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CSA M424.2-22 Certification

MVPC – October 5, 2023

Canada

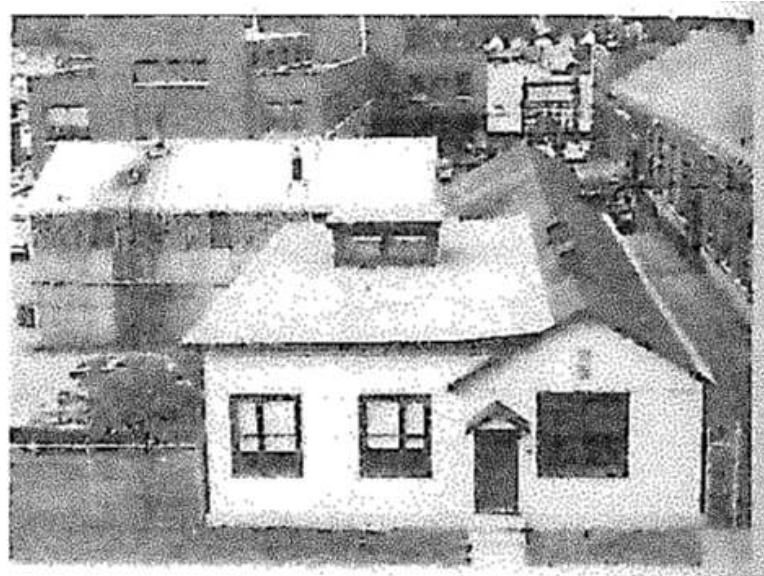
CSA Certification Workshop:

- Part 1: Certification History, Structure and Authority
- Part 2: Certification processes for CSA M424.2
- Part 3: Changes and Amendments to CSA M424.2-22
- Part 4: Standalone Emissions Control approval
- Part 5: EV / BEV Powertrain Certification to M424.4

Part 1: Certification History, Structure and Authority

Mining equipment certification in Canada

- 1939 – 1945: The exigences of wartime mining and resource extraction identify safety hazards in Canadian mines – especially coal.
- 1946 – 1950: Provincial Mines Ministers drive the development of proposals for a coal mine electrical certification program in Canada to be administered by the CSA in collaboration with the federal government.
- 1953: Mines Branch establishes an Electrical Certification Laboratory and conducts testing and approvals under the authority of the CSA.



Electrical Certification Laboratory (554 Booth St.) 1954, on site of old machine shop; new machine shop (556 Booth St.) is at left rear; Butler building for carbonization studies is in middle rear

Structure of Certification at NRCan

- 1958 – Parliamentary order-in-council issued to Mines Branch (EMR/NRCan) to provide a mandate for certification services for electric motors, batteries, and equipment for underground mining.
- G.K. Brown appointed the first CSA Certification Officer.
- Order later amended to include fire-resistant conveyor belting, hydraulic fluids and diesel equipment.
- The NRCan certification officer is authorized to test and approve against the CSA and other standards and issue certificates.
- NRCan advises the CSA; but CSA is independent, and its committees are made up of industry stakeholders.
- Provinces have final jurisdiction over mining and most have CSA compliance in legislation.

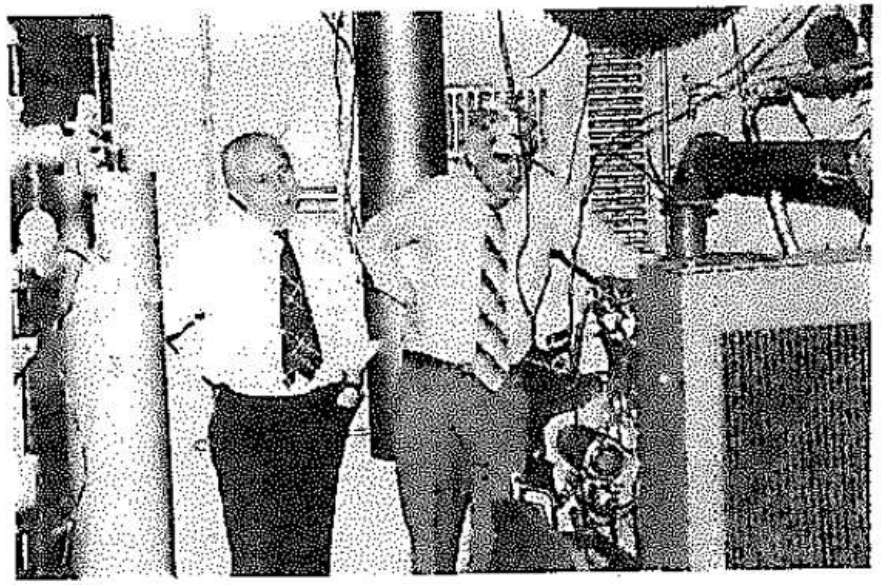
Examples of Early Certificate Type Approvals:

- Over 1,350 certificates have been issued since 1956 for compliance against UK standards and CSA M424, M421, M423, C22.2, MSHA and IEC standards.
- Certificate # 1: Type 524 CL Primary Cell Battery (*first battery 1956*)
- Certificate # 4: 50 HP, 500V, Induction Motor (*first electric motor 1958)*
- Certificate # 10: Model 3CML100 Continuous Miner (*first electric vehicle 1958*)
- Certificate # 11: Type LE4 100 BHP Diesel Engine (*first diesel engine 1960*)

Joy 3CM Continuous Miner

Early Diesel Engine Certification

- 1965: E.D. Dainty begins development of diesel emissions certification program based on UK practices.
- 1968: First certification of diesel power package for coal mining (Cummins HR-6).
- 1969: Electrical and diesel certification consolidated under the Canadian Explosives Atmospheres Laboratory (CEAL) operating at the NRCan Bells Corners Complex.
- J. Bossert appointed as second Certification Officer.



E.D. Dainty and P. Mogan in diesel bunker with engine under test

Expansion of Diesel Certification

- In 1971, electrical equipment and diesel engine certification moved to the new facility at Bells Corners in the Ottawa Greenbelt.
- Electrical equipment coal certification expanded to include other hazardous areas like oil and gas production.
- Diesel certification expanded to include emissions measurement and ventilation rate prescription.
- G. Lobay appointed Certification Officer, followed by M. Gangal and D.A. Young.

