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“Inclusive Mines, a Safe Future”

CSA M424.4:22

Self-propelled, electrically driven, non-rail-bound mobile machines for use in non-gassy underground mines

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Mining Health and Safety Conference_April 16-18, 2024

Top primary root causes for incidents involving battery electric vehicles (BEV)

*Thermal runaway events can result in unintended or adverse effects.

As identified by workers, supervisors, and employers in the Ontario mining industry through Ministry of Labour, Training and Skills Development-facilitated root cause analysis workshop in partnership with Workplace Safety North.



Processes: Inadequate maintenance processes



Measures: Ineffective company operator and maintenance procedures



Measures: Current lack of CSA standard for BEVs



Tools and machines: Improper live troubleshooting on issues with BEV machines



Processes: †Ineffective management of change on new equipment



People: Operator lack of training on BEVs



Tools and machines: Energy sources creating potential for electric shock



Culture: Lack of education and understanding of BEV safe use



Processes: Misuse of new BEV equipment

Culture: Rushed implementation of BEV use

Measures: Lack of common core training standards for BEV use

People: Improper or unclear work delineation for electricians and maintenance personnel

Environment: Inadequate battery storage

Source: WSN 2022





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Annex A (informative)



NRCan - CanmetMINING

- CanmetMINING is a branch of Natural Resources of Canada (NRCan)

CanmetMINING R&D is focused under three key priorities:

