

CSA M424.4:22

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

John Le (CanmetMINING),
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New Machine Technologies Transition in Underground mines



Why now?

How would end users establish procedures for safe operation without Standards?

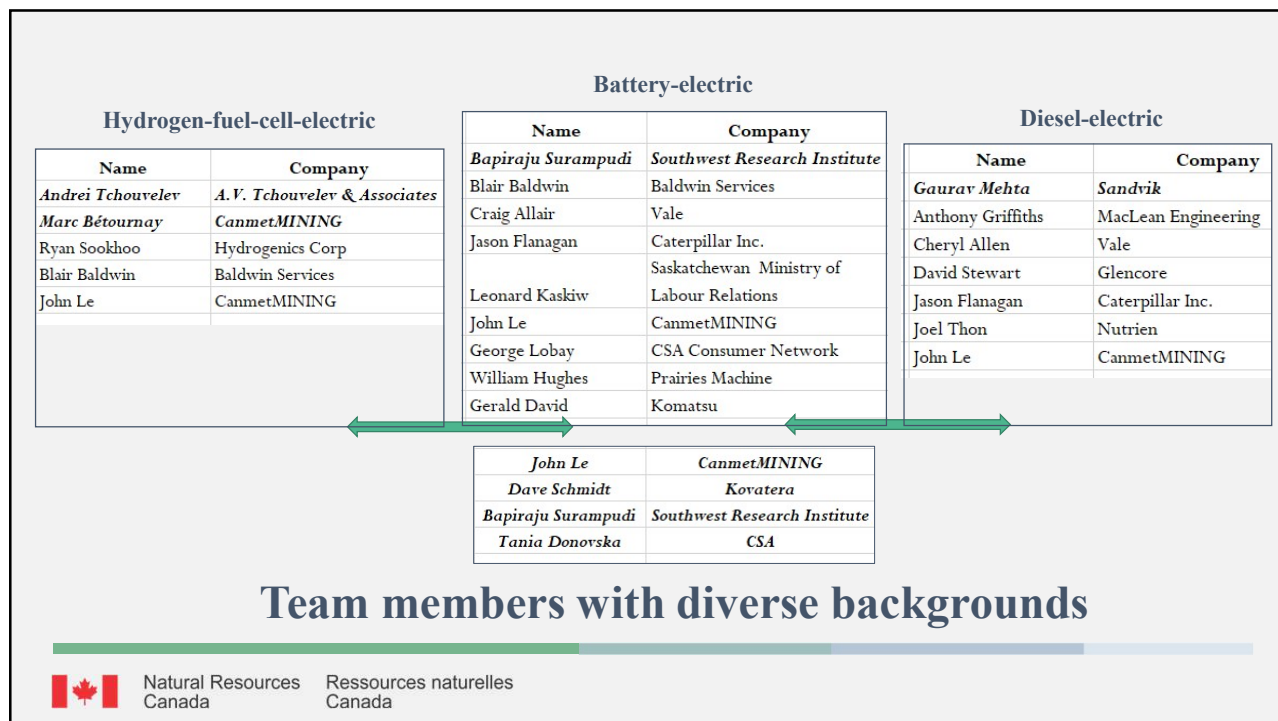
Which Standards shall be used to design and manufacture battery electric-powered, hydrogen-fuel-cell-electric powered, and diesel-electric powered machines to ensure safe operation for underground mines in Canada?