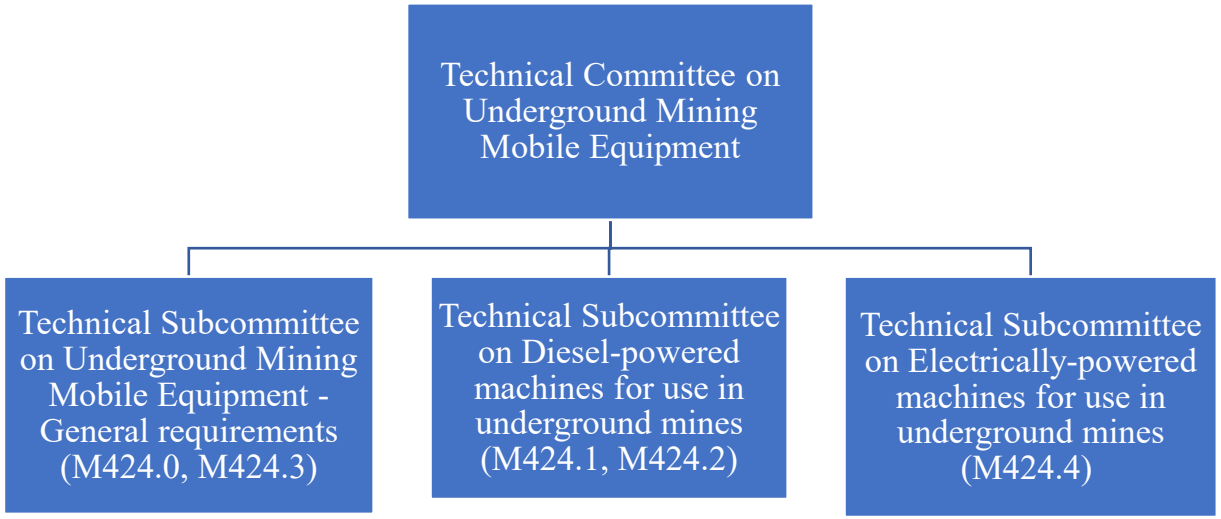
J. Vailleres with Deutz F6L912W Diesel

CSA standards development

- 1971: Publishing of “Certification of Diesel apparatus for use in mines”
- 1975: First investigations into diesel particulate matter
- 1988: Publishing of CSA M424.1-M88
- 1990: Publishing of CSA M424.2-M90
- 2016: First revision of M424.1-16 and M424.2-16; M424.3 reaffirmed to 2021.
- 2020-22: Major revisions and restructuring of the M424 family of standards. Publication of CSA M424.2-22.

NRCan and CSA Today

- NRCan / CanmetMINING and CSA are independent, but CanmetMINING advises and sits on technical committees.
- CSA Technical Committee on Underground Mining Mobile Equipment
  - Chair: Brent Rubeli, CanmetMINING
  - Co-chair: Cheryl Allen, Vale
- Technical subcommittees:
  - General, Diesel, Electric
  - John Le, Aaron Gibouleau
  - Cynthia Matikainen,
  - Raphael Tiangco



Certification at NRCan Today

- Bells Corners Building 9 – Primary Certification Facility.
- On-site witness tests at manufacturer facility.
- On-site at contract laboratories for engine tests.
- Latest certificate # 1358 Volvo Construction D8M.
- Certification Officer: B. Rubeli
- Engineering and Technical: G. Mahajan, S. Mullin

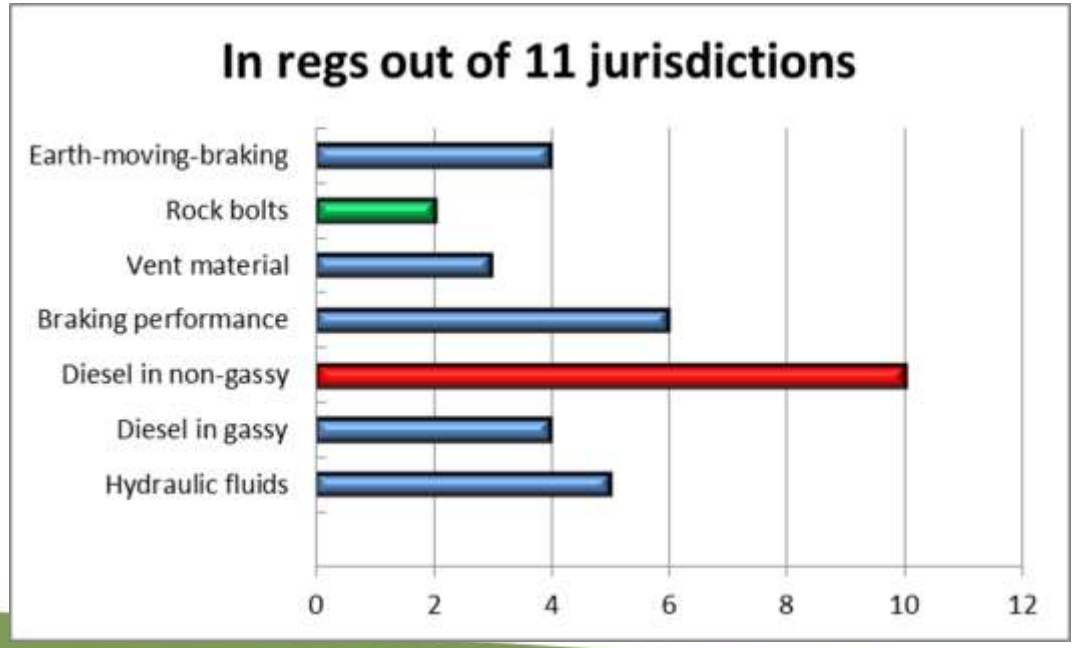
CMIN Diesel Certification Lab – BCC #9
Steve Mullin Gaurav Mahajan

Elphinstone C7.1 Diesel

Part 2: General Certification Processes for CSA M424.2

Practical application of M424.2 - Approval

- Primarily emissions testing for ventilation rate prescription.
- M424.2 is referenced in 10 of 11 jurisdictions in Canada.
- Also referenced by jurisdictions outside Canada and companies.



Engine Approval Testing

- Engine manufacturer submits an application along with a sample engine and all aftertreatment system components.
- Facility performs the certification test according to the CSA standard. If the engine passes, a ventilation rate prescription is calculated and published on the website.

Engine Manufacturer: **Kubota**
Engine Model: **V3800-TIEF4ZA6, V3800-TIEF4Z, V3800-TIEF4ZA**
Governing Standard: **CSA M424.2-16 (Non-Gassy Mines)**

