Maintaining Mobile Equipment
Controlling Hazardous Energy

By Damien Burlet-Vienney, Yuvin Chinniah and Barthélemy Aucourt

When workers must perform maintenance in hazardous zones of machines, North American regulations require application of hazardous energy control procedures (ANSI/ASSE, 2016; CSA, 2013; OSHA, 1989). ANSI/ASSE Z244.1-2016 presents three different approaches: lockout (the primary approach), tagout and alternative methods. Common alternative methods for lockout/tagout used are electronically interlocked access, trapped key system, presence-sensing device or remote lockout.

These procedures protect workers from risks related to the inadvertent release of hazardous energy on machines, equipment and processes. The release of hazardous energy includes unintended motion of mechanical parts, energization, start-up or release of stored energy. A lockout/tagout procedure requires 1) shutdown of the machine; 2) control of any residual or stored energy source; 3) isolation and control of the machine's energy source cutoff points; 4) verification; and 5) safely restarting the machine (ANSI/ASSE, 2016; CSA, 2013). In a lockout procedure, each worker must place a personal padlock on each energy-isolating device to complete the third step. In a tagout procedure, a less preferred method, identified tags are used instead of personal padlocks.

When maintenance is designed to be an integral part of the production process or when conventional lockout/tagout is not feasible or prevents specific tasks from being performed (e.g., energy required), a worker can use an alternative method. It is recommended that the choice of method be supported by means of a risk analysis documented under the responsibility of a qualified person (ANSI/ASSE, 2016; CSA, 2013).

Risk assessment is a series of steps used to examine the hazards associated with machinery and select optimized means to reduce risk. It is divided into two phases: 1) risk analysis and 2) risk evaluation (to determine whether the risk is acceptable) (ANSI/ASSE, 2016, Figure 2; ISO, 2010).

Risk analysis usually consists of three stages:
1) Determine the limits of the machinery.
2) Identify the hazards.
3) Estimate the risk (risk scoring).

The risk assessment process ends when the risk has been adequately reduced. Controls must be chosen according to this priority: 1) elimination through design; 2) substitution; 3) guards and safeguarding devices; 4) awareness devices; 5) procedures and training; 6) use of PPE (ANSI/ASSE, 2016).

Employers must review hazardous energy control procedures periodically (OSHA, 1989, 1910.147 Appendix A). The application of these procedures requires planning, training and resources (Mutawe, Tsunehara & Glaspey, 2002). Furthermore, the hazardous energy control program provides guidance to supervisors and employees on what is expected of them (Chinniah, 2010) (Figure 1, p. 28).

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Implementation Issues

Research indicates that companies have difficulies fulfilling their lockout/tagout obligations. For instance, Parker, Yamin, Xi, et al. (2016), found that just 8% of 160 small businesses audited in the U.S. were in compliance with recommended lockout/tagout procedures. By analyzing reports of serious and fatal accidents, Bulzachelli, Vernick, Sorock, et al. (2008), in the U.S. and Chinniah (2015) in Quebec also report that lockout is not applied properly when it should be.

An exploratory study of lockout in Quebec's municipal sector revealed a need for prevention with respect to mobile equipment. Although a source of serious and fatal incidents, mobile equipment is not taken into consideration by companies when hazardous energy control programs are implemented (Chinniah & Burlet-Vienney, 2013).

The Need to Include Mobile Equipment

Machinery that presents hazards due to its mobility is defined in the European Machinery Directive (European Parliament and Council, 2006) as:

> Machinery the operation of which requires either mobility while working, or continuous or semi-continuous movement between a succession of fixed working locations, or machinery which is operated without being moved, but which may be equipped in such a way as to enable it to be moved more easily from one place to another.

Examples of such equipment are loaders, lift trucks or forklifts, snowblowers, dump trucks, mobile cranes, tractors and cherry-pickers. Mobile equipment has been identified as a major occupational hazard in several countries. According to Marsh and Fosbroke (2015), in the U.S., from 1992 to 2010, the most hazardous machines by sector were 1) tractors in agriculture, forestry and fishing; 2) excavators in construction; and 3) lift trucks in several other industries. These machines are all types of mobile equipment. In Australia, in 2014, 116 (61%) of the 188 occupational fatalities involved mobile equipment or motor vehicles (Safe Work Australia, 2015).

