MAMMOTH

Navigating the DPM reduction journey in underground mines:

A practical approach

Presented by:
Ralph Deayton

STRONGER WITH MAMMOTH

OUR JOURNEY

About Mammoth Equipment

Mammoth is a 3rd generation family business that has been operating in the exhaust business since 1974 and has grown to become a leading global player in diesel exhaust and intake solutions in the mining, construction and trucking industries.

1974
It started out as Perth's 1st specialist exhaust fitting shop, **Perth Exhaust Centre**, by Bill Draffin and his sons.

Two stores were set up in Inglewood and Vic Park, WA.

1985
The **Finn-ex** name was established to manufacture and import automotive exhaust parts for distribution nationally.

1988
Started manufacture of earthmoving and mining exhaust parts to meet supply needs in the Australian market.

1993
Manufacturing moved to Kalannie to support regional development. A factory was built and manufacturing was started.

From this town of 200 people, **Mammoth** has grown globally with over 30 locations and approx. 300 staff.

1998
The **Mammoth** name was born to reflect the growing range of truck, earthmoving and mining exhausts being supplied to the Australian market (through resellers on the East Coast).

2005
In 2005 the business was split between the Draffin family.

Mammoth started out as a standalone entity seperate from Finn-ex.

2006
Developed and started manufacturing diesel particulate filters for the underground mining market to reduce emissions and improve operator health and safety, becoming leading provider globally.

2008
Built a premises in Canning Vale, Perth to distribute product nationally.

2010
Started manufacturing exhaust thermal blankets to meet the market requirement for thermal reduction of exhausts to prevent fires on mining machinery. Now have seven manufacturing locations globally.

2010
Started selling imported Adblue (by request from manufacturing and supplying SCR mufflers) and received VDA certification to manufacture Adblue under licence shortly after.

2012
Established a branch on the East Coast to support clients in mining and road transport sectors.

Kalannie took over next door factory to increase manufacturing space.

2014
North America was established, opening a branch in Winnipeg to support business opportunities in the underground mining sector.

Mackay QLD branch was opened and manufacturing was established to support our mining clients in the Bowen Basin.

2015
Added two more premises in Perth to meet growing requirements.

Secured large haul truck sound attenuation contract in Hunter Valley with Rio Tinto.

2015
2017-Darwin, Devonport, Christchurch, Tauranga NZ were established to support the Adblue market.

Winnipeg started manufacturing products for the North American market.

2016
A branch was established in the Hunter Valley to support our mining clients in the area.

Additional branches were opened and Adblue plants were commissioned in Melbourne, Adelaide, Brisbane and Mackay to support our 1st Tier 1 Fuel major adblue supply contract.

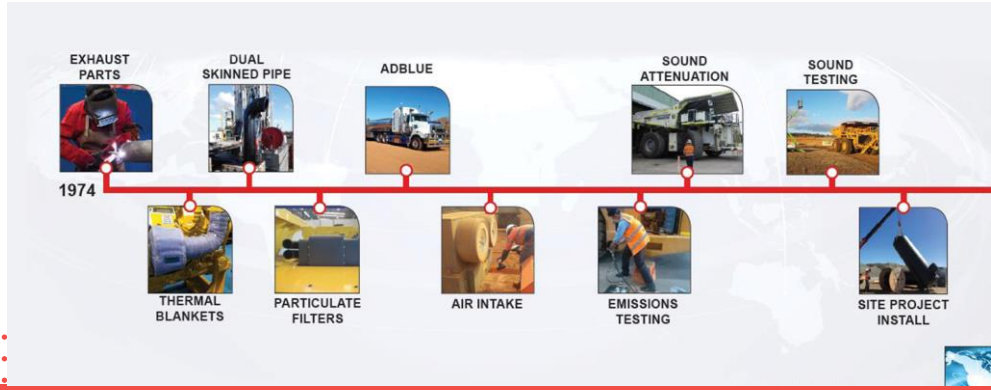
2018
South America was established, opening a branch in Buenos Aires, manufacturing and selling exhausts, thermal blankets and Adblue to Argentina, Chile, Brazil.

2019
Opened branches in Edmonton and Montreal.

2020
Set up operations in Malaysia to support future global manufacturing and shared services requirements.

2021
Established Chile, South Africa entities.

Winnipeg started building new Nth America HQ facility and manufacturing. Started large DPF supply arrangment with FMI Grasberg Underground Mine. Kalannie Factory and Township.



Mammoth – Product Divisions

MAMMOTH THERMAL SOLUTIONS

- Thermal Blankets Solutions
- Dual Skin Pipes Solutions
- Ceramic Coating Solutions
- Heated Thermal Solutions
- Thermal Sleeve Solutions

MAMMOTH EQUIPMENT SOLUTIONS

- Universal Exhaust Components
- OEM Direct Fit Replacement Parts
- Air Intake Solutions

MAMMOTH INDUSTRIAL SOLUTIONS

- Silencers
- Power Generation

MAMMOTH EMISSION TECHNOLOGIES

- Diesel Particulate Filters
- Sound Attenuation

ecoblue® POWERED BY MAMMOTH

- EcoBlue
- AdBlue/ EcoBlue Bulk Delivery
- Package Solutions
- AdBlue/ EcoBlue tanks
- AdBlue/ EcoBlue Accessories

Global Locations

Manufacturing Locations Globally throughout major mining regions

Operational Regions

- Australia Operations
- New Zealand Operations
- North America Operations
- Mexico Operations
- South America Operations

Global Experience

BHP

BARRICK

NEVADA GOLDMINES

ALAMOS GOLD INC.

IMPALA CANADA

FREEPORT-MCMORAN

GLENCORE

LAKE SHORE GOLD
a subsidiary of
PAN AMERICAN SILVER

VALE

WESDOME

GOLD FIELDS

NEWCREST MINING LIMITED

Where do I start?