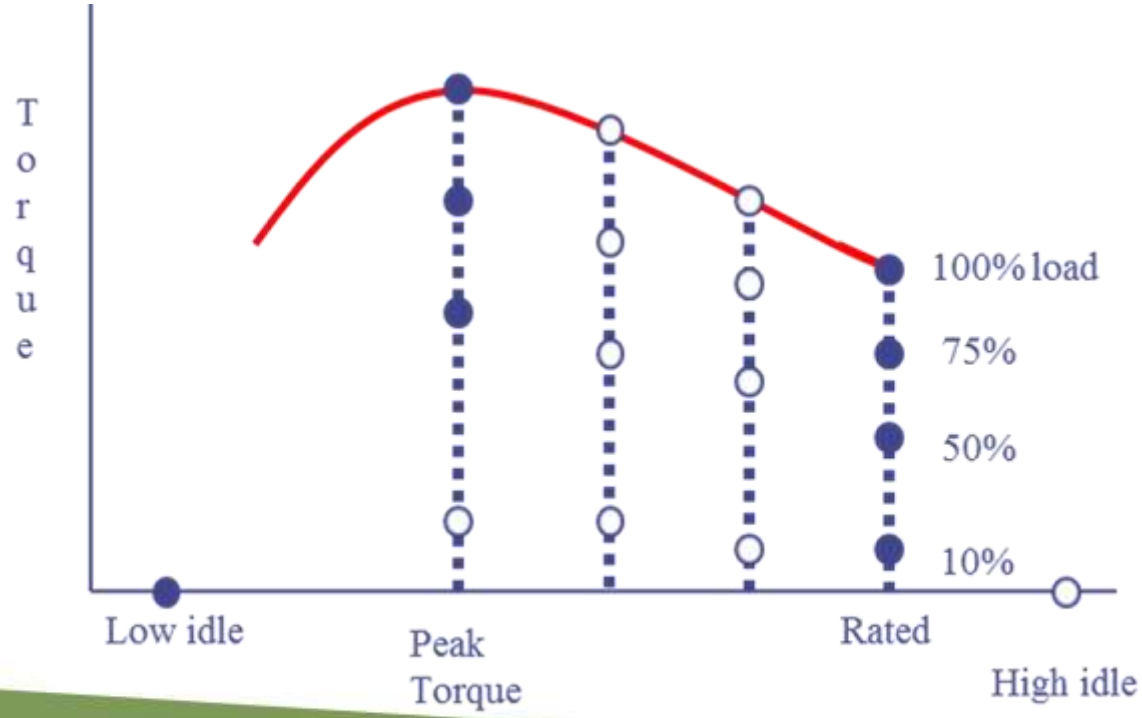
Certificate Number	Engine Rating and Fuel Rate at Sea Level	Sulphur in Fuel - ppm	Ventilation Prescription	
			CFM	m^3/s
1305	V3800-TIEF4ZA6 105 HP (78 kW) @ 2400 RPM, 38.4 lb/h	15	4100	1.93
	V3800-TIEF4Z 109 HP (81kW) @ 2600 RPM, 40.8 lb/h		4200	1.98
	V3800-TIEF4ZA 113 HP (84kW) @ 2600 RPM, 42.8 lb/h		4200	1.98

Emissions Testing Process

- Confirmation of engine power and fuel rate as per manufacturer specification
- Setting of engine intake vacuum and back-pressure as per engine specification
- Quick measurement of CO and NOx within engine operating range to determine Pass/Fail condition
- Steady state testing at 18 or more mode points, including ISO 8178-C1 8 modes
- Measure engine parameters, CO, CO2, NO, NO2, O2, DPM
- Calculate SO2 and ventilation rate at all mode points
- The highest calculated ventilation rate is the minimum vent rate for the engine approval

Engine Test Modes

- Based on ISO8178 with additional modes.
- Special tests for aftertreatment.



Engine Approval

- Approval letter to engine manufacturer.
- Certificate number.
- Ventilation rate appears on website.
- Conditions such as aftertreatment.
- Manufacturer may apply labels for importation.

- English version: http://www.diesel.NRCan.gc.ca
- French version: http://www.diesel.RNCan.gc.ca

- CSA (Canada) and MSHA (USA) testing can be performed concurrently at CanmetMINING.

General Questions 1

- Who can apply for certification?
  - *Engine manufacturers, machine builders, distributors or mining companies.*
- Is certification exclusive?
  - *No, the certificate is non-exclusive. The engine and rating are available for general use by anyone if the certificate conditions are met.*
- Which standard is used?
  - *As of March 31, 2022 all diesel approvals are against the new CSA M424.2-22 and CSA M424.1-22.*
- Are older M424.2-16 and –M90 certificates still valid?
  - *Yes, all earlier and current certificates to M424 are valid.*

General Questions 2

- Can I just submit EPA/EU test data to get approval?
  - *No. Unfortunately external data often does not separate NO and NO2 which is a requirement of M424 because they have different occupational exposure limits. In addition, EPA/EU tests do not include sufficient steady state points and often weight aftertreatment regen emissions which would underestimate worker exposure.*
- What if the engine fails?
  - *The application can be withdrawn or the engine modified or retrofitted with emission controls to pass but they become required condition for the certificate to be valid.*
- What does it cost?
  - *Cost varies with ratings and aftertreatment but approx. $50-$60,000 CAD*

General Questions 3

- How long does it take?
  - *Certification takes 2-3 months including engine installation, testing, removal, data analysis and issuing documents. Currently lead time is 6-8 months.*
- What are other options for testing?
  - *Testing can be witnessed at an engine manufacturer's facility or known contract laboratory subject to audit and review. Often this is faster but more expensive.*
- What about diesel-electric hybrid engines or stationary applications?
  - *The new M424.2 and M424.4 allow for hybrid vehicles and stationary diesel equipment to be approved.*

Questions?

