Instructions for operating the hoist and call system are given in Table A4-1.

A4.3 SYSTEM OVERRIDE CONTROLS

The single system override switch is a toggle switch mounted inside the cage pushbutton station. This switch is for the use of maintenance personnel only. Use of this switch allows one man to safely reset the overspeed brakes at any location in the raise. Operation of the switch deactivates the operation of the overspeed brake solenoids and also prevents drive unit operation.

A4.4 RUNNING TIME METER

An hour meter is located in the PCB. It records actual elapsed "in motion" time of the hoist in hours and tenths of hours.

A4.5 TRIP METER

The trip meter is located in the PCB and is used to record the number of "down" trips the system makes.

TABLE A4-1. - Hoist operation

Item	Description
1	Close and latch all station gates and front and rear cage doors
2	Press CONTROL (green CONTROL light will illuminate at control station and red IN USE light will illuminate at all stations. Now all push-buttons except STOP and CALL are inoperative at all other stations)
3	Press UP or DOWN
4	To halt hoist, press STOP. (Hoist can be stopped from any station at any time)
5	To release the hoist, press RELEASE and simply get out and close the door and station gate
	<u>Calling the Hoist</u>
1	If red IN USE light is on, hoist is in use
2	If footage counter is operating, hoist is moving. Hoist cannot be called when in use
3	Check footage counter for location of hoist
4	Press CONTROL then UP or DOWN to bring hoist to your station
5	When hoist arrives, press STOP
	<u>Loading Heavy Materials</u>
1	<u>Using Cage</u>
	The cage may be used to carry material weights up to but not in excess of 1,000 lb. Precautions must be taken not to damage the cage control box.
2	<u>Cage Removed</u>
	Materials weighing up to 1,250 lb can be attached to the guide frame at the three cage attachment points.

TABLE A4-1. - Hoist operation (continued)

Item	Description
3	<u>System Capacity</u> The maximum system materials capacity with the cage removed is 1,250 lb. If the system is loaded in excess of 1,250 lb, the hoist will not operate. <u>Call System</u> 1 To operate the horn, push CALL at any station control box. Horn will sound and CALL lights will illuminate at each station control box 2 To operate phone, remove receiver from its box and press red button in handle to talk and listen. Speak in a normal voice

A4.6 SYSTEM INSPECTIONS AND MAINTENANCE

The electrical inspection (table A3-1) is to be performed at installation only. This is a thorough check to ensure that all parts have been properly installed. Once this initial check is completed, routine checks are sufficient.

The pre-shift inspection (table A4-2) is performed during the required unmanned cycle before each shift. A weekly inspection (table A4-3) satisfies MSHA requirements. Table A4-4 covers replacement of wire rope when this becomes necessary and table A4-5 details the over-speed brake reset procedure.

TABLE A4-2. - Pre-shift inspection sheet

Date				
Time				
Inspector				
Hour Meter Reading				
Trip Meter Reading				
Electrical Wiring and Controls				
Rope Connections				
Umbilical Drum				
Drive Unit and Cage				
Raise Guides				
Cycle Test - Cage Empty				
Bottom Depth Reading				
Down Travel Time				
Top Depth Reading				
Up Travel Time				
Comments - Record All Adjustments				

TABLE A4-3. - Weekly inspection

Item	Description
1	Verify station gate electrical interlocks and cage main and rear door electrical interlocks. System should not move with any door open
2	Verify operation of top and bottom travel limits
3	Verify operation of top and bottom overtravel limits as follows: Position hoist such that travel limit switch is just above the travel limit ramp. Verify that the overtravel limit switch will be engaged by the ramp in the event of a travel limit failure. Manually activate the overtravel limit switch and verify that this switch does shut the system down. Repeat this procedure with hoist positioned just below the travel limit ramp at the top of the raise.
4	Verify overload by loading cage to in excess of 1,000 lb
5	Verify slack rope control by placing conveyance onto temporary supports. System should not move
6	Visually inspect both wire ropes over the complete raise length. Inspect for lubrication, wear, broken wires, marked distortion and corrosion. Measure average rope diameter with calipers at 30 ft intervals (measure ridge to ridge and not flat to flat around rope). Record location and degree of rope damage. Replace both ropes when one of the discard criteria specified in CFR Title 30 Part 57.19-128 exists. Replacement procedure is given in table A4-4
7	Visually check for correct operation and running freedom of guidance assembly
8	Visually inspect general condition of conveyance. Pay particular emphasis to correct tightness of all attachment bolts and electrical connections

TABLE A4-3. - Weekly inspection (continued)

Item	Description
9	Check oil level in differential case Top up with either: • Zurn EP No. 35 • Shell Gr. No. 33 • Texaco No. 1
10	Check oil level in umbilical drive gear reducer. Top off with SAE 90 gear oil
11	Grease all moving parts using medium temperature grease
12	Check cage front door guides for dirt buildup. Clean if necessary
13	Check drive gears in traction units. Grease with "Plastilube" Moly No. 1 (Parr, Inc.) if necessary
14	Check for wear on grooves in traction and transfer drums. Wear should begin on outside of drum. When this wear becomes pronounced, drums should be reversed
15	If more or less traction is needed for the drive unit, tension idlers at the bottom of the traction drum may need adjustment. Tighten for less tension, loosen for greater tension
16	Should any part of the drive system malfunction, it should be replaced
17	With conveyance at bottom, check that all counters are zeroed
18	Lubricate wire ropes by wiping on Witco SR-12X wire rope lubricant (Kendall Refining Co.).

TABLE A4-4. - Replacement of wire rope

Item	Description
1	Disconnect load cells in PCB
2	Lower hoist system onto temporary supports. These may be 6 in. timber lagging or any material that will support the weight of the complete conveyance
3	Detach wire rope and wedge socket assembly from each load cell
4	Unreeve wire ropes - reverse procedure in table A2-6
5	Change wedge socket assembly to new wire ropes
6	Attach wedge socket and wire rope assembly to load cells. Use 4 clips spaced 3 in. apart torqued to 45 ft-lb
7	Reeve new wire rope (table A2-6)
8	Raise hoist system off temporary supports
9	Reconnect load cells
10	Remove temporary supports
11	Lubricate new rope by wiping on Witco SR-12X wire rope lubricant (Kendall Refining Co.).

TABLE A4-5. - Overspeed brake reset procedure

Note: If the overspeed brakes trip <i>do not</i> attempt to reset the brakes until the cause has been determined and corrected. <i>Do not</i> use the hoist until the overspeed brakes have been reset.	
Item	Description
1	Push the UP button. Allow the hoist to move up the raise approximately 2 ft, then push the STOP button
2	Activate the overspeed brake solenoid override switch located inside the cage pushbutton station. (This switch also deactivates the motor starter circuitry preventing any hoist motion)
3	Insert the end of a 1/2 in. diam rod in one of the holes drilled in the brake reset handle. (A rod is attached to each brake.)
4	Using the rod for leverage rotate the brake cam shaft until the cam latch is reset in the trigger mechanism. Remove the rod and reattach to the overspeed brake
5	Deactivate the overspeed brake solenoid override switch. The hoist is ready for operation.

A4.7 SYSTEM TROUBLESHOOTING

Table A4-6 presents a cage and station troubleshooting guide. Section A5 describes system operation to allow detailed troubleshooting. Additional data is presented in the Appendix.

TABLE A4-6. Cage and Station Troubleshooting

Malfunction	Cause of Problem	Adjustment
Hoist stops	1. Door opened	Close
	2. Gate opened	Close
	3. Stop button at remote station depressed	Restart
	4. Travel limit reached	Reverse hoist direction
	5. Travel limit switch operated clear of travel limit ramps	Adjust switch position Remove obstruction
	6. Raise obstruction causing overload/slack rope shut-down	Clear obstruction
	7. Conveyance overloaded by additional weight of umbilical cable	Reduce conveyance load
	8. Electrical failure	Lower conveyance by manually slipping main brake to convenient level. <i>Extreme care must be taken to ensure that the overspeed condition is not approached</i>
Umbilical cable does not spool	1. Drive belt failure	Adjust or replace
	2. Insufficient drum torque	Adjust friction drive to increase drum torque

TABLE A4-6. - Cage and Station Troubleshooting (continued)

Malfunction	Cause of Problem	Adjustment
Hoist will not move	1. Cage door does not activate switch	Adjust or replace cage mounted "go-switch"
	2. Station gate does not activate switch	Adjust or replace gate mounted switch
	3. Conveyance over-loaded	Reduce load
	4. Slack ropes	Clear obstruction
	5. Overtravel switch acti- vated or faulty	Adjust switch position to clear obstruction or replace switch
	6. Circuit breakers tripped	Reset
	7. Overload heater tripped	Push red reset button on motor starter. (Located inside cage PBS)

A5. SYSTEM OPERATING SEQUENCES

A5.1 NORMAL TRAVEL OPERATING SEQUENCES

A5.1.1 Station Control Selection

- a. The TAKE CONTROL button at any of the four control boxes is momentarily pushed
- b. When a TAKE CONTROL button is pushed, the appropriate control logic is energized. This activates a self-holding circuit and also locks out control from all other control boxes
- c. The red IN USE light illuminates at all control stations. The green TAKE CONTROL light illuminates only at the active control station
- d. At this point only the active station has control. All other stations are inoperative with the exception of the STOP and CALL systems. These remain active at all stations

A5.1.2 Station Control Release

- a. System control can be released only at the active control station. This is achieved by momentarily pushing the RELEASE control button
- b. The red IN USE light goes out at all stations. The green TAKE CONTROL light goes out at the active control station

A5.1.3 UP Mode

- a. The UP button is momentarily pushed at the active control station
- b. The UP logic is energized. This activates a self holding circuit, which allows the UP button to be released and locks out the down mode
- c. The primary brake is power released
- d. The footage counter is activated
- e. The hour meter is powered
- f. Motor Starter (MS1) initiates and the system accelerates to 50 fpm travel speed

A5.1.4 DOWN Mode

- a. The DOWN button is momentarily pushed at the active control station
- b. The DOWN logic is energized. This activates a selfholding circuit which allows the DOWN button to be released and locks out the up mode
- c. The primary brake is power released
- d. The footage counter is activated
- e. The hour meter is powered
- f. Motor starter MS1 initiates and the system accelerates to 50 fpm travel speed
- g. The trip meter is powered.

A5.1.5 STOP System

- a. Any STOP is pushed (with hoist operating)
- b. All up and down logic is reset and the motor starter is de-energized
- c. If hoist is traveling down, the plugging sequence is initiated .

A5.2 LOAD CELLS

- a. Slack Rope Sensor
 - 1. Slack rope condition occurs. (Rope Tension less than 500 lb)
 - 2. Slack rope switches LS11 and/or LS12 close
 - 3. STOP signal is generated.
- b. Rope Overload Sensor
 - 1. Overload condition occurs (in excess of 1,000 lb payload). Rope tension greater than 1,250 lb
 - 2. Overload switches LS9 and LS10 close
 - 3. Stop signal is generated.

A5.3 CAGE

- a. Front and rear doors are closed, closing LS5 and LS6
- b. Stop signal no longer maintained.

A5.4 FOOTAGE COUNTER

- a. UP or DOWN is pushed
- b. The wire rope rotates an idler wheel which has a 1 ft circumference
- c. Idler wheel cam activates limit switch LS15 once per revolution, registering 1 ft of travel
- d. A signal is sent to the footage counters which register the position of the hoist in the raise.

A5.5 TRAVEL LIMITS

- a. Normal Travel Limits
 1. Travel limit switch (LS1 at top and LS2 at bottom) is tripped by ramp
 2. Stop signal is generated
 3. Hoist will operate in reverse direction only.
- b. Overtravel Limits
 1. Normal travel limit switch does not operate
 2. Overtravel switch (LS2 at top and LS1 at bottom) is tripped by raise ramp
 3. LS2-2 (top of raise) or LS1-3 (bottom of raise) is opened, shutting down system
 4. System will not move either up or down.

A5.6 POWER SUPPLY, PHASE DETECTOR AND GROUND BREAK MONITOR

- a. Circuit breaker CB1 is switched on
- b. Red light on phase monitor should be out, if light is on:
 - 480V ac source has missing phase
 - 480V ac source has wrong phasing sequence
 - The source voltage is too low

- c. Main power ON pushbutton is energized
- d. This energizes the main contractor providing 480V ac to MS1 and the control Power transformer T1
- e. If a ground fault exists (current flow in the equipment ground system - L4), the Ground Break monitor removes power from the main contractor which removes power from the entire system.

CAUTION

Always turn off power (CB1) before any work on electrical components.

A5.7 PLUGGING SWITCH

- a. STOP is pushed (hoist moving down), or, Overspeed brake is tripped (hoist moving down; power on), or, Bottom travel limit switch is tripped
- b. The up interlock from the down motor starters drops out, allowing the plugging switch to power Motor Starters MS1
- c. Motor Starter MS1 initiates in the up direction, thus applying a countertorque to the motor
- d. When the plugging switch slows to 40 rpm (≈ 15 fpm), its contacts open. This de-energizes Motor Starter MS1
- e. Primary brake sets. Hoist stops.

A5.8 PRIMARY BRAKE

- a. STOP is pushed
- b. Motor Starter is de-energized
- c. Main brake solenoid is de-energized
- d. Brake sets.

APPENDIX AA

MANUFACTURER'S INFORMATION

This appendix includes manufacturer's information on the following components:

Slip Ring Assembly

Phase Monitor

Motor and Primary Brake

Plugging Switch

Ground Break System

Differential.

AERO-MOTIVE

A SUBSIDIARY OF DANIEL WOODHEAD, INC.

AERO-MOTIVE MFG. CO.

P.O. Box 2678 • Kalamazoo, Michigan 49003

Telephone (616) 381-1242 • Telex: 224420

PARTS DATA SHEET SR300-11-73**PART NO. 1174-P-67****SUPERSEDES ALL PREVIOUS SHEETS****SERIES SR300 SLIP RING, 50 AMPS, 600 VOLTS**

Dear Customer:

Thank you for selecting an Aero-Motive Slip Ring. Years of Engineering and design experience.....and manufacturing know how have gone into the production of this slip ring to make it the finest available today. Aero-Motive's fine reputation and success have been built around the high standard of this slip ring.....and assures years of trouble free service to you.....our valued customer.

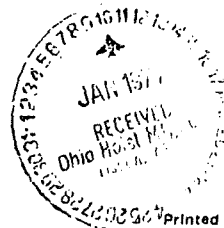
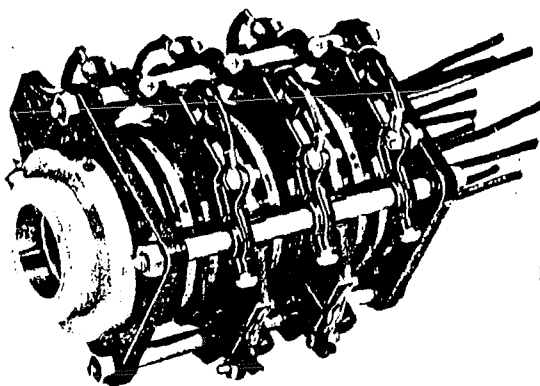
In addition to slip rings, Aero-Motive makes a complete line of reels for automatic cable and hose handling; and balancers that will take the weight out of your power tools. We welcome your request for more information about any of these job proven products.

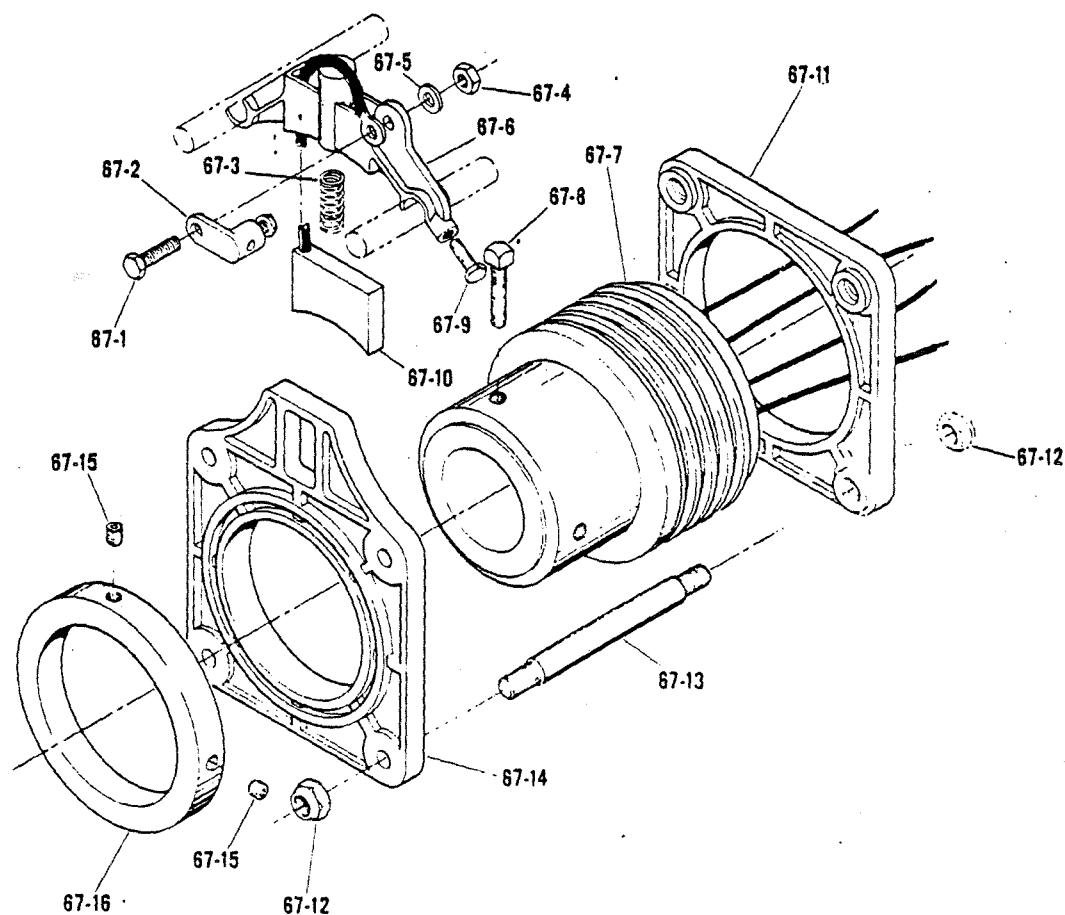
INSTALLATION—Mount the slip ring by sliding thrust ring (67-16) over mounting shaft and securing it tightly with set screws (67-15). The mounting hub has a 1.50 inch thru bore. The drive stud (customer supplies or mounted on reel) must protrude through hole on exterior part of plate (67-14) to allow the slip ring to rotate properly. Drive stud should not exceed .375 inches in diameter.

WIRING—To complete wiring, connect wires to brush (67-10) and lead wires on slip ring (67-7). Always insure that each lead is connected to corresponding brushes and lead wire. Always provide Slip Ring with fuse protection.

SERVICE—All parts illustrated on reverse side are available as repair parts should they require replacing. During disassembly and assembly of slip ring, always be especially careful to install all parts in their proper places as illustrated on opposite side. Brush holder (67-6) should always be centered with brush (67-10) centered between insulators on slip ring (67-7) and the brush surfaces making complete contact with the ring. Clamp brush holder in place securely.