Critical Minerals R&D

- The building blocks for the low-carbon transition



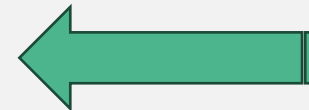
Efficient Mining Practices

- New mining technologies & best practices



Climate Resilient Mining

- Adaptable & carbon neutral



CSA Group



Established in 1919



Independent organization



A leader in standards research, development, education and advocacy



+ 3,300 Standards and codes



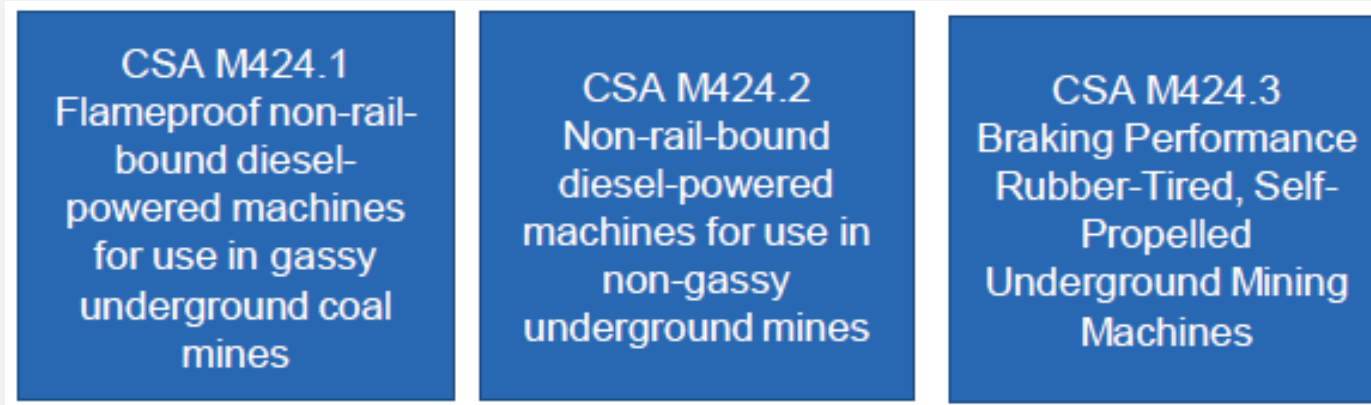
Over 10,000 dedicated members



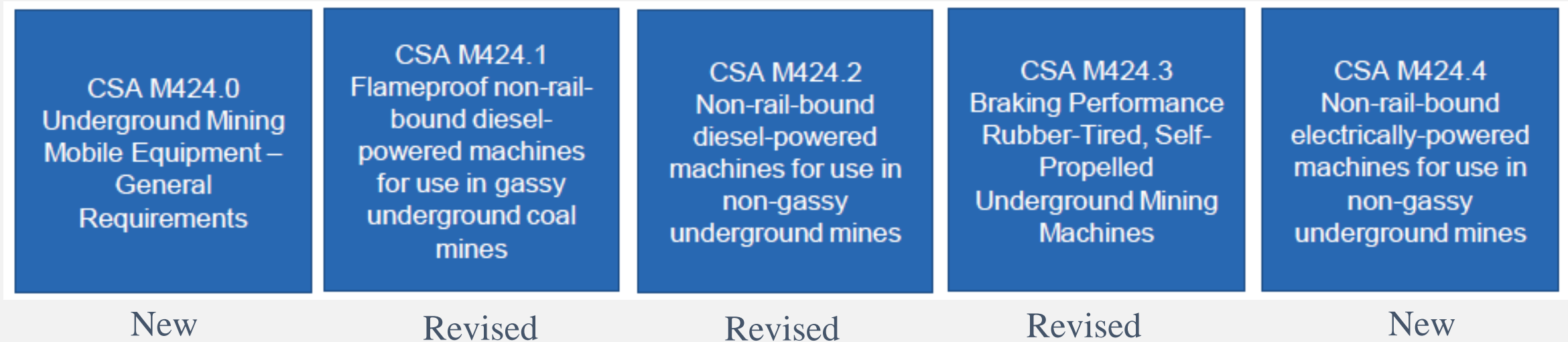
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CSA M424 Underground Mining Equipment Series of Standards