Part 3: Changes and Amendments to CSA M424.2-22

CSA M424 Review rationale

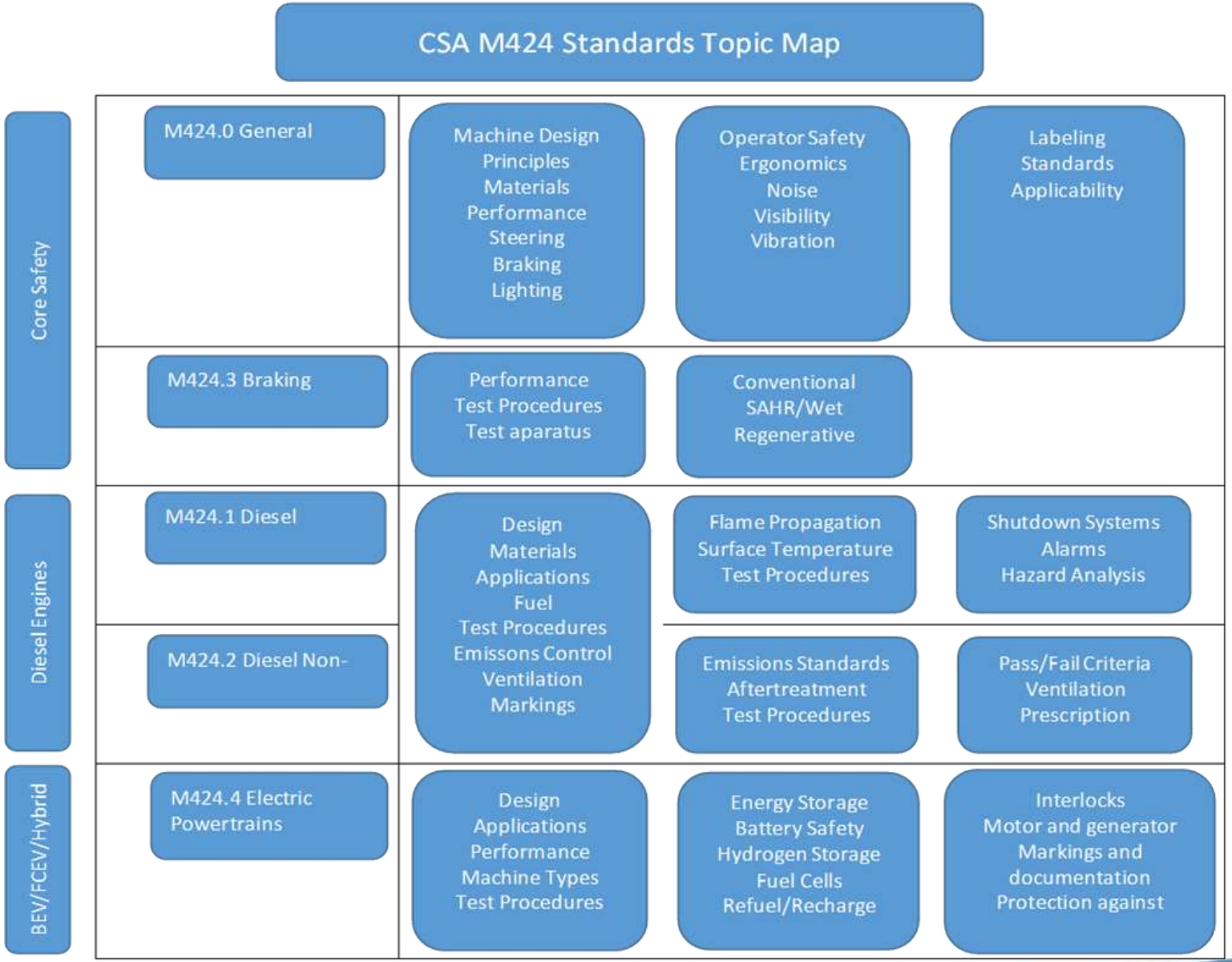
- General alignment/modernization of M424 family with ISO 19296.
- Diesel-specific:
  - It was becoming apparent that the M424.2-16 emissions pass/fail criteria were not comparable with current EPA/EU standards.
  - Underground auxiliary diesel machines like stationary pumps/generators were becoming larger and needed to be brought into scope.
  - New types of diesel/electric hybrid machines and special duty cycles were not addressed and needed to be enabled.
  - Very large haul trucks with powerful engines needed to be brought into scope.

CSA M424.2-22 "*Diesel-powered machines for use in non-gassy underground mines*"

- M424.2 is the conventional diesel engine standard.
- Intended to be used within the M424 family in conjunction with other parts.
- Machine type / use determines applicability based on topic map.

CSA M424.0 Underground Mining Mobile Equipment – General Requirements	CSA M424.1 Flameproof non-rail-bound diesel-powered machines for use in gassy underground coal mines	CSA M424.2 Non-rail-bound diesel-powered machines for use in non-gassy underground mines	CSA M424.3 Braking Performance Rubber-Tired, Self-Propelled Underground Mining Machines	CSA M424.4 Non-rail-bound electrically-powered machines for use in non-gassy underground mines

CSA M424 Topic Map



M424.2-22 Major Changes:

- Restructuring within M424 family:
  - Vehicle/machine core safety standards moved to M424.0-22.
  - Additional ignition hazard requirements for gassy mines diesels – M424.1-22.
  - Additional design requirements for diesel/electric hybrids – M424.4-22.
- Scope review:
  - Scope expanded to include larger/ more varied diesel-powered machines.
- Design review
  - Retain diesel-specific design requirements from M424.2-16.
- Performance criteria:
  - Engine emissions testing pass/fail criteria lowered to reflect modern technologies.
  - EQI concept for ventilation rate determination removed.
  - Ventilation rate determination for retrofit emission control devices enabled.

M424.2-22 Minor Changes:

- Design details
  - Fuel tanks to comply with ISO 21507 in whole or in part.
  - Fuel tank and supply system design details updated.
  - Improved protection for fuel lines

  - Electrical wiring, starter battery protection updated.
  - Mechanical protection / operator protection updated.

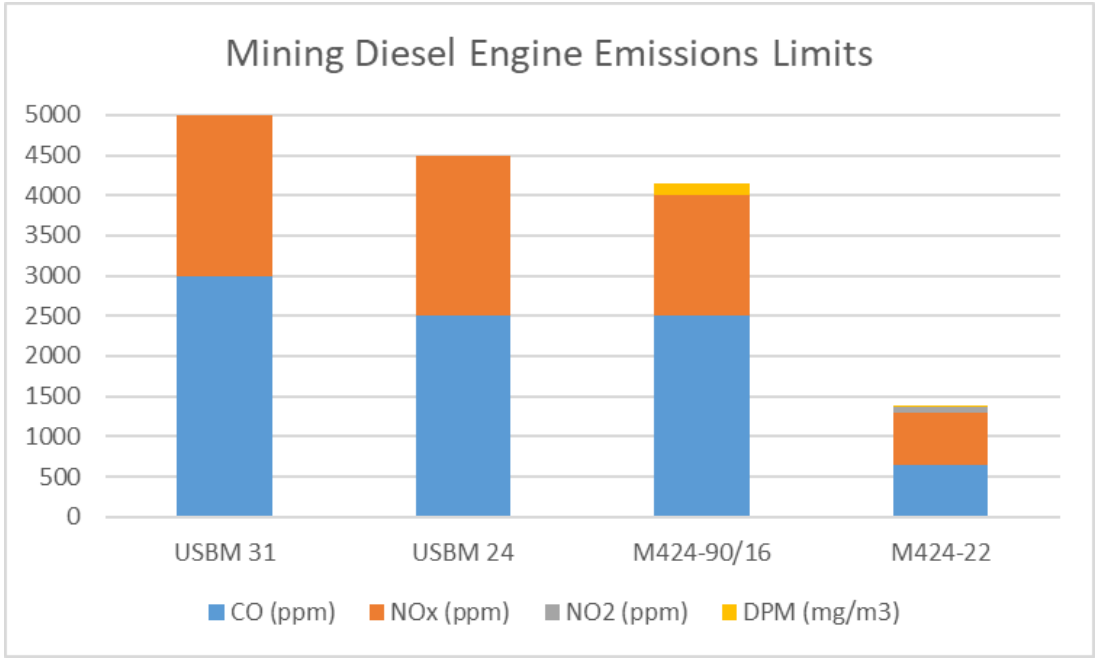
  - Exhaust system guarding and operator protection upgraded to ISO 3457.
  - Prohibition on modification of OEM exhaust system components (Clause 5.3).

Performance Criteria Changes M424.2-22

- Reduction of pass/fail limits for undiluted tailpipe CO, DPM.
- Separation of NOx limit into NO and NO2.
- New pass/fail limit for NO and NO_2.