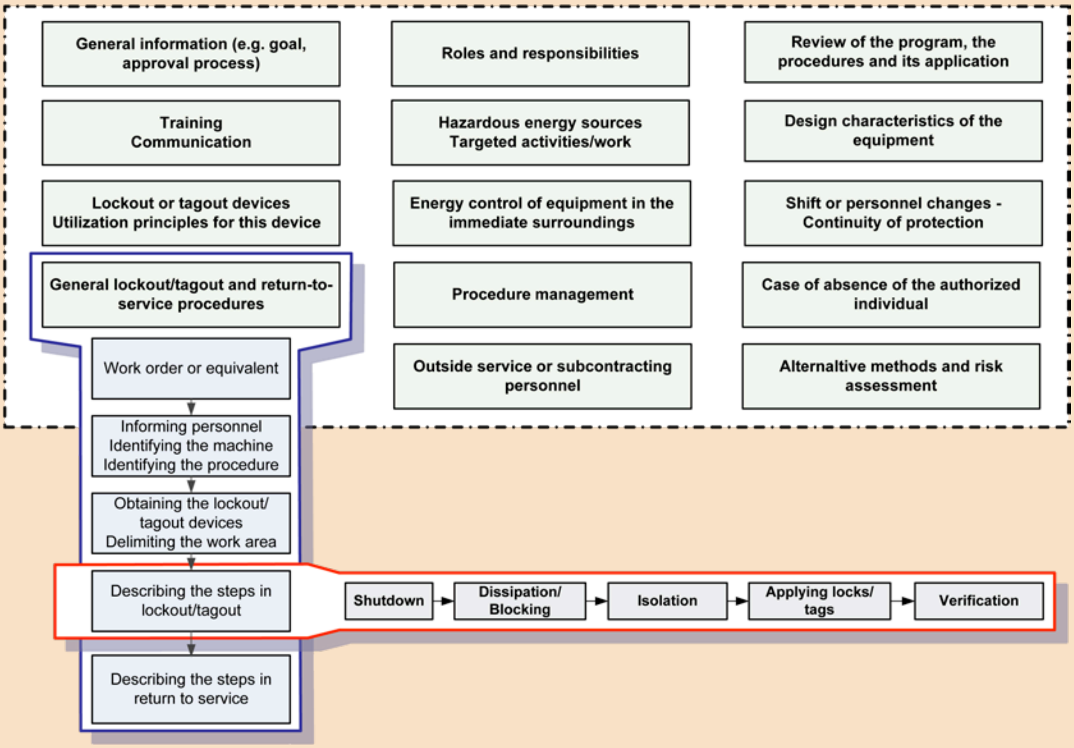
Theoretically, the regulatory requirements regarding hazardous energy control concern mobile equipment. No exclusions for this equipment are mentioned in OSHA 1910.147 and ANSI/ASSE Z244.1-2016 exempts only passenger vehicles and personal recreation devices. Mobile equipment maintenance procedures that comply with the manufacturer's instructions or certain specific regulations (e.g., OSHA 1910.178 on powered industrial trucks) are directives that complement lockout/tagout regulation. For example, Janicak and Cekada (2016) discuss the hazards and regulations associated with lift trucks in the U.S.

Maintaining and servicing mobile equipment exposes workers to hazards in several categories: 1) mechanical (e.g., moving parts, such as power take-off); 2) electrical (e.g., battery, generator); 3) hydraulic (e.g., pump, cylinder, flexible hoses);

IN BRIEF

- **Maintenance work or related activities on mobile equipment can be hazardous.**
- **Mobile equipment is rarely covered in companies' hazardous energy control program and procedures, even though serious incidents can occur during maintenance on this equipment.**
- **Removing the ignition key from mobile equipment and keeping control of it are important steps but are not always sufficient to control hazardous energies that may exist.**
- **Mobile equipment manufacturers and suppliers should systematically incorporate lockable battery cutoff, as well as blocking accessories, to make it easier for workers to follow energy control procedures.**

FIGURE 1
Hazardous Energy Control Program Overview



Note. *Adapted from Verifying the Content of Lockout Programs (RF-635), by D. Burlet-Vienney, S. Jocelyn, Y. Chinniah, et al., 2009, Montreal, Quebec: IRSST.*

4) gravitational (e.g., attachments placed at height); 5) thermal (e.g., hot parts); 6) pneumatic; and 7) chemical (e.g., battery acid, grease, oil). Photos 1 and 2 depict some of these hazards. In addition, hazards can be created by work in remote locations and tasks performed by solo workers in some sectors (e.g., forestry, construction).