Prior State



Current State: 2022 - current

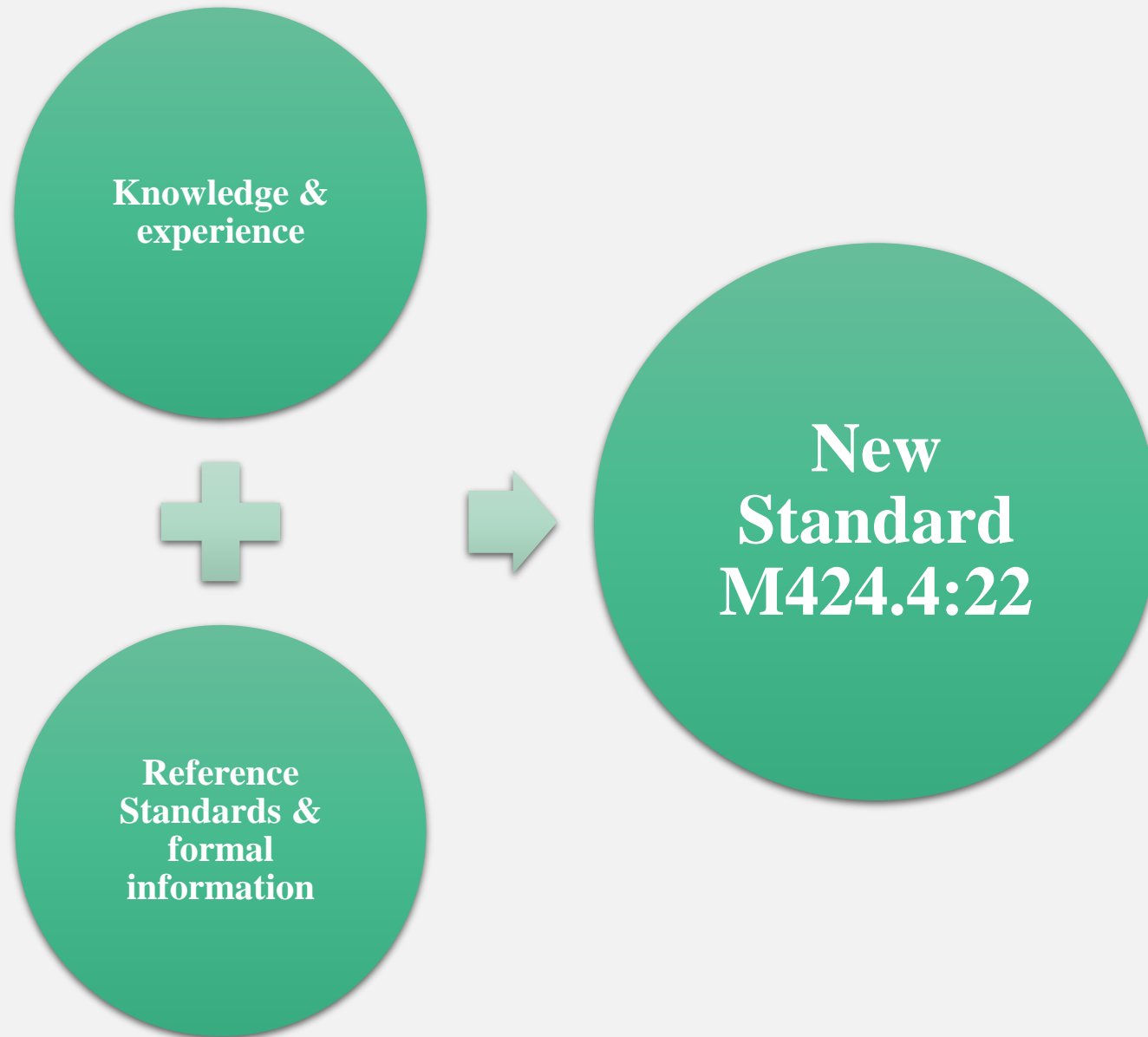


CSA M424 Series topic map



Core safety	CSA M424.0 General requirements	Machine design Principles Materials Performance Steering Braking Lighting ROPS/FOPS	Operator safety Ergonomics Noise Visibility Vibration	Labeling Standards Applicability
	CSA M424.3 Braking	Performance Test procedures Test apparatus	Conventional SAHR/wet Regenerative	
	CSA M424.1 Diesel gassy/coal	Design Materials Applications Fuel Test procedures	Flame propagation Surface temperature Test procedures	Shutdown systems Alarms Hazard analysis
Diesel engines	CSA M424.2 Diesel non-gassy	Emissions control Ventilation Markings	Emissions standards After treatment Test procedures	Pass/fail criteria Ventilation Prescription
	BEV/FCEV/Hybrid	CSA M424.4 Electric powertrains	Design Applications Performance Machine types Test procedures	Energy storage Battery safety Hydrogen storage Fuel cells Refuel/recharge





Battery-electric

Hydrogen-fuel-cell-electric

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Name	Company
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Gerald David	Komatsu


Diesel-electric

Name	Company
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Team members with diverse backgrounds



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1. Scope

This Standard M424.4 is relevant to:

- self-propelled, electrically driven, non-rail bound mobile machine that uses for non-gassy underground mine
- battery electric system which is a base configuration for battery electric, hydrogen-fuel-cell-electric and diesel-electric machine
- on-board voltages: 50V - 1.5 kV AC and 75V - 2.1 kV DC
- hazards during commissioning, operating and maintenance.
- use in conjunction with other CSA M424 Standards where applicable





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Annex A (informative)



2. Reference publications

- CSA group
- BNQ (Bureau de normalisation du Quebec)
- ISO (International Organization for Standardization)
- IEC (International Electrotechnical Commission)
- SAE International
- UL (Underwriters Laboratory)
- CGA (Compressed Gas Association)
- GTR (UN Global Technical Regulations)