MAINTENANCE—A light coat of grease may be required periodically on Drive Plate (67-14) and End Plate (67-11) depending on use and atmosphere. **CAUTION: ALWAYS WIPE OFF ANY EXCESS GREASE.**





PARTS LIST FOR 50 AMP., 600 VOLT SLIP RING

<u>REF. NO.</u>	<u>QTY.</u>	<u>DESCRIPTION</u>	<u>REF. NO.</u>	<u>QTY.</u>	<u>DESCRIPTION</u>
67-1	1/COND.	NUT (10-24 x 5/8)	67-9	1/COND.	SCREW (10-24 x 1/2 self tap)
67-2	1/COND.	TERMINAL	67-10	1/COND.	BRUSH
67-3	1/COND.	SPRINGS	67-11	1	END PLATE
67-4	1/COND.	NUT (10-24 lock)	67-12	8	NUT (1/4-20 lock)
67-5	1/COND.	WASHER (#10 flat)	67-13	4	STUD
67-6	1/COND.	BRUSH HOLDER	67-14	1	DRIVE PLATE
67-7	1	SLIP RING	67-15	2	SET SCREW (10-24 x 3/8)
67-8	2	SET SCREW (3/8-16)	67-16	1	THRUST RING

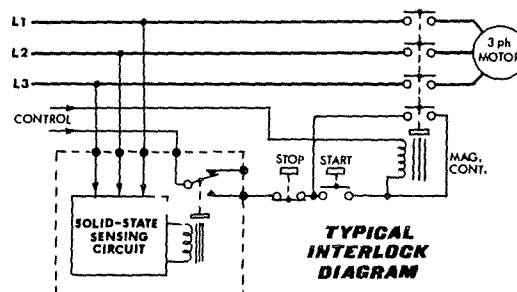
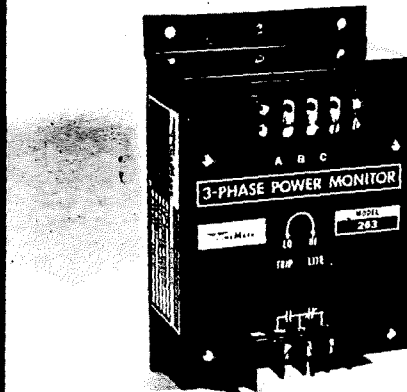


3-PHASE POWER MONITOR

RELAY DROPS OUT

- .. LOSS OF ANY PHASE
- .. LOW VOLTAGE ON ANY OR ALL PHASES
- .. PHASES REVERSED FROM A-B-C SEQUENCE

AUTOMATIC RESET



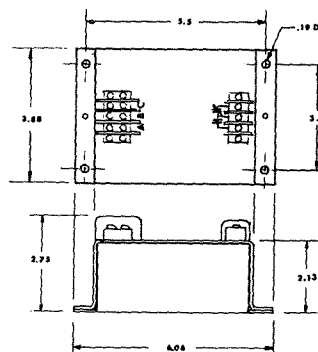
GENERAL INFORMATION

THE MODEL 263 SERIES OF 3-PHASE POWER MONITORS WERE DESIGNED TO CONTINUOUSLY MONITOR 3-PHASE POWER LINES FOR ABNORMAL CONDITIONS. THE DEVICES CONSIST OF A SOLID-STATE VOLTAGE AND PHASE ANGLE SENSING CIRCUIT DRIVING A SPDT ELECTROMECHANICAL RELAY. THE 263 SERIES DO NOT REQUIRE A NEUTRAL, THEREFORE CAN BE USED WITH EITHER WYE OR DELTA SYSTEMS. FOUR MODELS ARE AVAILABLE TO COVER THE 120, 240, 480 AND 575 VAC RANGES. ADJUSTMENT RANGES ARE SUFFICIENTLY WIDE TO ALLOW PROPER ADJUSTMENT WITHIN THESE RANGES. A FAILURE INDICATOR IS ALSO PROVIDED TO AIDE IN ADJUSTMENT AND SYSTEM TROUBLE-SHOOTING.

SPECIFICATIONS

MODEL NO. → FOR USE ON → (VOLTAGE BETWEEN PHASES)	A263 120	B263 240	C263 480	D263 575
MAXIMUM INPUT VOLTAGE	140 VAC 60 Hz	260 VAC 60 Hz	520 VAC 60 Hz	600 VAC 60 Hz
ADJUSTMENT RANGE	85-125 VAC	160-240 VAC	340-480 VAC	420-575 VAC
POWER CONSUMPTION	¼W PER PHASE	¼W PER PHASE	1¼W PER PHASE	2¼W PER PHASE
REPEAT ACCURACY (FIXED CONDITIONS)	0.1%	0.1%	0.1%	0.1%
REPEAT ACCURACY (0-60 DEG. C)	1.3% MAX	1.7% MAX	2.1% MAX	2.5% MAX
CONTACT RATING	0.48 KVA at 120 VAC	0.48 KVA at 120 VAC	0.48 KVA at 120 VAC	0.48 KVA at 120 VAC
DROP-OUT TIME (APPROX)	.05 SEC	.05 SEC	.05 SEC	.05 SEC
DEAD BAND BETWEEN FULL-IN AND DROP-OUT	2%	2%	2%	2%
TRANSIENT PROTECTION	2500 VOLTS FOR 10 MS	2500 VOLTS FOR 10 MS	2500 VOLTS FOR 10 MS	2500 VOLTS FOR 10 MS

DIMENSIONS



ADJUSTMENT PROCEDURE

TO ADJUST THE MODEL 263, CONNECT THE 3-PHASE POWER TO THE TERMINALS MARKED A, B, AND C MAKING SURE THAT THE PROPER SEQUENCE IS OBSERVED. TURN THE FAILURE LEVEL CONTROL FULLY CLOCK WISE, THEN TURN SLOWLY COUNTER-CLOCKWISE UNTIL THE "TRIP-LITE" EXTINGUISHES. A SLIGHT FURTHER COUNTERCLOCKWISE ADJUSTMENT MAY BE NECESSARY AFTER CONNECTING INTO THE CONTROL SYSTEM TO PREVENT NUISANCE DROP-OUTS DURING MOTOR START-UPS.



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APPLICATION GUIDE

No. 05015

PHASE LOSS PROTECTION

GENERAL

This application guide was written for use by equipment designers, maintenance personnel, electrical contractors, etc., to aid them in the installation of phase-loss or phase-unbalance protection for sensitive equipment. The application notes, charts and schematics are all centered around several models of 3-phase power monitors manufactured by TIME MARK CORPORATION. A simplified schematic diagram of the basic circuit and sensing method is shown in figure 1.

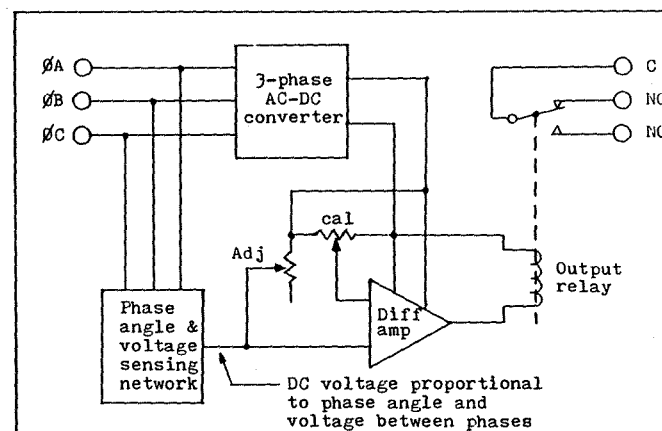


FIGURE 1 Schematic diagram (simplified)

The schematic shown in Figure 1 shows the basic circuit configuration used in all the 3-phase power monitors discussed in this application guide. The heart of the device is the exclusive "phase angle & voltage sensing network" developed by TIME MARK which allows lost phases to be detected even when regenerative loads cause very little voltage decrease to be measured between phases.

PHASE UNBALANCE

Unbalance of a 3-phase power system will occur when single phase loads are applied causing one or two of the lines to carry more or less of the load. On new installations of 3-phase power systems, normally careful attention is given to balancing of loads. However, as more and more single phase loads are added to the system, an unbalance begins to occur.

This phase voltage unbalance causes 3-phase motors to run at temperatures beyond their published ratings. These high temperatures soon result in insulation breakdown and shortened motor life. Thermal overloads, magnetic breakers and other such devices usually will not detect this gradual unbalance and therefore do not afford proper protection.

PHASE LOSS

The total loss of one of the three phases is an extreme case of a phase unbalance. This condition is generally known as "single-phasing". The most serious result of this condition is that it can go undetected on most systems for a long enough time to burn out a motor. A 3-phase motor running on single phase will continue to run, drawing all its current from two of the lines. In most all cases, this condition will be undetectable by measuring the voltage at the motor terminals because the open winding in the motor is generating a voltage almost equal to the phase voltage that was lost. (See chart in Fig 2) In this case, the phase angles will be displaced sufficiently to be detected by the TIME MARK method.

Phase loss can occur when a single phase overload condition causes a fuse to blow; by a 3-phase circuit being struck by lightning; or by a mechanical failure within the switching equipment on machinery. Attempting to start a 3-phase motor on a single phase will cause the motor to draw locked-rotor current. Thermal overloads are not al-

ways capable of preventing damage to the motor under these conditions.

Figure 2 shows voltage readings taken at the motor terminals on three different size induction motors and one synchronous type motor. The readings shown are with phase 3 disconnected and show the effect of the voltage being generated by the open motor winding under different load conditions.

% LOAD	1 HP			10 HP			100 HP			2 HP (sync)		
	1-2	2-3	3-1	1-2	2-3	3-1	1-2	2-3	3-1	1-2	2-3	3-1
0	480	402	434	480	432	443	480	446	451	480	405	431
25	480	401	422	480	439	438	480	454	438	480	404	420
50	480	399	405	480	430	437	480	459	429	480	401	404
75	480	394	376	480	426	430	480	453	410	480	397	382
100	480	391	364	480	410	416	480	440	325	480	392	371

VOLTAGE READINGS AT MOTOR TERMINALS WITH Ø3 DISCONNECTED

FIGURE 2

It can be seen from the charts in figure 2 that if a phase is lost and the normal line voltage varies from 420 volts to 480 volts that it would be impossible to detect the condition under all loads by sensing only voltages on the three lines. For this reason, phase angle detection in addition to voltage detection has been incorporated into the design of these power monitors. This method allows an additional 5 to 8% decrease in phase to phase voltage set-point. That is, to detect a lost phase on a 100 HP induction motor with no load, the line voltage would have to remain constant, and the detection point would have to be set at 95% of the line voltage. The addition of phase angle sensing allows the set-point to be made at 85% to 90% so that normal line variations are not sensed as a failure or unbalance.

PHASE REVERSAL

Reversing any two of the three phases may cause damage to driven machinery or injury to personnel. This can occur when modifications are made to power distribution systems, or when maintenance is performed on cabling and switching equipment. The National Electrical Code requires phase reversal protection on all equipment transporting people, such as elevators and escalators. All types of 3-phase power monitors shown in the table on page 7 will sense a phase reversal condition under all load conditions.

MODELS AVAILABLE

The table shown on the following page gives some general information for use in selecting the device that best suits the application. The sensing method on all models shown are for all practical purposes the same. Variations in the models are in the type of enclosure, the wiring method, output relay contact rating, failure delays and adjustment ranges. More detailed information and specifications may be obtained by referring to the data sheets which are available for each model.

APPLICATION

Figure 3 shows a typical application with a single motor load. Connecting the power monitor in this manner will protect against any of the following:

1. Loss of primary fuse.
2. Loss of phase in secondary protection circuits.
3. Failure in primary or secondary windings of transformer.
4. Phase reversal throughout the distribution system.
5. Low voltage on feeder lines.

The power monitor may be connected as shown in figure 3. This will allow installation without disturbing existing protection devices. Output contacts may be wired into a control circuit to trip the motor contactor should a failure occur.

QUICK REFERENCE - 3-PHASE POWER MONITORS

FIGURE 3
PHASE TO PHASE
NOMINAL
VOLTAGES
AVAILABLE

MODEL SERIES	NOMINAL VOLTAGES AVAILABLE	ADJUSTMENT RANGE	CASE TYPE	OUTPUT CONTACTS	TERMINATION METHOD	FAILURE DELAY	DEAD BAND	FAILURE INDICATOR
258	120 240 480	85-125VAC 160-240VAC 340-480VAC	OCTAL PLUG-IN	SPDT 3A-115V 1A-240V	OCTAL SOCKET	NO	2%	YES
259	120 240 480 575	85-125VAC 160-240VAC 340-480VAC 420-575VAC	OPEN CHASSIS	DPDT 10A-115V 6A-240V	TERM STRIP	ADJUSTABLE 1-5 SECONDS	.1%	YES
263	120 240 480 575	85-125VAC 160-240VAC 340-480VAC 420-575VAC	OPEN FLANGE MOUNT CHASSIS	SPDT 3A-115V 1A-240V	TERM STRIP	NO	2%	YES
264	120 240 480 575	85-125VAC 160-240VAC 340-480VAC 420-575VAC	CLOSED FLANGE MOUNT CHASSIS	ISOLATED NO & NC 3A-115V 1A-240V	TERM STRIP	FIXED 1-2 SEC	.1%	NO
266	240 480	175-240VAC 370-480VAC	CLOSED FLANGE MOUNT CHASSIS	SPDT 10A-115V 5A-240V	TERM STRIP	NO	2%	YES

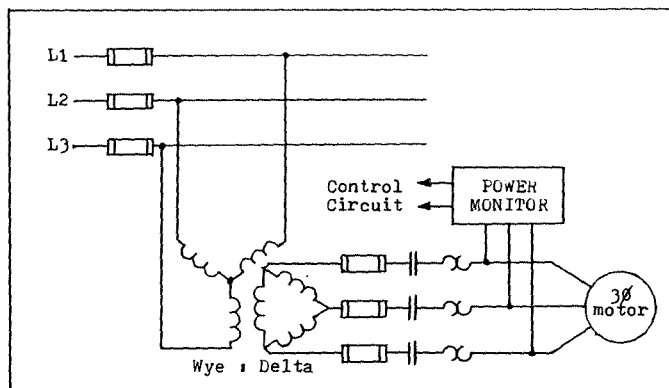


FIGURE 4. TYPICAL 3-PHASE MOTOR PROTECTION

The following figures 5 and 6 show examples of how to install the phase-loss/low voltage protection using the model 258 where line transients might cause accidental or nuisance tripping. The use of low cost solid state time delay relays to delay the actual tripping of the main breaker motor starter contacts are used. The amount of time delay may be adjusted to suit the application. The settings will vary with different installations but only in rare cases will the amount of delay exceed 10 seconds.

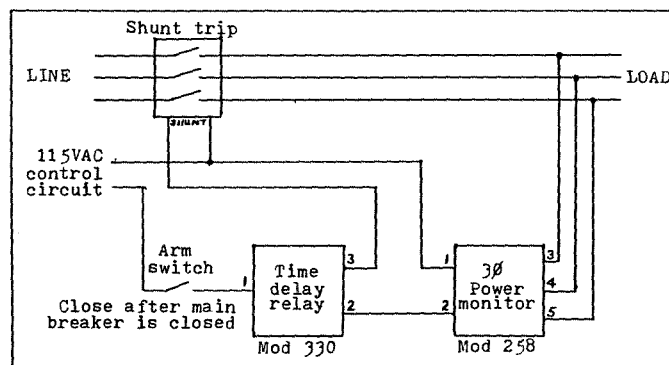


FIGURE 5 PHASE LOSS PROTECTION (manual restart)

PAGE 8

Figure 6 below shows how to install Phase-Loss protection when a typical motor starter is being used. The model 258 used with the model 330 time delay relay will prevent nuisance tripping from transients which last for 3 cycles of the line or more.

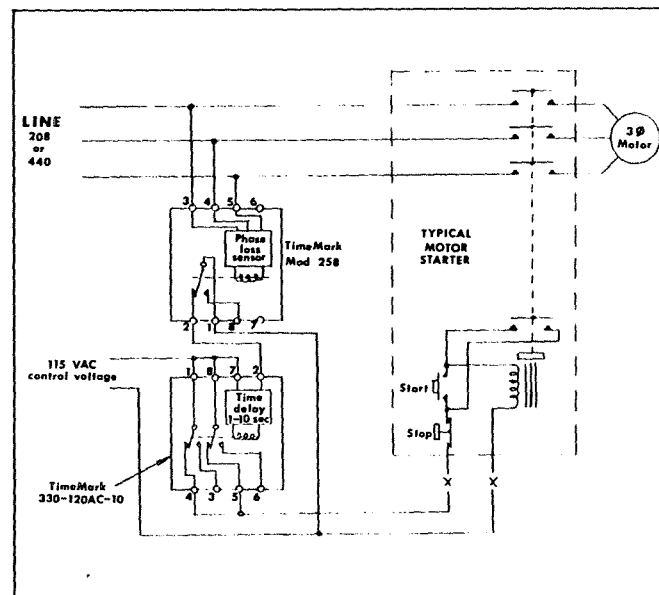


FIGURE 6 PHASE-LOSS PROTECTION (manual restart)

Figure 7 on the following page shows a method of protecting against phase loss, low voltage or unbalance when a group of motors are being fed from a single transmission line. Starting all motors at once would cause a surge on the line which could cause properly rated fuses to blow. This sequential starting method will cause immediate shut-down if abnormal line conditions occur, and automatic sequential start-up at fixed intervals when the line conditions return to normal.

PAGE 9

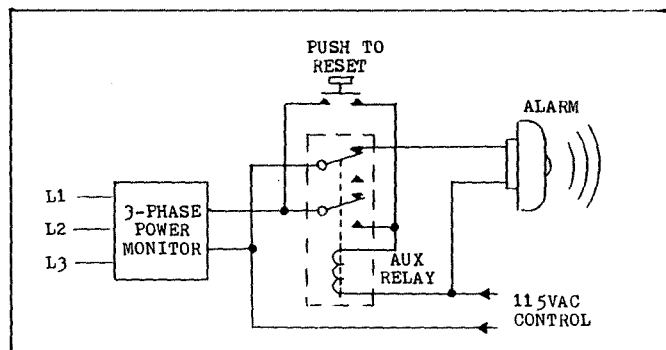


FIGURE 9 ALARM SYSTEM REQUIRING MANUAL RESET

AIR CONDITIONING SYSTEMS

Phase loss and low voltage protection for air conditioning systems is absolutely essential since compressor motors often run for long periods of time during summer months. An abnormal condition occurring on the 3-phase power lines should shut down the compressor motor immediately but allow enough time for the head pressure to bleed off before restarting. Failure to allow time for this pressure to bleed off can cause the compressor motor to draw locked-rotor current resulting in damage to the motor or the opening of other protective devices. Figure 10 shows a method of protecting against these problems.

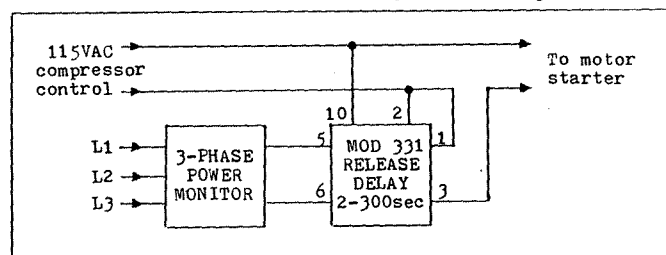


FIGURE 10 AIR COND COMPRESSOR PROTECTION (Auto reset)

WATER & SEWAGE LIFT STATIONS

The control of water levels is a continuous and demanding problem in many parts of the country and requires reliable equipment to prevent sewage back-ups, drainage system over-flows, and consequently, pollution of our lakes and streams. The drawing in figure 11 shows a typical sewage lift station and how liquid levels are monitored.