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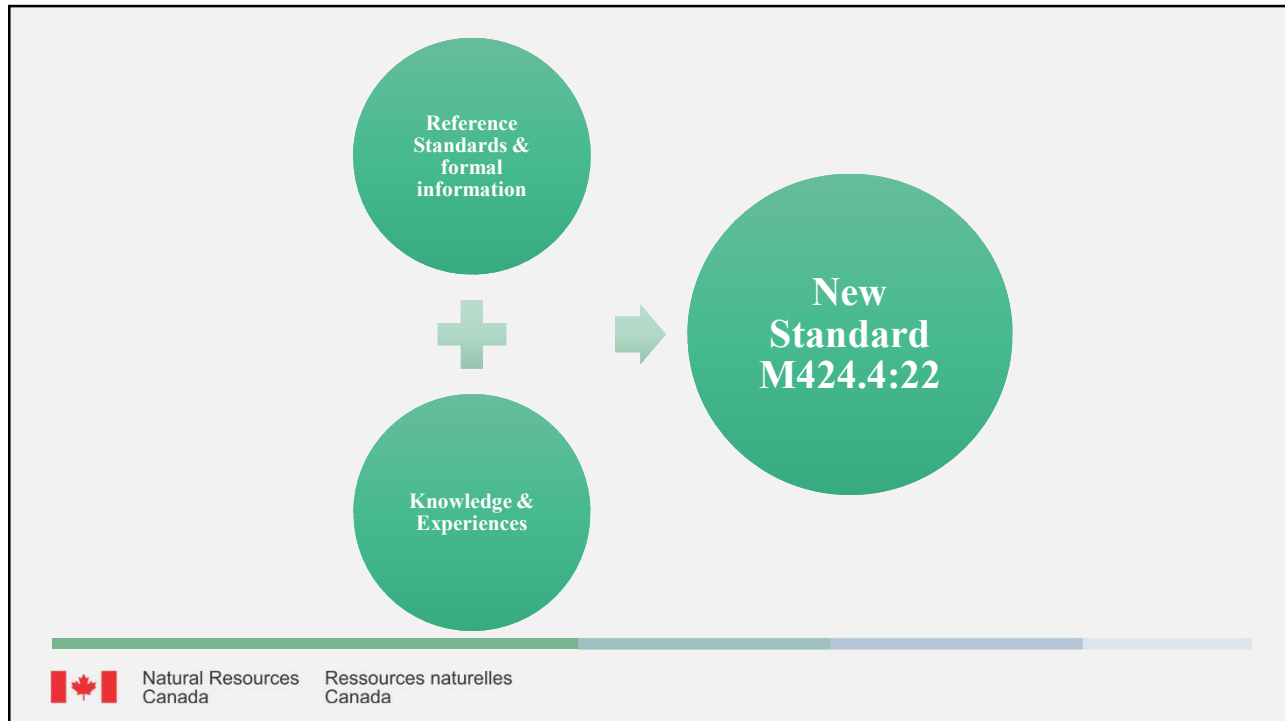
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1. Scope

1.1 This Standard applies to self-propelled, electrically driven, non-rail-bound mobile machines for use in non-gassy underground mines. It provides requirements for such machines and is intended to be used in conjunction with CSA M424.0, CSA M424.1, CSA M424.2, and CSA M424.3, each as applicable.

1.2 This Standard considers battery-electric as the base system configuration. Hydrogen-fuel-cell-electric and diesel-electric systems are also considered as on-board sources of electrical energy supply and are addressed by this Standard with additional specific requirements. Additionally, other energy storage technologies are considered by this Standard for application as possible sources for electric propulsion.

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Scope (Cont'd...)

1.3 This Standard applies to those self-propelled machines using on-board voltages in the ranges of 50 V-1.5 kV AC at any frequency and 75 V-2.1 kV DC, including any repetition rate of pulsating DC. Voltages contained within on-board devices are not considered in this Standard.

1.4 This Standard addresses hazards relevant to the voltage range for underground mobile machines within its scope when the machinery is used as intended. It specifies appropriate technical measures for eliminating or reducing risks arising from significant hazards during commissioning, operation, and maintenance. The safety of operators, technicians, service and maintenance personnel, and bystanders is addressed in this Standard.



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Scope (Cont'd...)

1.5 In this Standard, “shall” is used to express a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with the standard; “should” is used to express a recommendation or that which is advised but not required; and “may” is used to express an option or that which is permissible within the limits of the Standard.


Annexes are designated normative (mandatory) or informative (nonmandatory) to define their application.