What to do	How to do it
Benchmark current diesel equipment	Maintain an up-to-date equipment register, knowing which equipment is in service in which area
	Carry out tailpipe emissions testing with recognized emissions testing device(s)
Identify equipment with the greatest emissions output	Using the data collected above note the equipment with the greatest emissions output (considering DPM, HC, CO, NOx)
	Monitor Fuel Usage and note equipment with high emissions outputs (typically a concentration measure) against the equipment using the most fuel.
Evaluate Workplace Exposure by Work Area or Role depending on the operating nature of the site	Consider exposure/emitting time of equipment and location (prioritizing equipment emitting in intake air locations, open cab equipment, people movers and high emitters)
	Conduct NIOSH 5040 testing with personnel and work area sampling

In Field Testing Equipment

PERSONAL DPM SAMPLING

AREA SAMPLING

TAILPIPE DPM TESTING

TAILPIPE GAS TESTING

Baseline Emissions – Tailpipe Testing

Pre

****
* ECOM - EN2 *
****
Date Time
30.09.19 09:40:21

Gas analysis

Fuel type
Diesel Oil

T.Air	87	°F
T.Gas	606	°F
T.Sensor	87	°F
O2	14.8	%
CO	202	ppm
NO	379	ppm
NO2	30	ppm
NOx	409	ppm
CO2	4.5	%
Eff.	67.0	%
Losses	33.0	%
Exc. air	3.39	
Dew poi.	92	°F
Gas vel.	0.3	m/sec

VALE Canada Ltd.
STOBIE MINE

ECOM America Ltd.
Tel. 770-532-3280
Fax: 770-532-3620
Toll-Free 877-326-6411
www.ecomusa.com

Post

****
* ECOM - EN2 *
****
Date Time
30.09.19 09:42:42

Gas analysis

Fuel type
Diesel Oil

T.Air	89	°F
T.Gas	634	°F
T.Sensor	87	°F
O2	14.9	%
CO	15	ppm
NO	396	ppm
NO2	15	ppm
NOx	411	ppm
CO2	4.5	%
Eff.	64.7	%
Losses	35.3	%
Exc. air	3.44	
Dew poi.	92	°F
Gas vel.	0.4	m/sec

VALE Canada Ltd.
STOBIE MINE

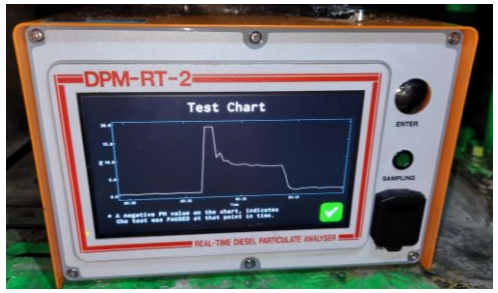
ECOM America Ltd.
Tel. 770-532-3280
Fax: 770-532-3620
Toll-Free 877-326-6411
www.ecomusa.com

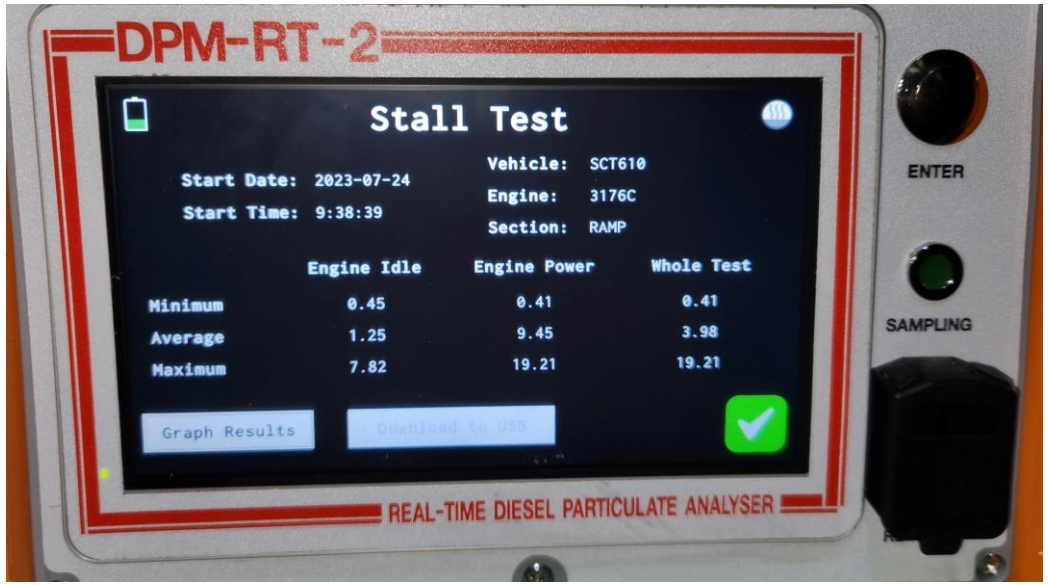
) ENSURE ONGOINC
LEASE COMMUNICAT
OUR INPUT IS VEI

ASK LIST GROUP#
REATED: OCT 201
EVISED: NOVEMBEI

O AVOID UNAUTHOI
F TASK LIST GROU
RIGINATOR OF THI

DIATELY.





What does an equipment emissions register look like?

