Maintainability Design Checklist

The following is a Maintainability Design Checklist for coal mining equipment. The purpose of the checklist is to provide a summary of design review points for the maintainability assessment of new or existing underground equipment. It specifically focuses on the identification of equipment design features, tasks, or procedures that impact equipment downtime, repair costs, labor hours and maintainer skill level requirements.

Some checklist points are general in nature. The checklist was designed to be used across all categories of underground equipment. The intent is to draw attention to design features and maintenance procedures that will increase maintainability requirements. You are encouraged to adapt this checklist to site specific or machine specific requirements by:

- Inserting specific performance criteria for various categories of maintenance tasks. For example; all hydraulic lines on a shuttle car should be replaceable in 15 minutes or 25 minutes, etc.
- Adding or deleting checklist items for different categories of equipment. You would include environmental control equipment, for example, on face equipment and not on shuttle cars or man trips.
- Adding additional checklist items based on site or equipment specific maintenance histories or experience, company maintenance standards, or other factors.

Some important checklist definitions include:

- ***Primary Maintenance Zone*** - The zone or area from the side or the end of a mining machine inward 45 cm (18 in).
- ***Secondary Maintenance Zone*** - The area from a point 45 cm (18 inches) from the side or end of the machine to a point 45 cm (18 in) from the opposite side or end of the machine.
- ***Tertiary Maintenance Point*** - A maintenance point outside the primary and secondary maintenance zone. An example would be a lubrication point on the end of a conveyer boom.
- ***Immediately Accessible*** - A component that you can reach, removed or repaired without having to open access covers, remove other components, or disassemble other components.
- ***Maintenance Point*** - Any point on the machine where you join two components, mount a component on the machine chassis, or where you attach hoses, cables and lines to a component.

The checklist categories include:

1. General Maintenance Reduction
2. Safety and Environmental System Design Features
3. Design Standardization Features
4. Design Features for Routine Maintenance
5. Design Features for Troubleshooting
6. Design Features for Repair and Replacement
7. Visual Inspections and Accessibility
8. Design for Physical Accessibility
9. Hydraulic System Maintenance Design
10. Mechanical System Maintenance Design
11. Electrical System Maintenance Design
12. Personal Protective Equipment Maintenance
13. Design for Mechanical Safety
14. Storage Battery Maintenance

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1. General Maintenance Reduction

ADEQUATE		
YES	NO	
9	9	Hydraulic hoses, electrical cables, and water hoses are securely attached along their length to protect against abrasive wear, pinching, or other damage.
9	9	All cables and hoses are protected to minimize exposure to impact or fall of roof damage.
9	9	Power feed cables enter the machine or the cable reel from the side to minimize exposure to vehicle wheels or tracks.
9	9	All components, systems, and devices are located where they are protected from fall of roof damage.
9	9	All exterior mounted machine features and components are protected from impact, scraping, or collision damage.
9	9	Operator controls and displays are protected from impact, fall of roof damage, or inadvertent activation.
9	9	Components subject to wear are designed for self-adjustment where possible.
9	9	Where self-adjustment is not practical, the design provides components that can be manually adjusted for wear to minimize the need to tear down.
9	9	Design provides for a self-lubricating system for all bearings, joints, and other wear points on the machine.

1. General Maintenance Reduction (cont.)

ADEQUATE YES	ADEQUATE NO	
9	9	Design provides for bearings and seals with wear or failure monitoring capability to permit scheduling of maintenance prior to actual component failure or component damage.
9	9	Design provides hour meters (e.g., on conveyer circuits), volt meters and ammeters (e.g., on electric drive motors) to assist in wear assessment and maintenance management.
9	9	Design provides for gears, bearing, hydraulic cylinders, and other impact or load-absorbing components of sufficient size or rating to handle peak impact loads.
9	9	Design provides for adequate derating for bearings, motors, and hydraulic systems to minimize overload related failures.
9	9	Vehicle frame is adequately designed to prevent cracking or other fatigue-induced failures at *hydraulic cylinder* attachment points.
9	9	Vehicle frame is adequately designed to prevent cracking or other fatigue-induced failures at *articulation points*.
9	9	Vehicle frame is adequately designed to prevent cracking or other fatigue-induced failures at *other frame load-bearing points*.
9	9	Vehicle frame is adequately designed to prevent cracking or other fatigue-induced failures at *welded seams*.
9	9	Provides for shock and vibration isolation of critical components.

