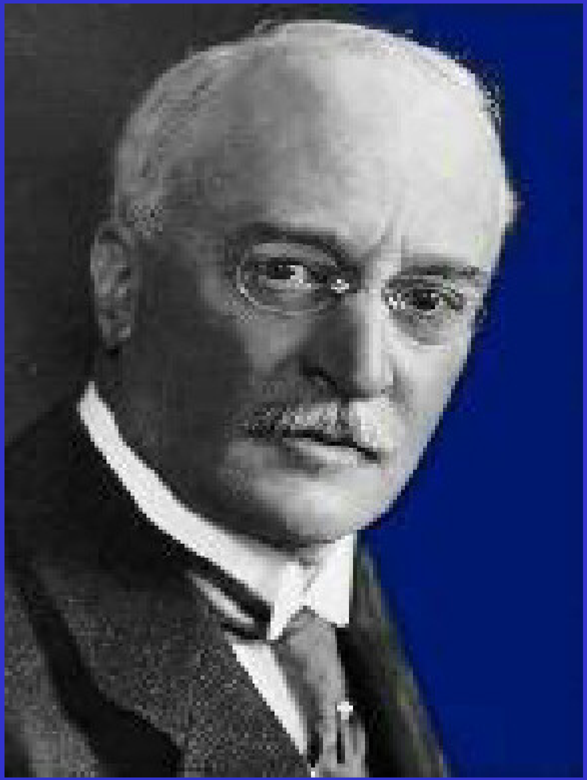
Control of Diesel Particulate Matter Exposures in Underground Stone Mines in the United States

Atlantic Alliance

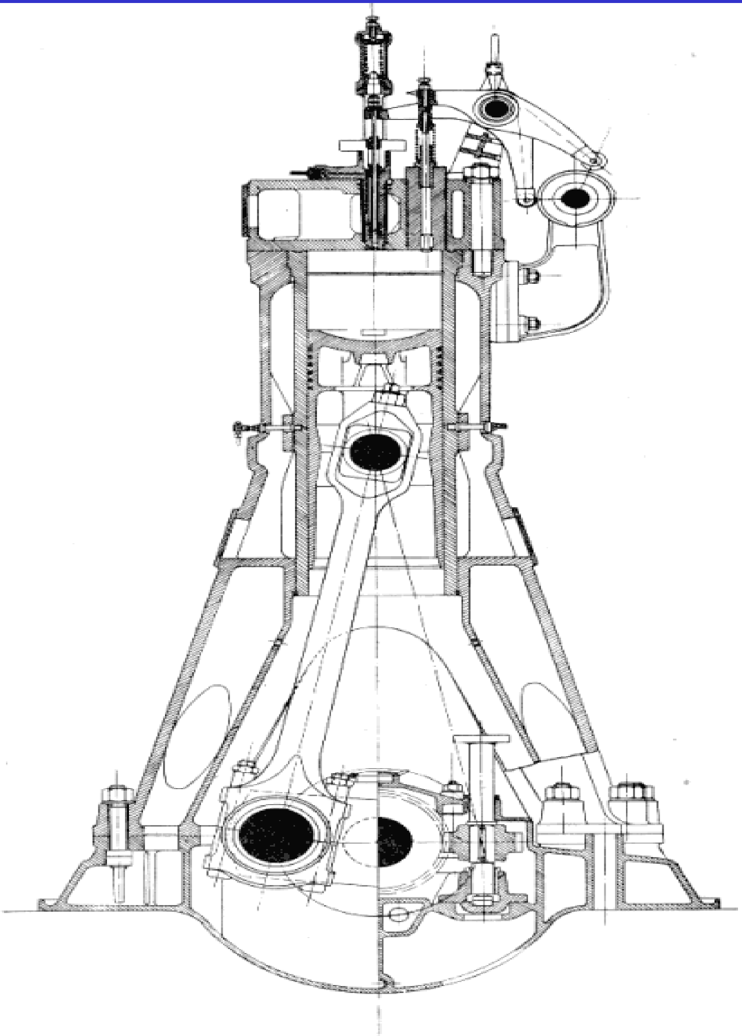
United States Department of Labor
MSHA
Mine Safety and Health Adminstration