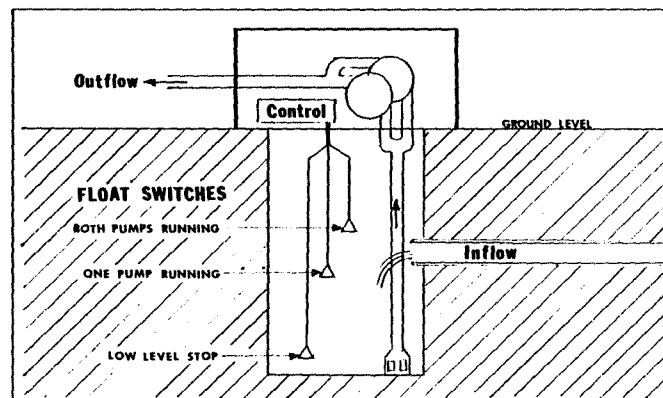


FIGURE 11 WATER & SEWAGE LIFT STATION

Control of the liquid level in the well is generally maintained by use of a duplex pump system as shown in figure 12. Operation of the control circuit depends on the use of float switches or other sensing devices suspended into the well. These switches tell the control circuit which pump to turn on and when both pumps are required. To keep one pump from being used more than the other, a solid-state alternating relay is used to alternately turn on one pump then the other as the liquid level moves between the "ONE PUMP RUNNING" switch and "LOW LEVEL STOP" switch. If one pump cannot handle the volume and the level rises to the "BOTH PUMPS RUNNING" switch, both will come on and remain on until the level returns to the "LOW LEVEL STOP" position.

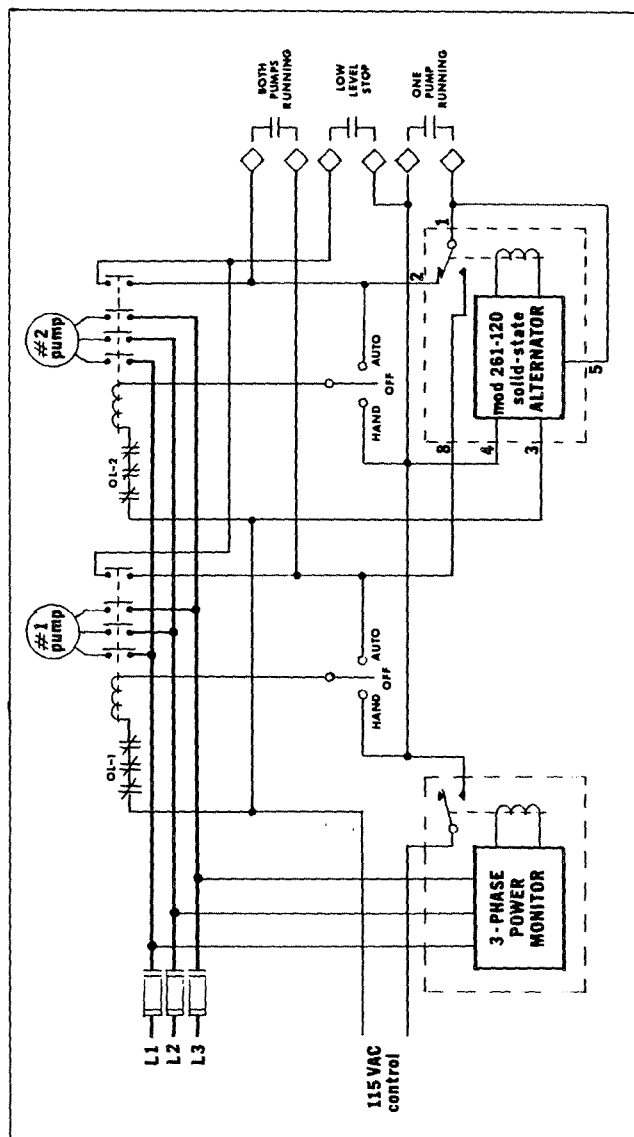


FIGURE 12 DUPLEX PUMP CONTROL WITH PHASE-LOSS PROTECTION AND SOLID-STATE ALTERNATOR

PAGE 14

ADJUSTMENT PROCEDURES

Adjustment of the drop-out point can be made by several methods. The simplest of these and the one most commonly used will be to adjust the unit after it is installed but not yet connected into its interlock circuit. Most models have failure indicators which make this adjustment very simple. Connect the 3-phase power to the proper terminals and adjust the failure level control so that the indicator is just "OUT". If the indicator will not go out, reverse any two of the three phases and re-adjust.

On models that do not have indicators, or if the adjustment described above is too sensitive and a lower drop-out setting is desired, Figure 13 shows an accurate adjustment method.

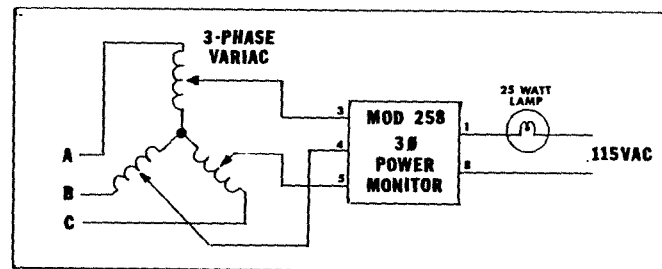


FIGURE 13 ACCURATE ADJUSTMENT METHOD

ENGINEERING ASSISTANCE

TIME MARK CORPORATION maintains an applications group to aid you in any special application or special device you may require. There is no charge for this service. Just write or call:

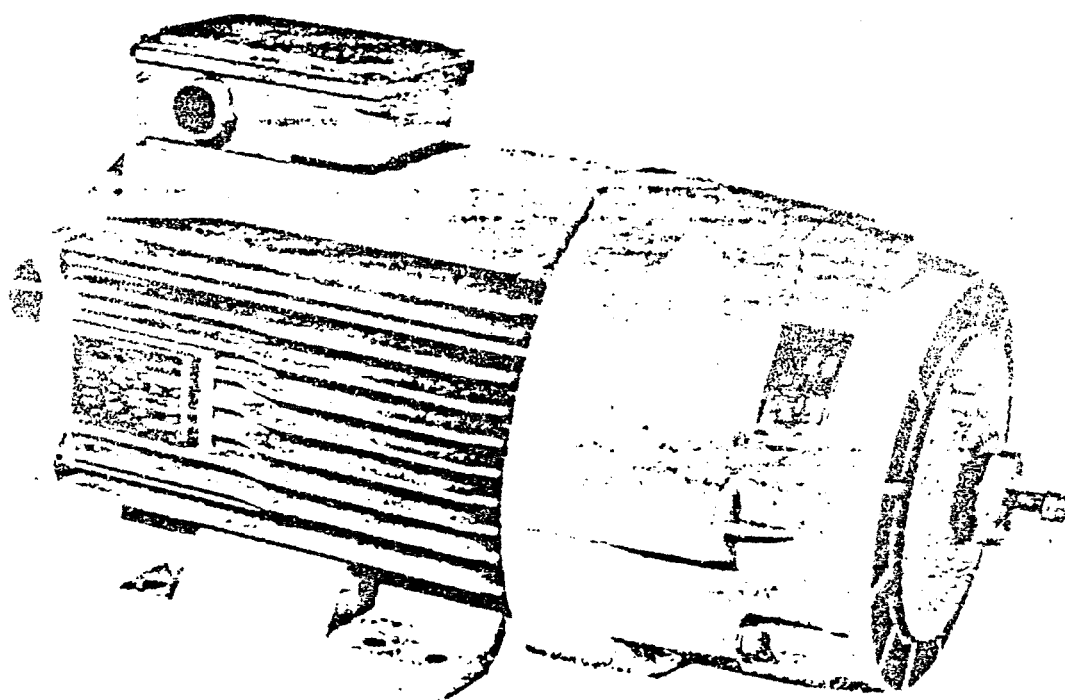
TIME MARK CORPORATION
Applications Engineering
PO Box 15127
Tulsa, OK 74115
Tel: 918-939-5811

PAGE 15

LS Powerbloc™

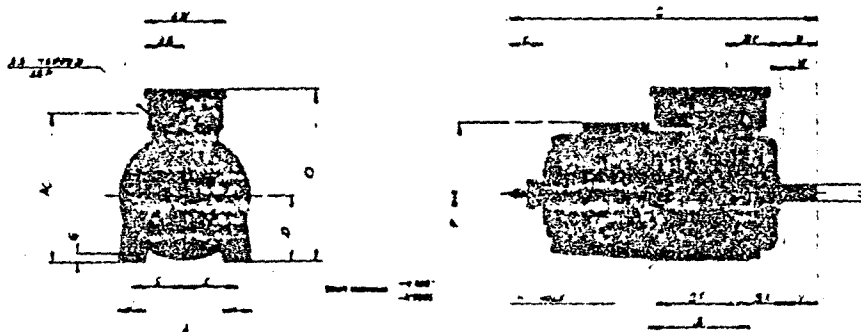
A.C. MOTORS TO NEMA/EEMAC STANDARDS

BRAKE MOTOR

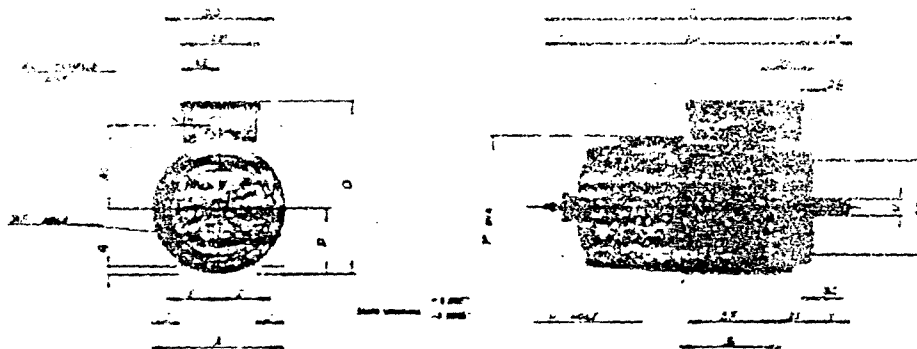
**LS LEROY
SOMER**

BETTER ORIGINAL TO COME

Dimensions



FOOT MOUNTING

[illegible][illegible]

C. FACE

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM	BN	BO	BP	BQ	BR	BS	BT	BU	BV	BW	BX	BY	BZ	CA	CB	CC	CD	CE	CF	CG	CH	CI	CJ	CK	CL	CM	CN	CO	CP	CQ	CR	CS	CT	CU	CV	CW	CX	CY	CZ	DA	DB	DC	DD	DE	DF	DG	DH	DI	DJ	DK	DL	DM	DN	DO	DP	DQ	DR	DS	DT	DU	DV	DW	DX	DY	DZ	EA	EB	EC	ED	EE	EF	EG	EH	EI	EJ	EK	EL	EM	EN	EO	EP	EQ	ER	ES	ET	EU	EV	EW	EX	EY	EZ	FA	FB	FC	FD	FE	FF	FG	FH	FI	FJ	FK	FL	FM	FN	FO	FP	FQ	FR	FS	FT	FU	FV	FW	FX	FY	FZ	GA	GB	GC	GD	GE	GF	GG	GH	GI	GJ	GK	GL	GM	GN	GO	GP	GQ	GR	GS	GT	GU	GV	GW	GX	GY	GZ	HA	HB	HC	HD	HE	HF	HG	HH	HI	HJ	HK	HL	HM	HN	HO	HP	HQ	HR	HS	HT	HU	HV	HW	HX	HY	HZ	IA	IB	IC	ID	IE	IF	IG	IH	II	IJ	IK	IL	IM	IN	IO	IP	IQ	IR	IS	IT	IU	IV	IW	IX	IY	IZ	JA	JB	JC	JD	JE	JF	JG	JH	JI	IJ	JK	JL	JM	JN	JO	JP	JQ	JR	JS	JT	JU	JV	JW	JX	JY	JZ	KA	KB	KC	KD	KE	KF	KG	KH	KI	KJ	KK	KL	KM	KN	KO	KP	KQ	KR	KS	KT	KU	KV	KW	KX	KY	KZ	LA	LB	LC	LD	LE	LF	LG	LH	LI	LJ	LK	LL	LM	LN	LO	LP	LQ	LR	LS	LT	LU	LV	LW	LX	LY	LZ	MA	MB	MC	MD	ME	MF	MG	MH	MI	MJ	MK	ML	MM	MN	MO	MP	MQ	MR	MS	MT	MU	MV	MW	MX	MY	MZ	NA	NB	NC	ND	NE	NF	NG	NH	NI	NJ	NK	NL	NM	NN	NO	NP	NQ	NR	NS	NT	NU	NV	NW	NX	NY	NZ	OA	OB	OC	OD	OE	OF	OG	OH	OI	OJ	OK	OL	OM	ON	OO	OP	OQ	OR	OS	OT	OU	OV	OW	OX	OY	OZ	PA	PB	PC	PD	PE	PF	PG	PH	PI	PJ	PK	PL	PM	PN	PO	PP	PQ	PR	PS	PT	PU	PV	PW	PX	PY	PZ	QA	QB	QC	QD	QE	QF	QG	QH	QI	QJ	QK	QL	QM	QN	QO	QP	QQ	QR	QS	QT	QU	QV	QW	QX	QY	QZ	RA	RB	RC	RD	RE	RF	RG	RH	RI	RJ	RK	RL	RM	RN	RO	RP	RQ	RR	RS	RT	RU	RV	RW	RX	RY	RZ	SA	SB	SC	SD	SE	SF	SG	SH	SI	SJ	SK	SL	SM	SN	SO	SP	SQ	SR	SS	ST	SU	SV	SW	SX	SY	SZ	TA	TB	TC	TD	TE	TF	TG	TH	TI	TJ	TK	TL	TM	TN	TO	TP	TQ	TR	TS	TT	TU	TV	TW	TX	TY	TZ	UA	UB	UC	UD	UE	UF	UG	UH	UI	UJ	UK	UL	UM	UN	UO	UP	UQ	UR	US	UT	UU	UV	UW	UX	UY	UZ	VA	VB	VC	VD	VE	VF	VG	VH	VI	VJ	VK	VL	VM	VN	VO	VP	VQ	VR	VS	VT	VU	VV	VW	VX	VY	VZ	WA	WB	WC	WD	WE	WF	WG	WH	WI	WJ	WK	WL	WM	WN	WO	WP	WQ	WR	WS	WT	WU	WV	WW	WX	WY	WZ	XA	XB	XC	XD	XE	XF	YG	YH	YI	YJ	YK	YL	YM	YN	YO	YP	YQ	YR	YS	YT	YU	YV	YW	YX	YY	YZ	ZA	ZB	ZC	ZD	ZE	ZF	ZG	ZH	ZI	ZJ	ZK	ZL	ZM	ZN	ZO	ZP	ZQ	ZR	ZS	ZT	ZU	ZV	ZW	ZX	ZY	ZZ
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[illegible]

Note: C face motors are available with or without feet

BETTER ORIGINAL TO COME



Plugging Switches

BULLETIN

808

INSTRUCTIONS



Plugging Switch
(equipped with lockout solenoid)



Plugging Switch
(without lockout solenoid)

Enclosure satisfies NEMA 1, 4, 5 & 12 requirements

DESCRIPTION — The Bulletin 808 is used, in conjunction with automatic starters arranged for reversing or plugging duty, to provide plugging and anti-plugging of squirrel cage motors. It is also used as a speed sensitive switch.

In plugging applications, the Bulletin 808 automatically interrupts reverse braking power as the motor approaches zero speed. The speed at which the Bulletin 808 contacts operate is easily adjusted so as to avoid coasting or reverse rotation of the motor. Contacts are normally open, arranged for plugging in either or both directions.

In anti-plugging applications, the Bulletin 808 is designed to keep the reverse circuit open until the motor speed has dropped to a pre-selected value. Contacts are normally closed, arranged for anti-plugging in either or both directions.

As a speed sensitive switch the Bulletin 808 can be used to sequence conveyors where it is essential for one conveyor to be running at nearly full speed before a second conveyor is started.

PRECAUTIONS IN PLUGGING APPLICATIONS — Although plugging is the best method of stopping a motor for many applications, care must be taken that its advantages are not lost through a mis-application. The following points should be considered before a decision to use a plugging switch is made.

1. Approximately six to eight times full load motor current is required for each plugging operation. If frequent plugging is required, this may create too great a demand on the power supply.
2. The shock of a sudden stop may be too great for the driven machine to withstand.
3. The motor may not withstand braking duty. Determine the WR^2 (flywheel effect) of the driven machine and the speed at which the motor will operate. Also determine the duty cycle, which includes frequency of starting and stopping, running time, rest time and load. From this data the motor manufacturer can determine whether the motor is adequate for braking duty.

LOCKOUT SOLENOID — In some applications, an accidental turn of the shaft might close the contacts and start the motor. To guard against this, the Bulletin 808 can be equipped with a lockout solenoid, which consists of a solenoid and cover mounted on top of the switch. A bracket connected to the solenoid plunger keeps the plugging switch contacts from closing unless the motor starting circuit is energized. The lockout solenoid can be supplied for installation in the "field". For Catalog Number refer to Page 2. To add a lockout solenoid simply remove the

top plate and put the assembly in place. Typical wiring connections for the lockout solenoid are shown on Page 3.

*CONTACT RATINGS — NEMA 8600

Max. AC Voltage	AC				DC	
	Amperes		Continuous Carrying Current	Voltamperes	Max. Voltage	Amperes
	Make	Break		Make	Break	
120	30	3	5	3600	360	
240	15	1.5	5	3600	360	
480	7.5	0.75	5	3600	360	115-125
600	6.0	0.6	5	3600	360	230-250
						0.12
						0.08

OPERATING SPEED — Styles G, GL, H & HL have contacts which may be adjusted to operate between 15 to 60 RPM. Styles C, CL, E & EL have contacts which may be adjusted to operate between 50 to 200 RPM.

Styles D, DL, F & FL have contacts which may be adjusted to operate between 150 to 900 RPM.

Styles C, CL, D, DL, G & GL have normally open contacts.

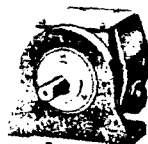
Styles E, EL, F, FL, H & HL have normally closed contacts.

The rate of speed at which the Bulletin 808 shaft is driven and the inertia of the machine load will determine when the contacts will open for plugging. Styles G and H have a highly magnetized alnico magnet to provide a minimum operating range of 15-60 RPM. Styles C, D, E and F all have the same magnet, therefore, the contact springs can be interchanged to provide ranges between 50 and 200 RPM or between 150 and 900 RPM. Styles C, D, E and F cannot reach a minimum operating range of 15-60 RPM because of the difference in the magnets on the Styles G and H.

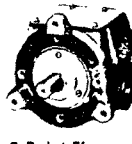
INSTALLATION — Coupling to the motor or machine shaft should be made either by gear, chain or direct flexible coupling. A direct coupling must be of the flexible type because the centerlines of the motor or machine shaft and the plugging switch shaft cannot be lined up accurately enough to use a rigid coupling. A belt drive should not be used, for it is important that the switch be driven by a positive means. It is also important that positive drive be employed between various parts of the machine being controlled, especially where these parts represent large amounts of inertia.