Incidents Related to Maintenance/Servicing of Mobile Equipment

Investigation reports regarding serious or fatal occupational incidents in Quebec between 2000 and 2013 involving machinery were examined (CNESST, 2016). Of the 813 serious or fatal incident reports available, 38% involved mobile equipment. Of these reports, 80% concerned incidents that occurred when the equipment was being operated (e.g., traffic crash, collision with pedestrian) and 20% during maintenance work (62 reports, 56 deaths).

Therefore, maintenance or related activities on mobile equipment involve four fatalities annually in Quebec and represent 6% of work-related fatalities over the period. The three most common types of incidents were 1) falling mobile equipment or part of the equipment; 2) a moving part; and 3) a moving vehicle (Table 1, p. 30). Closer analysis reveals that involving falling equipment or equipment part from a height typically have technical causes (e.g., resistance of the blocking mechanism), while incidents in the moving part or vehicle categories are often due to organizational or communication problems (e.g., ignition control).

Mobile machinery operators account for one third of the fatalities, with mechanics and technicians combined. Operator intervention takes place outside the workshop (100%) and is linked in particular to the type of incident: moving part (44%). They often leave the engine running during the intervention. Incidents involving mechanics are of a different nature with 40% of the cases related to a poorly blocked equipment or part of equipment in elevation.

Data Collection

How can workers effectively control hazardous energy of mobile equipment during maintenance or servicing tasks, given the technical and organizational challenges specific to these machines? To answer this question, the authors examined several sources of data, in addition to relevant workplace incidents: a) the literature (e.g., standards, manufacturers' reference manuals); b) mobile equipment manufacturer practices; and c) the hazardous energy control implementation steps taken by four organizations with respect to their mobile equipment units, including an 18-month follow-up.

The following discussion addresses principles to consider to implement efficient hazardous energy control procedures on mobile equipement. Key topics are: 1) raising awareness of the hazardous energy control when servicing a mobile equipment; 2) implementing comprehensive lockout procedures; and 3) managing work using an alternative method.

Raising Awareness

Traditionally, shop mechanics do not follow a formal lockout procedure and do not use personal padlocks to control the energy of mobile equipment. They do, however, perform a shutdown by removing the ignition key, keeping control of it and lowering attachments to the ground. Whateverer the procedure. the analysis of fatal incidents demonstrates shortcomings.

Awareness is lacking on several levels (i.e., among workers, employers and manufacturers) regarding the hazards associated with maintenance work on mobile equipment. Deficiences include stopping (e.g., moving part), blocking (e.g., falling equipement) and controlling the start-up (e.g., moving equipement). To ensure better protection of employees performing maintenance, companies should:

- Raise awareness among mobile equipment operators about the risks of performing maintenance tasks for which they are not qualified.
- Develop lockout procedures or formal alternative methods that meet regulatory requirements and follow them when necessary.
- Set up a diagnostic and preventive maintenance system to limit the number of unplanned jobs that workers must perform on mobile equipment.
- When purchasing mobile equipment, include in the tender requirements the installation of energy control devices (e.g., blocking accessories, lockable battery cutoff).

Developing & Applying Lockout Procedures

For major work on mobile equipment, the preferred procedure is lockout. The following recommendations address how to proceed with the key steps involved. Note that some of these steps (e.g., safe shutdown) may be useful in setting up alternative methods.

Safe Shutdown

The incident analysis revealed that more than 50% of incidents were caused by the equipment or part of the equipment being put into motion. In practical terms, these cases were related to intervention by a third party who was unaware of what was going on; accidental operation of a control mechanism (e.g., lever); or the machine or a part of the machine moving because it had not been properly immobilized. In most of these cases, the equipment's engine was still running or the key was still in the ignition.

A safe shutdown would prevent such incidents. Steps involved in a safe shutdown include:

1) Park equipment on firm, flat ground.
2) Apply parking brakes.
3) Put the transmission in the position recommended by the manufacturer.
4) Lower attachments to the ground or place them in the best position for the work.
5) Chock/block attachments that are not on the ground according to the manufacturer's recommendations (Photo 3).
6) Turn off the equipment by cutting off all sources of power (e.g., main engine, auxiliary motors, valve).
7) Remove the key (if any) from the ignition.
8) Chock the wheels if necessary (e.g., sloped ground, work required on brake system).
9) Mark off the work area and display signs to show that work is in progress (e.g., tag in cab and/or use personal padlock).
10) Lock the cab with the key if the equipment does not have an ignition key.
11) Notify personnel concerned about the work in progress,

Photo 1: Auger of a snowblower.

