HEAVY DUTY MOBILE EQUIPMENT

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1.0 SCOPE

This data sheet provides guidance for the protection, operation, inspection, and maintenance of heavy-duty mobile equipment. Such equipment is mobile; able to move with its own motor and wheels, caterpillar tracks or moving feet; and is not registered for highway use. Most of this equipment is used in mining, forestry, and heavy industry (e.g., draglines, haul trucks, front-end loaders, power shovels, drills, and wheel excavators) or logging.

The scope of this document does not include trailer-mounted equipment or cranes. Refer to Data Sheet 1-62, *Cranes*, for guidance on cranes, stackers, and reclaimers.

Other FM Property Loss Prevention Data Sheets are also applicable to protecting heavy duty mobile equipment. Apply these data sheets as appropriate; however, guidance in this data sheet supersedes that in other data sheets. This includes Data Sheets 5-4, *Transformers*; 5-19, *Switchgear*; 5-17, *Motors and Adjustable Speed Drives*; 5-31, *Cables and Bus Bars*; 7-12, *Mining and Mineral Processing*; 7-8, *Hydraulic Fluids*; 7-110, *Industrial Control Systems* and 13-7, *Gears*.

1.1 Hazard

Refer to the UTH brochure *Heavy Duty Mobile Equipment* (P0314) for information on the hazards associated with heavy duty mobile equipment.

1.2 Changes

January 2022. This document has been completely revised. Significant changes include the following:

A. Added guidance for the protection of autonomous equipment, and for equipment contingency planning.

B. Revised guidance for special protection systems to use systems that are FM Approved to *Examination Standard for Heavy Duty Mobile Equipment Protection System*, Class Number 5970, when available and appropriate.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

2.1.1 Use FM Approved equipment, materials, and services whenever they are applicable and available. When available and appropriate, use extinguishing systems FM Approved to *Examination Standard for Heavy Duty Mobile Equipment Protection Systems*, Class Number 5970. Currently there are systems with dry chemical, liquid chemical, dual (dry and wet chemical), and compressed air foam extinguishing agents.

When optical detectors (flame or infrared detectors) are used, provide “through lens supervision” because of the harsh environment of mine and construction sites. Also provide a trouble signal in the vehicle operator’s cab when the detectors are obscured, indicating the need for maintenance or cleaning. A 50% obstruction is considered an adequate threshold.

For a list of products and services that are FM Approved, see the *Approval Guide*, an online resource of FM Approvals. Figure 2.1.1-1 shows where extinguishing systems for heavy duty mobile equipment can be found in the *Approval Guide*.

2.1.2 If special protection systems are recommended, see Data Sheet 4-0, *Special Protection Systems*, and the specific data sheet for the type of system as follows (guidance in this data sheet supersedes that in other data sheets):

- Data Sheet 4-1N *Fixed Water Spray Systems for Fire Protection*
- Data Sheet 4-2, *Water Mist Systems*
- Data Sheet 4-3N *Medium and High Expansion Foam Systems*
- Data Sheet 4-7N *Low Expansion Foam Systems*
- Data Sheet 4-9 *Halocarbon and Inert Gas (Clean Agent) Fire Extinguishing Systems*
- Data Sheet 4-10 *Dry Chemical Systems*
- Data Sheet 4-11N *Carbon Dioxide Extinguishing Systems*
- Data Sheet 4-12 *Foam-Water Sprinkler Systems*

2.1.3 FM clients, submit plans for new installations or changes to existing extinguishing systems to FM for review.

Fig. 2.1.1-1. Location of extinguishing systems for heavy duty mobile equipment

2.2 Equipment and Processes

2.2.1 Smaller, More Mobile Equipment

Smaller, more mobile equipment includes drills, front-end loaders, and haul trucks (see Figure 3.1-1). Generally, these types of mobile equipment are rubber-wheeled vehicles.

2.2.1.1 Use FM Approved less hazardous hydraulic fluids where compatible with the hydraulic system.

2.2.1.2 Provide an FM Approved, fixed, automatically actuated extinguishing system to protect engine compartments with internal combustion engines and areas where non-FM Approved hydraulic fluids can be ignited. Select systems rated for site temperatures and *FM Approved to Examination Standard for Heavy Duty Mobile Equipment Protection Systems*, Class Number 5970, and include the following:

A. Provide manual system releases within the operator's compartment (including autonomous equipment with an operators' compartment) and at an outside location on the equipment readily accessible from the ground.

B. Interlock the engine, fuel, and hydraulic systems to automatically shut down with actuation of the extinguishing system. A time delay between detection and extinguishing system activation of up to 30 seconds can be incorporated.

C. Provide a connected reserve if the time delay exceeds 30 seconds. Tank(s) capacity should be the same as used for the primary tank(s).

2.2.1.3 Shield and insulate exhaust manifolds, electrical equipment, and other potential ignition sources to prevent combustible deposits from accumulating on them or them being sprayed by accidently released hydraulic fluid or fuel.

2.2.1.4 Provide a manual engine shutoff switch that is accessible from the ground and in a location not exposed by the engine compartment.

2.2.1.5 Provide at least one readily accessible 20 lb (9 kg) multipurpose dry chemical extinguisher on each vehicle.

2.2.1.6 Use explosionproof or intrinsically safe equipment for underground equipment operating where there are combustible dusts (e.g., coal mines and certain sulfide mines).

2.2.2 Large Mobile Equipment

Large mobile equipment includes power shovels (see Figure 3.1-2) and wheel excavators. This equipment can be the size of a multistory building.

2.2.2.1 In addition to recommendations 2.2.1.1 through 2.2.1.4, protect large mobile equipment as follows:

2.2.2.1.1 Use dry transformers (no oil). If dry transformers cannot be used, provide transformers with FM Approved less-hazardous fluid.

2.2.2.1.2 Protect hydraulic pumps and areas containing ignitable liquids or grease as follows:

2.2.2.1.2.1 Install in cutoff rooms with drains to a suitable location outside the vehicle.

2.2.2.1.2.2 Provide fixed automatically actuated extinguishing systems FM Approved to *Examination Standard for Heavy Duty Mobile Equipment Protection Systems*, Class Number 5970.

2.2.2.1.2.3 If the compartment walls are insulated, use closed cell non-absorbent insulation, such as foam glass. This will help prevent the insulation from becoming oil saturated.

2.2.2.1.3 Install switchgear and circuit breakers in cut-off rooms provided with automatically actuated compressed air foam extinguishing systems FM Approved to Examination Standard for Heavy Duty Mobile Equipment Protection Systems, Class Number 5970.