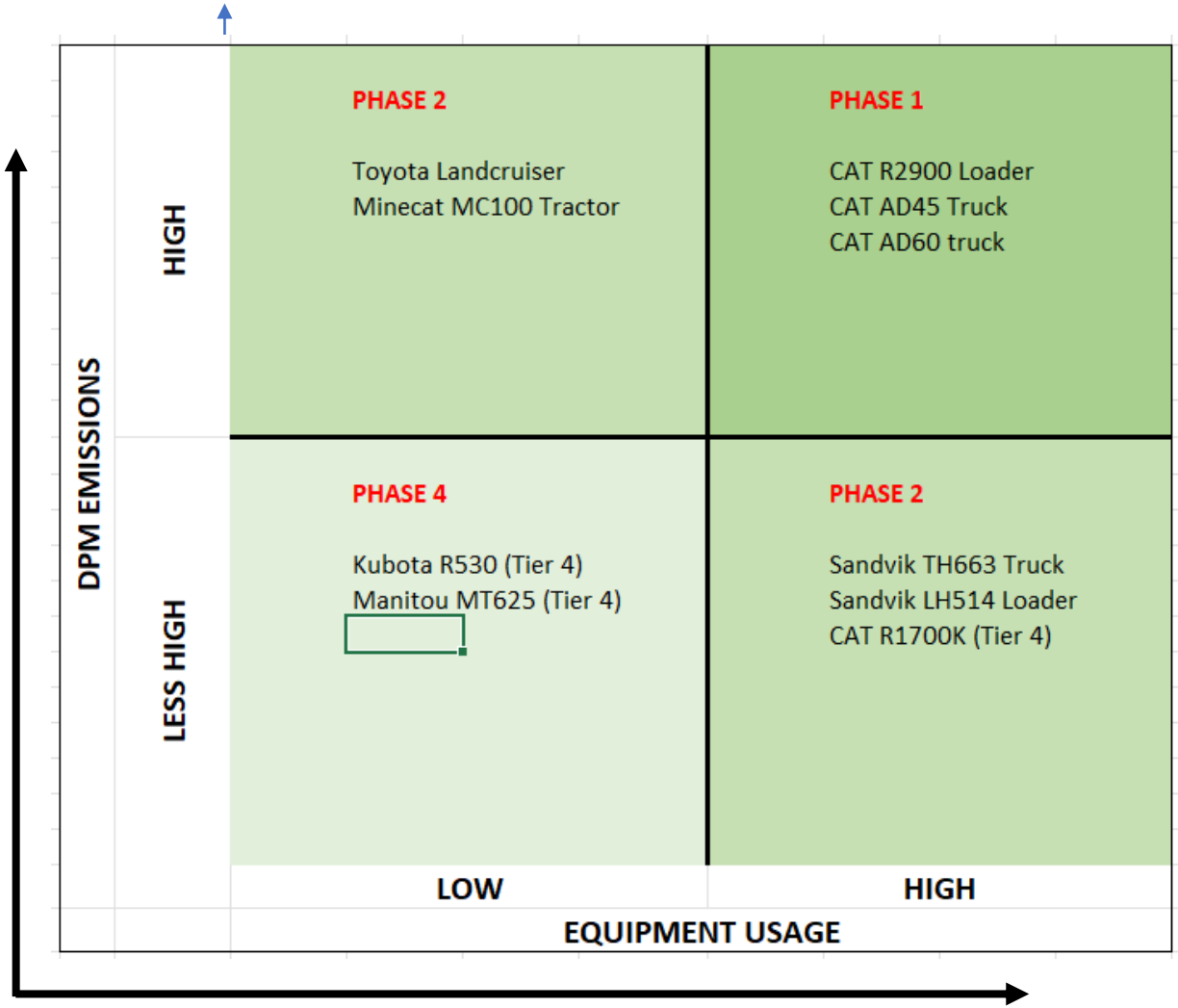
Date	Equipment Type	Asset Number	Description	Low Idle CO (ppm)	Low Idle NOX (ppm)	Low Idle Temp (°C)	High Idle CO (ppm)	High Idle NOX (ppm)	High Idle Temp (°C)	DPM mg/m3	Comments
27/01/14	Heavy Vehicle	GS1990	Sandvik 07-5	58	240	165	53	547	225	1.7	
31/01/14	Light Vehicle	TL1360	SANDVIK	0	180	122	0	191	222	0.1	
20/08/14	Heavy Vehicle	SC1964	Hitachi AH300 Agi	26	334	145	45	153	215	7	
31/01/15	Heavy Vehicle	UJ1904	Sandvik D07	87	240	155	130	184	205	0.5	
31/01/15	Heavy Vehicle	UJ1905	Sandvik D07	97	195	152	140	105	252	0.6	
31/01/15	Heavy Vehicle	UJ1907	Sandvik DD420	75	219	158	187	274	218	0.5	
31/01/15	Heavy Vehicle	PD1908	Sandvik DL430-7C	19	56	148	103	89	221	12	
31/01/15	Heavy Vehicle	PD1909	Sandvik DL430-7C	97	233	158	110	165	215	0.9	
31/01/15	Heavy Vehicle	GS1912	Sandvik DS420-C	135	215	191	160	185	231	0.8	
31/01/15	Heavy Vehicle	DR1907	Sandvik DD311	0	90	175	3	75	205	15	
31/01/15	Heavy Vehicle	DR1906	Sandvik DB120	27	720	168	19	390	209	0.65	
31/01/15	Heavy Vehicle	UC1981	Normet Charmec 9810B	109	348	167	91	334	220	22	
31/01/15	Heavy Vehicle	SC1965	Hitachi AH300 Agi	18	44	181	8	31	205	40	