Lansdowne Resort
Leesburg, Virginia
September 25 – 26, 2008

- History and background
- Regulation
- DPM Controls
- Compliance history



Rudolf Diesel
1858 - 1913

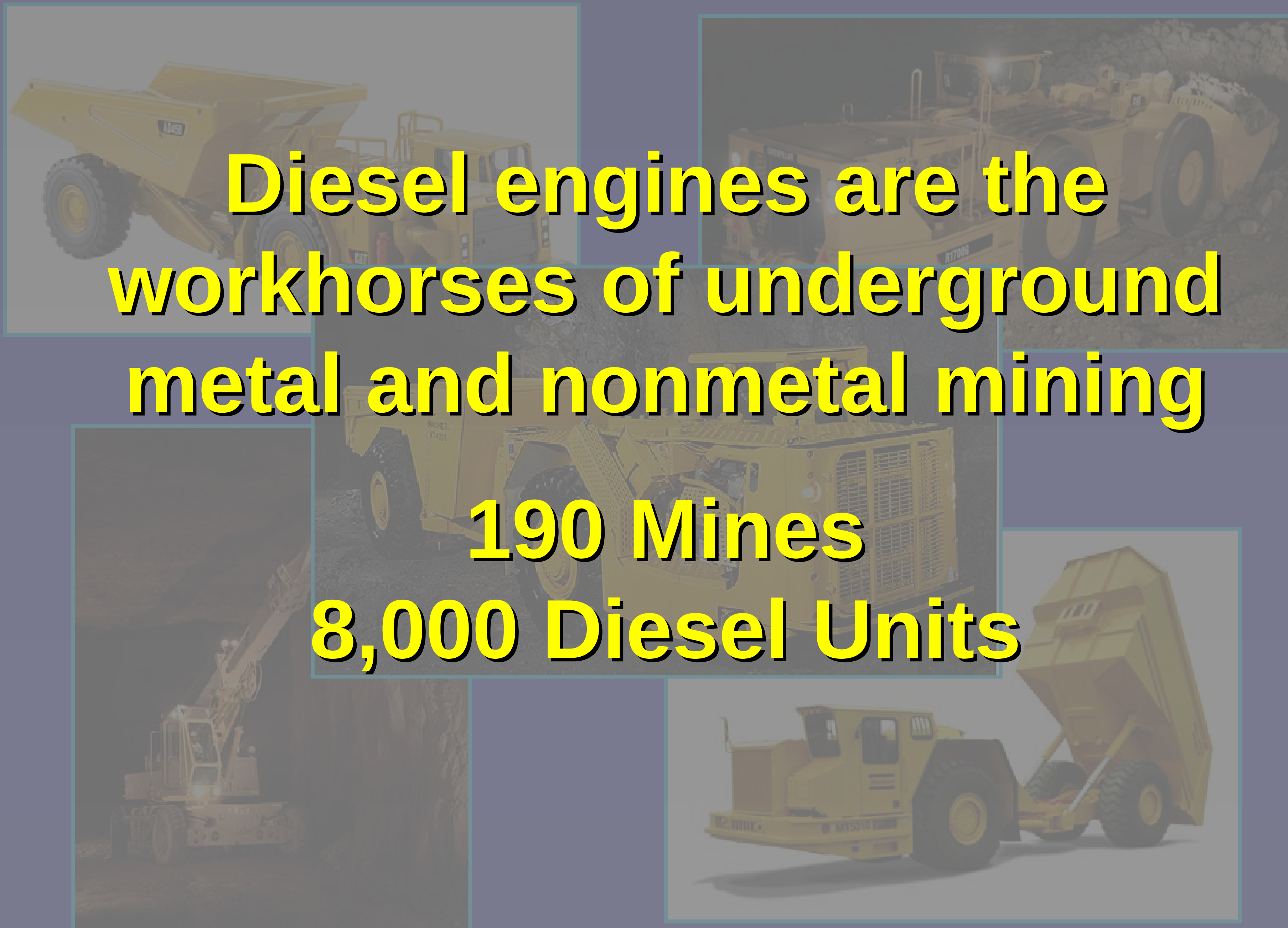


Diesel engine patented in Germany by Rudolf Diesel in 1892


AD45B


R1700G


MT5010



Diesel engines are the workhorses of underground metal and nonmetal mining

190 Mines