2.2.2.1.4 Install control equipment in a noncombustible room provided with an automatically actuated FM Approved clean agent fire extinguishing systems per Data Sheet 4-9, *Halocarbon and Inert Gas (Clean Agent) Fire Extinguishing Systems*.

2.2.2.1.5 Enclose hydraulic fluid and fuel lines of new equipment within another piping system if they are located within the body of the equipment, particularly where they pass through compartments containing ignition sources, such as electrical equipment. Drain enclosed piping systems to a suitable location outside the vehicle.

2.2.2.1.6 Provide electrical light fixtures within areas containing ignitable liquid (e.g., hydraulic oil areas) of the enclosed, gasket type that are guarded against mechanical damage.

2.2.2.1.7 Provide an audible alarm in the operator’s cab upon fire detection and/or actuation of any fixed protection system.

2.2.2.1.8 Protect electrical equipment against surges due to lightning. See Data Sheet 5-11, *Lightning and Surge Protection for Electrical Systems*.

2.2.2.1.9 Provide portable fire extinguishers throughout the equipment in accordance with Data Sheet 4-5, *Portable Extinguishers*.

2.2.2.1.10 Provide FM Approved smoke detectors or other FM Approved detection system in all important areas or compartments not having fixed protection. Design the smoke alarm system in accordance with Data Sheet 5-48, *Automatic Fire Detection* and the appropriate occupancy data sheet.

2.2.3 Draglines

2.2.3.1 Provide the following for draglines in addition to the recommendations in Section 2.2.2.

2.2.3.2 Provide automatic extinguishing system(s) for the ring-gear and center pintle area, and compartments containing non-FM Approved oil-filled transformers, circuit breakers, or hydraulic oil pumping facilities.

A. Special protection systems should be FM Approved to *Examination Standard for Heavy Duty Mobile Equipment Protection Systems*, Class Number 5970. Include a connected reserve.

B. Enclose the ring gear and pintle area to maintain a high concentration of extinguishing agent and provide flexible skirting on the exterior of the machine.

C. Automatic sprinkler protection can also be provided. Provide a minimum density of 0.20 gal/min/ft (8 mm/min) over the protected area for the ring gear and center pintle area. Protect compartments containing oil-filled transformers, circuit breakers, or hydraulic oil pumping facilities with automatic sprinklers designed in accordance with Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*; Data Sheet 3-26, Fire Protection for Nonstorage Occupancies; Data Sheet 5-4, *Transformers*; Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*; and Data Sheet 7-98, *Hydraulic Fluids*. Provide water supplies for a minimum of 10 minutes.

2.2.3.2.1 Arrange hydraulic oil pumps for safe, automatic shutdown if the protection system is activated or if there is a hydraulic system leak.

2.2.4 Autonomous Equipment

2.2.4.1 Provide the following for autonomous equipment and their supervisory systems in addition to other recommendations that apply to that type of equipment. Recommendations 2.2.1.1 through 2.2.1.5, which includes fire protection for the engine compartment, apply to haul trucks and other small mobile equipment.

2.2.4.2 Ensure the autonomous equipment controls meet the recommendations in Data Sheet 7-110, *Industrial Control Systems*.

2.2.4.3 Provide a mechanism for the remote operator to activate the on-board fire extinguishing system(s).

2.2.4.4 Provide a mechanism for the remote operator to be notified of alarm or release of the on-board fire extinguishing system, and supervisory or trouble signals from the on-board fire extinguishing system's control panel. All conditions should be promptly investigated.

2.2.4.5 Provide an all-stop system for the remote operator to bring all autonomous and semi-autonomous equipment under supervision to a halted state. Arrange it to require operator intervention to restart equipment motion.

2.2.4.6 Provide a remote stop system for all personnel in the autonomous operating zone to bring autonomous equipment within a safe range of the mobile stop device to a halted state. Operator intervention is needed to restart equipment motion.

2.2.4.7 Enable equipment to automatically and without operator intervention enter a halted state and notify the supervisory system when any of the following occur (require operator intervention to restart equipment motion):

A. Loss, degradation, or corruption of communications with the supervisory system

B. Loss of on-board electrical power

C. Activation of any fire, smoke or heat detection system or discharge of any fire extinguishing system(s)

D. When low tire inflation pressures or high tire temperatures reach dangerous levels

E. Loss of stored energy for the brake system

2.3 Operation and Maintenance

2.3.1 Smaller, More Mobile Equipment

2.3.1.1 Ensure only properly trained personnel operate heavy duty mobile equipment. Prepare detailed written operating and emergency procedures and have personnel periodically retrained and/or evaluated in these procedures. Training in emergency procedures will minimize damage through proper response. See Data Sheet 10-8, *Operators, for guidance*.

2.3.1.2 Visually check hydraulic fluid and fuel lines daily. Check fittings for tightness weekly. Pressure test hydraulic lines annually. Replace flexible hydraulic lines periodically on a programmed basis, or whenever necessary as indicated by inspection or test.

2.3.1.3 Use nonignitable cleaners where possible. Handle ignitable solvents and cleaners, if used, in FM Approved safety cans. Equip drums of these materials with FM Approved safety bungs. Follow general handling safeguards as outlined in Data Sheet 7-32, *Ignitable Liquid Operations*. Provide grounding as recommended in Data Sheet 5-8, *Static Electricity*.

2.3.1.4 Implement a thorough inspection and maintenance program for fixed extinguishing systems following manufacturer guidelines. Inspect the general condition of the extinguishing system including proper pressure at least weekly and check for free movement of the actuator mechanism at least quarterly.

2.3.1.5 Implement a housekeeping program. Develop a schedule to clean equipment of all grease, oil, and other combustible material. Use nonignitable solvents whenever possible. The service interval will depend on the nature of the operation and the rate at which material accumulates.

2.3.1.6 Park equipment in a safe location when not in use. If a fire exposure exists, use Data Sheet 1-20, *Protection Against Fire Exposure*, to determine the required safe separation distance between the exposure and the equipment. Consider the equipment as a combustible exposed building.

2.3.1.7 Provide facility fire trucks with fixed water supplies or dry chemical hand hose line systems when there is a large fleet of vehicles.

2.3.1.8 Provide a manual engine shutoff switch that is accessible from the ground and in a location not exposed by the engine compartment.

2.3.2 Large Mobile Equipment

Recommendations for smaller, more mobile equipment also apply to large mobile equipment.

2.3.2.1 Maintain high standards of housekeeping in and on the equipment. Store wiping rags in covered metal containers. Keep unnecessary combustibles (e.g., cardboard cartons) off equipment.