- IEEE (Institute of Electrical and Electronics Engineers)
- More reference Standards are listed in the Standard copy



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Annex A (informative)



3. Definitions and abbreviations

Extra-low voltage (ELV):

< 50 V AC or 75 V DC

Low voltage (LV):

> 50 V AC and < 1000 V AC, or

> 75 V DC and < 1500 V DC

High voltage (HV):

>1000 V AC and < 36 kV AC, or

>1500 V DC and < 36 kV DC.



Definitions

Shall = requirement compliant

Should = recommendation but not required

May = option to consider

Informative annexes= nonmandatory



Abbreviations

BEV = battery electric vehicle (machine)

CHSS = compressed hydrogen storage system

EVSE = electric vehicle (machine) service equipment

HFCEV = hydrogen-fuel-cell-electric vehicle (machine)

HVIL = hazardous voltage interlock loop

IP = ingress protection

PELV = protective extra-low voltage

RESS = rechargeable energy storage system

TPRD = temperature-actuated pressure relief device



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Annex A (informative)



4. General requirements – Self-propelled electrically driven machines

- General requirements for BEV, HFCEV and diesel-electric sections (5, 6, 7)
- Machine operator should be alerted fault or condition:
 - a) Loss of high-voltage system isolations;
 - b) Low state-of-charge (SoC)
 - c) Low oil pressure
 - d) Over temperature, temperature fault, or temperature out-of-range
 - e) Hazardous voltage fault; and
 - f) Failure of contactor to open when commanded (weld contacts)



General requirements – Risk Assessment

As per M424.0, the end user (mine operator/mine contractor), in conjunction with the equipment supplier (manufacturer), should complete a joint task-based technical assessment to include, but not limited to:

- a) transportation and storage of new, used, and damaged batteries;
- b) requirements for fire suppression/mitigation for the safe operation of the mobile equipment through its life cycle; and
- c) emergency protocol(s) in the event of imminent or complete battery failure

In addition, equipment supplier should provide documentation/training related to operation and maintenance of the intended use of the machine.