Photo 2: Raised plough blade and hydraulic flexible hoses of an abrasive spreader.

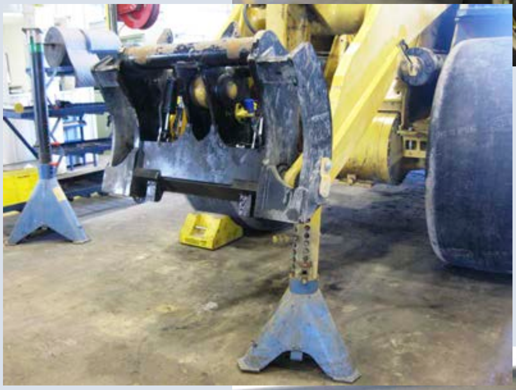


Photo 3: Blocking the front boom.

Photo 4: Key-operated battery cutoff that can be locked out with a latch.

Depending on the work, remaining residual energies (e.g., hydraulic system, hot parts, capacitor) also should be managed. For residual hydraulic energy in particular, all parts should be placed in a rest position (e.g., lowered on the ground, blocked), then the pressure released (e.g., with control levers, valve, bleed). In some cases, it may take much more effort than most mechanics are willing to invest (e.g., draining the entire system).

Isolating & Locking Out Energy Sources

Employees can use several methods to isolate and lockout energy sources. These include controlling the ignition key (with or without a lockout box) and using a lockable battery cutoff (Photo 4). Table 2 (p. 30) lists the advantages and limitations of these two approaches.

TABLE 1

Incidents Related to Maintenance or Servicing Work on Mobile Equipment

Type of incident	Fatalities	Examples of incidents
Falling equipment or part of equipment	18 (32%)	A worker was changing a hydraulic hose on a forklift. The mast was supported by a beam resting on the ground. The beam moved, causing part of the mast to hit the worker's head.
Moving part	17 (30%)	A worker entered the area under the dump box to add oil to the hoisting system. He accidentally activated the control to bring the box down and was crushed between the frame and the box.
Moving vehicle	12 (21%)	A mechanic is lying under a truck to evaluate repairs to be made. The truck driver moves the truck following a request from another mechanic. The truck's rear wheels partially crush the mechanic under the truck.
Tire explodes, comes off rim	6 (11%)	A truck driver was injured when a tire on his tractor trailer exploded. The accident occurred when the driver was lying under the truck trying to inspect the brake chamber.
Tank explosion	3 (5%)	A worker was repairing the air brake system on a box truck. When he used a propane torch to heat up the drain cock, the alternate gas tank exploded, injuring him.

Note. *Type, number and examples of incidents related to maintenance or servicing work on mobile equipment in Quebec, 2000-13. Adapted from Commission des normes, de l'équité, de la santé et de la sécurité au travail (CNESST), 2016, Documentation centre.*

TABLE 2

Considerations When Using Ignition Key

Points to consider in connection with using an ignition key or lockable battery cutoff for the isolating and locking out steps of a lockout procedure.

Method	Advantages	Limitations
Control of ignition key	•Ignition key available on almost all machines •Sufficient for most jobs requiring energy cutoff •Already standard when work done by mechanics	•Acts on control device and not on energy source isolating device. In theory, the engine can still restart (e.g., electrical problem) •In theory, all duplicate ignition keys should also be controlled •Not all machines are equipped with ignition keys (e.g., start button) •If no other measures are taken, it is impossible for each worker individually to have control over the machine
Control of battery (lockable battery cutoff or disconnection)	•Prevents any restarting of the engine at source. Remote start-up impossible •Complies with regulatory lockout requirements •Cutoff point can potentially be locked out •Ignition key available for verification step	•Not all machines are equipped with lockable battery cutoff. Adding one costs approximately $100 U.S. (purchase and installation) •Cuts the power supply to certain accessories, such as GPS (e.g., fire trucks) or onboard computers, which can cause settings to be lost when the condensers are discharged •Adds a step, although not all jobs require cutting off the battery to ensure safety

Based on the limitations noted in Table 2, controlling the ignition key does not meet the regulatory requirements for a lockout procedure. In practical terms, if the procedure is based on key control, it should be considered as an alternative method. For example, an employer must consider the management of duplicate ignition keys.