2.3.2.2 Establish a regular maintenance and inspection program for all equipment. Follow Data Sheet 5-4, *Transformers*; Data Sheet 5-19, *Switchgear and Circuit Breakers*; and 13-7, *Gears*. Include oil testing for oil-filled transformers and gears. Track trends and replace oils if testing indicates degradation in performance in accordance with the manufacturer's requirements.

Visually check electrical, mechanical, and hydraulic system components weekly. Replace flexible hydraulic oil lines periodically on a programmed basis, or whenever necessary as indicated by inspection. Check operating controls and all warning devices daily. At least semi-annually, inspect the equipment to ascertain its structural condition and the physical condition of all critical operating components. Make repairs as indicated by inspection. Prepare written, dated, and signed maintenance and inspection reports, and keep records available for review.

2.3.2.3 Implement an asset integrity program for key equipment in accordance with Data Sheet 9-0, *Asset Integrity*, and original equipment manufacturing (OEM) guidelines. The goals of the asset integrity program are to ensure production-critical equipment operates reliably, maintains a high degree of availability, and the end of service life is managed appropriately (i.e., asset replacement planning).

Assess criticality based on the exposure posed by the equipment breakdown scenario, which is driven by anticipated damage mechanisms and failure modes. The breakdown scenario should account for damage sustained to the equipment of origin as well as any connected or adjacent equipment, and/or buildings.

2.3.2.4 Include the following for draglines in the asset integrity program:

- Mast to boom, mast to A-frame, A-frame emergency support, and intermediate support cables
- Support cable sockets or lugs and the anchors for the support cables
- Boom and mast footings and anchors
- Rear A-frame leg welds and lugs of pins that serve as anchors for the A-frame legs
- Center pin or pintle
- Swing gear shafts
- Welded boom chord joints on non-pressurized booms
- Bolted chord joints normally have a butt plate bolted onto each end of the chords where they join. Because the bolts are holding the chords together, examine the bolts.

2.3.3 Draglines

Recommendations for smaller, more mobile equipment and large mobile equipment also apply to drag lines.

2.3.3.1 Establish procedures for proper operation of the dragline. These are established by the dragline manufacturer and posted/followed by the equipment user. Include items listed in Appendix C, Section C.12, in addition to those recommended by the manufacturer.

2.3.3.2 Create a written, dated, and signed inspection (pre-operation) checklist. Include items listed in Appendix C, Section C.13, in addition to those recommended by the manufacturer.

2.3.3.3 Ground Preparation

A. Adequately prepare the ground for the dragline. Strictly enforce operating parameters for ground condition outlined by the manufacturer. Slope the shelf area slightly away from the excavation area so the dragline will not slide into the excavation pit.

B. Ensure the ground supporting a dragline is as smooth as possible. Ensure the tub and walking shoes have full contact with the ground as point loads can cause damage to these assemblies. Remove large rocks and rock formations or cover these with fill material.

C. Ensure ramps on which draglines are walked are no greater than 10% in grade and within manufacturer's recommendations.

2.3.3.4 When it is necessary to walk a dragline, monitor the walking equipment, the temperature of the bearings, and the lubrication of bearings and gears.

2.3.3.5 Follow the manufacturer's written maintenance guidelines and amend them to fit local conditions. In addition, take the following actions:

A. Monthly, check for wear of intermediate gear meshes. Refer to Data Sheet 13-7, *Gears*, for descriptions of various types of wear.

B. Annually, test the various safety switches, including the selsyn-tie, safety valves, and pressure switches of the air system, hoist and drag limit switches, and the anti-tight line limit switch. These tests determine that the switches actuate the alarm and trip at approximate set points.

C. Perform electrical maintenance for motors and generators as described in Data Sheets 5-17, *Motors and Adjustable Speed Drives*, and 5-20, *Electrical Testing*.

D. Every six months, subject conventional gear oil samples from enclosed gear sets to a lab analysis. Some newer types of lubricants cannot be tested by conventional methods; plasma testing may be applicable. Consult the lubricant manufacturer.

E. Remove excessive accumulations of grease.

F. Annually, have qualified persons conduct nondestructive examination (NDE) of support cables and any structural members that hold the mast, boom, or A-frame. (Refer to Figures C.4-1 and C.5-1 in Appendix C.) It is not necessary to examine the entire cable. Because cables tend to break at their ends, examine them at about 2 ft (0.6 m) from the end of each cable.

G. Annually, clean and inspect gears. It may not be necessary to clean the entire gear; a portion of the gear face may be sufficient. If gears are split, give particular attention to the areas where the split edges join. It may also be appropriate to examine the cleaned area for cracks by NDE means. If unusual conditions are found, clean the entire gear and perform NDE. Clean all surface hardened gears and pinions and evaluate them by NDE annually. Refer to Data Sheet 13-7, *Gears*.

H. Annually, examine dragline walking camshafts. These camshafts support most of the weight of the machine while it is being walked. A broken camshaft can result in considerable damage to the propel assembly.

2.3.3.6 Keep oxygen and acetylene cylinder storage to a minimum: one each in service and one each in reserve. Secure and handle cylinders in accordance with the recommendations of Data Sheet 7-50, *Compressed Gases in Portable Cylinders and Bulk Storage*, making allowance for the extreme vibration present.

2.3.3.7 Keep any storage of grease, oil, and ignitable solvents on the equipment, if used, to a minimum.

2.3.3.8 Keep storage of combustibles, including in drums, a minimum 25 ft (7.6 m) from the equipment.

2.3.4 Autonomous Equipment

2.3.4.1 In addition to the previous recommendations, provide the following for autonomous equipment:

2.3.4.1.1 Daily, have a competent person(s) visually inspect the autonomous operating zone (including roads) for the following:

A. Hazardous conditions such as rocks, ruts, loose sidewalls, washouts, road deterioration, or other hazards.

B. That roads in the autonomous operating zone are within the operating parameters of the autonomous system.

2.3.4.1.2 Adapt machine speeds and operations to maintain safe operation for changes in environmental conditions such as rain, high winds, snow, dust etc.

2.3.4.1.3 Ensure safe operating temperatures and pressures in the braking and steering systems are reached prior to operating the machines.

2.3.4.1.4 Test and maintain the autonomous equipment system in accordance with the manufacturer's instructions. This includes calibration of the obstacle detection system.

2.3.4.1.5 Prevent unauthorized entry into the autonomous operating zone

2.4 Human Factor

2.4.1 Conduct cutting and welding operations in accordance with Data Sheet 10-3, *Hot Work Management*. Have a wheeled dry chemical unit immediately available during these operations.