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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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3. Definitions and abbreviations

Extra-low voltage (ELV): any voltage not exceeding 50 V AC or 75 V DC

Low voltage (LV):

voltage greater than 50 V AC and less than 1000 V AC r.m.s
or greater than 75 V DC and less than 1500 V DC

High voltage (HV):

voltage greater than 1000 V AC and not exceeding 36 kV AC r.m.s
or greater than 1500 V DC and not exceeding 36 kW DC.

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Abbreviations

The following abbreviations shall apply in this standard:

BEV = battery electric vehicle

CHSS = compressed hydrogen storage system

EVSE = electric vehicle service equipment

HFCEV = hydrogen-fuel-cell-electric vehicle

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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4. General requirements – Self-propelled electrically driven machines

- General requirements for BEV, HFCEV and diesel-electric sections (5, 6, 7)
- Vehicle operator should be alerted to the existence of a propulsion fault or condition that could lead to further damage to propulsion system hardware
 - 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)



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General requirements – Battery hazard rating

Hazard severity level	Description	Classification criteria and effect
0	No effect	No effect. No loss of functionality.
1	Passive protection activated	No damage or hazard; reversible loss of function. Replacement or re-setting of protection device is sufficient to restore normal functionality.
2	Defect/damage	No hazard but damage to RESS; irreversible loss of function. Replacement or repair needed.
3	Minor leakage/venting	Evidence of cell leakage or venting with RESS weight loss < 50% of electrolyte weight.
4	Major leakage/venting	Evidence of cell leakage or venting with RESS weight loss > 50% of electrolyte weight.
5	Rupture	Loss of mechanical integrity of the RESS container, resulting in release of contents. The kinetic energy of released material is not sufficient to cause physical damage external to the RESS.
6	Fire or flame	Ignition and sustained combustion of flammable gas or liquid (approximately more than 1 s). Sparks are not flames.
7	Explosion	Very fast release of energy sufficient to cause pressure waves and/or projectiles that can cause considerable structural and/or bodily damage, depending on the size of the RESS. The kinetic energy of flying debris from the RESS can be sufficient to cause damage as well.


As per SAE J2464 in various safety categories and abnormal operation of battery



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5. Battery electric-powered machines

A battery electric vehicle (BEV) 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

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Battery electric-powered vehicle 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)

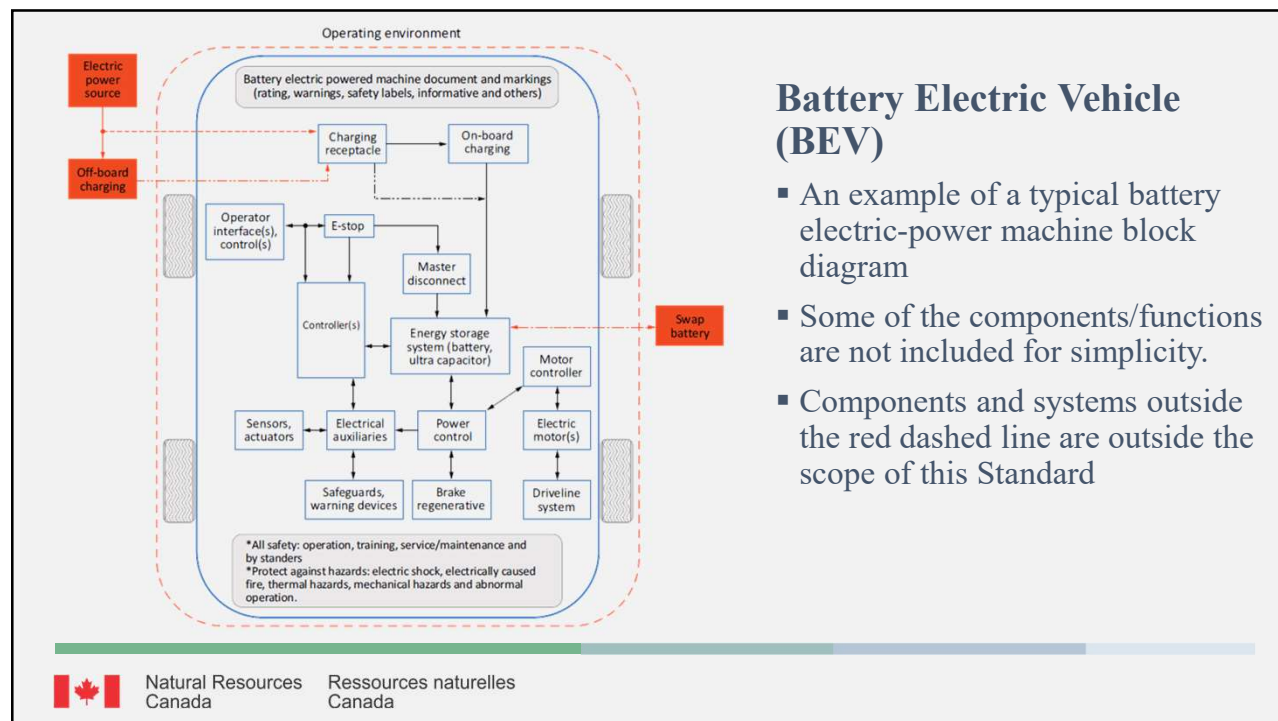
5.7 Tests (Ref. ISO 14990-1)