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Annex A (informative)



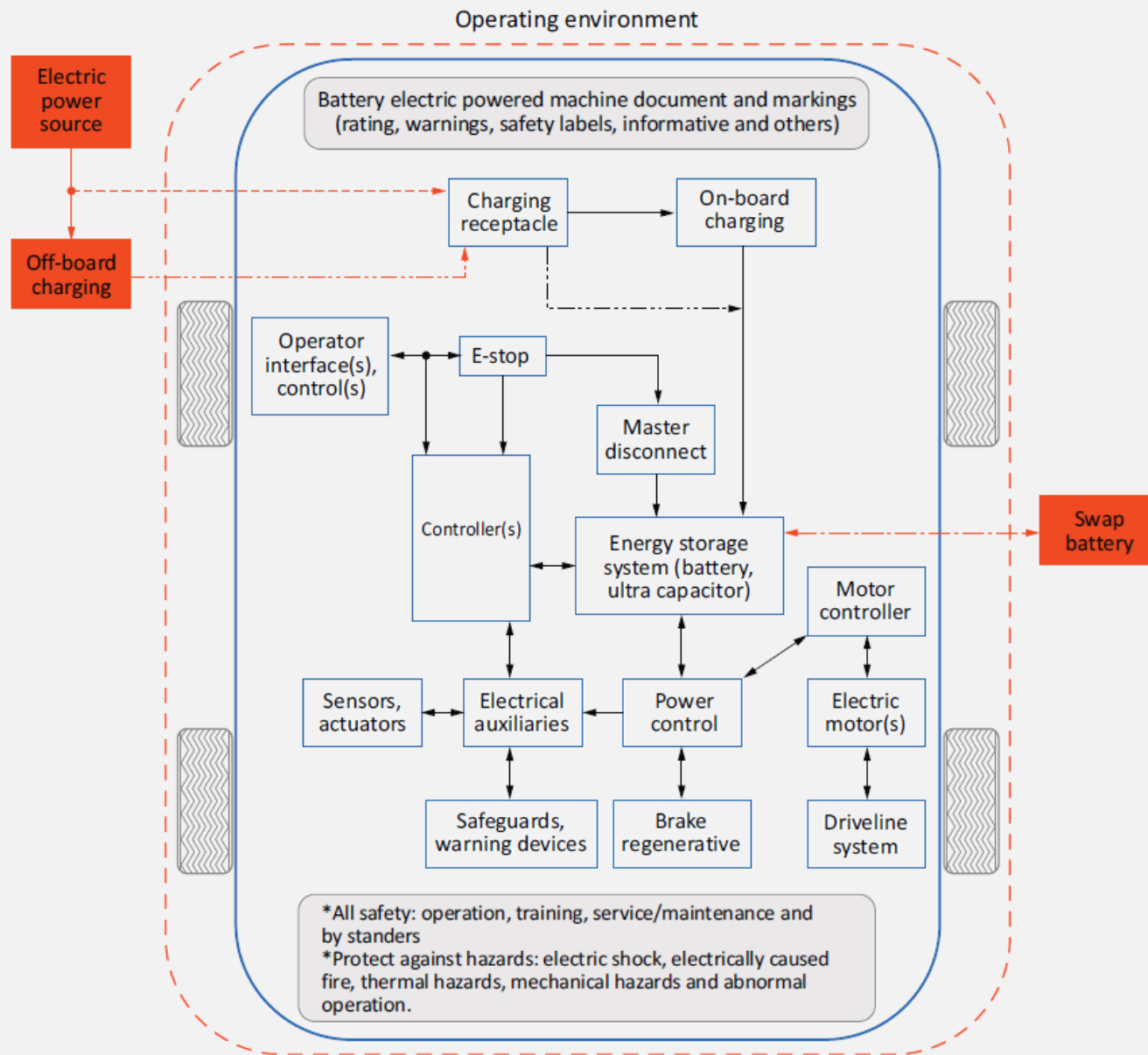
5. Battery electric-powered machines

A battery electric Machine exclusively uses chemical energy stored in a rechargeable energy storage system (RESS). BEV uses electric motor(s) and motor controllers for propulsion. BEV derives all power from battery pack(s) and thus has no hydrogen or diesel fuel tank.