2.4.2 Follow Data Sheet 10-7, *Fire Protection Impairment Management*, for all fire protection systems.

2.5 Continency Planning

2.5.1 Equipment Continency Planning

2.5.1.1 When an equipment breakdown would result in an unplanned outage to key site processes and systems, develop and maintain a documented, viable equipment contingency plan per Data Sheet 9-0, *Asset Integrity*. See Appendix C of that data sheet for guidance on the process of developing and maintaining a viable equipment contingency plan and for sparing, rental, and redundant equipment mitigation strategies.

In addition, include the following elements in the contingency planning process specific to the following equipment:

A. Autonomous equipment. Pre-plan to maintain mining operations if autonomous vehicle control system(s) become inoperable. Consider whether vehicles can be manually operated. If so, are adequately trained operators and living quarters available?

B. Drag line ring gears. Follow guidance in DS 7-12, *Mining and Mineral Processing*.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 General

Heavy duty mobile equipment is usually operated under hazardous conditions and is frequently remote from water supplies and public fire protection. The equipment is costly, often custom designed, and difficult to replace. Damage to the equipment can result in serious interruption or reduction of operations for an extended period.

Smaller equipment is most susceptible to engine fires from fuel and hydraulic line leaks. Refer to section 2.2.1 for a list of smaller equipment. Leaks have been ignited by hot exhaust manifolds, electrical components, or brake grids. Electrical control panels for such equipment have short-circuited and ignited combustible deposits and wiring with subsequent involvement of exposed hydraulic and fuel systems. In some cases, the vehicle's large rubber tires have become involved.

Fire spread is often so rapid that equipment operators have been unable to discharge the fire protection system prior to exiting the vehicle.

Extensive damage to smaller vehicles has occurred due to the inability or failure of the operator to take one or more of the following steps under fire conditions: (1) set the parking brakes, (2) shut off the engine, (3) manually actuate the fixed extinguishing system, (4) use portable extinguishers, and (5) summon the Emergency Response Team (ERT) and/or fire department. During a fire, there is usually not enough time for an operator to perform all these procedures; hence, there is a recommendation for automatic systems.

Extensive research on special protection systems for such equipment has been conducted by equipment manufacturers and users. In actual fire situations, facility fire trucks have occasionally proven very effective in limiting damage to these vehicles when able to reach the fire site promptly. In most situations, however, quick response is not possible due to the size of the operation.

Fig. 3.1-1. Self-propelled 190 ton (172 metric tonne) ore haul truck

On draglines, the ring gear is a potential fire hazard because of grease accumulations and the frequent cutting and welding repairs made on this equipment. The upper level is a potential fire area due to the common practice of drum storage of ignitable liquids. It may also be used for oxygen and acetylene cylinder storage for cutting and welding operations. This storage is acceptable provided the appropriate recommendations are followed.

Although larger equipment has fire hazard areas, the largest losses have been from other causes. Equipment has been severely damaged by collapse of head walls during strip mining operations. A power shovel (Fig. 3.1-2) sank while being moved over poor load-bearing terrain. Booms on draglines have collapsed from mechanical failure or operator error. A wheel excavator tipped over due to hydraulic jack rupture while being leveled. A digging ladder on a wheel excavator loosened and crashed into the stacking ladder because it was improperly secured.

Most dragline losses have been the result of structural failures, electrical defects, and collapse of the machine sitting on a supporting base. These deficiencies can be traced to poor preventive maintenance and inspection.

Many critical dragline components are subject to wear and deterioration which limit their useful life. If inspection and adjustment are neglected, these parts eventually reach a condition where they can fail, possibly causing more serious damage. Similarly, failure to replace various mechanisms and components on a regular basis can lead to unexpected downtime and possible extensive damage to the equipment. All

Fig. 3.1-2 Large excavating shovel loading a haul truck in a hard rock open pit mine

draglines in active service need to be inspected at regular intervals for proper adjustment of operating mechanisms, excessive wear of components, system cleanliness, and other operation deficiencies.

An ongoing, documented program of inspection and evaluation will minimize unscheduled downtime and equipment loss. Awareness of unusual conditions generally provides warning before a breakdown occurs. Parts wear to varying degrees depending on operating conditions; they rarely fail without giving some warning. Constant checking, especially of parts prone to extremes of wear and/or failure, will usually provide sufficient advance warning of failure.

Before starting the dragline, it is important the machine be inspected to ensure it is ready to be put into operation. Failure to perform a routine check of the machine could result in unnecessary downtime or damage. For example, an undetected oil leak in a gear case could result in a dry gearbox causing extensive mechanical problems. Broken strands in running ropes or boom structural strands, if undetected, could result in serious damage beyond that of the component.

HDME undergoes tremendous stress. Abuse, neglect, and mismanagement will damage equipment more than continuous operation and normal wear. Sound judgment should govern the operation of power equipment.

3.1.1 Autonomous Equipment

Recommendations 2.2.1.2 and 2.6.1.1 for autonomous equipment industrial control systems to meet Data Sheet 7-110, *Industrial Control Systems*, and for contingency planning for failure of the industrial control system, are critical to maintain operations. A cyber attack or other failure can stop operation of all autonomous equipment with many mines relying on autonomous haul trucks.

Other recommendations for autonomous equipment protect from on-board fires and collisions with many based on ISO 17757 (2019-07), Earth-Moving Machinery and Mining: Autonomous and Semi-Autonomous Machine System Safety. ISO 17757 can be referred to for additional information.

Autonomous haul trucks typically need a road width of at least 130 ft (40 m) with each lane approximately 50 ft. (15 m) wide. Trucks vary their travel paths by approximately 13 ft (4 m) from trucks in front of them. This reduces ruts and assists in keeping roads in good condition, but well-trained grader operators are essential.

3.2 Loss History

Between 2010 and 2019, FM clients reported 215 HDME-related losses totaling US$216.3 million. The average loss was US$1 million. Fire losses were the most frequent, representing 54% of all losses, and accounted for 50% of the total loss amount. Mechanical breakdown had the highest average loss at US$2.8 million. See details in table 3.2-1 (“Other” includes collapse, electrical breakdown, flood, lightning, riot & civil commotion, theft, and miscellaneous).

Haul trucks accounted for 29 losses totaling US$40.6 million with an average loss of US$1,400,000. The top three causes by value were fire, overturning and impact. See details in Table 3.2-2 (“Other” includes lightning and theft).

The Government of Western Australia, Department of Mines, Industry Regulations and Safety has information on incidents at mines at https://www.dmp.wa.gov.au/Safety/Mines-safety-alerts-13194.aspx. This can be searched, including for incidents involving autonomous equipment.