1. General Maintenance Reduction (cont.)

ADEQUATE YES	ADEQUATE NO	
9	9	Protective covers are over all body cavities containing components, hoses, lines, or maintenance points to prevent buildup of muck and debris.
9	9	Interlocks are provided to prevent vehicle from being trammed or moved with *stab jacks* extended.
9	9	Interlocks are provided to prevent vehicle from being trammed or moved with *drill booms* deployed or extended.
9	9	Interlocks are provided to prevent vehicle from being trammed or moved with *tail booms* extended.
9	9	Interlocks are provided to prevent vehicle from being trammed or moved with *Automated Temporary Roof Supports (ATRS)* extended.
9	9	Interlocks are provided to prevent vehicle from being trammed or moved with *cutting heads* deployed or extended.
9	9	Interlocks are provided to prevent vehicle from being trammed or moved with *canopies* extended.
9	9	Expanded metal grating is used for floors or other designs to prevent accumulation of water, mud, and other materials in equipment bays, crevices, and body cavities.
9	9	Rubber tires are protected by fenders, bumpers, or guards from collision and rib impact.

1. General Maintenance Reduction (cont.)

ADEQUATE		
YES	NO	
9	9	Mechanical linkage systems are protected from impact and fall of roof.
9	9	Roof bolter geometry is designed to prevent over elevation damage to boom lift mechanism.
9	9	Disc and drum-type brake systems and components are protected from coal dust, rock, and other debris to minimize wear and damage.
9	9	Mounting holes and brackets are designed to permit installation of functionally similar parts produced by different manufacturers.
9	9	_____
9	9	_____

2. Safety And Environmental System Design Features

ADEQUATE YES	ADEQUATE NO	
9	9	*MSHA-required lighting* equipment is properly installed and protected, but easily accessed for repair.
9	9	*Fire suppression system* is properly installed and protected, but easily accessed for repair.
9	9	*Panic bars* are properly installed and protected, but easily accessed for repair.
9	9	*Methane detectors* are properly installed and protected, but easily accessed for repair.
9	9	Dust bins and filters are easily accessed, opened, and serviced.
9	9	Dust control water spray nozzles are easily accessed for adjustment or replacement.
9	9	Dust control equipment fan motors are readily accessed for repair or replacement.
9	9	_____
9	9	_____

3. Design Standardization Features

Design provides for standardization of the following items throughout the machine:

ADEQUATE		
YES	NO	
9	9	All mechanical components.
9	9	Hydraulic connectors, valves, hoses.
9	9	Electrical components and connectors.
9	9	Water hoses and connectors.
9	9	Fasteners and other attachment devices.
9	9	Bolts, nuts, and fasteners.
9	9	_____
9	9	_____

4. Design Features For Routine Maintenance

ADEQUATE YES	ADEQUATE NO	
9	9	Fluid-level indicators are provided on fluid reservoirs and in the primary maintenance zone for ease of inspection.
9	9	Test points for stand-alone or built-in test equipment are located in the primary maintenance zone.
9	9	All mechanical adjustment points are located in primary maintenance zones.
9	9	Quick connect type couplers are installed on frequently changed hydraulic lines, water hoses, and cables.
9	9	Quick-release fasteners are used on doors or covers for routine inspection points.
9	9	Only one type of hydraulic fluid is used on the machine.
9	9	Oil seals are easy replaceable types.
9	9	Routine service points are not located behind other components or structural members, in enclosed spaces, or in the secondary maintenance zone (e.g., more than 46 cm (18 in) from the side or the end of the machine).

4. Design Features For Routine Maintenance (cont.)

Routine inspection points are all clearly visible and labeled including:

ADEQUATE YES	ADEQUATE NO	
9	9	Relief valves.
9	9	Drain plugs.
9	9	Wear points.
9	9	Hydraulic line connections.
9	9	Personnel safety equipment.

Routine service points are clustered in one or two service locations in the primary maintenance zone including:

ADEQUATE YES	ADEQUATE NO	
9	9	Lube points.
9	9	Hydraulic reservoir tank fill points.
9	9	Hydraulic filters.
9	9	Environmental system filters.
9	9	Fuel tanks on diesel-powered equipment.

4. Design Features For Routine Maintenance (cont.)

9 9 Belt or chain adjustments.

9 9 Line bleed valves.

Design reduces to a minimum the number of spare parts and components required to support maintenance:

ADEQUATE
YES NO

9 9 Common hoses.

9 9 Connectors.

9 9 Valves.

9 9 Drive belts, chain, etc.

9 9 Cables.