DPM contribution by machine

Unit Number	Description of technical object	Blended DPM	Engine	BHP	BHP CFM	CANMET	Hours/Day	DPM x Utilization	% Share	Rank	Stage
HTK-318	HAUL TRUCK - CAT AD30 HTK-318	6.159	C15 AD30 PN#319-7503	409	40,900	20,700	8.16	50.24	1.80%	15	1
HTK-317	HAUL TRUCK - CAT AD30 HTK-317	4.3945	C15 AD30 PN#319-7503	409	40,900	20,700	6.24	27.43	1.00%	43	1
HTK-319	HAUL TRUCK - CAT AD30 HTK-319	4.3945	C15 AD30 PN#319-7503	409	40,900	20,700	5.84	25.66	0.90%	48	1
TRT-020	TRACTOR MINECAT KM200 TRT-020	29.264	0	100	10,000	-	3.27	95.64	3.40%	1	2
SCT-703	SCOOPTRAM-ATLAS COPCO ST1030- 7Y SCT 703	1.339	QSL 9	250	25,000	20,900	1.56	2.09	0.10%	114	2
SCT-604	SCOOP - TAMROCK EJC 210-6Y-REM SCT 604	6.08	MBE926	230	23,000	18,858	0.3	1.82	0.10%	115	2
MCT-793	TOYOTA - HZJ79L - CAPT MCT 793 MINE	9.267	1HZ PCNA	136	13,600	7,300	3.93	36.39	1.30%	31	3
SCT-613	SCOOPTRAM - CAT R1600G Rental-6Y SCT 613	2.31	C11	263	26,300	24,500	5.55	12.82	0.50%	69	3
SCT-707	SCOOPTRAM - CAT R1700G Rental-7Y SCT 707	2.31	C11	353	35,300	21,300	5.22	12.05	0.40%	72	3
MCT-816	TOYOTA - MCT-816 SERVICE BOX ENG SURVEY	9.267	1HZ PCNA	136	13,600	7,300	2.39	22.16	0.80%	52	4
MCT-819	TOYOTA - MCT-819 MANCARRIER H & S	9.267	1HZ PCNA	136	13,600	7,300	1.97	18.22	0.60%	61	4
BOL-002	BOLTER MACLEAN MEM-975 BOL-002	3.08	904	150	15,000	9,196	1.01	3.11	0.10%	101	5
BOL-003	BOLTER MACLEAN MEM-975 BOL-003	3.08	904	150	15,000	9,196	1.01	3.11	0.10%	102	5
MCT-825	TOYOTA - MCT-825-MAN CARRIER-MINE DEVELO	9.267	1HZ PCNA	136	13,600	7,300	0.33	3.09	0.10%	103	5
JUD-008	JUMBO - ATLAS COPCO BOOMER 282 JUD-008	2.93	D914L04	75	7,500	13,700	1.05	3.08	0.10%	104	5

Phased Approach - Matrix

- Once emissions data and equipment usage data has been collected
- Ansoff Matrix style approach for emissions vs usage is a useful and simple tool to categorise equipment into targeted phases.



Balancing DPM reduction with DPF servicing

ALATF
As Low As Technically Feasible

ALARP
As Low As Reasonably Practicable

Light:
LVs
Welders
Generators

Light-Med:
Jacon
Normet
Drills

Med-Heavy:
R1700s
LH514s
Loaders similar

Heavy:
AD55/AD60
R2900s
LH621s
MT65
TH663

Higher service frequencies expected

Lower service frequencies expected

Factors to consider in the approach

Life of Equipment		
How old is the equipment?	Should we consider upgrading to newer equipment?	Do we have any open cab equipment we can convert or change out as a priority?

Life of Mine		
How long is the operation going to run for?	Are we doing exploration works or expanding?	How is the ventilation across the operation – where are we upgrading?

Mine Profile / Duty Cycle Conditions		
Are there areas of operation where equipment is unlikely to reach regen temp?	Is there certain equipment that is unlikely to reach regen temp (low duty cycle)?	Do we need DPF cleaning and restoration capabilities on site?

Occupational Exposure Limits and Legislative Requirements	
Are there any exceedances against current standard OEL Limits?	What will it take to rectify areas of non-compliance?

Emissions Profile	
Is there certain equipment with disproportionately high emissions?	What does the emissions profile tell us about mechanical or engine condition?

Insights from emissions

Truck #	TRUCK 1		TRUCK 2		TRUCK 3	
Truck hrs	3721hrs		3892hrs		4258hrs	
Emissions	PRE	POST	PRE	POST	PRE	POST
DPM (mg/m3)	321	0.041	20.53	0.03	19.9	0.1
CO (PPM)	589	132	294	176	347	208
NO (PPM)	612	606	641	628	594	445
NOx (PPM)	636	617	680	638	626	451
O2 (%)	14.43	14.45	14.24	14.36	17.95	17.82

- Consistent testing highlights areas of non-compliance i.e. Truck 1 shown here has a pre-DPF DPM result 15X higher than the other 2 trucks.
- Truck 1 also has the highest CO result which typically indicates incomplete combustion (consistent with high DPM)
- Reviewing the mechanical history of Truck 1 it was found there was severe issues with intercooler clogging –> increasing the intake temp -> negatively impacting the air fuel ratio -> premature blocking of the DPF

What emissions are indicating?
high co

High Carbon Monoxide (CO):

- *Mechanical Indication:* High CO emissions can be attributed to various mechanical issues, including those affecting intake air temperature, fuel injectors, air filters, and emissions control devices like DPFs.

Possible Mechanical Causes:

- **Blocked Radiator or Intercooler**
- **Malfunctioning Fuel Injectors**
- **Air Intake Issues**
- **DPF Regeneration Issues**
- **DOC Failure or Contamination**

What emissions are indicating?
high HC

High Hydrocarbons (HC):

- *Mechanical Indication:* Elevated HC emissions are indicative of incomplete combustion, the presence of unburned fuel and burnt engine oil in the exhaust gases.