Source: Kovatera, MacLean Engineering, Caterpillar





Battery Electric Machine (BEV)

- An example of a typical battery electric-power machine block diagram
- Some of the components/functions are not included for simplicity.
- Components and systems outside the red dashed line are outside the scope of this Standard
- The brake systems shall meet M424.3 requirements



Battery electric-powered machine content and structure

Used ISO 14990-1 for relevant content and structure for this subsection

- Topics covered:

- 5.1 Protection against shock (Ref. ISO 14990-1, ISO 3457, ISO 20474-1, M424.0, UL 2251, GTR 20 and various SAE J1772, J2464)

- 5.2 Wiring (Ref. ISO 14990-1)

- 5.3 Electric motors and generators (Ref. ISO 14990-1)

- 5.4 Controls (Ref. ISO 14990-1, M424.0, M424.3)

- 5.5 Manuals and technical documentation (ISO 14990-1, M424.0)

- 5.6 Marking (Ref. ISO 14990-1)

- 5.7 Tests (Ref. ISO 14990-1)



Battery electric-powered machine – Protect against hazards

- ***Electric shock:*** Electrical isolation are normally achieved either through physical separation means, such as the use of insulated wire, enclosures, or other barriers to direct contact.
- ***Residual voltages:*** Service literature with a method for verification of discharge of residual voltages prior to servicing.
- ***Thermal:*** overheating protection, battery cell thermal stability tests
- ***Mechanical:*** Mining vehicles should meet on-road vehicle standards at a minimum and go beyond this rating for being safe and service-worthy in mine operations.
- ***Chemical:*** The BEV product and equipment should not release any hazardous gases or effluents
- ***Abnormal operation, overcurrent protection, earth fault protection.....etc.....***



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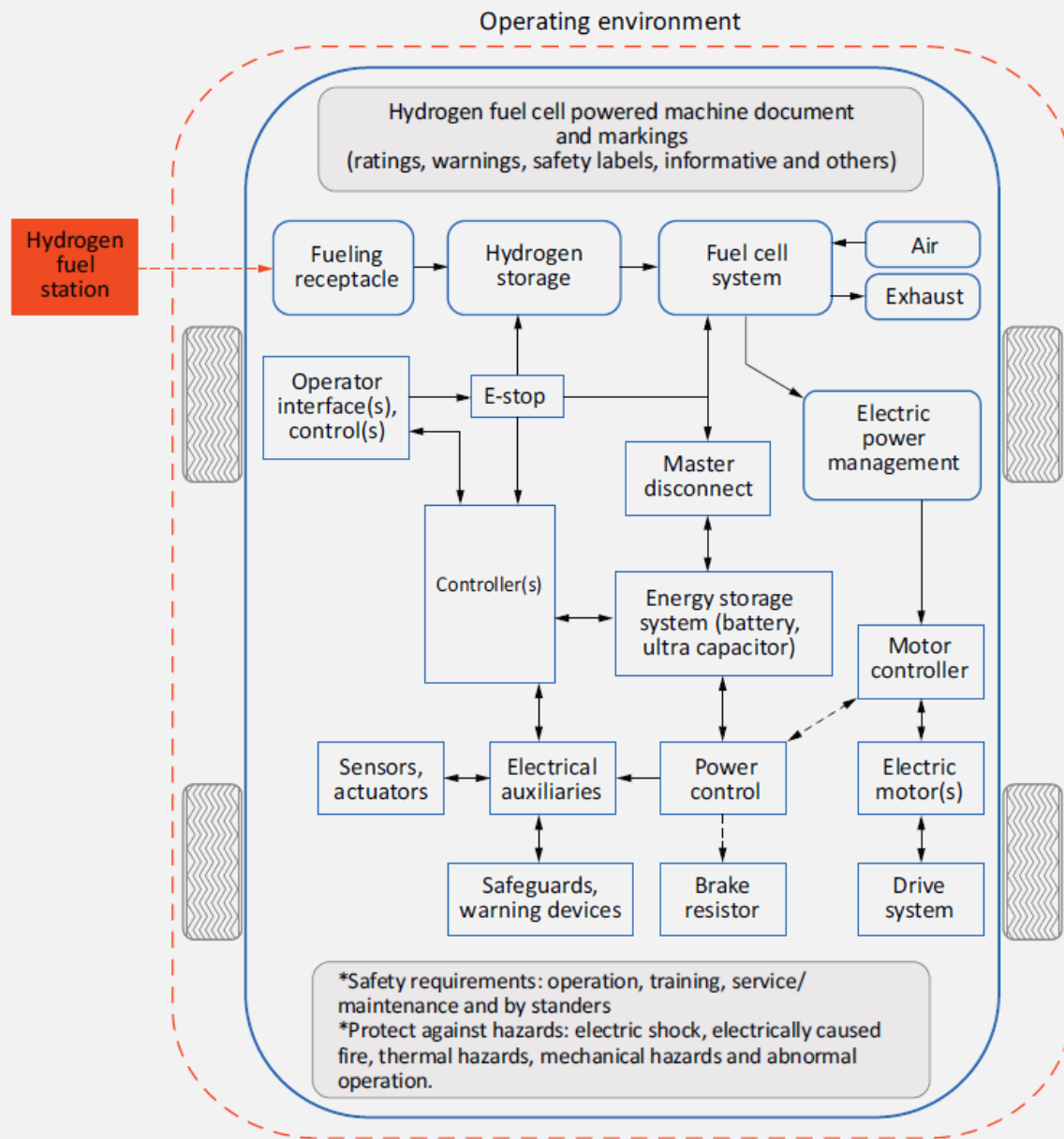
6. Hydrogen-fuel-cell-electric powered machines (HFCEV)