9 9 Nuts and bolts.

9 9 Washers.

9 9 _____

9 9 _____

5. Design Features For Troubleshooting

ADEQUATE YES	ADEQUATE NO	
9	9	General layout facilitates visual inspection of major components, connections, couplers, interfaces, and potential damage points.
9	9	Hydraulic, electrical, and mechanical system schematics permanently affixed to machine to facilitate troubleshooting.
9	9	Hydraulic, electrical, and other systems can be easily traced throughout the machine.
9	9	All mechanical interfaces are visible from the sides or end of the machine.
9	9	Manual test points are located in the primary maintenance zone for all critical systems or subsystems.
9	9	Test points are designed to eliminate or minimize the need to remove components for testing.
9	9	Locate test points in one or two locations where practical or in a single test panel.
9	9	Test points are coded or labeled to identify recommended or acceptable pressure, temperature, or voltage ranges.
9	9	Test points are labeled and are located close to the control or display they are associated with.
9	9	Test set instructions for built-in test equipment (BITE) are attached to the machine at the point of service.

5. Design Features For Troubleshooting (cont.)

ADEQUATE
YES NO

9 9 Automatic test equipment (ATE) sensors are provided that operate without disturbing or loading the system under test.

9 9 Fail-safe design for all ATE where failure of test equipment will not cause failure of the mining machine.

General design and layout provides for rapid and positive identification of component malfunction:

ADEQUATE
YES NO

9 9 Fluid leaks.

9 9 Pressure loss.

9 9 Shorts.

The following pertinent information is immediately available to the maintainer:

ADEQUATE
YES NO

9 9 Component or system identification.

9 9 Proper direction of motion or fluid flow.

9 9 Proper adjustment, pressure level, or setting.

9 9 Correct fluids.

9 9 Amperage and other electrical information.

5. Design Features For Troubleshooting (cont.)

Self-checking features are designed into critical components or systems where possible:

ADEQUATE

YES	NO	
9	9	Major hydraulic systems.
9	9	Cooling systems.
9	9	Electrical circuits.

Built-in test capability and/or test equipment provided to monitor wear on critical bearings or other wear points such as:

ADEQUATE

YES	NO	
9	9	Continuous miner cutter head.
9	9	Gathering arms.
9	9	Articulation bearings on scoops.
9	9	Hydraulic pumps.
9	9	_____
9	9	_____

6. Design Features For Repair And Replacement

ADEQUATE

YES	NO	
9	9	All areas of the machine are designed to be self-cleaning and designed to eliminate (minimize) the accumulation of rock, coal, mud, and water.
9	9	All components are labeled to positively identify part number-type, component ratings, types of lubricant-fuel required, direction of flow, and other pertinent information.
9	9	All components and interfaces are designed to be installed only one way - the correct way.
9	9	Design eliminates the need for special tools or jigs to perform required maintenance.
9	9	All major parts used are available from local suppliers or vendors.
9	9	All mounting bolts are directly accessible and unobstructed to permit use of required hand tools without having to remove or disassemble adjoining components.

Provisions are made for adequate towing or movement of disabled machine to maintenance area:

ADEQUATE

YES	NO	
9	9	Tow cable attachment points.
9	9	Designated push points.
9	9	Tow bar attachment points.

6. Design Features For Repair And Replacement (cont.)

Design features are incorporated to facilitate jacking, hoisting, or lifting of machine to expedite maintenance and repair:

ADEQUATE YES	ADEQUATE NO	
9	9	Designated jack points with jack plates designed to prevent jack slippage.
9	9	Attachment points for overhead lifting devices.

Design features are incorporated to facilitate lifting, hoisting, or manipulating heavy components and machine features:

ADEQUATE YES	ADEQUATE NO	
9	9	Built-in attachment hooks.
9	9	Lift bolt attachment points.
9	9	Lifting guides or pins.
9	9	Provisions for forklift arms.
9	9	Built in swing boom arm.
9	9	Designated lift points.
9	9	_____
9	9	_____

7. Visual Inspections And Accessibility

ADEQUATE YES	ADEQUATE NO	
9	9	All maintenance points should be visually accessible from the side or the end of the machine and should provide line-of-sight inspection capability.
9	9	Design provides for clear and rapid visual identification of parts that may have to be replaced or repaired.
9	9	Approved glass covers should be installed in all access opening covers if routine visual inspections are required.
9	9	Access openings should be large enough to permit visual contact with the component while the work is being performed on it.
9	9	Visual access openings should not be located on the top of machines unless the average roof height above the top of the machine is 61 cm (24 in) or more.
9	9	Visual access openings should never be located under the main chassis or behind components that restrict visibility.
9	9	For less frequently performed maintenance tasks, the maintenance point may be located behind a protective cover. The component, however, should be directly visible when the protective cover is removed.
9	9	Maintenance and service points should be located no further than 91 cm (36 in) from the maintainer's head at time of inspection.
9	9	_____