Mining Diesel Engine Emissions Limits (US/Canada)					
	USBM 31	USBM 24	M424-90/1	M424-22	
CO (ppm)	3000	2500	2500	650	
NOx (ppm)	2000	2000	1500	650	(as NO)
$NO_{2\ (ppm)}$	n/a	n/a	n/a	75	(as NO_2)
DPM (mg/m3)	n/a	n/a	150	15	

Note that pass/fail limits for coal engines were not lowered as these engines are still EPA T1/T2 level.



Performance Criteria Changes -EQI

- EQI concept removed.
- New lower pass/fail limits have resulted in ventilation rates being set by individual gases.
- EQI is not relevant any more as it would be higher than the individual gas vent rates and thus would never be used.

$$EQI = \frac{CO}{50} + \frac{NO}{25} + \frac{DPM}{2} + 1.5 \times \left\{ \frac{SO_2}{3} + \frac{DPM}{2} \right\} + 1.2 \times \left\{ \frac{NO_2}{3} + \frac{DPM}{2} \right\}$$

- Also the EQI used a TLV of 50ppm for CO and elimination of the EQI allows the lower current TLV of 25ppm to be used for dilution rate calculation.

Performance Criteria – Emissions Control

- Emissions control device certification enabled.
- OEM Tier4 and EU Stage V already have emissions control.
- Package certification with retrofit or aftermarket emissions control has always been allowed under M424.2-88/16.
- Possibility for stand-alone emissions control device certification to M424.2-22 with conditions;
  - Can only be retrofit to a previously- certified engine with known emissions and ventilation rates.
  - Full engine bench emissions test (MAPTEST) to determine reductions and secondary emissions.
  - Engineering analysis for engine model applicability and ventilation rates.

Future Development of M424.2

- Transient test cycles
  - Use of a transient test cycle would harmonize M424.2 emissions testing with other engine certifications.
  - CanmetMINING has done some comparative studies on LHD cycles vs NRTC off-road certification test cycles.
  - Challenge to get separate NO/NO2 data / vent rate input.
- In-use verification
  - Field verification of compliance with M424.2 emissions.
  - Many jurisdictions already do pass/fail emissions testing.
  - How to extract certification data from in-use data.

Part 4: Standalone Emissions Control System Approval

Emissions Control Device Approval

- Most new EPA Tier4/EU Stage 5 engine will have comprehensive emissions control comprised of particulate control (DPF) and NOx control (SCR).
- The CSA M424.2-22 pass/fail limits are aligned with this level of emissions control.
- What if mines want to improve air quality by retrofitting emission controls? How do they see a benefit in terms of ventilation rate?
- CSA M424.2 has always allowed “package” approval and now M424-22 enables standalone device approval through the MAPTEST

Technology Levels

- What is achievable with different types of retrofit technologies?
- We can look at existing certifications for the same engine family over time as technology changes to get an estimate.

Deutz 914 Series Air-cooled Engines						
Certificate	Model	Power (hp)	Emissions Control	Vent Rate (CFM)	CFM/HP	Retrofit (%)
1245	BF6L914	96	none	11300	118	0
1312X	F6L914	96	oxidation catalyst	9000	94	20
1300X	D914L06	100	partial DPF system	6900	69	41
Caterpillar C18 Haul Truck Engines						
Certificate	Model	Power (hp)	Emissions Control	Vent Rate (CFM)	CFM/HP	Retrofit (%)
1183	C18	589	none	35500	60	0
1281X	C18	589	partial DPF system	33700	57	5
1299X	C18	589	CRT + LNT	27500	47	23
1319	C18	598	OEM T4F DPF	22000	37	39
Kubota Utility RTV Engines						
Certificate	Model	Power (hp)	Emissions Control	Vent Rate (CFM)	CFM/HP	Retrofit (%)
NA (failed)	D902	22	T2 (vent rate est.)	3400	155	0
1218X	D902	22	T2 pDPF system	2700	123	21
1237	D902	22	OEM T4 Interim	2600	118	24

Note that 90% DPM reductions by good aftertreatment do not translate directly to a 90% reduction in ventilation rates!

Realistically the best available aftertreatment (T4 Final) only gives a 40% reduction in rates.

What is the MAPTEST?

- **Ma**nufacturer's **p**ro**t**ocol for **e**xhaust **s**ystems **t**esting.
- Reference: MMSL 97-064.
- Based on the ISO 8178 test and the CSA M424.2-90.
- Used for laboratory emissions testing of oxidation catalysts, diesel particulate filters, etc.

ISSUE #1 (1997)

MAnufacturer's **P**ro**T**ocol
for
Exhaust **S**ystems **T**esting
(**MAPTEST**)

Document Number MMSL 97-064 (CR)
September 1997

authored by: members of the Diesel Exhaust Evaluation PROtocol Committee (DEEPROC)

prepared for: segments of the North American Mining Industry utilizing diesel exhaust treatment systems

Project No: 603206 06 2

NATURAL RESOURCES CANADA
CANADA CENTRE FOR MINING AND MINERALS TECHNOLOGY (OTTAWA)
MINING AND MINERAL SCIENCES LABORATORIES
REPORT MMSL 97-064 (CR)

Why was the MAPTEST created?

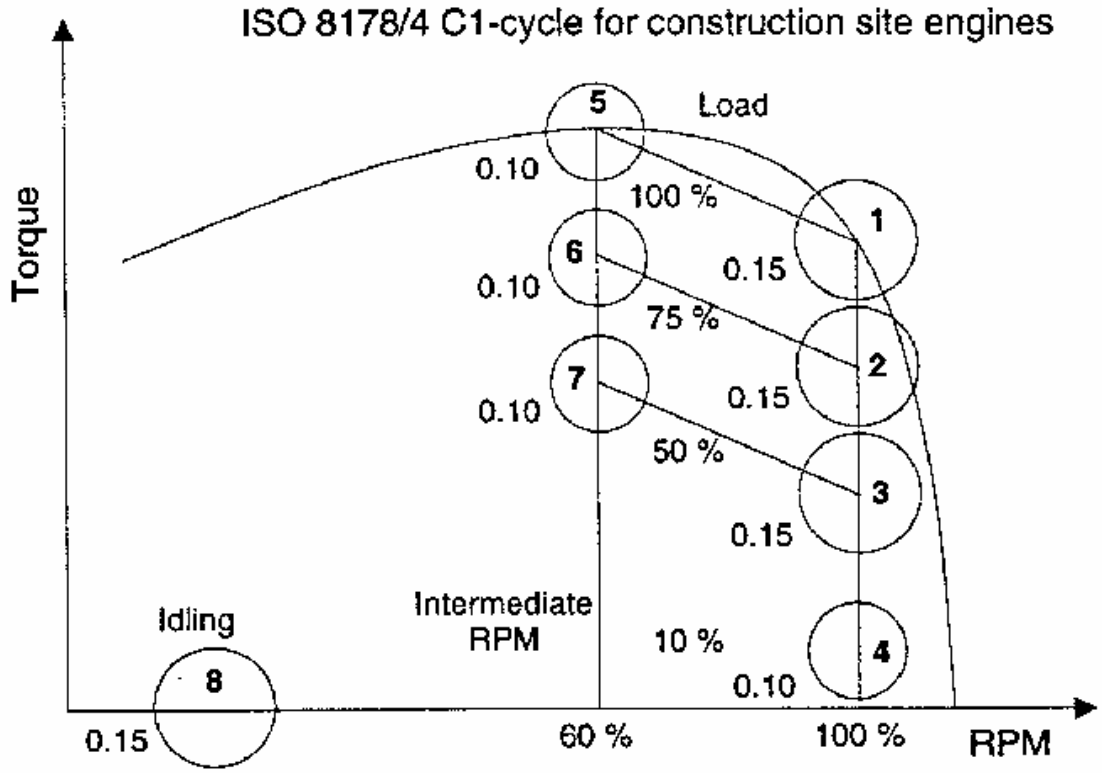
- Emissions data from manufacturers often did not include nitric oxide (NO) and nitrogen dioxide (NO_2) separately.
- This is important because they have different exposure limits.
- It was known that certain diesel oxidation catalysts produce NO_2 as a secondary emissions and this was of specific concern.
- The diesel emissions measurement and analysis from M424.2-90 had become widely accepted and it was thought this could be used to evaluate emissions control devices.