The use of a lockable battery cutoff compliant with current standards [e.g., IEC 60204-1 (2005)] is sufficient to satisfy the regulatory principles of lockout and address the specific issues of remote starting and electric vehicles.

Verification & Return to Service

Verification and return to service are steps that receive limited attention, both in the literature and in the field. The verification step is applicable in cases where a lockable battery cutoff is used to isolate and lockout the energy source. In this situation, an employee can perform a start-up test with the ignition key. A safety perimeter must be established beforehand. In cases where the ignition key is locked out (e.g., in a box), a worker does not have many options for a verification test. However, the employee must confirm the installation of immobilization devices (e.g., chocks) and the release of residual energy (e.g., hydraulic).

Lockout Procedures

Based on the preceding discussion, the main steps suggested for a comprehensive lockout procedure for most types of mobile equipment are:

1) Shut down safely.

2) Isolate battery by means of a lockable battery cutoff or by disconnecting it.

3) Place a hasp and a personal padlock on the lockable battery cutoff or the battery terminal covers.

4) Control other isolating devices as required (e.g., valves).

5) Control residual energy sources other than those controlled by safe shutdown.

6) Verify the procedure by means of a start-up test (e.g., ignition button or key) and by reviewing the steps completed above.

7) Follow instructions for return to service.

Some of these steps (e.g., safe shutdown) are common to most types of equipment, while others (e.g., residual energy) are specific to each machine. Figure 2 presents a method to follow when developing lockout procedures for mobile equipment. In step 5, one must identify types of work that will require a specific position for the equipment (e.g., raised bed), a specific energy source (e.g., for diagnostic purposes) or a specific procedure. Maintenance or servicing of this kind will require alternative methods (step 7).