9 9 _____

8. Design For Physical Accessibility

ADEQUATE		
YES	NO	
9	9	All components are accessible from the side or the end of the machine.
9	9	All drain valves for compressor tanks, reservoirs, and sumps are accessible from the side or end of the machine.
9	9	All other maintenance points are accessible from the sides or ends of the machine.
9	9	All components that require repair, replacement, or adjustment every 2,000 h or less should be directly accessible (can be removed-replaced without having to remove other components) from the sides or ends of the machine.
9	9	For components with an expected service life of over 2,000 h, only one other component should have to be removed to access for removal or replacement (R/R).
9	9	For components that must be disassembled to be repaired or inspected (e.g., bearings), no more than four R/R task steps (e.g., remove part A, remove part B, etc.) should be required to access the targeted part.
9	9	All components weighing more than 23 kg (50 lb) or more should be removed from the side or the end of the machine and should not have to be lifted up and over the machine frame or other components.
9	9	Hinged or quick-release access opening covers should be used where practical with the hinges on the side or bottom so that door will remain open during maintenance.

8. Design For Physical Accessibility (cont.)

ADEQUATE YES	ADEQUATE NO	
9	9	A minimum number of bolts or fasteners should be used on access covers, equipment bay doors, or other protective shielding.
9	9	For components weighing more than 45 kg (100 lb), access openings and work space should be sufficient to permit the attachment of hoisting or lifting devices.
9	9	Screws, nuts, and bolts should be located to permit use of requisite hand tools to remove or replace them.
9	9	Access openings should be sufficiently large to permit removal and replacement of all components contained in that area.
9	9	Non-hinged access opening covers weighing more than 23 kg (50 lb) are designed with built-in handles or lifting device attachment points.
9	9	All components can be removed and replaced in a straight line from their place of attachment. (Components do not have to be maneuvered around or over structural features or components.)
9	9	Design provisions are made to support components weighing over 23 kg (50 lb) while they are being unbolted or bolted into place.
9	9	_____
9	9	_____

9. Hydraulic System Maintenance Design

ADEQUATE		
YES	NO	
9	9	Fluid reservoirs have adequate storage capacity to ensure uninterrupted operation between shifts.
9	9	Dual in-tank or stand-alone filters are installed on each fluid system to minimize component and control valve wear.
9	9	Hydraulic system filters are located in the primary maintenance zone and use permanent or cartridge-type filters.
9	9	Hydraulic meters and gauges are located in the primary maintenance zone.
9	9	Quick-disconnect-type hydraulic line connectors are used where practical.
9	9	Hydraulic systems are designed to be fail safe with the system or components reverting to a safe or neutral position in event of loss of power.
9	9	Hydraulic circuits are permanently labeled to identify circuit, direction of fluid flow, recommended pressure settings, and high- and low-pressure lines.
9	9	All hydraulic valves are labeled to positively identify the system-subsystem operated by that valve; the label should not be on the valve itself.
9	9	Design uses seals that are visible after installation to ensure that they are not inadvertently left out during maintenance.

9. Hydraulic System Maintenance Design (cont.)

ADEQUATE		
YES	NO	
9	9	Design uses armor-coated flex hoses where hoses are subject to abrasive wear or impact damage.
9	9	Design provides for automatic bleeding of major hydraulic system(s).
9	9	Physically incompatible connectors are specified where there is a danger or mismating connectors from adjoining systems.
9	9	Design provides metal shielding to protect electrical and other sensitive equipment in the event of hydraulic fluid leak.
9	9	Design prevents the accumulation of hydraulic fluids in the event of leaks or hose breaks.
9	9	Design provides for hydraulic system drains at the lowest physical level in the system.
9	9	Hydraulic system fittings and valves are staggered to provide improved access to each system's connectors.
9	9	_____
9	9	_____

10. Mechanical System Maintenance Design

ADEQUATE		
YES	NO	
9	9	Design provides for minimum manual adjustment of all mechanical systems, except to correct for wear.
9	9	Self-adjustment designs are incorporated where practical.
9	9	Design precludes the need for special tools or hardware to install, adjust, or align mechanical components.
9	9	Components and mechanical interfaces are designed with the minimum number or pivots, bearing surfaces, and other moving part wear points to minimize maintenance requirements.
9	9	Mechanical system locks or locking devices are incorporated wherever mechanical locking is required for maintenance.
9	9	Design avoids the use of through bolts for installation or assembly where the nuts are not accessible to the maintainer.
9	9	Design locates high-failure-rate components outboard in the primary maintenance zone.
9	9	Design provides for coverings or boots for exposed connectors, universal joints, and other interacting mechanical parts to protect them from mud, coal dust, and other debris.