How does it work? - Test Cycles

- Based on ISO8178 eight mode test.

Table 1 - **Engine Operating Conditions (8-Mode Schedule)**

Mode	Speed *1	% Load *2	Weighting factor *3
1	rated	100	0.15
2	rated	75	0.15
3	rated	50	0.15
4	Rated	10	0.10
5	intermediate	100	0.10
6	intermediate	75	0.10
7	intermediate	50	0.10
8	low idle	0	0.15



Emissions Sampling

- Conventional emissions only.
- Test equipment to ISO8178.

Table 2 - **Exhaust Gas Components to be Measured**

component measurement	measured principle
O_2	paramagnetic
CO	infra-red
CO_2	infra-red
NO	chemiluminescent or FTIR (Fourier Transform)
NO_2	chemiluminescent or FTIR (Fourier Transform)
SO_2	infra-red or ultra-violet
THC	heated flame ionization detection
diesel particulate matter (DPM)	gravimetric analysis

Evaluation

- Uses the exhaust quality index (EQI) for the integrated ISO8178 emissions results as an indicator of overall emissions.

$$EQI = \frac{CO}{50} + \frac{NO}{25} + \frac{DPM}{2} + 1.5\left[\frac{SO_2}{3} + \frac{DPM}{2}\right] + 1.2\left[\frac{NO_2}{3} + \frac{DPM}{2}\right]$$

- The emissions system effectiveness (ESE) is calculated from the change in EQI.

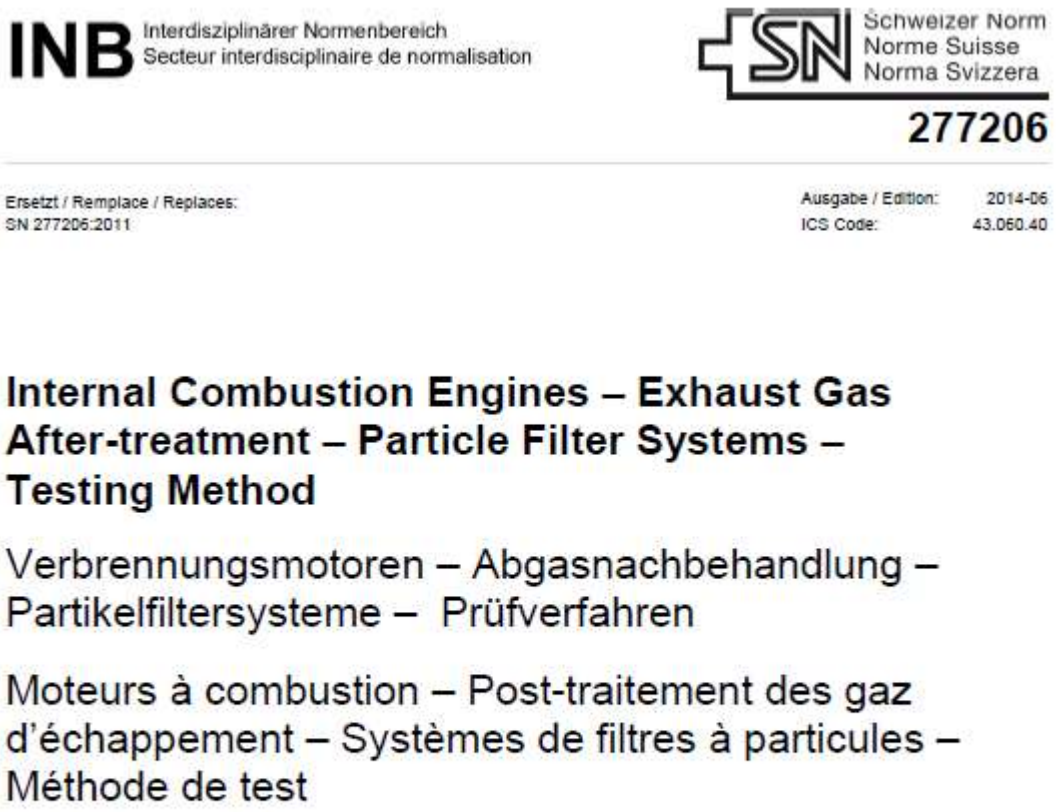
$$\%ESE = \frac{EQI_{baseline} - EQI_{addon}}{EQI_{baseline}} x100$$

Why revise the MAPTEST?

- The ESE gave the mining industry their own evaluation tool for aftertreatment device performance.
- But no effect on ventilation rates and no changes to certification.
- No consideration for secondary emissions like PAHs and VOCs despite VOC mutagenicity tests being common around that time.
- Other protocols have become popular in the industry including the VERT test, MSHA particulate filter requirements and EPA and CARB verification programs.
- Time to revise the protocol.

VERT Test – SN277206

- The VERT test is very well known especially for comprehensive analysis of secondary emissions.
- Very expensive and time consuming but accepted globally.
- Also based on ISO8178 C1 cycle.
- Tests emissions during DPF regeneration similar to M424.2-22.
- In-use verification component.



INB Interdisziplinärer Normenbereich
Secteur interdisciplinaire de normalisation

SN Schweizer Norm
Norme Suisse
Norma Svizzera

277206

Ersetzt / Remplace / Replaces:
SN 277206:2011

Ausgabe / Edition: 2014-06
ICS Code: 43.060.40

Internal Combustion Engines – Exhaust Gas After-treatment – Particle Filter Systems – Testing Method

Verbrennungsmotoren – Abgasnachbehandlung – Partikelfiltersysteme – Prüfverfahren

Moteurs à combustion – Post-traitement des gaz d'échappement – Systèmes de filtres à particules – Méthode de test

MSHA particulate filter requirements

- MSHA requires diesel particulate filters to have a minimum performance to achieve the PM g/h emissions rule.