MOUNTING BRACKETS — Three types of mounting brackets are available for the Bulletin 808 NEMA Type 1, 4, 5, and 12 Switches. These brackets are held to the switches with four Allen-head screws and lock washers and are easily interchangeable between switches. The brackets can be mounted to the switch in any of eight positions depending upon the conduit opening location most convenient for the application. Switches are shipped with mounting brackets unattached.

INTERCHANGEABLE MOUNTING BRACKETS



Base
X-188113



3 Point Flange
A-48584



4 Point Flange
A-43568

* Added or changed since previous issue.

Instructions 808-802 — August, 1971
Supersedes Instruction Sheet 808-802 Dated October, 1968

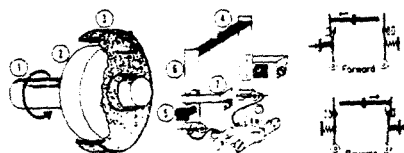
Plugging Switches

OPERATION—In the diagram at the right, a Bulletin 808 zero speed plugging switch with normally open contacts is represented. Normally closed contact operation is similar.

When the Bulletin 808 shaft (1) rotates, the field of the alnico magnet (2) induces currents in the copper cup (3). These currents produce an electromagnetic torque proportional to shaft speed, tending to rotate the cup in the same direction as the shaft. The cup engages a contact operating lever (4) which limits cup rotation.

As the shaft speed increases from a standstill, the operating torque increases; when the torque is great enough to overcome an opposing spring force (5), the movable contact (6) is forced against the stationary contact (7). The contacts remain closed as the shaft speed increases to its normal value.

Similarly, as the shaft speed is reduced, a point is reached where the spring force again exceeds the operating torque and the contacts return to their normally open position. The contacts do not, however, open at the same speed at which they close. The operating point on increasing speed exceeds that on decreasing speed by a differential determined by internal friction.

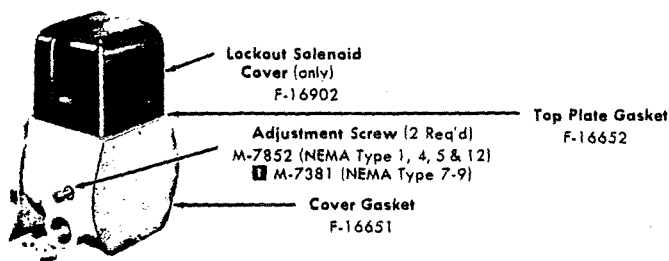


ADJUSTMENT — The contact operating speed is easily adjusted by means of two external adjustment screws — one for each set of contacts. After the Bulletin 808 plugging switch has reached its normal operating temperature, the screw is turned in or out to vary the contact spring compression and thus change the contact operating speed.

ACCURACY — Repetition of the contact operating speed, depends on the speed at which the Bulletin 808 shaft is driven. For dependable operation, the minimum driven speed must be at least two times the speed at which the contacts are set to operate. For accuracy, the shaft should be driven at the highest available speed within its maximum operating speed. The speed should not be greater than 1800 RPM on all switches except Styles G, GL, H & HL on which speed should not be greater than 1200 RPM.

LOCKOUT SOLENOID KIT

Volts	Hz	Catalog No.
120	60	808-LA1
110	50	
208	60	808-LA20
240	60	808-LA2
220	50	
480	60	808-LA4
440	50	
600	60	808-LA6
550	50	



Bulletin 808		Switch Plate Assembly Includes Contact Springs	Contact Springs (2 Req'd)
Style	*Series Identification Letter	Part No.	Part No.
C - CL	A - B - C	X-332580	B-15118
	D - E	X-332581	
D - DL	A - B - C	X-332582	B-15119
	D - E	X-332583	
E - EL	A - B - C	X-332584	B-15118
	D - E	X-332585	
F - FL	A - B - C	X-332586	B-15119
	D - E	X-332587	
G - GL	A - B - C	X-332588	B-26679
	D - E	X-332589	
H - HL	A - B - C	X-332584	B-15118
	D - E	X-332585	

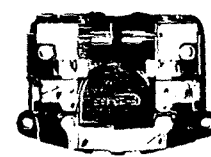
NOTE — The contacts are fed electrically thru a common terminal jumper. (See switch plate assembly front view illustration). If isolated contacts are desired — remove jumper thereby causing current to flow to each contact individually.

Also used on NEMA Type 4 Series identification letters A, B, or C.

ORDERING INFORMATION — Your order cannot be entered unless the following information is given: Part number, description of part, catalog number and series letter of switch. This instruction sheet applies also to the above switches when used on control apparatus listed under other Bulletin numbers.

*Added or changed since previous issue.

Front View
Switch Plate Assembly



Common Jumper Terminal

Back View
Contact Springs



Plugging Switches

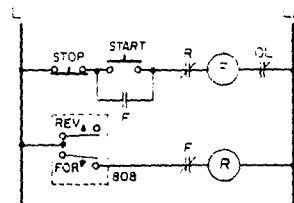
See Applicable Codes and Laws for all Applications

TYPICAL PLUGGING CIRCUIT

The diagram at the right is the control circuit for forward direction plugging without lockout protection. Operation is as follows —

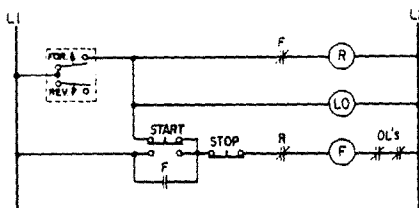
Pushing "Start" button closes forward contactor and motor runs forward. Contact "F" opens circuit to reverse contactor. Forward contact on plugging switch closes.

Pushing "Stop" button drops out the forward contactor. Reverse contactor is energized and motor is plugged. Motor speed decreases to the pre-set speed setting of plugging switch at which point plugging switch contact opens and drops out the reverse contactor.



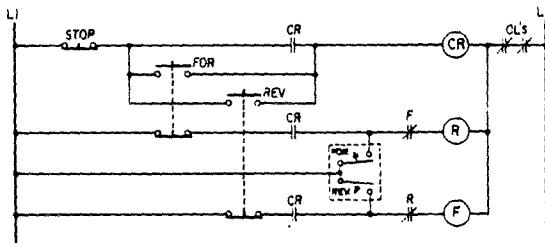
A Bulletin 808 plugging switch used with a Bulletin 705 reversing starter to bring a motor to a fast stop.

FORWARD PLUGGING



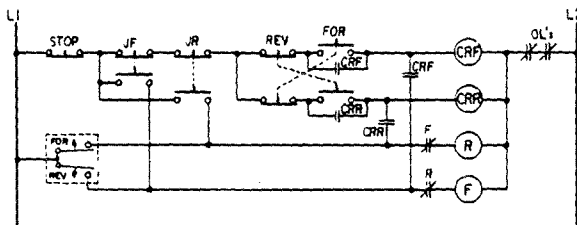
This circuit provides lockout protection, with the lockout coil wired in the control circuit. The lockout coil may also be wired to motor terminals T1 and T2 (see below); in this case, the typical plugging circuit above is used.

FORWARD AND REVERSE PLUGGING



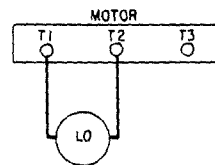
Depressing Stop while running the motor in either forward or reverse plugs the motor to a stop. Lockout protection may be added by connecting the lockout coil to the motor terminals as shown below.

RUNNING AND JOGGING IN EITHER DIRECTION, WITH PLUGGING ACTION

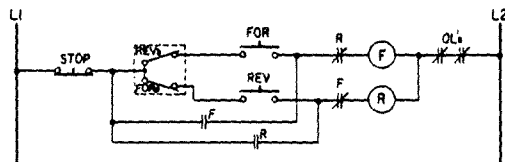


The motor is plugged when releasing the jog buttons as well as when pressing the stop button. Lockout protection may be added by connecting the lockout coil to the motor terminals as shown at the right.

LOCKOUT COIL CONNECTIONS

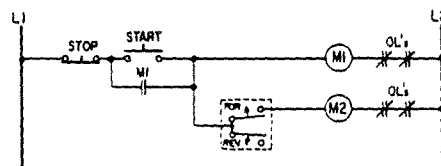


ANTI-PLUGGING



This circuit is used in cases where damage would result from a sudden reversal of power. The Bulletin 808 contacts are designed to keep the reverse circuit open until the motor has coasted to a pre-set speed.

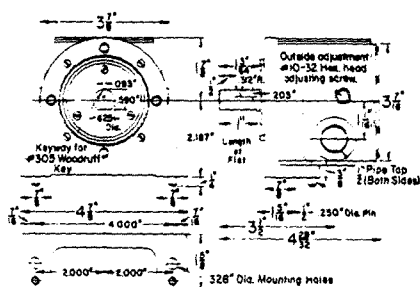
CONVEYOR SEQUENCING



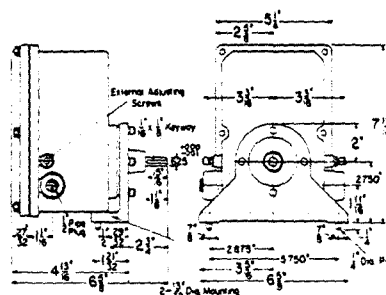
M2 starts automatically when M1 comes up to speed.

Plugging Switches

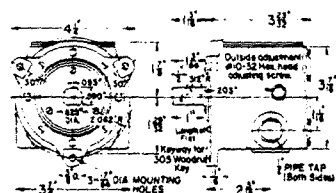
* APPROXIMATE DIMENSIONS AND SHIPPING WEIGHTS



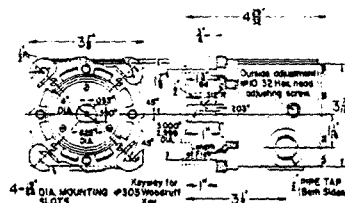
Base Type—NEMA Type 1, 4, 5, 12 Enclosure
Add $2\frac{1}{4}$ " to height if lockout solenoid is used.



Base Type—NEMA Type 7-9 Enclosures
Lockout solenoid is mounted inside the enclosure.



3-Point Flange—NEMA Type 1, 4, 5, 12 Enclosure
Add $2\frac{1}{4}$ " to height if lockout solenoid is used.



4-Point Flange—NEMA Type 1, 4, 5, 12 Enclosure
Add $2\frac{1}{4}$ " to height if lockout solenoid is used.

Approximate Shipping Weights: Without lockout: NEMA 1, 4, 5, 12, 6 Lbs.; NEMA 7-9, 10 Lbs.
With lockout: NEMA 1, 4, 5, 12, $7\frac{1}{2}$ Lbs.; NEMA 7-9, $11\frac{1}{2}$ Lbs.

*Added or changed since previous issue.

Milwaukee • ALLEN-BRADLEY COMPANY • Wisconsin



INSTRUCTIONS

TM

GEI-86126
REV. F

GROUND-BREAK™ SYSTEM

For Ground-Fault Protection

GROUND BREAK™ SYSTEM

○ MONITOR PANEL CIRCUIT NO. ○

IF LAMP LIGHTS.

GROUND FAULT HAS OCCURRED:

1. Locate and clear ground fault condition.
2. Push yellow reset button—then release.
3. Reset and close breaker/interrupter.

SYSTEM TEST WITHOUT SERVICE INTERRUPTION 1. Push and hold red Test button. Ground fault lamp should light within one second. 2. Push and hold yellow Reset button. 3. Release red Test button. 4. Release yellow Reset button.	SYSTEM TEST WITH SERVICE INTERRUPTION 1. Push red Test button. Ground Fault lamp should light. 2. Release red Test button, breaker/interrupter should open. 3. Push and release yellow Reset button. 4. Reset and close breaker/interrupter.
---	---

MADE IN U.S.A. () For additional instructions see GEI-86126 () NPS602382

RESET

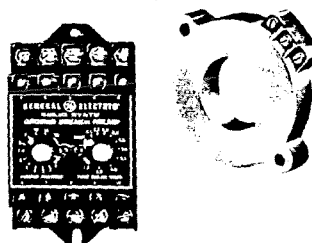
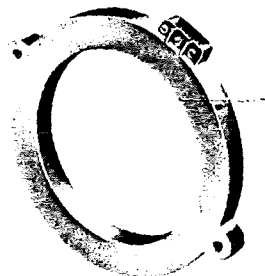
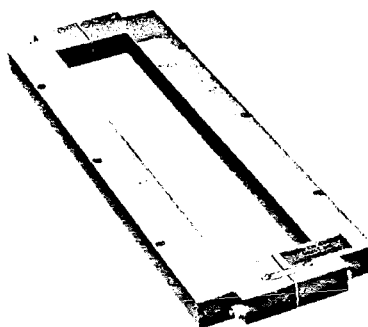
CONTROL

POWER

TEST

GENERAL ELECTRIC

CIRCUIT PROTECTIVE DEVICES PRODUCT DEPARTMENT, PLAINVILLE, CONN. 06062



For additional information, see GET-2964

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

GENERAL ELECTRIC

CIRCUIT PROTECTIVE DEVICES DEPT. PLAINVILLE, CONN. 06062

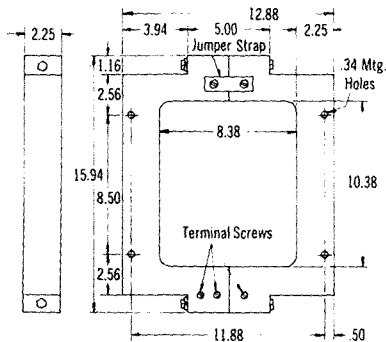


Figure 2E

Cat. No. TGS0810

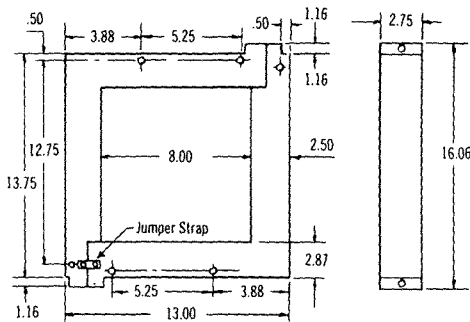


Figure 2F

Cat. No. TGS0808

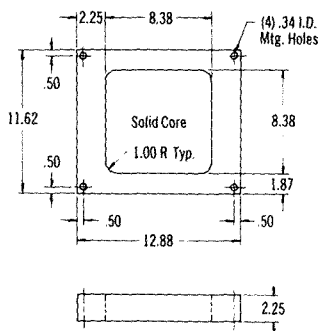


Figure 2G

Cat. No. TGS0808S

SENSOR MOUNTING INSTRUCTIONS

1. Bolt the two halves of the split core sensors together, using the hardware provided, and torque bolts to 70 inch lbs.
2. Attach jumper strap with hardware provided to both halves of split core sensor. Torque strap mounting screws to 20 inch lbs.
3. Attach sensor to supporting brackets with a minimum of four bolts for the rectangular sensors and two bolts for the round sensors. Bolt torque should not exceed 45 inch lbs.

RELAYS (Figures 3, 4, 5 and 6)

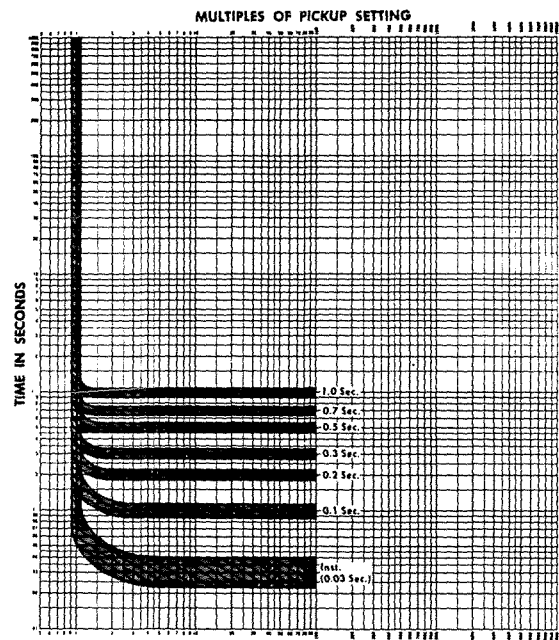
General

Used in conjunction with a circuit protective device having a shunt trip, this relay, with its sensor, will detect ground currents and cause the circuit protecting devices to open (or activate a signalling device) when these currents reach preselected values of current and time. Optional Type Z zone selective interlocking provides instantaneous tripping in each protected zone, and time delay back-up protection between zones for a fully coordinated and selective system. Two sizes of relays are available: Continuously adjustable range of 5-60 amperes; or continuously adjustable range of 100-1200 amperes. All relays except Type P have a continuously adjustable time delay range of Instantaneous (0.03) to 1.0 seconds. The time delay characteristic is flat, as shown in Fig. 4. Once settings have been selected, adjusting knobs can be clamped in position by means of the clamping bar on the face of the relay. (Fig. 5).



Figure 3

Time Current Curve GES-1635



10 1/2" x 15" Translucent Paper available for systems coordination studies. Order from GE Distribution Unit, Hoerle Bldg., Plainville, CT 06062.

Figure 4

UL LISTED RATINGS

System Input Ratings	
Primary Amps *	Min. Withstand Time
100-1200 Amp Relay	
200,000	.1 Seconds
60,000	1.0 Seconds
4,000 **	Continuous
5-60 Amp Relay	
60,000	1.0 Seconds
4,000 **	Continuous

* Through fault current, phase-to-phase or phase-to-ground.

** Except as reduced by sensor continuous current ratings below.

Sensor Single Phase Thermal Ratings	
Sensor	Continuous Current Rating
TGS0408 and TGS0808	4000 Amperes
TGS0005	2500 Amperes
TGS0002	1600 Amperes
All other sensors	3000 Amperes

Relay Output Ratings		
Max. Time	Max. Current	Max. Volts
0.25 Sec.	30 Amps	240VAC / 125VDC
Continuous	5 Amps	

Control Power

The Ground-Break system will function with a choice of control voltages for the relay and for the shunt trip coil. (See Table II.)

Monitor panels are available to match the selection of control voltage. However, a source of 120VAC, at least 200V.A. in size, is needed to test the system by connection to the test tap provided with each sensor.

Selectivity

Selectivity between upstream and downstream Ground-Break relays can be accomplished by either of two methods:

1. Time Delay Selectivity.
2. Zone Selective Interlocking.

1. Time Delay Selectivity

Time Delay Selectivity can be obtained by using Ground-Break relays without interlocking connections between relays. Using the preferred time delay steps shown in Figure 4, set each relay at least one step above the relays immediately downstream.

For any overcurrent protective devices which require more than .04 seconds of clearing time, the time delay steps should be increased by at least as much as the clearing time exceeds the .04 seconds.

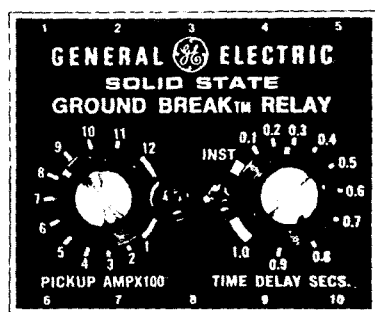


Figure 5

2. Zone Selective Interlocking

Zone Selectivity can be obtained with interlocking connections between Ground-Break relays, Type Z, (Cat. No. Suffix Z). See wiring diagram Figure 11. Time delay settings (not provided on Type P) should be determined in the same way as for Time Delay Selectivity. However, each such relay will operate instantaneously if a ground-fault occurs in its zone of protection.