Table 3.2-1. FM Heavy-Duty Mobile Equipment Loss History 2010-2019

Peril	*No. of Losses*	*% Number*	*Est. Gross[1] (US$1,000)*	*% Amount*	*Average (US$1,000)*
Fire	115	53.5	104.9	50.1	0.9
Mechanical Breakdown	16	7.4	42.7	20.4	2.8
Impact	19	8.8	19.0	8.8	1.0
Overturning	20	9.3	15.9	7.4	0.8
Earth Movement (non-Earthquake)	8	3.7	9.8	4.5	1.2
Vehicle	4	1.9	7.9	3.6	2.0
Other	33	15.3	11.1	5.1	0.3
Grand Total	215	100.0	216.3	100.0	1.0

Note 1: Amounts indexed to 2021 values.

Table 3.2-2. FM Haul Truck Loss History 2010-2019

Peril	*No. of Losses*	*% Number*	*Est. Gross (US$1,000)[1]*	*% Amount*	*Average (US$1,000)*
Fire	14	48.3	18.2	44.8	1.3
Overturning	7	24.1	7.8	19.2	1.2
Impact	4	13.8	5.4	13.3	1.4
Other	4	13.8	9.2	22.7	2.3
Total	29	100	40.6	100	1.4

Note 1: Amounts indexed to 2021 values.

4.0 REFERENCES

4.1 FM

Data Sheet 1-62, *Cranes*
Data Sheet 4-0, *Special Extinguishing Systems*
Data Sheet 4-5, *Portable Extinguishers*
Data Sheet 4-9, *Halocarbon and Inert Gas (Clean Agent) Fire Extinguishing Systems*
Data Sheet 4-10, *Dry Chemical Extinguishing Systems*
Data Sheet 4-11N, *Carbon Dioxide Extinguishing Systems*
Data Sheet 5-4, *Transformers*
Data Sheet 5-8, *Static Electricity*
Data Sheet 5-11, *Lightning and Surge Protection for Electrical Systems*
Data Sheet 5-17, *Motors and Adjustable Speed Drives*
Data Sheet 5-19, *Switchgear and Circuit Breakers*
Data Sheet 5-20, *Electrical Testing*
Data Sheet 5-31, *Cables and Bus Bars*

Data Sheet 7-12, *Mining and Ore Processing Facilities*
Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*
Data Sheet 7-32, *Ignitable Liquid Operations*
Data Sheet 7-50, *Compressed Gases in Portable Cylinders and Bulk Storage*
Data Sheet 7-98, *Hydraulic Fluids*
Data Sheet 7-110,*Industrial Control Systems*
Data Sheet 10-1, *Pre-Incident and Emergency Response Planning*
Data Sheet 10-3, *Hot Work Management*
Data Sheet 10-7, *Fire Protection Impairment Management*
Data Sheet 13-7, *Gears*

FM Approvals. *Examination Standard for Heavy Duty Mobile Equipment Protection Systems*. Class Number 5970.

4.2 Others

International Standard. ISO 17757, 2019-07 *Earth-moving machinery and mining*: Autonomous and semi-autonomous machine system safety.

APPENDIX A GLOSSARY OF TERMS

Autonomous equipment: Mobile equipment that performs all operations and safety functions without operator interaction.

FM Approved: Products and services that have satisfied the criteria for FM Approval. Refer to the Approval Guide, an online resource of FM Approvals, for a complete listing of products and services that are FM Approved.

Heavy duty mobile equipment (HDME): Widely used in mining, lumbering, road building, and plant construction. Most HDME units have high pressure hydraulic systems. Larger pieces of equipment, such as power shovels, draglines, and wheel excavators, are usually electrically powered. Smaller pieces of equipment, such as logging vehicles, front-end loaders, and haulage trucks, are usually diesel powered. Some haulage trucks and drills are electrically powered or have a diesel engine powering a traction motor through an alternator.

Ignitable liquid: Any liquid or liquid mixture that is capable of fueling a fire, including flammable liquids, combustible liquids, inflammable liquids, or any other term for a liquid that will burn. An ignitable liquid is one that has a fire point.

Industrial control system (ICS):

1. General term that encompasses several types of control systems, including supervisory control and data acquisition (SCADA) systems, distributed control systems (DCS), and other control system configurations such as programmable logic controllers (PLC's), safety logic solvers often found in the industrial sectors and critical infrastructures. An ICS consists of combinations of control components (e.g., electrical, mechanical, hydraulic, pneumatic) that act together to achieve an industrial objective (e.g., manufacturing, generating, and transportation of matter or energy).

2. Collection of personnel, hardware, and software that can affect or influence the safe, secure, and reliable operation of an industrial process.

Pintle: A large pin on which the entire revolving frame of a dragline swings.

Power shovels, draglines, and wheel excavators: Used extensively in strip mining operations for removing overburden to gain access to the coal veins. This equipment may be the size of a multistory building and valued at several millions of US dollars. It consists primarily of two sections: a large upper revolving section, and a lower stationary section with several compartmented areas and a heavily greased ring-gear area between the sections. The upper level is the operating area, which normally contains the electric motors that operate the bucket or other earth-moving or earth-lifting components. The lower section may contain high-pressure hydraulic systems and usually electrical control equipment and transformers.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

January 2022. This document has been completely revised. Significant changes include the following:

A. Added guidance for the protection of autonomous equipment, and for equipment contingency planning.

B. Revised guidance for special protection systems to use systems that are FM Approved to *Examination Standard for Heavy Duty Mobile Equipment Protection System*, Class Number 5970, when available and appropriate.

April 2012. Terminology related to ignitable liquids has been revised to provide increased clarity and consistency with regard to FM's loss prevention recommendations for ignitable liquid hazards.

May 2010. Minor editorial changes were made for this revision.

March 2006. Revisions were made to clarify the fire protection requirements for large mobile equipment. Also, further detail has been provided on fixed extinguishing agents (other than dry chemical) that are currently being used in some parts of the world to protect heavy duty mobile equipment.

January 2005. Updated with editorial changes.

May 2004. The revisions were made to recommendations 2.2.1.2 and 2.2.2.7 to incorporate language regarding the current industry change to use optical flame detection rather than thermal detection as the means to actuate fixed extinguishing systems on mobile equipment.

May 2003. Minor editorial changes were made for this revision.