Table I-1

Type of Equipment	Emissions Limit	When Applicable (from date final rule published)
Permissible		
newly introduced	2.5 grams per hour	60 days
existing fleet	2.5 grams per hour	18 months
Heavy duty nonpermissible		
newly introduced	5.0 grams per hour	60 days
existing fleet (interim)	5.0 grams per hour	30 months
existing fleet (final)	2.5 grams per hour	4 years
Generators and compressors	same as heavy duty	same as heavy duty
Other light duty nonpermissible		
newly introduced	5.0 grams per hour (or listed EPA standards)	60 days
entire fleet	no requirements	

Approval No.	Manufacturer	Engine Model	Rated	PI	DPM gm/hr	Weighted Avg.	DPM	Filter Efficiency	Filter Efficiency
		* Meets EPA	Horse power	CFM	Weighted Avg.	Horsepower	gr/bhp-hr	To Obtain 5.0gm/hr	To Obtain 2,5gm/hr
A001	DEUTZ	MWM 916	94	15000	25.49	51.1	0.50		90.2
A002	CATERPILLAR	3306 PCNA	150	27000	45.88	87.2	0.53		94.6
A003	CATERPILLAR	3304 PCNA	100	17500	29.74	58.1	0.51		91.6
A004	ISUZU	QD 100-306	70	50000	84.96	40.7	2.09		97.1
A004	ISUZU	QD 100-306	66	10000	16.99	34	0.50		85.3
A005	Caterpillar	3306PCTA	190	31000	52.68	95	0.55		95.3
B070	Farymann	43F	14	4000	6.80	7.00	0.97	26.4	63.2
B042	Lister Petter	LPU2 MKI	17.5	5000	8.50	9.1	0.93	41.2	70.6
B053	Kubota	V1200*	25.8	1500	2.55	13	0.20	0.0	1.9
B041	Lister Petter	LPU3 MKI	26.3	7000	11.89	13.7	0.87	58.0	79.0
B062	Deutz	F2L1011*	28.2	1000	1.70	14	0.12	0.0	0.0
B044	Lister Petter	LPU3 MKII	29	4500	7.65	15.1	0.51	34.6	67.3
B015	DEUTZ	F2L 1011F*	30	3500	5.95	15.6	0.38	15.9	58.0

CARB Emissions Control Verification

- Verified diesel emissions control strategy (VDECS).
- (CCR 2700-2710) by the California Air Resources Board (CARB) to reduce either particulate matter or oxides of nitrogen, or both.
  - Level 1 PM VDECS is verified to reduce PM emissions by at least 25%,
  - Level 2 by at least 50%, and
  - Level 3 by at least 85% or to achieve PM emission levels of 0.01 grams per brake-horsepower-hour (g/bhp-hr) or less.

How can we build on this experience?

- Include secondary emissions in the MAPTEST.
- Include DPF regeneration performance evaluation and safety.
- Look at potential for in-use verification.
- Lessons learned
  - MSHA – Revisions because of NO_2 formation potential.
  - CARB – Recalls due to unsafe regen control in some DPFs.
- Ensure that specific needs of the mining industry are met.
  - Emissions control for good air quality.
  - Device safety for operator protection.

How can you help?

- Revision of the MAPTEST will be a collaborative effort by device manufacturers, mining companies, regulators and government.
- Please contact CanmetMINING if you are interested in joining the MAPTEST review committee.

  - Brent Rubeli
  - brent.rubeli@nrcan-rncan.gc.ca

Part 5: Electric Vehicle / BEV Powertrain Certification to M424.4

Diesel Approval and Certification

- The Certification Lab currently has four roles:
  - Clean diesel engine certification to CSA M424.2 / M424.1
  - Research into low-carbon fuels / diesel emission controls
  - Provincial / Federal regulatory support
  - CSA standards development
- With the release of the new CSA M424.4 standard, EV, BEV and electric machine certification is anticipated to become part of an expanded role.

CMIN Diesel Certification Lab – BCC #9
Steve Mullin Gaurav Mahajan

Capacity Building: BEV Test and Certification

- BEV component certification has been performed in parallel with diesel at the Bells Corners Lab since 1970.
- Over 1,350 pieces of certified electrical and diesel equipment for mining.
- *But facility needs upgrades for large e-motor and battery module testing*.

- Four major areas of electric machine research/certification:
  - Powertrain batteries
  - Electric motor (e-motor)
  - BEV machine/vehicle integration
  - Battery handling / abuse tests

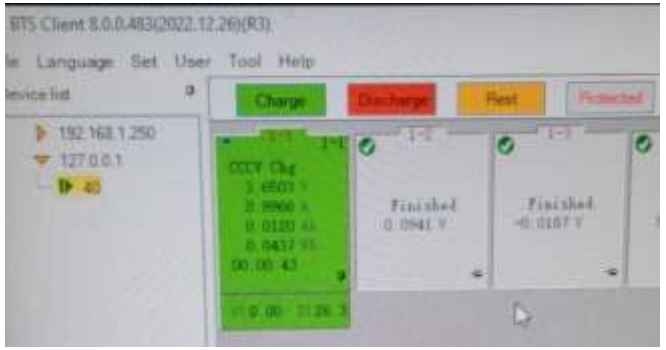

Maclean BEV carrier in Sudbury adit CMIN visit Dec. 2022

EV / BEV & Battery Certification to Date:

- EV and BEV packs have already been approved at the Bells Corners facility for use in traction locomotives, monorails, etc.

CSA Certificate	BEV/EV Machine Description	Manufacturer
449	Model 601 through 605 and model 610 through 615 battery scoop, type Versatrac	Ingersoll-Rand Mining Machinery Group
702	Clayton locomotives (battery powered) type 3.5/4	NEI Mining Equipment (Clayton) Ltd.
843	Battery powered loco, type BLO65	NEI Mining Equipment (Clayton) Ltd.
882	Type BZ 43-2-31 battery powered monorail	Scharf Maschinenfabrik GmbH
1057	Fletcher roof bolter model DDM-15 C-D	Fletcher Equipment
1067	Joy loader Model 14BU10-41BH	Komatsu Co. Ltd.
1155	Joy Model 12CM12 miner for use in highwall mining system	Komatsu Co. Ltd.

BEV Battery Research



- Cell-level test battery operational in BCC Bldg 9 for lithium ion 3.0 Ah cells (Testing in progress).
  - Neware BTS-4000 charge/discharge cycler
  - TSC 2500ST temp/humidity chamber
  - Depth simulation pressure chamber
- Program Goals:
  - Test batteries with mining machine cycles.
  - Provide data on battery operation in simulated underground mine conditions.
  - Fill knowledge gap for battery suppliers.

CMIN Battery Laboratory – Bells Corners Complex BCC #9

Electric Motor Certification to Date:

- Many electric motors have been tested and approved at the Bells Corners Certification facility for use in all types of mining machines.