If interruption is not completed in normal time, for any reason, then an interlocked upstream relay, still sensing the ground-fault, will operate at the expiration of its selected time delay if it is Type Z, but will NOT operate if it is Type P.

CAUTION

All relays in a zone selective system must operate from a single source of control voltage unless otherwise approved by the factory.

RELAYS — Ambient Range —35°C thru 80° TABLE II

Adjustable Trip Range		Relay and Shunt Trip Voltage	Cat. No. without Zone Selectivity	Cat. No. with Type Z	Cat. No. with Type P
Lo	Hi				
2A.	12A.	120/240 VAC	TGMR1	.....	.....
2A.	12A.	125 VDC	TGMR1	.....	.....
2A.	12A.	48 VDC	TGMRB	.....	.....
2A.	12A.	32 VDC	TGMRC	.....	.....
2A.	12A.	24 VDC	TGMRD	.....	.....
5A.	60A.	120/240VAC	TGSR06	TGSR06Z	TGSR06P
5A.	60A.	125VDC	TGSR06	TGSR06Z	TGSR06P
5A.	60A.	48VDC	TGSR06B	TGSR06BZ	TGSR06BP
5A.	60A.	36VDC	TGSR06C	TGSR06CZ	TGSR06CP
5A.	60A.	24VDC	TGSR06D	TGSR06DZ	TGSR06DP
100A.	1200A.	120/240VAC	TGSR12	TGSR12Z	TGSR12P
100A.	1200A.	125VDC	TGSR12	TGSR12Z	TGSR12P
100A.	1200A.	48VDC	TGSR12B	TGSR12BZ	TGSR12BP
100A.	1200A.	36VDC	TGSR12C	TGSR12CZ	TGSR12CP
100A.	1200A.	24VDC	TGSR12D	TGSR12DZ	TGSR12DP

① Shunt trip can operate at 120 or 240VAC, but relay operates from 120VAC in either case.

② A downstream relay, while sensing a ground fault above its pickup setting, will block an upstream Type Z relay only for the length of time-delay for which the Type Z relay is set, but will block an upstream Type P relay for as long as the fault is sensed by the downstream relay.

③ Not recommended for general purpose applications.

RELAY OUTLINE DIMENSIONS (Inches)

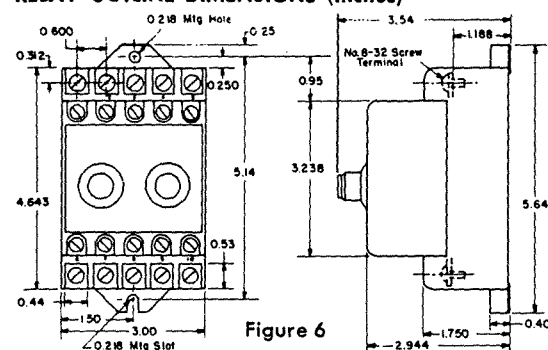


Figure 6

SYSTEM OPERATION

Recommended Relay Settings

Ground-Break relay settings of pick-up current and time-delay for main, feeder and branch circuits should be selected so as to provide optimum ground-fault protection and coordination with the conventional overcurrent devices in the distribution system. Since the ratings of the conventional devices will vary with application, no general statement can be made. However, the following recommendations are basic for satisfactory performance of most systems:

Pick-up Current

Relay pick-up current setting should be preferably 20% of circuit rating. Consideration should be given to higher settings for the purpose of having ground faults interrupted downstream by phase overcurrent devices so as to affect only the faulted circuit. Motor branch circuits may justify settings much lower.

Time Delay

The instantaneous (.03 seconds) setting generally should be used only for motor or branch circuits. Using the other preferred time delay steps shown in Figure 4, set each other relay at least one step above any relays immediately downstream.

For any overcurrent protective devices which require more than .04 seconds of clearing time, the time delay steps should be increased by at least as much as the clearing time exceeds .04 seconds.

MONITOR PANELS

A flush mounted monitor panel is a component part of the Ground-Break system. It provides the functions of monitoring and testing the Ground-Break system.

A pilot light is provided to indicate presence of control power. If the pilot light is "out", control power fuses and circuit should be checked.

There are two pushbuttons provided — red marked "Test" and yellow marked "Reset". The ground-fault lamp (red) lights or a mechanical indicator "pops out" to show that the Ground-Break relay has operated to trip a breaker/interrupter. The reset button must be pushed to reset the relay after the fault has been located before the breaker/interrupter can be reclosed, or the mechanical indicator can be manually reset.

The monitor panel has the ability to test the complete ground-break system with or without tripping the circuit protective device. Instructions for performing tests are printed on the face plate.

During the few seconds of each test operation, the monitor panel energizes the sensor test windings. This energy requirement dictates the use of a 120 VAC. test power source of at least 200 V.A. The test signal simulates a ground-fault of approximately 1600 amperes. (See Table III)

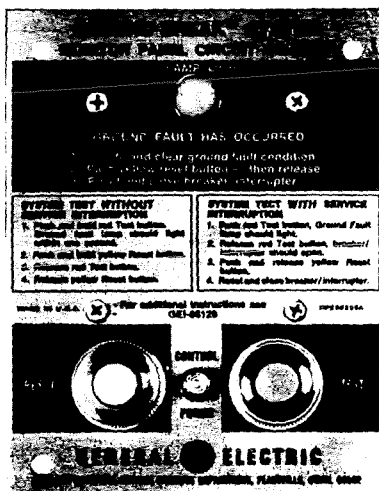


Figure 7

Monitor Panels (Cat. Nos.)	Application Voltages		Ground Fault Indicator
	Relay	Shunt Trip	
TGSMP	120VAC	120 to 240VAC	Lamp
TGSMPA	125VDC	125VDC	Lamp
TGSMPB	48VDC	48VDC	Lamp
TGSMPD	36VDC	36VDC	Lamp
TGSMPD	24VDC	24VDC	Lamp
TGSMA	120VAC	120 to 240VAC	Mechanical Indicator

MONITOR PANEL OUTLINE DIMENSIONS (Inches)

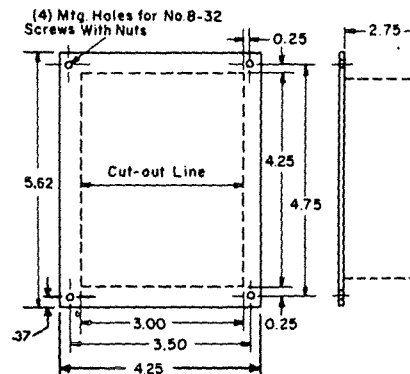


Figure 8

INSTALLATION

Mounting the Components

RELAY — See outline dimensions Figure 6. Should be surface mounted in such a position that the settings are accessible for adjustment by the operator without risk of electrical shock. Avoid mounting locations with excessive vibration or mechanical shock.

MONITOR PANEL — See outline dimensions Figure 8. — Designed to be flush mounted in such a position that the fault indication will be readily visible and pushbuttons can be operated conveniently.

SENSORS See outline dimensions page 1 and 2.

For Ground Strap Application

For the main circuit only, the Ground Strap Application is desirable if the neutral connection to ground of the service entrance is available. The sensor should be mounted to encircle only this neutral connection to ground.

For Zero Sequence Application

Sensors should be so mounted that all phase (and neutral when used) conductors pass through the sensor window. **Equipment ground conductor must not pass through the window.*** The service neutral must be grounded only on the line side of the sensor window. To minimize saturation effects, a 1-inch clearance should be maintained between phase/neutral conductors and the inside of the sensor window (except as noted on sensor outline drawings).

*Unless it also passes through window in opposite direction.

OPERATION OF SYSTEM

If a ground-fault occurs which exceeds the pick-up and time delay settings of the relay, it will energize the shunt trip or other load. The relay will remain ON (closed) to continue energizing any ground-fault signaling devices. The relay should not be reset until the cause of the ground-fault indication has been investigated and cleared. Only after the relay is reset, by operating the reset push-button, or by operating switch S1, Figures 9 and 10, will it be possible to reclose the breaker/interrupter.

TESTING THE SYSTEM

The reliability of the ground-break system is excellent. However, since testing is so convenient, it is recommended that a test be performed monthly, or after the breaker has experienced a fault of any kind.

Complete instructions on testing the ground-fault system are printed on the face of the monitor panel, Figure 7.

For wiring diagrams, see Figures 9, 10, 11, 12 and 13. Reduction of the simulated ground-fault signal below 1600 Amps (see Table III) is completely optional, but can substantially reduce the V.A. requirements of the test power source in some cases.

TABLE III

Wirewound Test Resistors

The simulated Ground-Fault Signal should be at least 20% higher than the pick-up setting of the Ground-Break Relay.

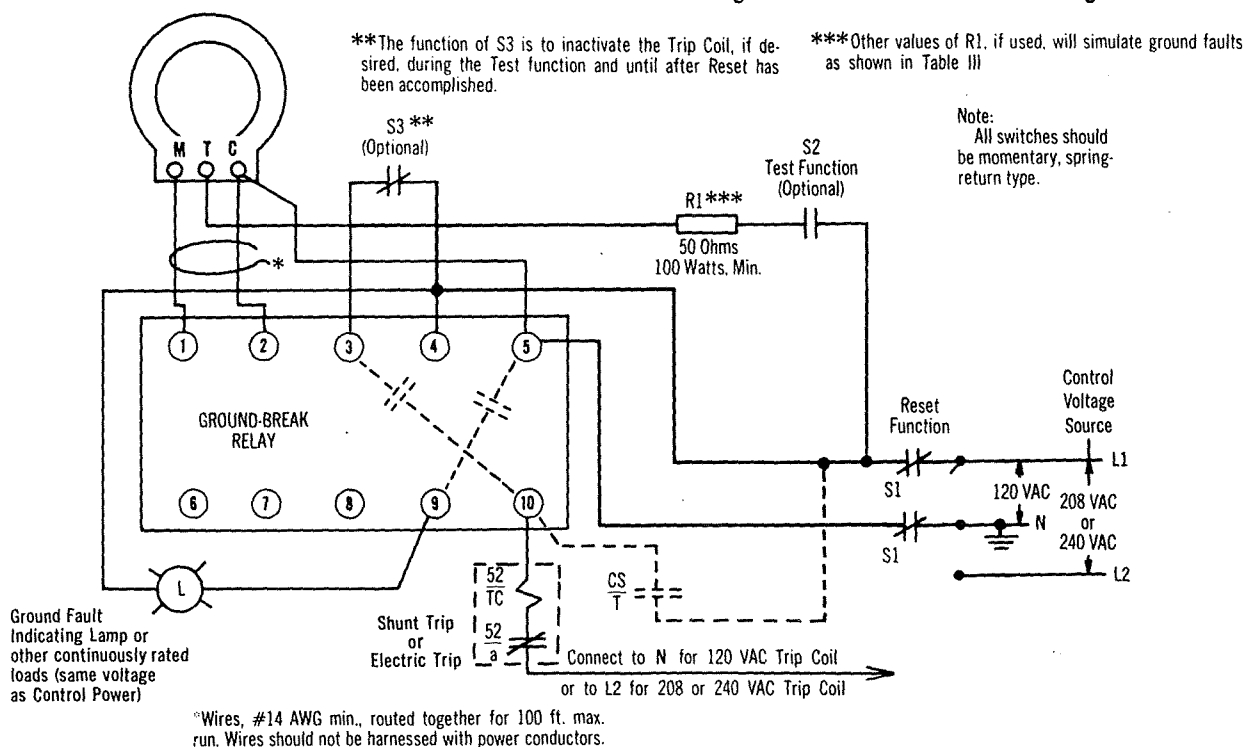
Simulated Ground-Fault Current Amperes	With Monitor Panel		Without Monitor Panel		Min. V.A. of 120 VAC Test Power Source Volt/Amps
	Add R1 Ohms	Min. Watts	Total R1 Ohms	Min. Watts	
1600	None	None	50	100	200
1200	20	50	70	100	150
1000	30	50	80	100	150
800	50	50	100	50	100
600	90	25	140	50	75
400	150	25	200	25	50
200	350	25	400	25	25
100	750	20	800	20	25
60	1400	12	1400	12	25
40	2000	8	2000	8	25
20	4000	5	4000	5	25

CAUTION

Sensors should have a shorting jumper between terminals C and M whenever the sensor is disconnected from the ground-break relay circuit, to prevent a possible shock hazard to personnel if a ground-fault should occur.

Control Wiring Insulation Tests

High voltage tests are not recommended for Ground-Break control wiring. However, if it is required, temporarily remove ground connections of control power and sensors, bond all Ground-Break relay terminals together, and apply test voltage between the bonded terminals and ground.



Wiring Diagram for Ground-Break without Monitor Panel using AC Control Voltage

Figure 9

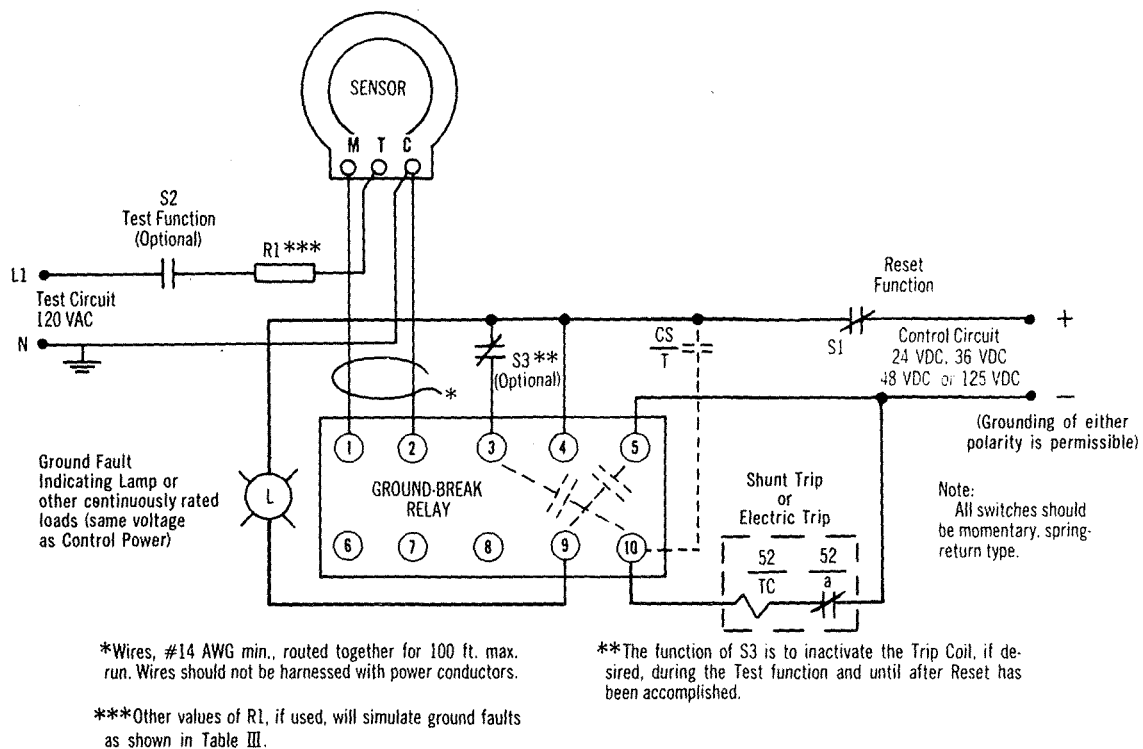


Figure 10

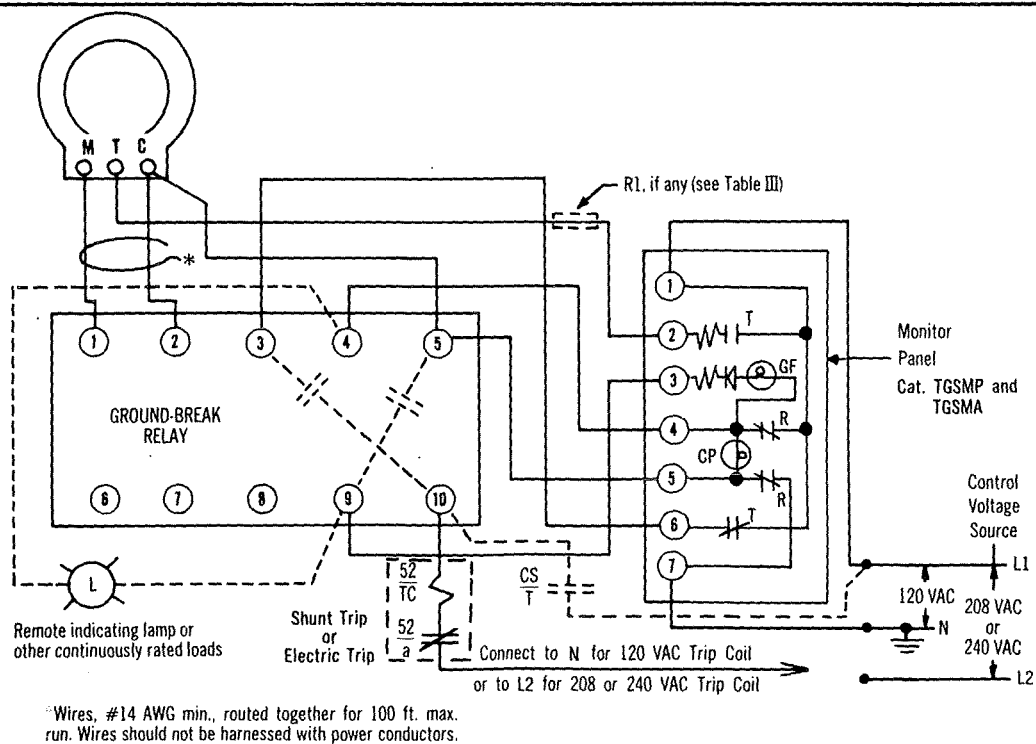
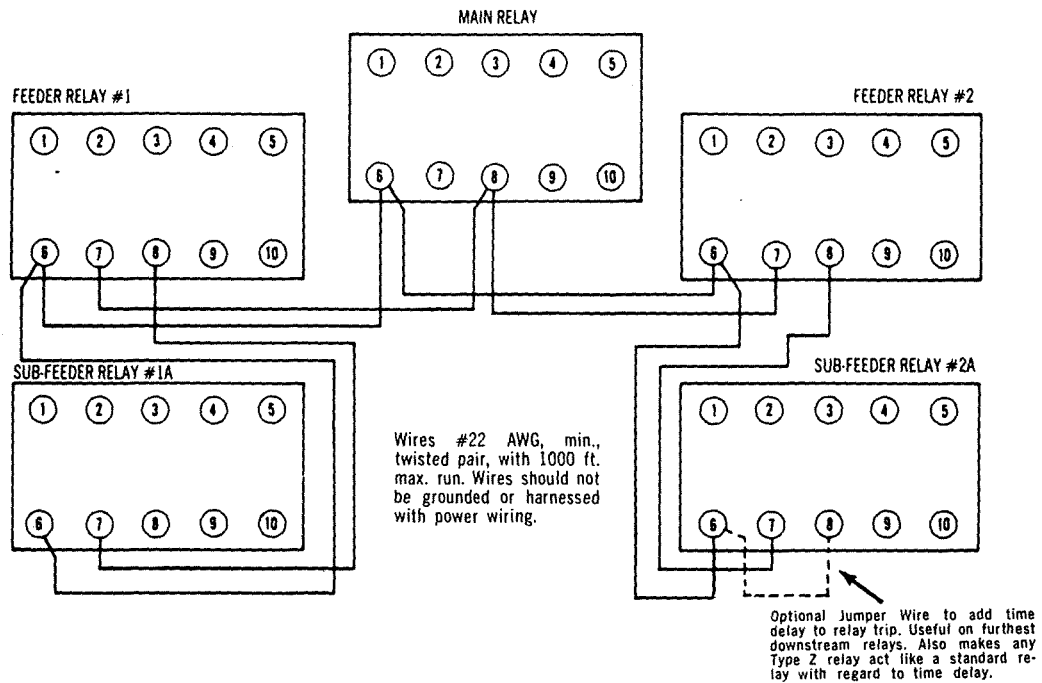
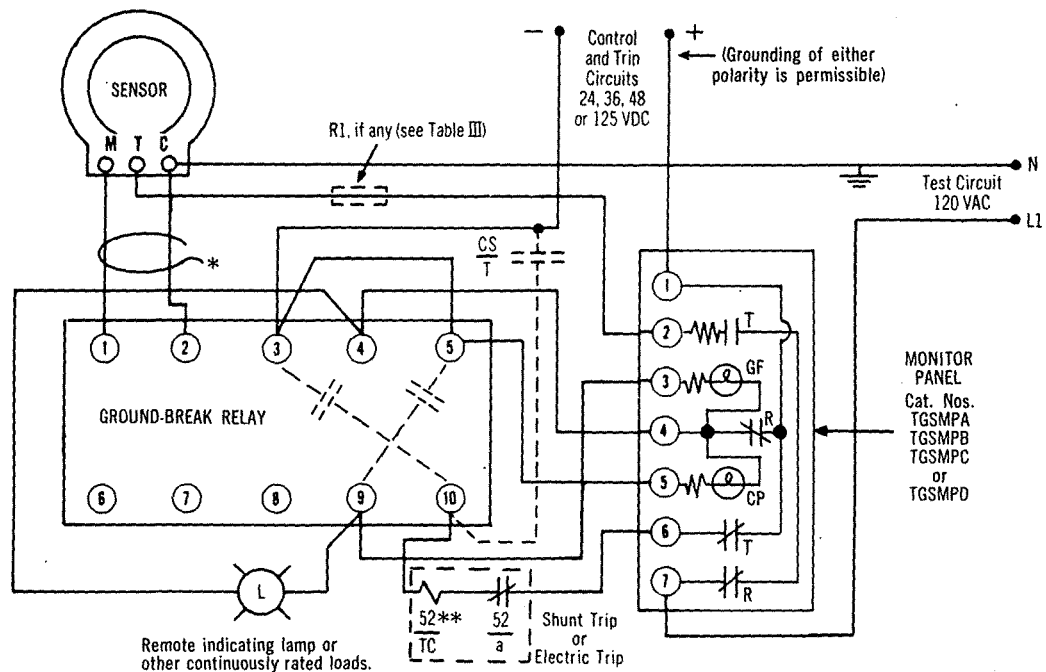