Possible Mechanical Causes:

- **Burnt Engine Oil**
- **Ignition Problems**
  - E.g. Carbon build up in engine pistons
- **Fuel Delivery/Injection Issues**
- **Emissions Control Device Efficiency**
  - E.g. turbo failure -> oil bypass -> DOC poisoning -> runaway regeneration -> substrate failure

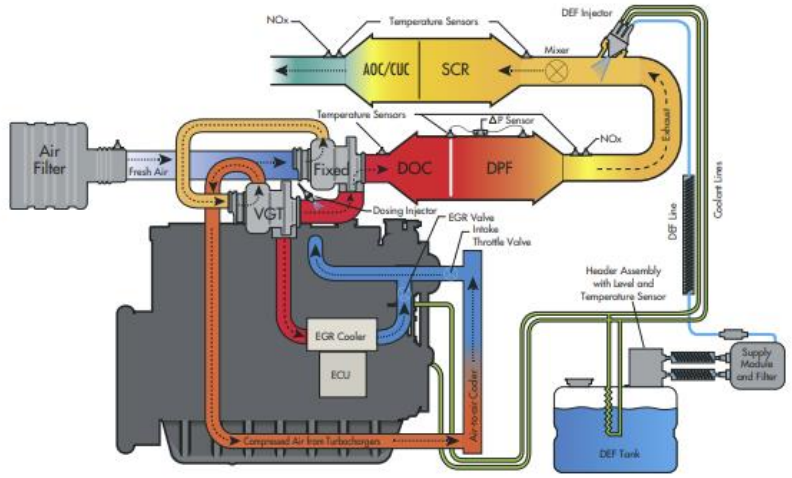
What emissions are indicating?
high NOx

High Nitrogen Oxides (NOx):

- *Mechanical Indication:* Elevated NOx emissions can be influenced by mechanical factors related to intake air temperature, combustion efficiency and temperature and/or the emissions control devices.

Possible Mechanical Causes:

- Blocked Radiator or Intercooler
- Faulty EGR System
- DPF Efficiency
- SCR System Issues
    - E.g. SCR catalyst contamination, DEF dosing, DEF injectors, DEF quality issues etc.



What emissions are indicating?
high DPM

High Diesel Particulate Matter (DPM):

- *Mechanical Indication: The mass of particulate matter emissions is a measure of solid particles, including soot and other fine particles, released in the exhaust.*

Possible Mechanical Causes:

- **Incomplete Combustion**
- **DPF Efficiency**
- **Air Intake Issues**

Equipment emissions dashboards

Equipment Emissions Registers are being powered by Business Intelligence tools like Power BI.

The accessibility and insight is significantly enhanced.

Examples:

- Performance Measuring (how effective are the controls implemented)
- Troubleshooting (easy to spot outliers between similar equipment)
- Emissions monitoring – customer notes
  - *'NO2 levels are either decreasing or staying at Pre-DPF levels. DPF installation has not affected the level adversely.'*