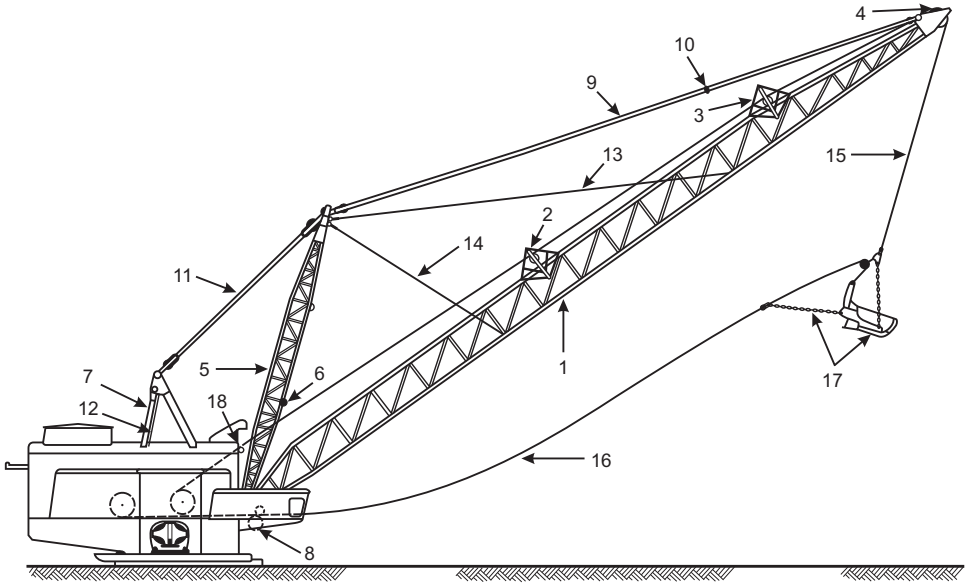
January 2000. This revision of the document has been reorganized to provide a consistent format.

APPENDIX C DESCRIPTION OF DRAGLINES

C.1 Draglines

Draglines are excavating machines, suited to excavating material below the grade on which they sit. They consist of three major units: the upper and lower sections (described above) and the front-end equipment. The front-end equipment is comprised of the A-frame, fairlead, mast, boom, running ropes, boom structural strands, and dragline bucket (See Figures C.1-1 and C.1-2).

Fig. C.1-1. Walking drag line in a strip mine



1. Boom
2. Lower tower
3. Upper tower
4. Point sheave
5. Mast
6. Deflection roller
7. A-frame
8. Fairlead
9. Upper structural strand
10. Strand diaphragm
11. Lower structural strand
12. Safety structural strand
13. Upper int. structural strand
14. Lower int. structural strand
15. Hoist rope
16. Drag rope
17. Bucket and rigging
18. Deflection roller

Fig. C.1-2. Dragline components

C.2 Electrical Equipment

Most draglines are electrically driven. Power is provided through a feeder cable to the drive mechanisms. Electrical cables to various equipment usually run in cable trays. The electric feeder cable contains a provision for a ground connection. The power line end is attached to a reliable permanent ground. The machine end is attached through a bolted connection to ground the machine frame. This provides a constant ground for the machine and electrical equipment.

C.3 Dragline Boom and Mast

There are several types of booms and masts. Some are of tubular construction with welded chord sections. Most of these are pressurized with air, which acts as a detection system for cracks. The entire length of the boom or mast is not necessarily pressurized; it may be pressurized in only one section. Some booms and masts are made of steel beams with welded chord sections. Others have steel chord sections bolted together using butt plates where the sections join. Boom and mast lengths vary, and the number of chord sections varies with boom length.

The A-frame (Figure C.3-1) is the anchor for the mast and boom structural support cables. The front legs are in compression; the rear legs are in tension. On some machines, the rear A-frame legs are also pressurized.

The A-frame (Figure C.3-1) is the anchor for the mast and boom structural support cables. The front legs are in compression; the rear legs are in tension. On some machines, the rear A-frame legs are also pressurized.

Booms are generally provided with stairways, and masts with ladders. These should be walked daily to inspect chords and lacing. Any distortion or broken paint may be an indication of a crack or other problem and should be investigated.

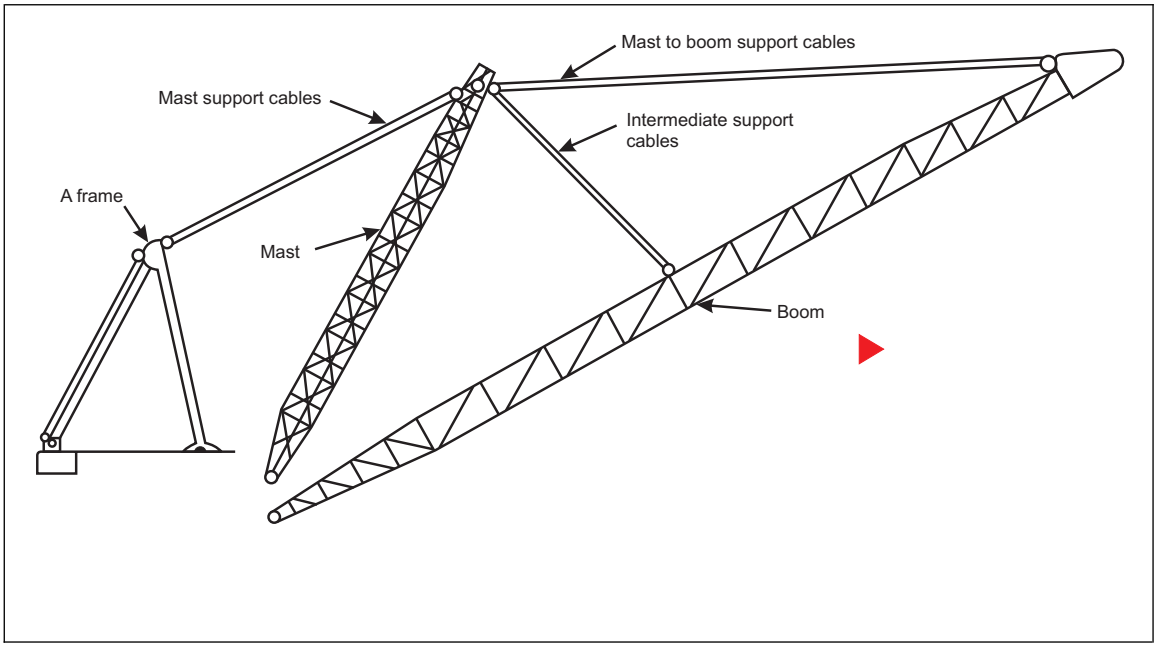


Fig. C.3-1. Dragline boom, mast, and A-frame

The structural strands of a walking dragline consist of the upper structural strands connecting the boom point to the mast head; the upper and lower intermediate structural strands connecting the boom at intermediate points to the mast head; the lower structural strands connecting the mast head to the A-frame head; and the A-frame safety structural strands connecting the A-frame head to the rotating deck.