Figure 11



Typical Zone Selective Interlocking Connections for a system having a main protective device and two feeders, with each feeder having a sub-feeder.

Figure 12



*Wires, #14 AWG min., routed together for 100 ft. max. run. Wires should not be harnessed with power conductors.

**Same voltage rating as DC control circuit

Wiring diagram for Ground-Break Relay and Monitor Panel using DC control voltage

Figure 13

SENSORS (Figure 1)

GE Type TGS sensors must be used with the Ground-Break system. All sensors are electrically identical. Select each sensor so that conductors will have the required electrical and magnetic spacings to the edge of the sensor window. See Table I for a listing of the available sensors.

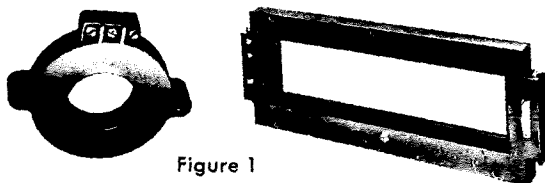


Figure 1

TABLE I — GROUND-BREAK™ SENSORS

Cat. No.	Window Size	Type Core	Wt.
ROUND (Solid Core)			
TGS0002	2½ in. I.D.	Solid	3 lbs
TGS0005	5 in. I.D.	Solid	4 lbs
TGS0008	8 in. I.D.	Solid	7 lbs
RECTANGULAR (Split Core)			
TGS0408	4 x 8 in.	Split	17 lbs
TGS0418	4 x 18 in.	Split	18 lbs
TGS0424	4 x 24 in.	Split	21 lbs
TGS0429	4 x 29 in.	Split	23 lbs
TGS0432	4 x 32 in.	Split	25 lbs
TGS0808	8 x 8 in.	Split	25 lbs
TGS0808A	8 x 8 in.	Split	20 lbs
TGS0808S	8 x 8 in.	Solid	20 lbs
TGS0810	8 x 10 in.	Split	22 lbs
TGS0818	8 x 18 in.	Split	31 lbs
TGS0824	8 x 24 in.	Split	37 lbs
TGS0832	8 x 32 in.	Split	50 lbs
TGS0838	8 x 38 in.	Split	57 lbs
TGS1113	11 x 13 in.	Split	30 lbs

SENSOR OUTLINE DIMENSIONS (Inches)

Round Sensor Dimensions							
Cat. No.	A	B	C	D	E	F	G
TGS0002	6.62	2.50	2.56	5.12	5.75	5.62	0.50
TGS0005	9.50	5.00	3.94	7.88	8.50	8.50	0.50
TGS0008	12.75	8.00	5.44	10.88	11.50	11.50	0.62

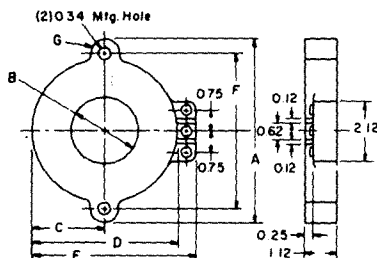


Figure 2

SENSOR OUTLINE DIMENSIONS (Inches)

Rectangular Sensor Dimensions *					
Cat. No.	No. of Mfg. Holes	A	B	C	Fig. No.
TGS0418	6	23.25	18.00	2.12	2a
TGS0424	6	29.25	24.00	5.12	2a
TGS0432	10	37.25	32.00	0.62	2a
TGS0808	6	See Outline Drawing			2b
TGS0818	6	23.25	18.00	2.12	2c
TGS0824	6	29.25	24.00	5.12	2c
TGS0832	10	37.25	32.00	0.62	2c
TGS0838	10	43.25	38.00	3.62	2c
TGS0808A	6	See Outline Drawing			2b

* Additional sizes available. Consult factory.

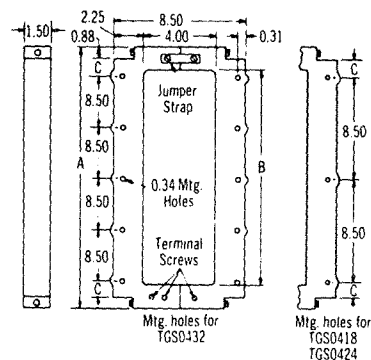


Figure 2A

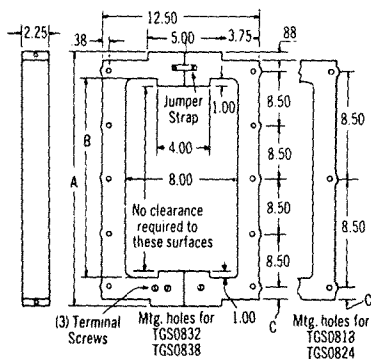


Figure 2B

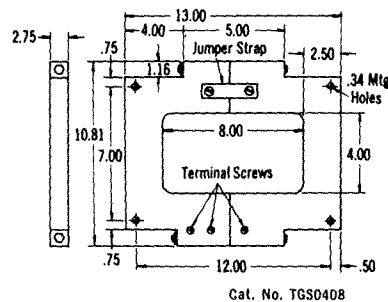


Figure 2C

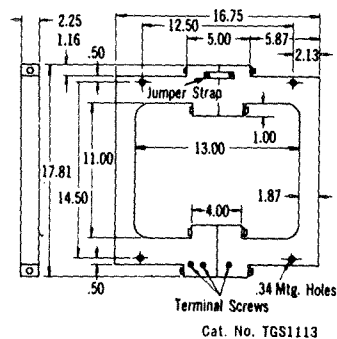
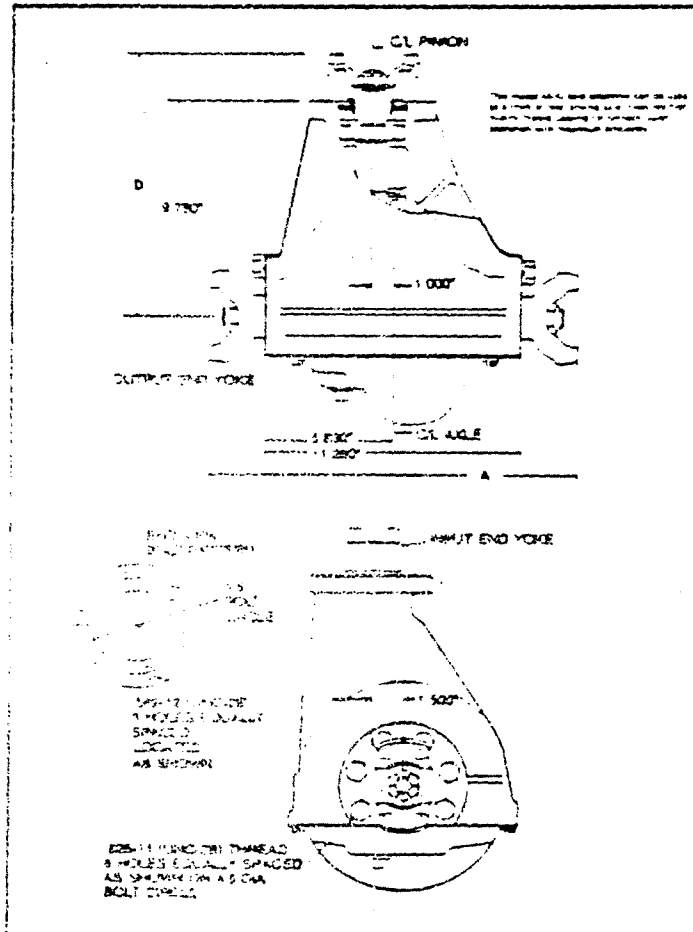


Figure 2D

MODEL 44-IC SPECIFICATIONS

Rigid Independent Carrier



GENERAL SPECIFICATIONS

Output Torque (max.): 4,400 Ft.-Lbs.
Output Torque (continuous) 1,100 Ft.-Lbs.

RATIO OPTIONS

Ratios 2.73, 3.07, 3.31, 3.54
..... 3.73, 4.09, 4.55
..... 4.89, 5.38, 5.55

GEARS:

Ring Gear Dia. 8.50 in.
Differential Standard
Optional Track-Lok Limited S&P

INPUT JOINTS:

Series	End Yoke Asst.	Connection Range Asst.	Dimension in Inches
1250/1250/1310	2-4-22B1X	—	11.306
1350	2-4-27B1X	—	11.301
1250/1310	—	2-4-28B1X	11.071

OUTPUT JOINTS:

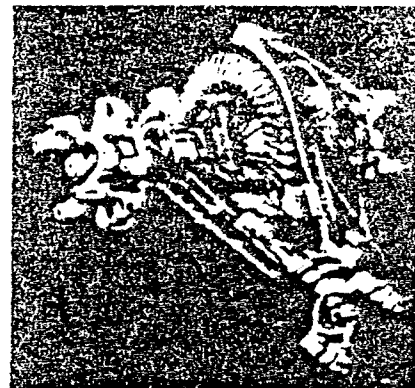
Series	End Yoke Asst.	Connection Range Asst.	Dimension in Inches
1250/1250/1310	2-4-22B1X	—	11.306
1350	2-4-27B1X	—	11.301
410	2-4-27B1X	—	11.301
1250/1310	—	2-4-28B1X	11.071
1350	—	2-4-28B1X	11.071

LUBRICATION

Capacity 3.0 Pts.

WEIGHT

Weight (dry) 80 Lbs. approximately



APPLICATION AND SPECIFICATION POLICY:

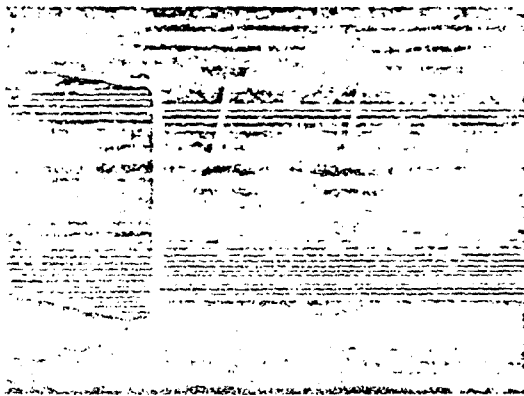
- Spicer Heavy Axle Suspension ratings and/or designs are subject to change without notice or obligation. The axle capacity rating will vary with specific applications and category of industrial service.
- Nominal carry capacity ratings are presented as a standard guide for axle selection and can be used more or less after an analysis.
- Approvals for each vehicular application must be obtained from Spicer Heavy Axle Division's Engineering Department.

BETTER ORIGINAL TO COME

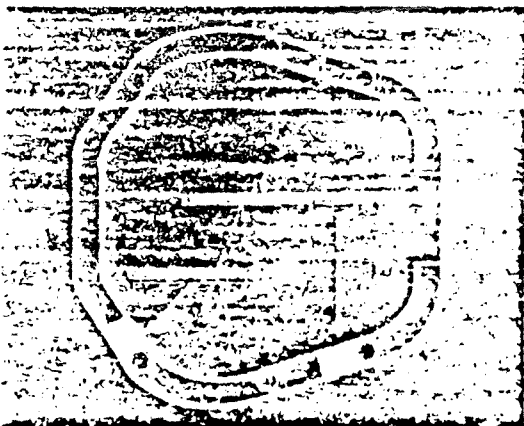
CARRIER TYPE AXLE IDENTIFICATION

Models 30, 44, 60, 70, 70HD, 7020

All Dana axles are identified with a manufacturing date and the complete part number stamped in the right hand tube. Also each axle contains a gear ratio tag; and if the axle is equipped with a limited slip differential, it will contain a tag requesting the use of limited slip lubricant.



In this figure the axle is identified with 14" float numbers stamped in the tube. For example, the numbers 11-21-248 is the manufacturing or build date of the axle and is interpreted as follows: The first number is the month, second number is the day of the month, third number is the year, the letter is the shift, and the last number is the line that built the axle. For example: November 21, 1972, First Shift, Line 18.



NOTE

In the event there are two build dates, the later will be the date in which the brake components were assembled. The number stamped next to the manufacturing date is the complete axle assembly part number and will always contain six digits, followed by a dash number. (Example 803366-2)

It is recommended that when referring to the axle, obtain the complete part number and build date. To do this, it may be necessary to wipe or scrape off the dirt, etc., from the tube.

NOTE

On industrial driving axles, the above examples can be either on the long or short tube.

SPECIAL SERVICE TOOLS

Special service tools can be obtained from the following company:

Miller Special Tool Co.
32815 Paradise
Garden City, Michigan 48135
(313) 522-6717

Gear Ratio Tag

The gear ratio tag is located at the bottom left hand side or left side of the cover plate, and is held in place with one or two cover plate screws. This tag gives the tooth combination of the ring and pinion, and also the total gear ratio.

Axles which are equipped with a limited slip differential (optional) will have a special tag stating to use proper or special lubricant. This tag is located at the bottom right hand side of the cover plate, and is held in place by one of the cover plate screws.

BETTER ORIGINAL TO COME

APPENDIX B.--FOUR HOIST SYSTEMS

The cost, cash flow tables, and the incremental rate-of-return tables for the four hoist systems are given in this appendix.

B.1 NIPPER-MATERIAL-HOIST AND LADDER-MANWAY COSTS

Capital Cost

Tugger: \$5,500

Material cage: \$1,000

Rope:

- a. Assume rope costs are incurred in year zero at \$1,700/2,100-ft spool
- b. Assume one rope change every 2 yr
Therefore $10 \text{ yr} / 2 \text{ yr} = \text{five rope changes required during study period}$
- c. Possible rope changes in 2,100 ft of wire rope:
 1. 50-ft raise: $2,100 / 50 = 42 \text{ changes}$
 2. 123-ft raise: $2,100 / 123 = 17 \text{ changes}$
 3. 200-ft raise: $2,100 / 200 = 10 \text{ changes}$
- d. Rope cost charged to hoist:
 1. 50-ft raise: $\$1,700 \times (5/42) = \$200$
 2. 123-ft raise: $\$1,700 \times (5/17) = \$500$
 3. 200-ft raise: $\$1,700 \times (5/10) = \$850$

Installation Cost

Set tugger and cage:

- a. Four men for 6 h at \$14.13/h for each move.
Installation cost = $4 \times 6 \times \$14.13 = \$339.00$
Use \$300 for each move

Usage

- a. Man-trips in terms of one-way trip for one man:

$$6 \text{ man} \times 2 \frac{\text{trips}}{\text{shift}} \times 2 \frac{\text{shifts}}{\text{day}} \times 255 \frac{\text{days}}{\text{yr}} \\ = 6,120 \frac{\text{man-trips}}{\text{yr}}$$

- b. Man-trips for supplies in terms of one-way trip for one man:

$$2 \text{ man} \times 2 \frac{\text{trips}}{\text{shift}} \times 2 \frac{\text{shifts}}{\text{day}} \times 255 \frac{\text{days}}{\text{yr}} = 2,040 \frac{\text{man-trips}}{\text{yr}}$$

- c. Supply trips in terms of one-way trip for one man:

$$2 \text{ men waiting to} \times 11 \frac{\text{trips}}{\text{shift}} \times 2 \frac{\text{shifts}}{\text{day}} \times 255 \frac{\text{days}}{\text{yr}} \\ \text{move supplies} \\ = 2 \text{ men} \times 5,610 \frac{\text{trips}}{\text{yr}} = 11,220 \frac{\text{man-trips}}{\text{yr}}$$

- d. Hours used per year:

1. 50-ft raise:

$$50 \frac{\text{ft}}{\text{trip}} \div 34 \frac{\text{ft}}{\text{min}} \times (6,120 + 2,040 \frac{\text{trips}}{\text{yr}}) \\ = 1.47 \times 8,160 = 12,000 \frac{\text{min}}{\text{yr}}$$

$$50 \frac{\text{ft}}{\text{trip}} \div 150 \frac{\text{ft}}{\text{min}} \times 11,220 \frac{\text{trips}}{\text{yr}} \approx 0.45^1 \\ \times 11,220 = 5,049 \frac{\text{min}}{\text{yr}}$$

$$\text{Total time} \\ \text{per year} = 12,000 + 5,049 = 17,049 \frac{\text{min}}{\text{yr}} = 284 \frac{\text{h}}{\text{yr}}$$

¹Assume average speed of 111 ft/min.