CSA Certificate	Electric Motor Type	Manufacturer
4	50 HP, 500V, 3 Phase, 60 Cycle, 1800 RPM, Air Cooled Induction Motor, Frame 3	Tamper Ltd.
147	Flameproof Electric Motor type HSA	Westinghouse Canada Inc.
156	100 HP, 3 Phase, 60 Hz, 1100/550 V, 1775 RPM, type HSB Squirrel Cage Inducti	Westinghouse Canada Inc.
167	100 HP, 3 Phase, 575 V, 60 Cycles, 1180 RPM, Squirrel Cage Induction Motor, Fr	Westinghouse Canada Inc.
204	125 HP, 3 Phase, 575 V, 60 Cycles, 3560 RPM Induction Motors, Frame 445TSZ	Westinghouse Canada Inc.
255	140 HP, 3 Phase, 575 V. 60 Hz, type HSB, 1770 RPM Induction Motor, Frame 44	Westinghouse Canada Inc.
256	50 HP, 3 Phase, 575 V, 60 Cycles, type HSB, 880 RPM, Inductin Motors, Frame 4	Westinghouse Canada Inc.
258	75 HP, 3 Phase, 575 V, 60 Cycles, type HSB 1775 RPM, Induction Motors, Frame	Westinghouse Canada Inc.
270	75 HP, 3 Phase, 575 V, 60 Cycles, 1800 RPM, Induction Motor, Frame 365 TSCZ,	Westinghouse Canada Inc.
334	Flameproof Electric Motors Frame BS9860 and Frame BS14580	Reyrolle Parsons of Canada Ltd.
340	Frames E215T, E256T, E405TS and E444T	NEI Mining Equipment (Canada) L
689	Motors types E/EJ400 and EW/EWJ400, with junction boxes types BTB33/160, B	Brush Electrical Machines Ltd.
780	Motors series XD; voltage 380 to 7000 VAC incl; 30 to 2000 kW; 2 to 30 pole; 25 t	NEI Mining Equipment (Canada) L
984	Electric Motors WEG Brand, Types EXT, EXT HEMA, EXT HEMB, EXT PHEMB w	V.J. Pamensky Canada Inc.
1064	Electro-Hydraulic Power Pack, 50 HP, 1100 VAC	Long-Airdox Company
1126	Conveyor motorized pulley type TM315-A60-230T2 rated at 30HP, 975VAC	Van Der Graaf Inc.

Electric Motor Testing and Research

- Advanced electric motor development:
  - The existing facility dynamometer is capable of e-motor testing up to 450kW.
  - Certification of advanced e-motors to CSA M424.4 a clear pathway to transition from diesel.
- Demonstration projects:
  - Trial test with 100kW EMRAX 220 e-motor and LiPo battery packs on loan from Carleton University (In design phase).
  - UQM HDPP100 AC motor testing for retrofit to Taylor Dunn Electruck (In progress).

CMIN BEV Machine Integration

- Taylor-Dunn ET-150 light-duty EV.
  - Transferred from CanmetENERGY
  - ANSI B56.8 compliant vehicle
  - Repower June 2023 (Completed)

- Goal: operational vehicle test bed for:
  - Lithium-ion battery / AC motor (In progress).
  - Model validation (CSA M424.3 in progress)
  - Vehicle integration for battery management system (BMS)
  - E-axle, braking resistor and fire suppression system tests
  - Potential CSA M424.4 BEV standard demonstrator

Battery Handling/Abuse Tests

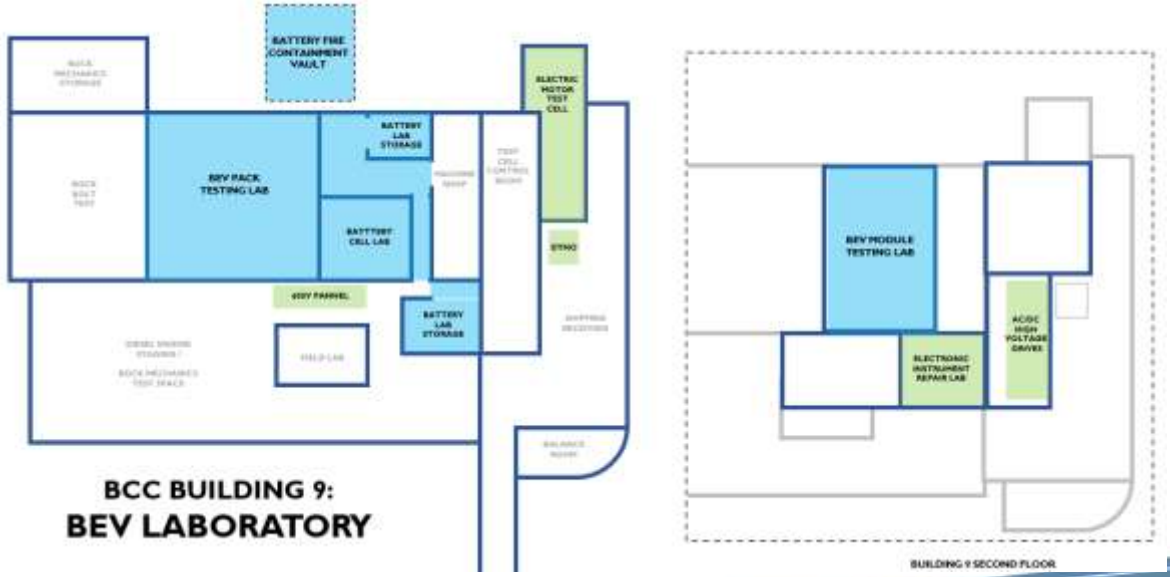
- Mining industry needs information on fire risk and thermal runaway.
  - CMIN-developed method for thermal ignition of lithium-ion cells. (Completed)
  - Potential use testing of storage, transport and containment systems.
- Potential collaboration /certification effort with:
  - CanmetCERL fire/explosion testing
  - NRC Battery Test Facility


CMIN thermal ignitor


Lithium-ion thermal runaway test June 2023 Bells Corners Complex

BCC Bldg 9 - Facility Resources Upgrade

- Larger capacity battery cyclers needed for module and pack testing:
  - 100kW to 650kW packs in operation underground.
  - Full BEV pack testing may not be suitable inside Bldg 9 – new expansion / addition needed for testing and safe storage of large mining packs.
- Existing 450kW dynamometer and regenerative drive are becoming limiting for e-motor speed and torque – larger capacity needed (650kW).
- Space required for BEV integration lab – four-wheel drive chassis dynamometer for full machine powertrain tests.



Client Survey and Industry Needs

- CMIN Diesel Lab had a series of meetings with some of our clients and potential collaborators over the past year
- Research Gaps: Clients are not able to get battery and motor performance data from suppliers under mining conditions of high temp/humidity/pressure.
- Expansion of Certification: Clients are asking for CSA certification to be expanded from diesel to include newer EV components.
- CanmetMINING will work with industry to facilitate EV/BEV component testing for research and approval/certification.