C.4 Machinery Units

The machinery units of a walking dragline consist of the hoist, drag, swing, and propel machinery (motors, gears, and drums). All machinery units are mounted on and/or in the revolving frame. It should be noted that each motion of the hoist, drag, and swing machinery is interrelated with the others.

The hoist and drag machinery are similar. Differences are the orientation of the units in the machine, height of the pedestals and bases, and design characteristics of the drums. On many draglines, the bearings, gears, pinions, and seals are interchangeable between the hoist and drag units.

The propel machinery on the walking dragline has two different designs. On earlier machines, the propel machinery consisted of two motor pinion shafts, coupled to drive motors, which drive a common gear keyed to intermediate shafts. The intermediate shafts drive a common shaft which runs the full width of the machine. Pinions mounted on each end of this shaft drive intermediate gears. These, in turn, drive the cam shafts and cams, which are connected to the walking shoes. The motor pinion shafts and first intermediate shaft are mounted in a gear case and run in oil. The rest of the gearing is open and is lubricated by a spray lube system. (See Data Sheet 13-7, *Gears*.)

On newer machines, the propel machinery consists of two identical units, one on each side of the machine. Each unit consists of a motor pinion shaft coupled to a drive motor, which drives intermediate gears. These in turn drive the cam shaft and cams. As on older machines, the motor pinion shaft and first intermediate shafts are enclosed in a gear case and run in oil. The rest of the gear train is usually open and is spray lubricated.

The cams, cam frames, and shoes are mounted exterior to the machinery house on both designs.

C.5 Swing Timing

Unequal wear of the intermediate gear meshes is an indication of the need for adjusting the swing timing. The purpose of swing timing is to center the motor input pinion to the intermediate gears so proper axial movement can be accomplished without damage to the motor coupling and bearing or the motor input pinion support bearings. Restricting the axial flotation by improper assembly can result in bearing damage or unequal intermediate gear loading.

C.6 Selsyn-Tie

The selsyn-tie monitors the position of the shoes while the machine is being walked. If the shoes become out of synchronization during walking, the selsyn-tie will indicate the degree of misalignment on a dial in the cab. If the shoes become 10° apart in angular displacement, a warning alarm will sound. If the shoes become more than 15° apart, the propel motion will be stopped.

Serious damage can result from walking the machine on uneven ground. If one shoe is higher than the other, or one or both shoes become tilted with respect to the base, off-center loading can damage the walking cam and cam frames.

When one shoe offers no support, either by being on soft ground or by not touching the ground, the machine will rotate around that side. This will cause a twisting effect on the ground shoes as well as in the cam frame, stressing them beyond their design capabilities. Excessive stresses will also be introduced in the tub and center pintle.

C.7 Air System

The air system supplies pressurized air to the brakes, boom pressurization system, lubrication system, propel transfer switch, and miscellaneous components. The system is protected and monitored for failure by safety valves, check valves, and pressure switches. The compressed air is filtered, lubricated, and regulated as it passes through the air lines. In addition, electro-mechanical valves are located in the system to control the air to the various components. Brakes are air-released and spring set.

C.8 Anti-Tight-Line Limit Switch

Tight-line units can be installed on the machine, one switch at the boom apex and the other near the boom point. The switches will de-energize hoist and drag power whenever the hoist, drag rope, or bucket approaches the boom underside.

The arrangement consists of a wire rope drawn taut across the underside of the boom. If the hoist rope strikes the wire rope at boom point or the drag rope strikes the apex rope, the rope deflection will actuate a microswitch connected to the hoist and drag motor control circuit. Without this device, serious damage to the boom could result. For example, if the bucket is hoisted from the digging face and the drag ropes are not arranged properly or too much tension is held on drag, the bucket will be pulled up near the boom. The hoist ropes will strike the boom lacing at the deep section (center of boom). The bucket can strike the boom also. Likewise, if the bucket is hoisted to boom point with too much tension on drag ropes, the drag ropes can strike the boom lacing at the apex.

C.9 Dragline Bucket

Dragline bucket digging capacity is determined by the calculated geometry of the design. Buckets are adjustable at three points:(1) drag chain attachment, (2) hoist chain attachment, and (3) length of dump rope. (Refer to Figure C.1-4.)

Two bosses, one at each side of the bucket, are provided for connecting the drag chain. The position of the drag chain connection affects the bucket teeth angle of entry. If the drag chain is connected at the top, the bucket angle of entry is the greatest and the cutting edge is suitable for digging loose material. If the drag chain is connected at the bottom, the angle of entry is decreased with a more direct line of pull, suitable for hard digging.

The hoist chain is attached to each side of the bucket at a point to the rear of and below the center of gravity of the loaded bucket. When the distance from the center of gravity is increased, dumping response is faster,