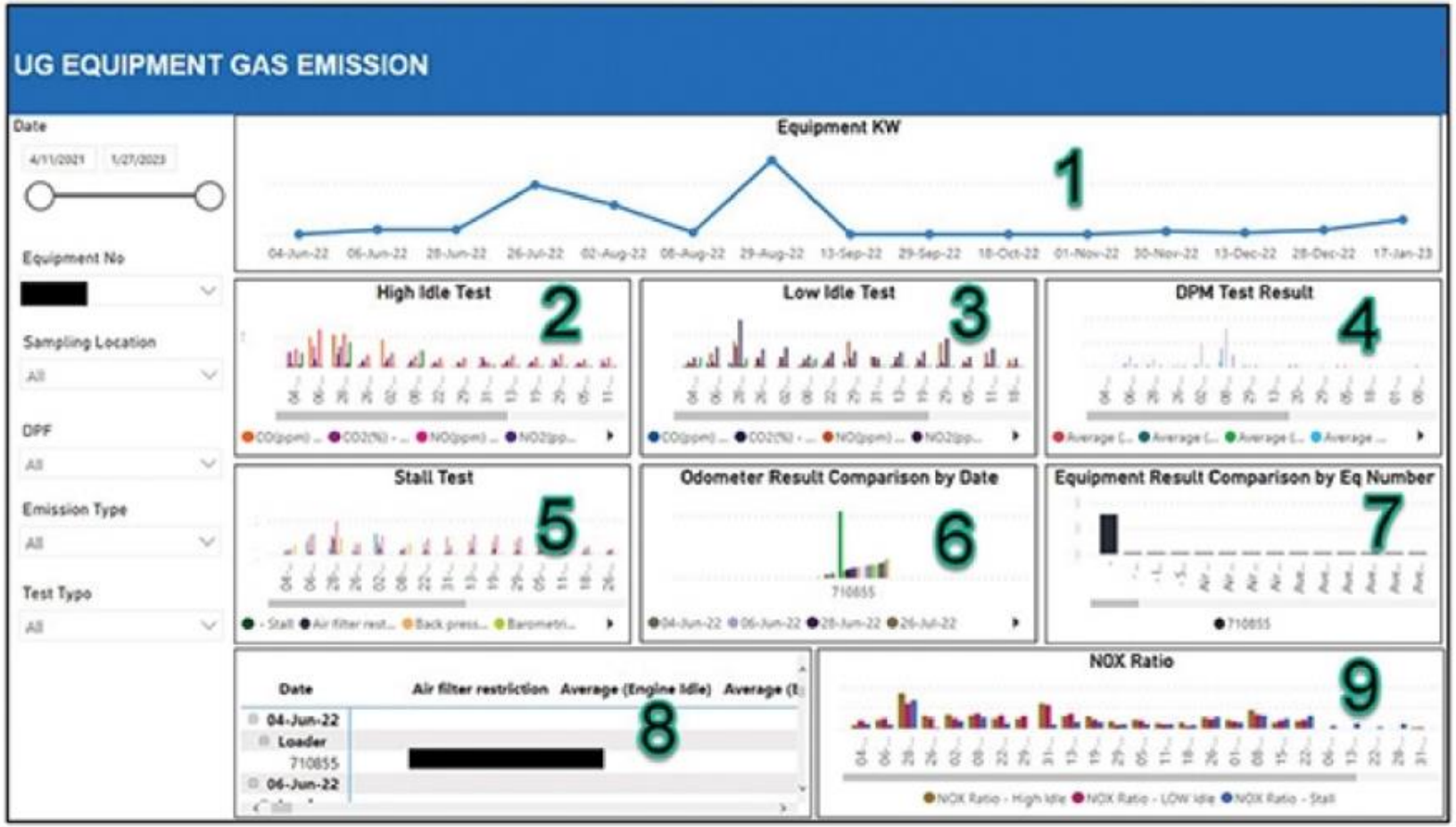
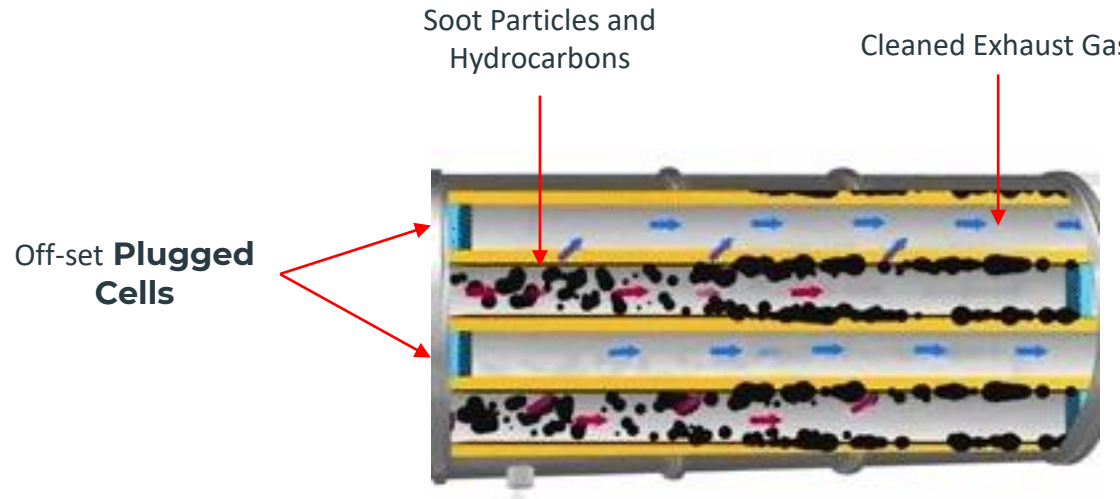
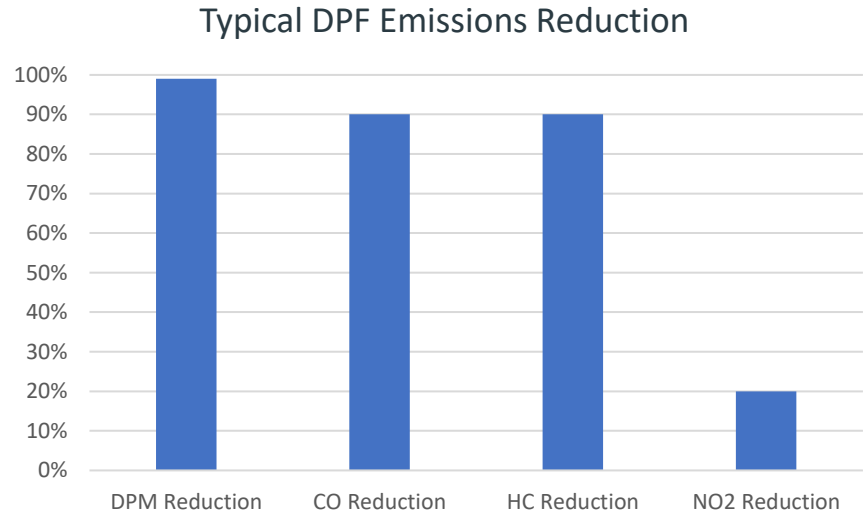


Figure5. Dashboard – overview page, first revision.

How does a DPF work?

- A Diesel Particulate Filter is an emissions control device.
- The primary purpose of which is to capture and oxidize diesel particulates within the filter trap (substrate).
- Particles are trapped within the micropores of the substrate
- They accumulate and oxidize through regeneration to form ash.
- Accumulated ash is cleaned by removing the DPF substrate from the vehicle and cleaning with specialized DPF cleaning equipment
- Typical results are 98% reduction in DPM, 90% reduction in CO and 10-30% reduction in NO2 emissions





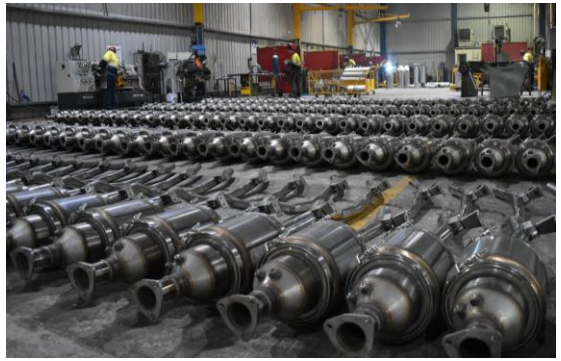
Mammoth DPF systems

Service / Support Reasons:

- Expertise – (30+ years of DPF product knowledge)
- Experience – (worked with industry leaders such as BHP, Freeport, Curtin University – lessons from R&D, Product successes and issues)
- Product Support – Drawings, diesel emissions management and operator training and guidance documentation and document and report writing services.
- Capacity – the right DPF supply partner can meet your project goals (i.e. preparing site for fit out of an entire category of equipment)

Product Reasons:

- Function - Mammoth full DPFs exceed 98-99% DPM reductions.
- **Material specifications** – Mammoth DPF substrates use high quality rSIC known for its hardness and conductivity (less susceptible to cracking and runaway regeneration).
- **3rd Party Verification –** Our full DPFs have been tested to NIOSH5040 by Curtin University and Sunset Laboratories and independent field studies by CANMET.
- Cost Effective – Mammoth's DPFs use modular DOC-DPF configurations (if the DOC is contaminated by unburnt fuel or oil this can be replaced at much lower cost than the whole unit).