8,000 Diesel Units

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8,000 Diesel Units

$\bar{x}$ = 42 units/mine


1303

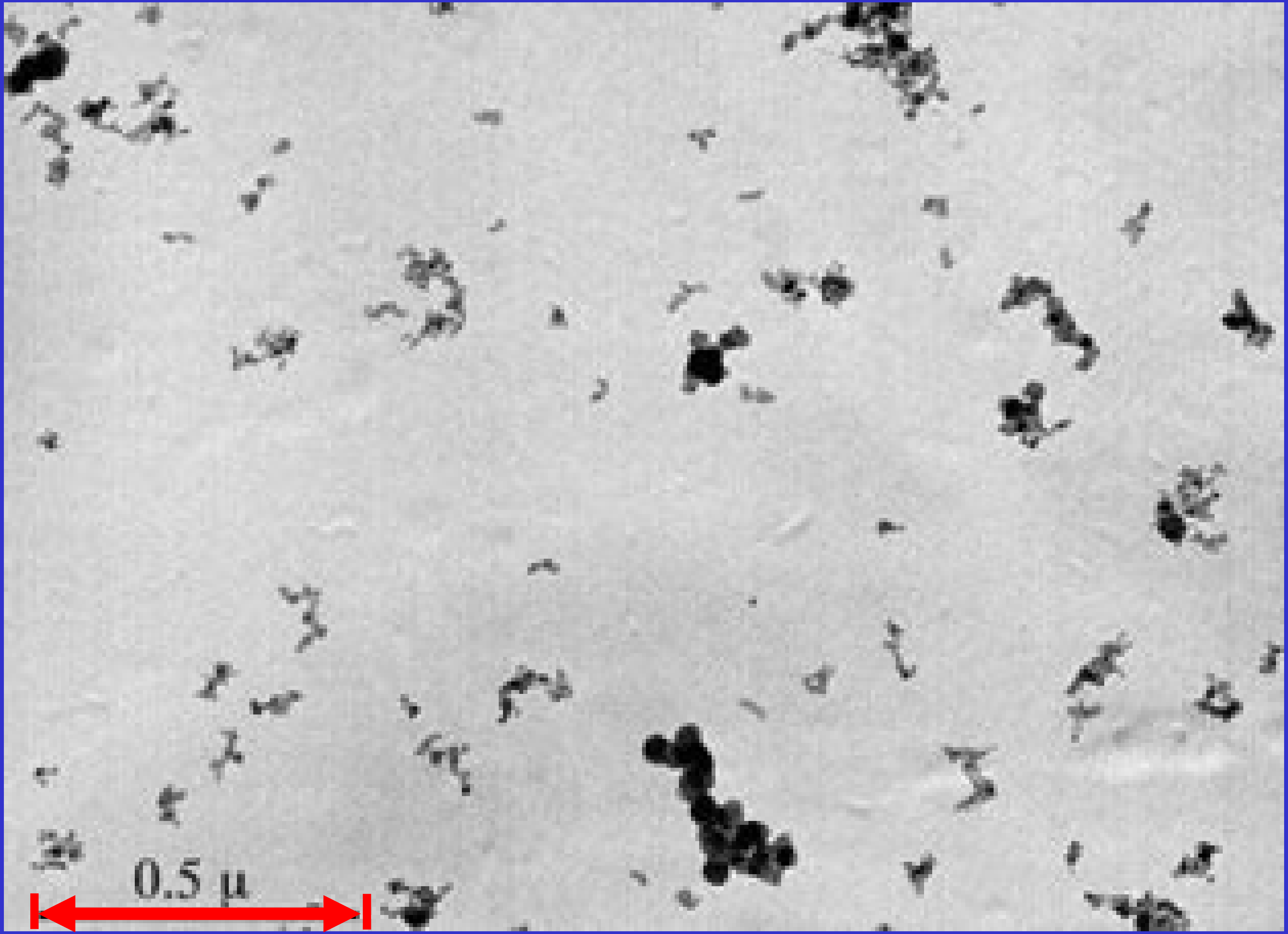
Diesel Particulate Matter (DPM) consists of:

- Solids, liquids, and vapors;
- Burned and unburned hydrocarbons; fuel, lube oil;
- Oxides of sulfur, nitrogen;
- Metal fragments, metal oxides, acids, salts, ash, other substances