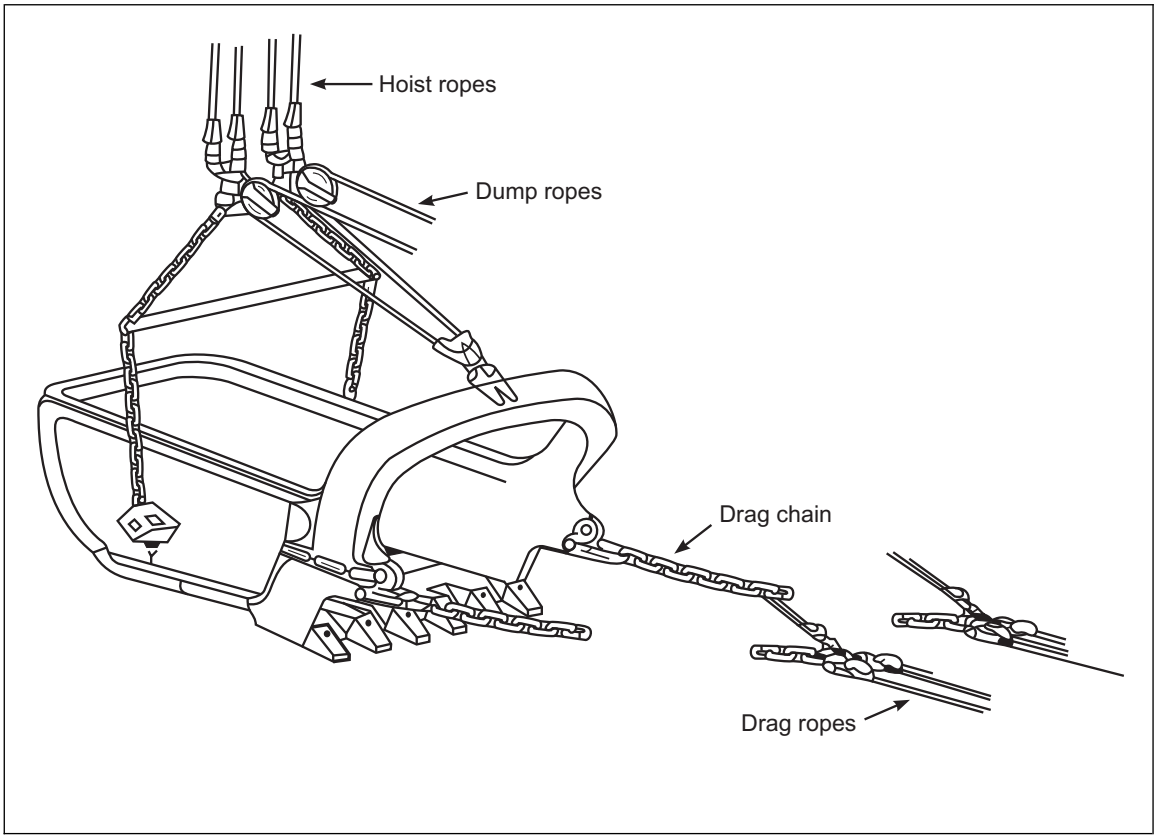


Fig. C.9-1. Dragline bucket

but the load on the dump rope is greater and the amount of tension required on the drag rope to carry the load is increased. When hoist ropes are attached near the center of gravity, the dump action is sluggish but drag rope pull is less.

C.10 Wire Rope

Wire rope is more vulnerable to abuse and neglect than most any other part of a dragline. Replacement of hoist, drag, and support ropes represents a sizeable investment, so effort should be made to extend their useful life.

Ropes of the correct size, grade, type, and construction are specified by either the equipment or rope manufacturer, who base their recommendations on actual working conditions. The maximum load carrying capacity is the primary factor when determining the diameter and material of wire rope. A minimum factor of safety of five times the working load or greater is best.

Rope functioning in static service, such as boom and bridge supports, requires little flexibility. Hoist and drag ropes need flexibility to perform repeatedly while bending, yet remain unbroken from fatigue and internal friction. The smaller and more numerous the wires, the more flexible the rope.

The proper fit of the sheave and the spiral drum groove supports the rope and prevents creating an elliptical shape as rope bends around the sheave or drum.

C.11 Maintenance

Maintenance is vital for uninterrupted operation and reduction of property loss. From an economic standpoint, it is advisable to perform as much of the upkeep as can be safely accomplished while the dragline is running. Obviously, there are some maintenance procedures, such as gear tooth inspection and replacement, which require machine shutdown. However, many support duties can be safely and effectively handled at shift change when the dragline is still activated.

Ideally, all maintenance should be approached from the preventive standpoint on a regularly scheduled basis. This approach keeps downtime to a minimum and results in reduced maintenance costs. To establish a preventive upkeep program, scheduled inspections and operators' daily reports are the most useful tools available. Scheduled inspections are usually conducted by the Mine Mechanical and Electrical Maintenance Departments. Inspection records should be explicit and complete.

C.12 Operating Procedures

The following is a list of proper operating procedures to be posted by the equipment user. This list is intended to supplement a list established by the equipment manufacturer.

1. Conduct digging under the boom point (center of gravity).
2. Conduct swing cycles smoothly.
3. Ensure only one operator is in charge when propelling the machine.
4. Do not return the swing until the bucket is free of material.
5. To prevent roll-up, do not pull the bucket too close to the machine.
6. Avoid tight lining to prevent damage to the drive system and boom.
7. Lift the bucket before walking the machine.
8. Check excessive sparking at motor and motor-generator (M-G) set brushes.
9. Check hoist, drag, swing and propel machinery for unusual sounds and overheated bearings.
10. Ensure the ropes (cables) do not become crossed on the drums.
11. Check the boom air pressure gauge frequently. Investigate any drop in air pressure. Correct all air leaks.
12. Monitor the selsyn-tie dials (gauges) for drag and hoist behavior and walking action.
13. Ensure all internal and external work areas of the dragline are well lighted at all times.

C.13 General Inspection

Proper inspection is vital for uninterrupted operation and prevention of property loss. Two important areas of preventive maintenance are adequate lubrication and alignment of moving parts. Conduct the following inspections at regular intervals:

1. Check the area around the mast and boom footpins for cracks, deformity, excessive wear, and proper lubrication.
2. Check the fairlead assembly for damage and proper lubrication.
3. Inspect the base (tub) assembly for damage. Check the roller circle and swing rack for proper lubrication and damage. Remove any foreign objects. Perform housekeeping tasks, such as cleanup of spent lubricants.
4. Walk out to the bucket along the drag rope, checking for signs of damage. Inspect the bucket itself for missing or damaged teeth and cracks. Also check the rigging and connections to the bucket for damage.
5. Check the walking shoes and cam assembly for structural damage and evidence of proper lubrication.
6. Check the position and connection of the power cable. Relocate it if it would be subject to damage by rocks or traffic.
7. Ensure the inspection includes climbing the boom and mast catwalks and checking for damage. Note the condition of the boom chords, lacing and gussets.
8. Check the motors, M-G sets and commutators for foreign material. Keep the M-G sets and motors clean.
9. Verify the oil levels for the gear cases, the compressor, and the M-G set bearing pedestals. Also, check these areas for oil leaks. Repair as required.

10. Check the open gears in the gear trains for good lubricant film on the teeth. Adjust lubricant requirements as needed.

11. Check drag and hoist drums and ropes for wear. Common forms of wear to wire rope include: broken wires, corrosion, reduction in diameter, mechanical distress, and abrasion. Also, check the rope for adequate lubrication.

12. Inspect all electrical accessories to ensure they are securely mounted and properly adjusted.

13. Check the automatic lubrication system to verify that all points serviced by the system are properly lubricated. Check all lubricant supplies.

14. Check all operating controls for freedom of movement. Ensure controls work freely without binding.

15. Clean the windows in the cab to provide an unobstructed view in all directions.

16. Ensure all guards are in place.

APPENDIX D BIBLIOGRAPHY

Mine and Mill Equipment Costs. An Estimator's Guide 2009. Spokane Valley, WA: CostMine InfoMine USA, Inc.