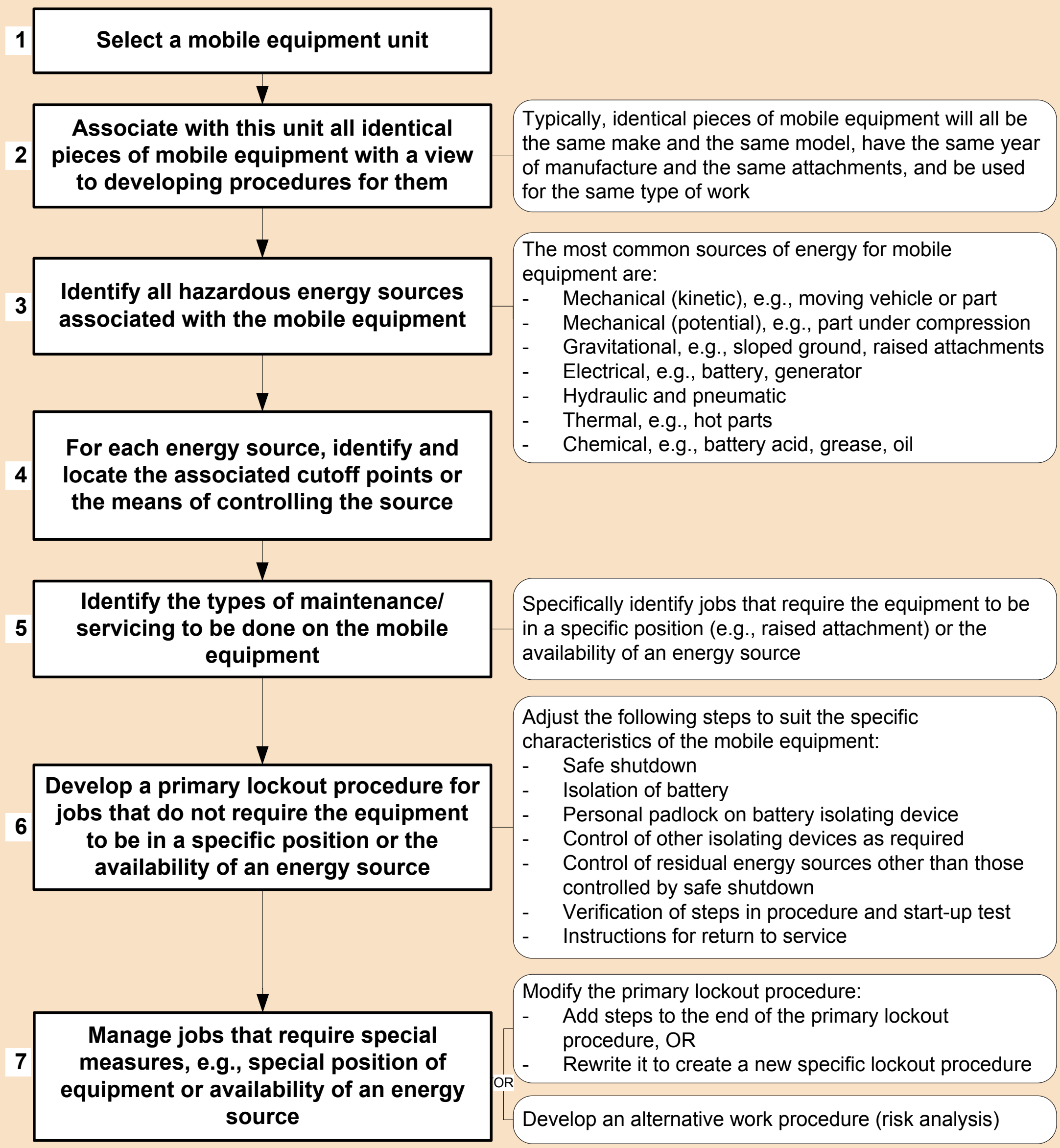
Alternative Methods

An alternative method for mobile equipment may apply in the following situations:

1) Need for an energy source to perform a task, such as diagnostic and verification steps, in the hazardous zone. In these situations, some parts of the equipment may need to be in motion when a worker is nearby.

2) Short, small jobs. In the shop, this means jobs such as changing windshield wiper blades, replac-

FIGURE 2
Method for Developing Lockout Procedures for Mobile Equipment



ing headlight bulbs and conducting visual inspections. Out of the shop, it refers to jobs that must be done to allow production to continue, such as unjamming or performing minor repairs. This is the case in particular for snowblower mechanisms (e.g., drum or auger) that can get jammed several times a shift.

For short, minor repair jobs involving only one worker, a safe shutdown with control of the ignition key and the display of work-in-progress signs may be sufficient. When a problem must be diagnosed, a safety perimeter and appropriate signage may be required. In all cases, the method selected must be documented by a risk assessement. Risk assessement enables the employer to validate, formalize and harmonize the alternative methods used by workers. Employers should consult manufacturer's instructions, their mechanics and literature on risk analysis and acceptable risk during this process (Cantrell & Clemens, 2009; Chinniah, Paques & Champoux, 2007; Eaton & Little, 2011; Lyon & Hollcroft, 2012; Lyon & Popov, 2016; Manuele, 2010; Piampiano & Rizzo, 2012).

Conclusion

As is the case with stationary industrial machinery, written procedures establishing the energy control method for all maintenance or servicing work on mobile equipment are similarly required. Removing the ignition key from mobile equipment and keeping control of the key are not sufficient; there is no substitute for lockout/tagout since the ignition key does not act on an energy-isolating device, residual energies may exist and there may be more than one ignition key.

To ensure more effective start-up control, mobile equipment manufacturers and suppliers should incorporate lockable energy cutoff devices compliant with current standards (e.g., IEC 60204-1) into their designs. Prevention through design is an effective principle that is widely promoted in the OSH field (ANSI/ASSE, 2011; Lamba, 2013; Manuele, 2008; Walline, 2014).

Similarly, mobile equipment should systematically (not as an option) be equipped with a single starter device; this creates a certain degree of confidence in the role of the ignition key. Furthermore, energy control is not limited to equipment start-up. Elevated loads, lack of chocks to immobilize vehicles or the presence of stored energy can present safety issues as well. Therefore, employers should address all steps and all accessories required to apply comprehensive energy control procedures when performing maintenance work (e.g., wheel, cylinder and truck bed chocks; articulation blockage devices; tire cages; draining of fuel tanks). A safe shutdown enables the control of most hazardous energies including residual energies.

Finally, improving the professional training of mobile equipment operators, mechanics and designers is another consideration. Raising awareness of this issue is a critical factor in making workplaces safer. **PS**

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