2. 123-ft raise:

$$123 \frac{\text{ft}}{\text{trip}} \div 34 \frac{\text{ft}}{\text{min}} \times 8,160 \frac{\text{trips}}{\text{yr}} = 29,520 \frac{\text{min}}{\text{yr}}$$

$$123 \frac{\text{ft}}{\text{trip}} \div 150 \frac{\text{ft}}{\text{min}} \times 11,220 \frac{\text{trips}}{\text{yr}} \approx 0.85^2$$

$$\times 11,220 = 9,537 \frac{\text{min}}{\text{yr}}$$

$$\text{Total time per year} = 29,520 + 9,537 = 39,057 \frac{\text{min}}{\text{yr}} = 651 \frac{\text{h}}{\text{yr}}$$

3. 200-ft raise:

$$200 \frac{\text{ft}}{\text{trip}} \div 34 \frac{\text{ft}}{\text{min}} \times 8,160 \frac{\text{trips}}{\text{yr}} = 48,000 \frac{\text{min}}{\text{yr}}$$

$$200 \frac{\text{ft}}{\text{trip}} \div 150 \frac{\text{ft}}{\text{min}} \times 11,220 \frac{\text{trips}}{\text{yr}}$$

$$= 1.33 \times 11,220 \times 14,960 \frac{\text{min}}{\text{yr}}$$

$$\text{Total time per year} = 48,000 + 14,960 = 62,960 \frac{\text{min}}{\text{yr}}$$

$$= 1,049 \frac{\text{h}}{\text{yr}}$$

Operating Cost

Nipper cost:

$$\frac{\$14.13}{\text{h}} \times 8 \frac{\text{h}}{\text{shift}} \times 2 \frac{\text{shifts}}{\text{day}} \times 255 \frac{\text{days}}{\text{yr}} = \frac{\$57,650}{\text{yr}}$$

²Assume average speed of 145 ft/min.

Power cost:

$$\frac{14 \text{ hp}}{0.7457 \text{ hp/kW}} \times \frac{\$0.035}{\text{kW-h}} \times (\text{h/yr}) = \frac{\$0.66}{\text{h}} \times \frac{\text{h}}{\text{yr}}$$

a. 50-ft raise:

$$\frac{\$0.66}{\text{h}} \times 5,049 \frac{\text{min}}{\text{yr}} \times \frac{1}{60} \frac{\text{h}}{\text{min}} = \frac{\$55}{\text{yr}}$$

b. 123-ft raise:

$$\frac{\$0.66}{\text{h}} \times 9,537 \frac{\text{min}}{\text{yr}} \times \frac{1}{60} \frac{\text{h}}{\text{min}} = \frac{\$105}{\text{yr}}$$

c. 200-ft raise:

$$\frac{\$0.66}{\text{h}} \times 14,960 \frac{\text{min}}{\text{yr}} \times \frac{1}{60} \frac{\text{h}}{\text{min}} = \frac{\$164}{\text{yr}}$$

Maintenance Cost

a. Based on usage at \$0.31/h for overhaul and \$0.49/h for field repair and lube for a total of \$0.80/h

b. 50-ft raise:

$$\frac{\$0.80}{\text{h}} \times 5,049 \frac{\text{min}}{\text{yr}} \times \frac{1}{60} \frac{\text{h}}{\text{min}} = \frac{\$67}{\text{yr}}$$

c. 123-ft raise:

$$\frac{\$0.80}{\text{h}} \times 9,537 \frac{\text{min}}{\text{yr}} \times \frac{1}{60} \frac{\text{h}}{\text{min}} = \frac{\$127}{\text{yr}}$$

d. 200-ft raise:

$$\frac{\$0.80}{\text{h}} \times 14,960 \frac{\text{min}}{\text{yr}} \times \frac{1}{60} \frac{\text{h}}{\text{min}} = \frac{\$199}{\text{yr}}$$

Ownership Costs

- a. Based on 9% of cage and tugger cost
- b. Annual cost = $0.09 \times 6,500 = \$585.00$

Miners' Lost Productive Time Cost

- a. Based on usage and miner wage of \$21.75/h
- b. 50-ft raise: $284 \text{ h/yr} \times \$21.75 = \$6,180/\text{yr}$
- c. 123-ft raise: $651 \text{ h/yr} \times \$21.75 = \$14,159/\text{yr}$
- d. 200-ft raise: $1,049 \text{ h/yr} \times \$21.75 = \$22,816/\text{yr}$

Summary of Cost

Item (cost)	Raise length		
	50 ft (\$)	123 ft (\$)	200 ft (\$)
Capital (one time)	6,700	7,000	7,400
Installation (each move)	300	300	300
Operating (annual)	57,700	57,800	57,800
Maintenance (annual)	100	100	200
Ownership (annual)	600	600	600
Lost miner time (annual)	62,000	14,200	22,800
Total annual	64,600	72,700	81,400

Cost Index Factors to Account for 11% Inflation

Year	Index Number
0	100
1	111
2	122
3	133
4	144
5	155
6	166
7	177
8	188
9	199
10	210

TABLE B-1. - Cash flow table - nipper-material-hoist
and ladder-manway cost

End of year	Condition 1 (\$)	End of year	Condition 2 (\$)	End of year	Condition 3 (\$)	End of year	Condition 4 (\$)	End of year	Condition 5 (\$)	End of year	Condition 6 (\$)	End of year	Condition 7 (\$)
0	-7,000	0	-7,000	0	-7,000	0	-7,000	0	-8,000	0	-7,000	0	-7,000
1	-81,000	1	-81,000	1	-81,000	1	-72,000	1	-91,000	1	-96,000	1	-113,000
2	-89,000	2	-89,000	2	-89,000	2	-79,000	2	-100,000	2	-106,000	2	-124,000
3	-97,000	3	-97,000	3	-97,000	3	-86,000	3	-109,000	3	-116,000	3	-136,000
4	-105,000	4	-105,000	4	-105,000	4	-94,000	4	-118,000	4	-125,000	4	-147,000
5	-113,000	5	-113,000	5	-113,000	5	-101,000	5	-127,000	5	-135,000	5	-158,000
6	-121,000	6	-121,000	6	-121,000	6	-107,000	6	-136,000	6	-144,000	6	-169,000
7	-129,000	7	-129,000	7	-129,000	7	-115,000	7	-145,000	7	-154,000	7	-180,000
8	-137,000	8	-137,000	8	-137,000	8	-122,000	8	-154,000	8	-164,000	8	-192,000
9	-145,000	9	-145,000	9	-145,000	9	-129,000	9	-163,000	9	-173,000	9	-203,000
10	-153,000	10	-153,000	10	-153,000	10	-136,000	10	-172,000	10	-183,000	10	-214,000

End of year	Condition 8 (\$)	End of year	Condition 9 (\$)	End of year	Condition 10 (\$)	End of year	Condition 11 (\$)
0	-7,000	0	-7,000	0	-7,000	0	-7,000
1	-81,000	1	-81,000	1	-81,000	1	-101,000
2	-89,000	2	-89,000	2	-89,000	2	-111,000
3	-97,000	3	-97,000	3	-97,000	3	-121,000
4	-106,000	4	-105,000	4	-105,000	4	-131,000
5	-114,000	5	-113,000	5	-113,000	5	-141,000
6	-122,000	6	-121,000	6	-121,000	6	-151,000
7	-130,000	7	-129,000	7	-129,000	7	-161,000
8	-138,000	8	-137,000	8	-137,000	8	-171,000
9	-146,000	9	-145,000	9	-145,000	9	-181,000
10	-154,000	10	-153,000	10	-153,000	10	-191,000

B.2 MAN-MATERIAL-NIPPER HOIST

Capital Cost

Tugger: \$5,500

Two-man cage: \$2,000

Guides:

- a. Assume guides moved with machine
- b. Assume 40 lb/ft channel at \$0.40/lb and two required
- c. Cost per foot = 2 pcs x 40 lb/ft x \$0.40/lb
= \$32.00/ft

Use \$35.00/ft
- d. 50-ft raise: 50 ft x \$35.00/ft = \$1,750
- e. 123-ft raise: 123 ft x \$35.00/ft = \$4,305
- f. 200-ft raise: 200 ft x \$35.00/ft = \$7,000

Rope:

- a. Rope costs are incurred in year zero at \$1,700/2,100-ft spool
- b. Assume rope change every year

Therefore, (10/1) = 10 rope changes required during study period
- c. Rope cost charged to hoist:
 - 1. 50-ft raise: 1,700 x (10/42) = \$405
 - 2. 123-ft raise: 1,700 x (10/17) = \$1,000
 - 3. 200-ft raise: 1,700 x (10/10) = \$1,700

Installation Cost

Set tugger and cage: \$300 for each move

Set channel:

- a. Assume 8 manhours/10 ft section of raise
- b. Cost per foot of raise:

$$8 \frac{\text{manhours}}{\text{ft}} \times \frac{\$2,175}{\text{h}} = \frac{\$17.40}{\text{ft of raise}}$$

- c. Cost for set and salvage assumed equal, each move will have a set cost and a salvage cost:
 1. 50-ft raise: 50 ft x \$17.40/ft = \$870
 2. 123-ft raise: 123 ft x \$17.40/ft = \$2,140
 3. 200-ft raise: 200-ft x \$17.40/ft = \$3,480

Usage

- a. Man-trips: 6,120 man-trips/yr
- b. Supply man-trips: 2,040 man-trips/yr
- c. Supply trips: 11,220 equivalent man-trips/yr
- d. Hours used per year:
 1. 50-ft raise:

$$\left(\frac{50 \text{ ft}}{111 \text{ ft/min ave}} \frac{6,120 \text{ trips/yr}}{2 \text{ man-trips}} + 2,040 + 11,220 \right) \frac{1}{60}$$

$$= 122 \frac{\text{h}}{\text{yr}}$$

2. 123-ft raise:

$$\left(\frac{123 \text{ ft}}{145 \text{ ft/min ave}} \frac{6,120 \text{ trips/yr}}{2 \text{ man-trips}} + 2,040 + 11,220 \right) \frac{1}{60}$$

$$= 231 \frac{\text{h}}{\text{yr}}$$

3. 200-ft raise:

$$\left(\frac{200 \text{ ft}}{150 \text{ ft/min ave}} \frac{6,120 \text{ trips/yr}}{2 \text{ man-trips}} + 2,040 + 11,220 \right) \frac{1}{60}$$

$$= 362 \frac{\text{h}}{\text{yr}}$$

Operating Cost

Nipper cost:

$$\frac{\$14.13}{\text{h}} \times 8 \frac{\text{h}}{\text{shift}} \times 2 \frac{\text{shifts}}{\text{day}} \times 255 \frac{\text{days}}{\text{yr}} = \frac{\$57,650}{\text{yr}}$$

Power cost:

$$\frac{\$0.66}{\text{h}} \times \frac{\text{h}}{\text{yr}}$$

- a. 50-ft raise: $\$0.66/\text{h} \times 122 \text{ h/yr} = \$80/\text{yr}$
- b. 123-ft raise: $\$0.66/\text{h} \times 231 \text{ h/yr} = \$152/\text{yr}$
- c. 200-ft raise: $\$0.66/\text{h} \times 362 \text{ h/yr} = \$239/\text{yr}$

Maintenance Cost

- a. Based on usage at $\$0.80/\text{h}$ total
- b. 50-ft raise: $\$0.80/\text{h} \times 122 \text{ h/yr} = \$97.6/\text{yr}$
- c. 123-ft raise: $\$0.80/\text{h} \times 231 \text{ h/yr} = \$184.8/\text{yr}$
- d. 200-ft raise: $\$0.80/\text{h} \times 362 \text{ h/yr} = \$290/\text{yr}$

Ownership Costs

- a. Based on 9% of cage and tugger cost
- b. Annual cost = $0.09 \times 7,500 = \$675.00$

Miners' Lost Productive Time Cost

- a. Based on usage and miner wage of \$21.75/h
- b. 50-ft raise: $122 \text{ h/yr} \times \$21.75 = \$2,654/\text{yr}$
- c. 123-ft raise: $231 \text{ h/yr} \times \$21.75 = \$5,024/\text{yr}$
- d. 200-ft raise: $362 \text{ h/yr} \times \$21.75 = \$7,873/\text{yr}$

Summary of Cost

Item (cost)	Raise length		
	50 ft (\$)	123 ft (\$)	200 ft (\$)
Capital (one time)	9,600	12,800	16,200
Installation (1st)	1,200	2,400	3,800
(each move)	2,000	4,600	7,300
Operating (annual)	57,700	57,800	57,800
Maintenance (annual)	100	200	300
Ownership (annual)	700	700	700
Lost miner time	2,600	5,000	7,900
Total annual	61,100	63,700	66,800

TABLE B-2. - Cash flow table - man-material-nipper hoist

End of year	Condition 1 (\$)	End of year	Condition 2 (\$)	End of year	Condition 3 (\$)	End of year	Condition 4 (\$)	End of year	Condition 5 (\$)	End of year	Condition 6 (\$)	End of year	Condition 7 (\$)
0	-15,000	0	-15,000	0	-15,000	0	-11,000	0	-20,000	0	-15,000	0	-15,000
1	-75,000	1	-75,000	1	-75,000	1	-70,000	1	-82,000	1	-82,000	1	-88,000
2	-83,000	2	-83,000	2	-83,000	2	-77,000	2	-90,000	2	-90,000	2	-96,000
3	-90,000	3	-90,000	3	-90,000	3	-84,000	3	-98,000	3	-98,000	3	-105,000
4	-98,000	4	-98,000	4	-98,000	4	-91,000	4	-106,000	4	-106,000	4	-114,000
5	-105,000	5	-105,000	5	-105,000	5	-98,000	5	-115,000	5	-115,000	5	-122,000
6	-113,000	6	-113,000	6	-113,000	6	-104,000	6	-123,000	6	-123,000	6	-131,000
7	-120,000	7	-120,000	7	-120,000	7	-112,000	7	-131,000	7	-131,000	7	-140,000
8	-128,000	8	-128,000	8	-128,000	8	-118,000	8	-139,000	8	-139,000	8	-148,000
9	-135,000	9	-135,000	9	-135,000	9	-125,000	9	-147,000	9	-147,000	9	-157,000
10	-143,000	10	-143,000	10	-143,000	10	-132,000	10	-155,000	10	-155,000	10	-166,000

End of year	Condition 8 (\$)	End of year	Condition 9 (\$)	End of year	Condition 10 (\$)	End of year	Condition 11 (\$)
0	-15,000	0	-15,000	0	-15,000	0	-16,000
1	-81,000	1	-71,000	1	-75,000	1	-94,000
2	-89,000	2	-83,000	2	-83,000	2	-104,000
3	-97,000	3	-85,000	3	-90,000	3	-113,000
4	-105,000	4	-98,000	4	-98,000	4	-122,000
5	-113,000	5	-99,000	5	-105,000	5	-132,000
6	-121,000	6	-113,000	6	-113,000	6	-141,000
7	-129,000	7	-113,000	7	-120,000	7	-150,000
8	-137,000	8	-128,000	8	-128,000	8	-160,000
9	-145,000	9	-127,000	9	-135,000	9	-169,000
10	-153,000	10	-143,000	10	-143,000	10	-178,000

B.3 COMPACT HOIST

Capital Cost

Itemized cost:

Safety locks (2 required)	= \$ 2,600
Gearbox	= 3,500
Differential unit	= 600
Traction unit (2 required)	= 2,600
Motor/brake unit	= 1,100
Reel/reel drive	= 1,600
Electrical system	= 9,000
Mechanical system	= 15,000
Total	<u>\$36,000</u>

Estimated costs for production units:

1 unit	= \$36,000
5 unit	= \$25,000
20 unit	= \$22,500

Wire rope cost:

- a. Assume 2,100 ft of rope purchased at \$1,700/2,100 ft in year zero, also \$20 rope preparation for each change of ropes
- b. Possible rope changes per 2,100 ft
 1. 50-ft raise: 21 changes (2 - 50-ft length)
 2. 123-ft raise: 8 changes (2 - 123-ft length)
 3. 200-ft raise: 5 changes (2 - 200-ft length)
- c. Cost of rope preparation per 2,100-ft spool
 1. 50-ft raise: 21 x 20 = \$420
 2. 123-ft raise: 8 x 20 = \$160
 3. 200-ft raise: 5 x 20 = \$100

Installation Cost

- a. Required installation time: 240 manhours or 4 men at 10, 6 h/shifts (from past experience)
- b. Installation cost: 240 x \$14.13 = \$3,391.20
= \$3,400

Usage

- a. Man-trips/yr with a 2-man cage = 3,060 trips/yr
- b. Material man-trips/yr = 2,040 trips/yr
- c. Time waiting on materials = 11,220 trips/yr
- Total equivalent 1-man trips = 16,320 trips/yr
- d. Hours used per year:

$$\frac{50 \text{ ft/trip}}{50 \text{ ft/min}} \times 16,320 \frac{\text{trips}}{\text{yr}} \times \frac{1}{60} \frac{\text{h}}{\text{min}} = 272 \frac{\text{h}}{\text{yr}}$$

$$\frac{123 \text{ ft/trip}}{50 \text{ ft/min}} \times 16,320 \frac{\text{trips}}{\text{yr}} \times \frac{1}{60} \frac{\text{h}}{\text{min}} = 669 \frac{\text{h}}{\text{yr}}$$

$$\frac{200 \text{ ft/trip}}{50 \text{ ft/min}} \times 16,320 \frac{\text{trips}}{\text{yr}} \times \frac{1}{60} \frac{\text{h}}{\text{min}} = 1,088 \frac{\text{h}}{\text{yr}}$$

Operating Cost

- a. Power cost: $5 \text{ h}/0.7457 = 6.71 \text{ kW}$ at \$0.035/kw-h
= \$0.23/h
- 1. 50-ft raise: $\$0.23/\text{h} \times 272 \text{ h/yr} = \$63/\text{yr}$
- 2. 123-ft raise: $\$0.23/\text{h} \times 669 \text{ h/yr} = \$154/\text{yr}$
- 3. 200-ft raise: $\$0.23/\text{h} \times 1,088 \text{ h/yr} = \$250/\text{yr}$

Maintenance Cost

- a. Major overhaul cost: 1/2 cost of traction unit every 1-1/2 to 2 yr
- 1. Major overhaul cost: 1,300 every 2 yr
- 2. Assume routine maintenance same as tuggers at \$0.49/h
- 3. 50-ft raise: $\$0.49/\text{h} \times 272 \text{ h/yr} = \$133/\text{yr}$
- 4. 123-ft raise: $\$0.49/\text{h} \times 669 \text{ h/yr} = \$328/\text{yr}$
- 5. 200-ft raise: $\$0.49/\text{h} \times 1,088 \text{ h/yr} = \$533/\text{yr}$

Ownership Cost

- a. Based on 9% of total production cost
- b. Annual cost: $0.09 \times \$22,000 = \$1,980 \approx \$2,000/\text{yr}$

Miners' Lost Productive Time Cost

a. Based on usage and miner wage \$21.75/h

b. 50-ft raise:

$$272 \frac{h}{yr} \times \frac{\$21.75}{h} = \$5,916 = \$6,000$$

c. 123-ft raise:

$$669 \frac{h}{yr} \times \frac{\$21.75}{h} = \$14,550 = \$14,600$$

d. 200-ft raise:

$$1,088 \frac{h}{yr} \times \frac{\$21.75}{h} = \$23,664 = \$23,700$$

Summary of Cost

Item (cost) ⁴	Raise length		
	50 ft (\$)	123 ft (\$)	200 ft (\$)
Capital (one time)	24,600	24,400	24,300
Installation (each move)	3,400	3,400	3,400
Operating (annual)	100	200	200
Maintenance (annual)	100/yr	300/yr	500/yr
(biannual)	1,300/2 yr	1,300/2 yr	1,300/2 yr
Ownership (annual)	2,000	2,000	2,000
Lost miner time (annual)	6,000	14,600	23,700
Total annual	8,200/yr 1,300/2 yr	17,100/yr 1,300/2 yr	26,400/yr 1,300/2 yr