150 Land Cruiser DPFs preparing for shipment

Custom Laser Cut Flow and Serial Tag

Implementation of DPF's - results

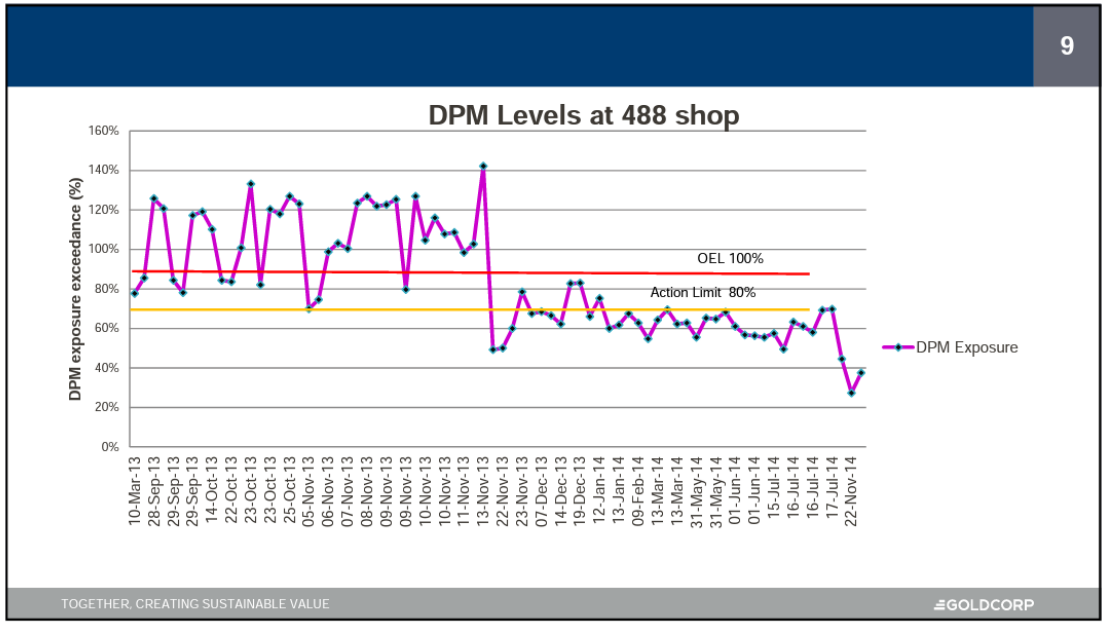
	2020 DPM Sampling Results				Limiting Concentration (0.32 mg/m3 limit)	DPM Limit Exceedances
	Date	Location	Shift Length	Occupation		
1	2/01/2020	1230	10	Sill Miner	0.436	>Exceedance
2	13/01/2020	1230	10	Sill Miner	0.904	>Exceedance
3	14/01/2020	1230	10	Sill Miner	0.44	>Exceedance
4	18/01/2020	1230	10	Area Sample	0.411	>Exceedance
5	21/01/2020	1185	10	Area Sample	0.403	>Exceedance
6	21/01/2020	1160 (ramp just below the level)	10	Area Sample	0.292	Clear (Prev Ontario Limit)
7	23/01/2020	1040 (ramp just below the level)	10	Area Sample	0.202	Clear (Prev Ontario Limit)
8	23/01/2020	1230	10	Area Sample	0.359	>Exceedance
9	28/01/2020	1075 (just below in the ramp)	10	Area Sample	0.318	Clear (Prev Ontario Limit)
10	28/01/2020	985 Ramp	10	Area Sample	0.272	Clear (Prev Ontario Limit)
11	28/01/2020	1160 Ramp	10	Area Sample	0.296	Clear (Prev Ontario Limit)
12	28/01/2020	1230 Level	10	Area Sample	0.338	>Exceedance
13	30/01/2020	1040 Ramp	10	Area Sample	0.267	Clear (Prev Ontario Limit)
14	30/01/2020	1075 Ramp	10	Area Sample	0.276	Clear (Prev Ontario Limit)
15	1/02/2020	415 Vent Acc	10	Area Sample	0.104	Clear Current Limit of 0.12
16	7/02/2020	415 RAR	10	Area Sample	0.189	Clear (Prev Ontario Limit)
17	7/02/2020	1230 Level	10	Area Sample	0.334	>Exceedance
18	7/02/2020	1250 Level	10	Area Sample	0.331	>Exceedance
23	27/02/2020	1230 Level	10	Area Sample	0.272	Clear (Prev Ontario Limit)
24	27/02/2020	1075 Ramp	10	Area Sample	0.186	Clear (Prev Ontario Limit)
25	27/02/2020	1160 Ramp	10	Area Sample	0.316	Clear (Prev Ontario Limit)
26	4/03/2020	1230 Level	6	Area Sample	0.257	Clear (Prev Ontario Limit)