10. Mechanical System Maintenance Design (cont.)

Adjustments that cannot be designed out should:

ADEQUATE YES	ADEQUATE NO	
9	9	Be completed without the requirement to disassemble the unit.
9	9	Be reduced to the minimum number of steps possible to complete.
9	9	Not require removal or replacement (R/R) of other components to complete.
9	9	Be incorporated into other required maintenance on the same component.
9	9	Incorporate range limits to prevent over-adjustment damage.
9	9	_____
9	9	_____

11. Electrical System Maintenance Design

ADEQUATE		
YES	NO	
9	9	Design routes all electrical cables on machine to avoid damage from abrasion, pinching, or cutting.
9	9	All electrical cabling is routed to permit easy removal and replacement. Cabling is not routed under machine chassis, in the center of boom arms, or in other difficult-to-access locations.
9	9	Electrical connectors are isolated from hydraulic fluid leaks, fuels, water, and other liquids.
9	9	Quick-disconnect-type electrical connectors are used where possible.
9	9	All electrical equipment cabinets are equipped with interlock that terminates power to the unit when the access cover is removed.
9	9	A manual override is provided for all cabinets equipped with shutoff interlock.
9	9	Breakers and other overload protective devices are in a central location in the primary maintenance zone.
9	9	Electrical connector pin patterns are coded to permit connecting cables only to the appropriate receptacle.
9	9	Uses electrical plugs in which the alignment pins extend beyond the electrical pins.
9	9	Design makes receptacles "hot" or "cold."

11. Electrical System Maintenance Design (cont.)

ADEQUATE

YES	NO	
9	9	Uses contact pins no larger than 30 cm (12 in) to resist being bent upon insertion and withdrawal of the connector.
9	9	Design uses right-angle plugs to avoid sharp bends in the electrical cable.

Design provides overload or other electrical protective devices for all major electrical circuits, each of which is equipped with a "kick out" indicator light for easy troubleshooting on:

ADEQUATE

YES	NO	
9	9	Drive, conveyor, cutter head, and gathering arm motors.
9	9	Lighting.
9	9	Electric power takeoffs.
9	9	_____
9	9	_____

12. Personnel Protective Equipment Maintenance

Personnel protective equipment is designed and located to facilitate inspection, repair, and replacement of the following systems:

ADEQUATE		
YES	NO	
9	9	Dust control.
9	9	Methane monitoring.
9	9	Operator protective canopy (as required).
9	9	Operator panic bars.
9	9	Emergency power cutoff devices.
9	9	_____
9	9	_____

13. Design For Mechanical Safety

ADEQUATE		
YES	NO	
9	9	Protective guards are provided on or around all moving mechanical parts adjoining to where maintenance personnel will be working.
9	9	Mechanical lockout devices are provided where maintenance must be performed at location that exposes maintainer to moving components (e.g., under a cutter head).
9	9	Design prevents components from slipping or falling as they are being unbolted for repair or replacement.
9	9	Mechanical components are located to prevent maintainer from being exposed to energized equipment, hazardous fumes, hot surfaces, or other hazards during repair operations.
9	9	Mechanical components that require the use of heavy springs are designed so that the springs cannot inadvertently dislodge, causing damage or personnel injury.
9	9	Design provides for warning plates where mechanical assemblies, linkages, or components are under high strain or loading.
9	9	Design routes hot exhaust pipes away from locations where routine maintenance will be performed.
9	9	Design prevents failure of high-stress-loaded component from damaging other components or injuring personnel.
9	9	_____

14. Storage Battery Maintenance

ADEQUATE YES	ADEQUATE NO	
9	9	Design isolates routine machine maintenance points from battery fumes.
9	9	Design prevents leaking battery acid from accumulating in equipment compartments or operator station.
9	9	Batteries are installed in a location that permits use of overhead lifting device to remove or replace them.
9	9	_____
9	9	_____