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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 for motor controllers and electric motor(s) to derive power from. The following major systems are common to most HFCEVs:

- hydrogen fuelling;
- hydrogen storage;
- hydrogen fuel delivery;
- fuel cell; and
- electric propulsion and power management.

This section contains requirements for hydrogen-fuel-cell systems of the machine that include layout and key design and test requirements for safety and certification.

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Hydrogen-fuel-cell-electric content and structure

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

■ Topics covered:

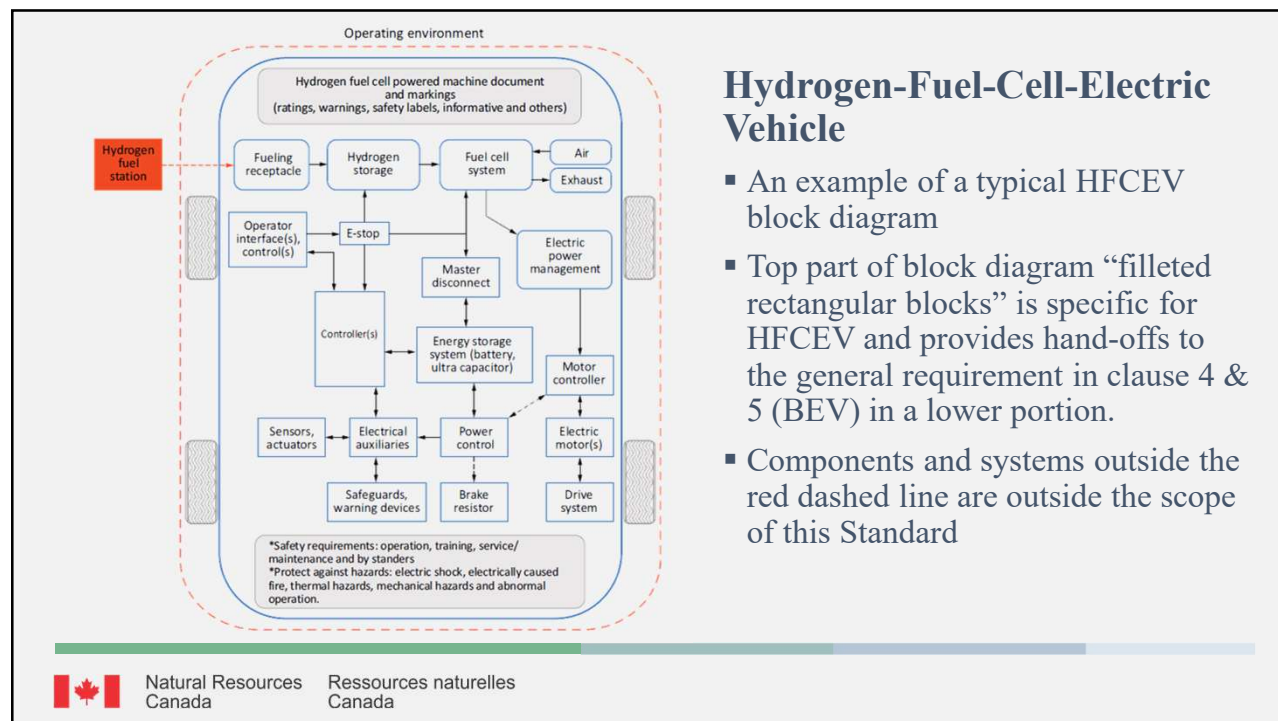
- 6.1 Hydrogen-fuel-cell-electric systems (Ref. BNQ 1784-000, CSA HGV 4.1...)
- 6.2 Compressed hydrogen storage system (Ref. SAE J2579, ISO 19881...)
- 6.3 Fuel cell system (Ref. IEC 62282-2-100)
- 6.4 Electric propulsion power management (Ref. Meet Clause 5 BEV)
- 6.5 Protection against hazards (Ref. MSHA Approval-Criteria ACRI2001)
- 6.6 Controls (Ref. Specific requirement in this clause, meet Clause 5 BEV)
- 6.7 Manuals and technical documentation (SAE J2615, CGA C-6.4, SAE J3089..)
- 6.8 Marking (Ref. Specific requirement in this clause)
- 6.9 Testing (Ref. Specific requirement in this clause)