HFCEVs have an electric drivetrain powered by a fuel cell that generates electric power electrochemically using hydrogen and stored in a RESS.

Specific information for HFCEV is from BNQ, ISO, IEC, SAE, GTR 13, GTR 20... other content shall meet clause 4 & 5 (BEV)

- Topics covered: Clause 6.1 to 6.9
 - Hydrogen-fuel-cell main systems: hydrogen fueling, hydrogen delivery, fuel cell system
 - Protection against hazards: defueling hydrogen fuel containers before shipping
 - Controls
 - Manuals and technical documentation
 - Marking
 - Testing





Hydrogen-Fuel-Cell-Electric Machine

- An example of a typical HFCEV block diagram
- Top part of block diagram “filleted rectangular blocks” is specific for HFCEV and provides hand-offs to the general requirement in clause 4 & 5 (BEV) in a lower portion.
- Components and systems outside the red dashed line are outside the scope of this Standard





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Annex A (informative)



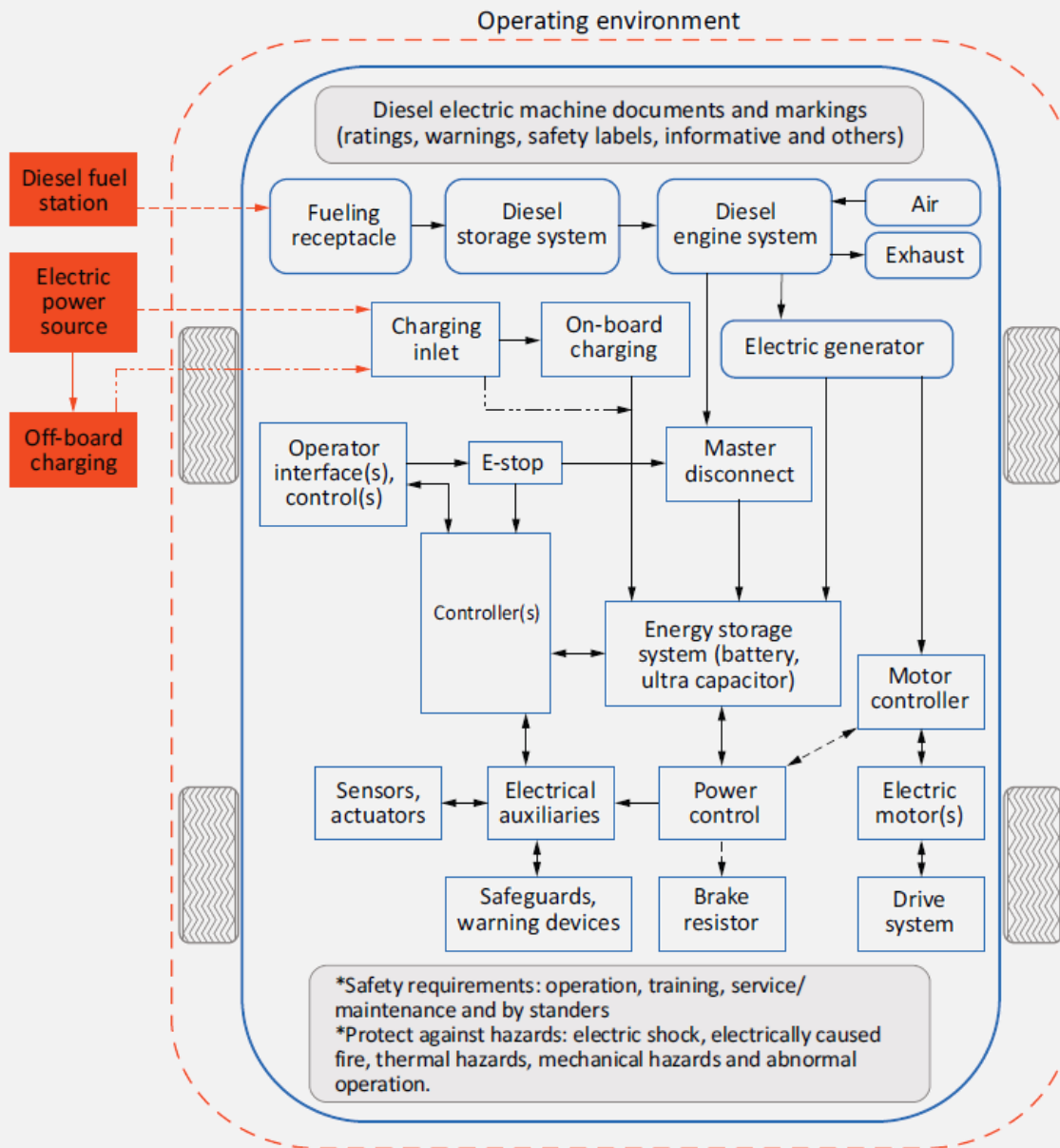
7. Diesel-electric powered machines (hybrid)

- Diesel-electric machines (hybrid) have an electric drivetrain powered by a diesel engine that generates electric power through a generator and stores the excess energy in the energy storage system. The RESS can also be charged by various types of chargers.

Included specific information for Diesel-electric and reference M424.2 for diesel engine and clauses 4 & 5 (BEV)

- Topics covered: Clause 7.1 to 7.10
 - Diesel engine system: engine, fuel tank
 - Engine driven electric generator
 - Controls, manuals and technical documentation, machine identification, tests
 - Transport dangerous goods





Diesel-electric machine

- An example of a typical diesel-electric block diagram
- Top part of block diagram “filleted rectangular blocks” is specific for diesel-electric and provides hand-offs to the general requirement in clause 4 & 5 (BEV) in the lower portion.
- Components and systems outside the red dashed line are outside the scope of this Standard





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Annex A (informative)



Annex A (Informative)

Additional information on battery electric-powered machines

■ Topics covered:

- A.1 Protection against electric shock (Ref. A list of various standards and clause#)
- A.2 Protection against fire (Ref. A list of various standards and clause#)
- A.3 Protection against thermal hazards (Ref. SAE J2929)
- A.4 Protection against mechanical hazards (Ref. A list of various standards and clause#)
- A.5 Protection against chemical hazards (Ref. SAE J2464, IEEE 1578)
- A.6 Electromagnetic compatibility (Ref. SAE. J2344)
- A.7 Wiring (Ref. A list of various standards and clause#)
- A.8 Tests (A list of various standards and clause#)



Future Work



Collect feedback on user experience and revise M424.4



Revise the M424.3 Braking Performance from 20% grade to flat ground test



New technical content for transportation, storage RESS and hydrogen fuel in underground mine



We would like to acknowledge

- Marc Bétournay and David Young for initiating this project
- CanmetMINING and The Canadian Association of Administrators of Labour Law-Occupational Safety and Health for funding this project
- All subcommittee and Technical committee members for their efforts to create this standard.

“Your contribution is greatly appreciated”



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THANK YOU!

Q & A

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