TABLE B-3. - Cash flow table - compact hoist

End of year	Condition 1 (\$)	End of year	Condition 2 (\$)	End of year	Condition 3 (\$)	End of year	Condition 4 (\$)	End of year	Condition 5 (\$)	End of year	Condition 6 (\$)	End of year	Condition 7 (\$)
0	-28,000	0	-28,000	0	-28,000	0	-28,000	0	-28,000	0	-28,000	0	-28,000
1	-22,000	1	-22,000	1	-22,000	1	-13,000	1	-33,000	1	-41,000	1	-58,000
2	-27,000	2	-27,000	2	-27,000	2	-16,000	2	-38,000	2	-45,000	2	-67,000
3	-27,000	3	-29,000	3	-27,000	3	-16,000	3	-42,000	3	-52,000	3	-72,000
4	-32,000	4	-32,000	4	-32,000	4	-19,000	4	-45,000	4	-53,000	4	-77,000
5	-34,000	5	-34,000	5	-31,000	5	-19,000	5	-46,000	5	-60,000	5	-83,000
6	-36,000	6	-36,000	6	-36,000	6	-22,000	6	-54,000	6	-61,000	6	-91,000
7	-35,000	7	-39,000	7	-35,000	7	-21,000	7	-53,000	7	-65,000	7	-95,000
8	-41,000	8	-41,000	8	-41,000	8	-24,000	8	-62,000	8	-70,000	8	-100,000
9	-40,000	9	-44,000	9	-40,000	9	-24,000	9	-60,000	9	-74,000	9	-107,000
10	-46,000	10	-46,000	10	-46,000	10	-25,000	10	-65,000	10	-78,000	10	-116,000

End of year	Condition 8 (\$)	End of year	Condition 9 (\$)	End of year	Condition 10 (\$)	End of year	Condition 11 (\$)
0	-28,000	0	-28,000	0	-40,000	0	-29,000
1	-26,000	1	-19,000	1	-24,000	1	-28,000
2	-31,000	2	-26,000	2	-28,000	2	-28,000
3	-32,000	3	-23,000	3	-28,000	3	-33,000
4	-36,000	4	-31,000	4	-33,000	4	-38,000
5	-40,000	5	-29,000	5	-36,000	5	-42,000
6	-42,000	6	-36,000	6	-38,000	6	-44,000
7	-42,000	7	-30,000	7	-38,000	7	-44,000
8	-47,000	8	-41,000	8	-43,000	8	-49,000
9	-51,000	9	-38,000	9	-46,000	9	-53,000
10	-53,000	10	-46,000	10	-48,000	10	-55,000

B.4 ALIMAK U-500 HOIST

Capital Cost

Itemized cost:

- a. Cage/traction unit = \$55,800
 - b. Landing gates at stations = \$ 1,700 (2 required minimum)
 - c. 10-ft section of guide rail = \$1,100
 - d. Anchor hardware/10-ft section = \$200
 - e. Total guide rail assembly = \$1,300/10 ft
- } Guide rail assembly

Total capital cost: $55,800 + 2(1,700) = \$59,000$

- a. 50-ft raise: $\$1,300/10 \text{ ft} \times 50/10 = \$6,500$
- b. 123-ft raise: $\$1,300/10 \text{ ft} \times 123/10 = \$16,000$
- c. 200-ft raise: $\$1,300/10 \text{ ft} \times 200/10 = \$26,000$

Installation Cost

- a. Equipment installation:
 - 4 men at 10, 6h shifts at \$14.13
 - $240 \times \$14.13 = \$3,400$
- b. Raise preparation: 4 manhours/10 ft at 21.75/h
 - = \$87.00/10 ft
 - 1. 50-ft raise: $5 \times 87 = \$435$
 - 2. 123-ft raise: $12.3 \times 87 = \$1,070$
 - 3. 200-ft raise: $20 \times 87 = \$1,740$

Usage

- a. Man-trips/yr with a 2-man cage = 3,060 trips/yr
- b. Material man-trips/yr = 2,040 trips/yr
- c. Time waiting on materials = 11,220 trips/yr
- Total equivalent 1-man trips = 16,320 trips/yr

d. Hours used per year:

1. 50-ft raise:

$$50 \frac{\text{ft}}{\text{trip}} \times \frac{1}{90} \frac{\text{min}}{\text{ft}} \times 16,320 \frac{\text{trips}}{\text{yr}} \times \frac{1}{60} \frac{\text{h}}{\text{min}} = 151 \frac{\text{h}}{\text{yr}}$$

2. 123-ft raise:

$$123 \frac{\text{ft}}{\text{trip}} \times \frac{1}{90} \frac{\text{min}}{\text{ft}} \times 16,320 \frac{\text{trips}}{\text{yr}} \times \frac{1}{60} \frac{\text{h}}{\text{min}} = 372 \frac{\text{h}}{\text{yr}}$$

3. 200-ft raise:

$$200 \frac{\text{ft}}{\text{trip}} \times \frac{1}{90} \frac{\text{min}}{\text{ft}} \times 16,320 \frac{\text{trips}}{\text{yr}} \times \frac{1}{60} \frac{\text{h}}{\text{min}} = 604 \frac{\text{h}}{\text{yr}}$$

Operating Costa. Power cost: $10 \text{ h}/0.7457 = 13.41 \text{ kW}$ at $\$0.035/\text{kW-h}$
= $\$0.47/\text{h}$

$$1. \quad 50\text{-ft raise: } 151 \text{ h/yr} \times \$0.47/\text{h} = \$71/\text{yr}$$

$$2. \quad 123\text{-ft raise: } 372 \text{ h/yr} \times \$0.47/\text{h} = \$175/\text{yr}$$

$$3. \quad 200\text{-ft raise: } 604 \text{ h/yr} \times \$0.47/\text{h} = \$284/\text{yr}$$

Maintenance Costa. Routine maintenance cost: at $\$6.03/\text{h}$

$$1. \quad 50\text{-ft raise: } 151 \text{ h/yr} \times \$6.03/\text{h} = \$910/\text{yr}$$

$$2. \quad 123\text{-ft raise: } 372 \text{ h/yr} \times \$6.03/\text{h} = \$2,243/\text{yr}$$

$$3. \quad 200\text{-ft raise: } 604 \text{ h/yr} \times \$6.03/\text{h} = \$3,642/\text{yr}$$

b. Major overhaul: at 1% of total capital cost to repair track, drive gear, etc. Cost incurred at 5 yr

$$1. \quad 50\text{-ft raise: } (\$59,200 + \$6,500) \times 0.01 \\ = \$657 \text{ at } 5 \text{ yr}$$

$$2. \quad 123\text{-ft raise: } (\$59,200 + \$16,000) \times 0.01 \\ = \$752 \text{ at } 5 \text{ yr}$$

$$3. \quad 200\text{-ft raise: } (\$59,200 + \$26,000) \times 0.01 \\ = \$852/\text{yr}$$

Ownership Cost

- a. Based on 9% of total production cost
- b. Annual cost:
 - 1. 50-ft raise: $0.09 \times (\$65,700) = \$5,913/\text{yr}$
 - 2. 123-ft raise: $0.09 \times (\$75,200) = \$6,768/\text{yr}$
 - 3. 200-ft raise: $0.09 \times (\$85,200) = \$7,668/\text{yr}$

Miners' Lost Productive Time Cost

- a. Based on usage and miner wage \$21.75/h
- b. 50-ft raise: $151 \text{ h/yr} \times \$21.75/\text{h} = \$3,284/\text{yr}$
- c. 123-ft raise: $372 \text{ h/yr} \times \$21.75/\text{h} = \$8,091/\text{yr}$
- d. 200-ft raise: $604 \text{ h/yr} \times \$21.75/\text{h} = \$13,137/\text{yr}$

Summary of Cost

Item (cost)	Raise length		
	50 ft (\$)	123 ft (\$)	200 ft (\$)
Capital (one time)	65,700	75,200	85,200
Installation (each move)	3,800	4,500	5,100
Operating (annual)	100	200	300
Maintenance (annual) (5 yr)	900/yr 600/5 yr	2,200/yr 800/5 yr	3,600/yr 800/5 yr
Ownership (annual)	5,900	6,800	7,700
Lost miner time (annual)	3,300	8,100	13,100
Total annual	10,200/yr 600/5 yr	17,300/yr 800/5 yr	24,700/yr 800/5 yr

TABLE B-4. - Cash flow table - ALIMAK U-500 hoist

End of year	Condition 1 (\$)	End of year	Condition 2 (\$)	End of year	Condition 3 (\$)	End of year	Condition 4 (\$)	End of year	Condition 5 (\$)	End of year	Condition 6 (\$)	End of year	Condition 7 (\$)
0	-80,000	0	-80,000	0	-80,000	0	-70,000	0	-90,000	0	-80,000	0	-80,000
1	-24,000	1	-24,000	1	-24,000	1	-16,000	1	-33,000	1	-36,000	1	-48,000
2	-27,000	2	-27,000	2	-27,000	2	-17,000	2	-37,000	2	-39,000	2	-54,000
3	-29,000	3	-29,000	3	-29,000	3	-19,000	3	-40,000	3	-44,000	3	-57,000
4	-32,000	4	-32,000	4	-32,000	4	-20,000	4	-43,000	4	-46,000	4	-63,000
5	-36,000	5	-36,000	5	-36,000	5	-23,000	5	-48,000	5	-51,000	5	-68,000
6	-36,000	6	-36,000	6	-36,000	6	-23,000	6	-50,000	6	-53,000	6	-71,000
7	-39,000	7	-39,000	7	-39,000	7	-25,000	7	-53,000	7	-57,000	7	-78,000
8	-41,000	8	-41,000	8	-41,000	8	-26,000	8	-56,000	8	-62,000	8	-81,000
9	-44,000	9	-44,000	9	-44,000	9	-28,000	9	-60,000	9	-64,000	9	-88,000
10	-48,000	10	-48,000	10	-48,000	10	-32,000	10	-65,000	10	-69,000	10	-92,000

End of year	Condition 8 (\$)	End of year	Condition 9 (\$)	End of year	Condition 10 (\$)	End of year	Condition 11 (\$)
0	-80,000	0	-80,000	0	-80,000	0	-81,000
1	-29,000	1	-19,000	1	-24,000	1	-28,000
2	-32,000	2	-26,000	2	-27,000	2	-30,000
3	-34,000	3	-23,000	3	-29,000	3	-33,000
4	-37,000	4	-31,000	4	-32,000	4	-36,000
5	-41,000	5	-28,000	5	-36,000	5	-40,000
6	-43,000	6	-36,000	6	-36,000	6	-42,000
7	-46,000	7	-30,000	7	-39,000	7	-44,000
8	-49,000	8	-41,000	8	-41,000	8	-47,000
9	-52,000	9	-34,000	9	-44,000	9	-50,000
10	-57,000	10	-47,000	10	-48,000	10	-55,000

TABLE B-5. - Incremental cash flow table - nipper-material hoist and ladder manway versus material nipper hoist

End of year	Condition 1 (\$)	End of year	Condition 2 (\$)	End of year	Condition 3 (\$)	End of year	Condition 4 (\$)	End of year	Condition 5 (\$)	End of year	Condition 6 (\$)	End of year	Condition 7 (\$)
0	-8,000	0	-8,000	0	-8,000	0	-4,000	0	-12,000	0	-8,000	0	-8,000
1	+6,000	1	+6,000	1	+6,000	1	+2,000	1	+9,000	1	+14,000	1	+25,000
2	+6,000	2	+6,000	2	+6,000	2	+2,000	2	+10,000	2	+16,000	2	+28,000
3	+7,000	3	+7,000	3	+7,000	3	+2,000	3	+11,000	3	+18,000	3	+31,000
4	+7,000	4	+7,000	4	+7,000	4	+3,000	4	+12,000	4	+19,000	4	+33,000
5	+8,000	5	+8,000	5	+8,000	5	+3,000	5	+12,000	5	+20,000	5	+36,000
6	+8,000	6	+8,000	6	+8,000	6	+3,000	6	+13,000	6	+21,000	6	+38,000
7	+9,000	7	+9,000	7	+9,000	7	+3,000	7	+14,000	7	+23,000	7	+40,000
8	+9,000	8	+9,000	8	+9,000	8	+4,000	8	+15,000	8	+25,000	8	+44,000
9	+10,000	9	+10,000	9	+10,000	9	+4,000	9	+16,000	9	+26,000	9	+46,000
10	+10,000	10	+10,000	10	+10,000	10	+4,000	10	+17,000	10	+28,000	10	+48,000

End of year	Condition 8 (\$)	End of year	Condition 9 (\$)	End of year	Condition 10 (\$)	End of year	Condition 11 (\$)	Condition	Internal ROR (%)	Payback (yr)
0	-8,000	0	-8,000	0	-8,000	0	-9,000	1	80	2
1	+0	1	+10,000	1	+6,000	1	+7,000	2	80	2
2	+0	2	+6,000	2	+6,000	2	+7,000	3	80	2
3	+0	3	+12,000	3	+7,000	3	+8,000	4	56	2
4	+1,000	4	+7,000	4	+7,000	4	+9,000	5	84	2
5	+1,000	5	+14,000	5	+8,000	5	+9,000	6	187	1
6	+1,000	6	+8,000	6	+8,000	6	+10,000	7	325	1
7	+1,000	7	+16,000	7	+9,000	7	+11,000	8	<0	>10
8	+1,000	8	+9,000	8	+9,000	8	+11,000	9	115	1
9	+1,000	9	+18,000	9	+10,000	9	+12,000	10	80	2
10	+1,000	10	+10,000	10	+10,000	10	+13,000	11	83	2

TABLE B-6. - Incremental cash flow table - man and
material nipper hoist versus compact hoist
nipper-material hoist and ladder
manway versus compact hoist

End of year	Condition 1 (\$)	End of year	Condition 2 (\$)	End of year	Condition 3 (\$)	End of year	Condition 4 (\$)	End of year	Condition 5 (\$)	End of year	Condition 6 (\$)	End of year	Condition 7 (\$)
0	-13,000	0	-13,000	0	-13,000	0	-17,000	0	-8,000	0	-13,000	0	-13,000
1	+53,000	1	+53,000	1	+53,000	1	+57,000	1	+49,000	1	+41,000	1	+30,000
2	+56,000	2	+56,000	2	+56,000	2	+61,000	2	+52,000	2	+45,000	2	+29,000
3	+63,000	3	+61,000	3	+63,000	3	+68,000	3	+56,000	3	+46,000	3	+33,000
4	+66,000	4	+66,000	4	+66,000	4	+72,000	4	+61,000	4	+53,000	4	+37,000
5	+71,000	5	+71,000	5	+74,000	5	+79,000	5	+69,000	5	+55,000	5	+39,000
6	+77,000	6	+77,000	6	+77,000	6	+82,000	6	+69,000	6	+62,000	6	+40,000
7	+85,000	7	+81,000	7	+85,000	7	+91,000	7	+78,000	7	+66,000	7	+45,000
8	+87,000	8	+87,000	8	+87,000	8	+94,000	8	+77,000	8	+69,000	8	+48,000
9	+95,000	9	+91,000	9	+95,000	9	+101,000	9	+87,000	9	+73,000	9	+50,000
10	+103,000	10	+97,000	10	+97,000	10	+107,000	10	+90,000	10	+77,000	10	+50,000

End of year	Condition 8 ¹ (\$)	End of year	Condition 9 (\$)	End of year	Condition 10 (\$)	End of year	Condition 11 (\$)	Condition	Internal ROR (%)	Payback (yr)
0	-21,000	0	-13,000	0	-25,000	0	-13,000	1	415	1
1	+55,000	1	+52,000	1	+51,000	1	+66,000	2	415	1
2	+58,000	2	+57,000	2	+55,000	2	+76,000	3	415	1
3	+65,000	3	+62,000	3	+62,000	3	+80,000	4	343	1
4	+70,000	4	+67,000	4	+65,000	4	+84,000	5	620	1
5	+74,000	5	+70,000	5	+69,000	5	+90,000	6	325	1
6	+80,000	6	+77,000	6	+75,000	6	+97,000	7	233	1
7	+88,000	7	+83,000	7	+82,000	7	+106,000	8	269	1
8	+91,000	8	+87,000	8	+85,000	8	+111,000	9	410	1
9	+95,000	9	+89,000	9	+89,000	9	+116,000	10	213	1
10	+101,000	10	+97,000	10	+95,000	10	+123,000	11	520	1

TABLE B-7. - Compact hoist versus ALIMAK hoist

End of year	Condition 1 (\$)	End of year	Condition 2 (\$)	End of year	Condition 3 (\$)	End of year	Condition 4 (\$)	End of year	Condition 5 (\$)	End of year	Condition 6 (\$)	End of year	Condition 7 (\$)
0	-52,000	0	-52,000	0	-52,000	0	-42,000	0	-62,000	0	-52,000	0	-52,000
1	-2,000	1	-2,000	1	-2,000	1	-3,000	1	0	1	+5,000	1	+10,000
2	0	2	0	2	0	2	-1,000	2	+1,000	2	+6,000	2	+13,000
3	-2,000	3	0	3	-2,000	3	-3,000	3	+2,000	3	+8,000	3	+15,000
4	0	4	0	4	0	4	-1,000	4	+2,000	4	+7,000	4	+14,000
5	-2,000	5	-2,000	5	-5,000	5	-4,000	5	+2,000	5	+9,000	5	+15,000
6	0	6	0	6	0	6	-1,000	6	+4,000	6	+8,000	6	+20,000
7	4,000	7	0	7	-4,000	7	-4,000	7	0	7	+8,000	7	+17,000
8	0	8	0	8	0	8	-2,000	8	+6,000	8	+8,000	8	+19,000
9	-4,000	9	0	9	-4,000	9	-4,000	9	0	9	+10,000	9	+19,000
10	-2,000	10	-2,000	10	-2,000	10	-7,000	10	0	10	+9,000	10	+24,000

End of year	Condition 8 (\$)	End of year	Condition 9 (\$)	End of year	Condition 10 (\$)	End of year	Condition 11 (\$)	Condition	Internal ROR (%)	Payback (yr)
0	-52,000	0	-52,000	0	-40,000	0	-52,000	1	-	Never
1	-3,000	1	0	1	0	1	0	2	-	Never
2	-1,000	2	0	2	+1,000	2	-2,000	3	-	Never
3	-2,000	3	0	3	-1,000	3	0	4	-	Never
4	-1,000	4	0	4	+1,000	4	+2,000	5	<0	>10
5	-1,000	5	+1,000	5	0	5	+2,000	6	7.5	8
6	-1,000	6	0	6	+2,000	6	+2,000	7	24.8	4
7	-4,000	7	0	7	-1,000	7	0	8	-	Never
8	-2,000	8	0	8	+2,000	8	+2,000	9	<0	>10
9	-1,000	9	+4,000	9	+2,000	9	+3,000	10	<0	>10
10	-4,000	10	-1,000	10	0	10	0	11	<0	>10