	2023 DPM Sampling Results				**Limiting Concentration (0.32 mg/m3 limit)**	**DPM Limit Exceedances**
	Date	Location	Shift Length	Occupation		
1	4/01/2023	1450 Mucking	10	Sill Miner	0.051	Clear Current Limit of 0.12
2	6/01/2023	1345 NA2 East	10	Sill Miner	0.568	>Exceedance
3	6/01/2023	Down Ramp	10	Sill Miner	0.095	Clear Current Limit of 0.12
4	26/01/2023	1345 Level	10	Area Sample	0.097	Clear Current Limit of 0.12
5	27/01/2023	1475-115 Level	10	Area Sample	0.146	Clear (Prev Ontario Limit)
6	27/01/2023	1345 Level	10	Area Sample	0.274	Clear (Prev Ontario Limit)
7	1/02/2023	Down Ramp	10	Area Sample	0.218	Clear (Prev Ontario Limit)
8	26/05/2023	1475 RAR ACC	10	Area Sample	0.297	Clear (Prev Ontario Limit)
9	6/06/2023	1275 NB2 E	10	Area Sample	0.145	Clear (Prev Ontario Limit)
10	6/06/2023	Mine General	10	Area Sample	0.2	Clear (Prev Ontario Limit)
11	6/06/2023	Mine General	10	Area Sample	0.2	Clear (Prev Ontario Limit)
12	20/07/2023	1450 NB West	10	Area Sample	0.197	Clear (Prev Ontario Limit)
13	20/07/2023	1475 RAR	10	Area Sample	0.173	Clear (Prev Ontario Limit)
14	27/07/2023	1450 Level ACC	10	Area Sample	0.251	Clear (Prev Ontario Limit)
15	8/08/2023	1345 Shop Area Sample	10	Area Sample	0.27	Clear (Prev Ontario Limit)
16	9/08/2023	1345 Shaft Area Sample	10	Area Sample	0.184	Clear (Prev Ontario Limit)
17	16/08/2023	1475 RAR Area Sample	10	Area Sample	0.005	Clear Current Limit of 0.12
18	16/08/2023	1345 Shop Area SAmple	10	Area Sample	0.04	Clear Current Limit of 0.12
19	24/08/2023	1475 Area Sample	8	Area Sample	0.138	Clear (Prev Ontario Limit)
20	29/08/2023	Mine General	8	Area Sample	0.03	Clear Current Limit of 0.12

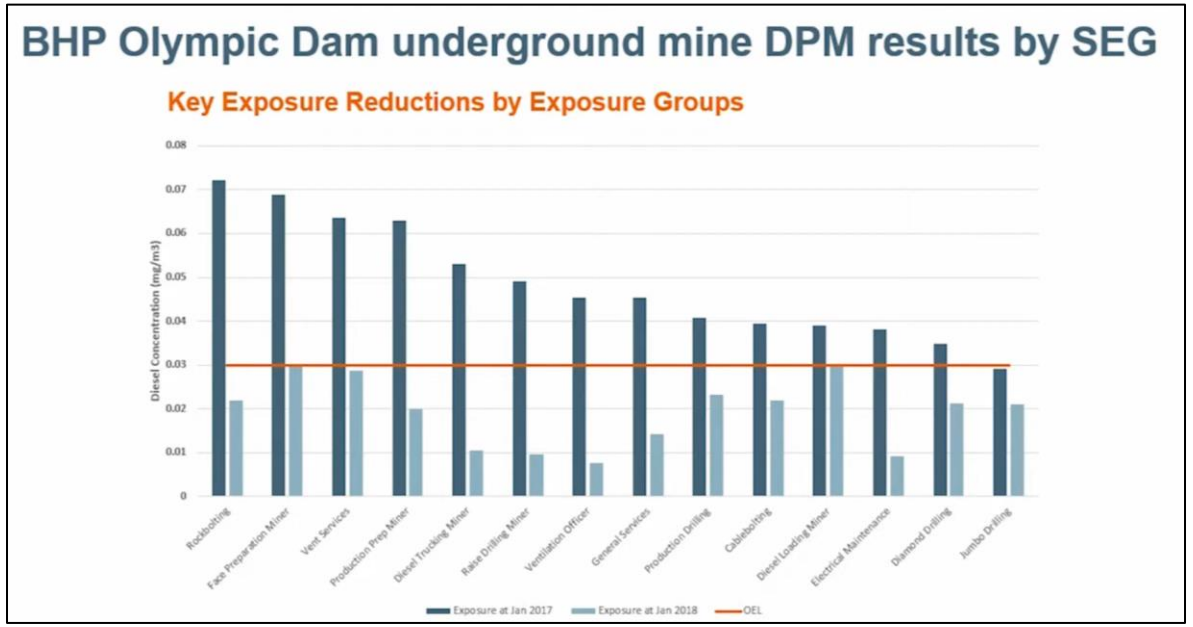
Jan 2020 (Pre DPFs) Average Concentration:	0.372	>Exceedance
Feb 2020 (2 Truck DPFs) Average Concentration:	0.247	Clear (Prev Ontario Limit)

Jan 2023 (All Trucks with DPFs) Average Concentration:	0.205	Clear (Prev Ontario Limit)
August 2023 (+Loaders with DPFs) Average Concentration:	0.111	Clear Current Limit of 0.12

DPM exposure levels reduced by DPF implementation



November 2013 – Fit out of selected prime movers with Diesel Particulate Filters



Jan 2017 vs Jan 2018 – Post Fleet Implementation of Diesel Particulate Filters

Summary

Define	Measure	Analyse	Improve	Control	Verify
Business Case - equipment, current emissions, current situation, desired outcomes	Tail-pipe Emissions	Analyse Equipment Emissions Profiles	Prioritize and explore improvement initiatives such as; eliminating open cab equipment,	Implement Initiatives	Set cadence for periodic and systematic review of emissions by machinery
Preliminary Project Budget and Costs	Equipment Utilisation	Prioritize Equipment and Work Areas	Sourcing DPFs and routable substrates	Implement Standard Operating Procedures (i.e. Inspection criteria)	Setup workflow triggers - automation such as alerts/alarms and responses to real time monitoring of emissions levels in designated work areas
Establish Project Scope and Committee	Personnel Monitoring	Review and itemize opportunities to communicate, educate and work with operational teams and engage their buy in and support	Undertaking cabin air pressure testing to ensure air filtration is effective	Maintenance	Setup and use Equipment Emissions Register or data warehouse / data visualization tools
Research into available technology and best practices	Site / Area monitoring		Tail-pipe DPM Limits		
Partnering with a DPF supplier and other 3rd party technical SMEs (i.e. OEM)			OEL Limits		
Legislative Compliance Review			Planning equipment end of life and change out to newer and cleaner machinery		


MAMMOTH
Thank you
For your time!