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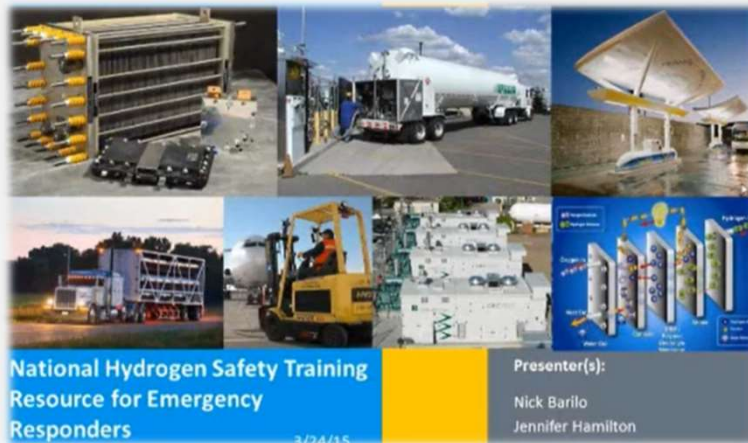
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Note: Resources for hydrogen safety training and hydrogen safety training for first responders can be found at <https://h2tools.org/training-materials> and <https://www.energy.gov/eere/fuelcells/webinar-national-hydrogen-safety-training-resource-emergency-responders> or other hydrogen industry-recognized sources for hydrogen safety information



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7. Diesel-electric powered machines (hybrid)

- Diesel-electric vehicles (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. While the various hybrid systems are likely to differ in their design, hardware, and software implementations, the concepts are common to most hybrid vehicles.
- This section provides additional safety requirements for a diesel-electric (hybrid) mining machine powertrain that includes layout, key design and test requirements for safety, and certification. Also provided are specific requirements for protection against hazards, controls, manuals, technical documentation, marking, and tests.



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Diesel-electric content and structure

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

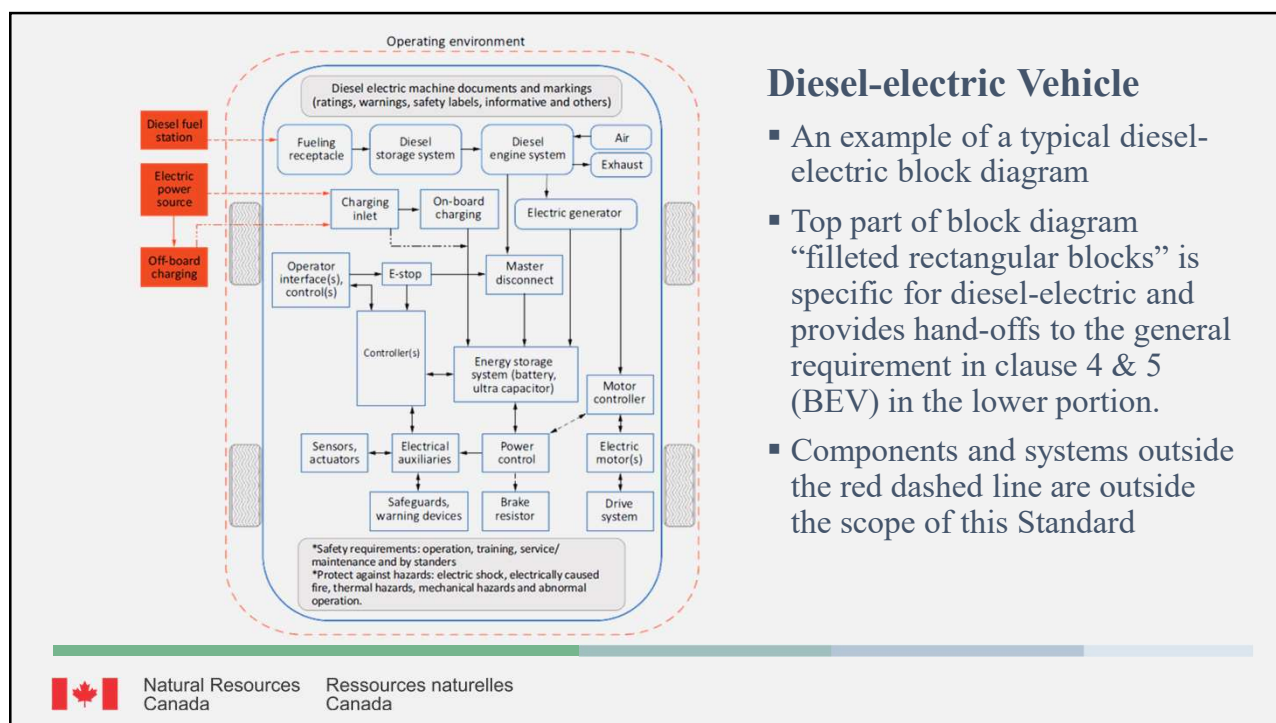
- Topics covered:
 - 7.1 General (Ref. Specific requirements in this clause)
 - 7.2 Diesel fuel and fuel tanks (Ref. M424.2)
 - 7.3 Diesel engine system (Ref. M424.2)
 - 7.4 Engine driven electric generator (Ref. meet clause 5 BEV)
 - 7.5 Protection against hazards (Ref. M424.2, M424.0, ISO 20747, IEC 60034...)
 - 7.6 Controls (Ref. M424.2, SAE J1772)
 - 7.7 Manuals and technical documentation (Specific requirements in this clause)
 - 7.8 Machine identification (Ref. M424.2, M424.0)
 - 7.9 Tests (Ref. M424.2)
 - 7.10 Transport dangerous goods (Ref. M424.0)



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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#)



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Future Work



Collect feedback on user
experience



BEV, HFCEV and diesel-electric
for gassy underground mine



Revise the M424.4 with more
machine design content that is
specific to underground mobile
equipment



Transport RESS, hydrogen-
fuel-cell stack, and storage
to/from underground mine



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We would like to acknowledge

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- All subcommittee and Technical committee members for their efforts to create this standard.

“Your contribution is greatly appreciated”



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