2,000+ identified compounds

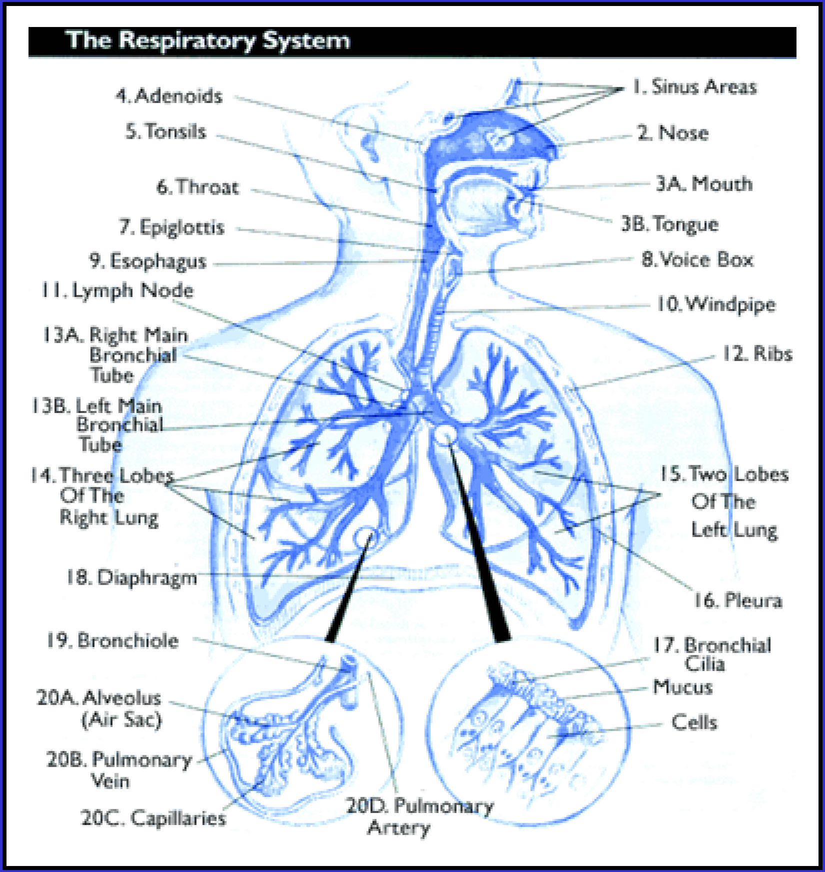
- Nucleation mode – 5 to 50 nm
- Agglomeration mode – 50 nm to 1 µm

Photo Micrograph of DPM



Health Effects of DPM

- Due to particle size, DPM particles are respirable in size
  - Can reach the deep lung (alveoli)



Health Effects of DPM

- Principal adverse health effects
  - Sensory irritations and respiratory symptoms serious enough to distract or disable miners
  - Immunologic effects (allergenic responses and asthma-like symptoms)
  - Premature death from cardiovascular, cardiopulmonary, or respiratory causes
  - Lung cancer

Many agencies and organizations regard DPM as hazardous to human health

Year	Organization	Conclusion
2002	US EPA	Likely human carcinogen
2001	ACGIH (proposal)	Suspected human carcinogen
2001	US Dept of HHS	Reasonably anticipated to be a human carcinogen
1998	CARB	Toxic air contaminant
1996	World Health Org	Probable human carcinogen
1989	IARC	Probable human carcinogen
1988	NIOSH	Potential occupational carcinogen

MSHA Rulemaking Background and Timeline

1960's to present DPM epidemiological and occupational exposure studies

1980's Interagency task forces evaluated DPM health risks, DPM sampling, and DPM control technologies

Mid-1990's MSHA DPM rulemaking initiated

October 1998 MSHA issues Proposed Rule

January 2001 MSHA issues Final Rule

- DPM limit phased in over 5 years
  - Total Carbon surrogate for DPM
  - Interim Limit of 400_{TC} µg/m^3; Final Limit of 160_{TC} µg/m^3
  - Control of exposures by engineering or work practices
- Special Extensions to Final Limit
- Overexposure prompts requirement for Control Plan
- "Best Practice" standards for fuel, maintenance, engines, training, and recordkeeping

MSHA Rulemaking Background and Timeline

<u>January 2001</u> Legal challenges to Final Rule; USWA intervenes in litigation

<u>February 2001</u> Parties agree to negotiations

<u>July 2001</u> Enforcement of "Best Practice" standards (fuel, maintenance, engines, etc.)

<u>July 2003</u> Enforcement of Interim DPM Limit

<u>June 2005</u> Final Rule creates interim permissible exposure limit (PEL), other changes

<u>May 2006</u> Final Rule creates 3-step Final DPM PEL, changes to PPE and Special Extensions

<u>February 2007</u> US Court of Appeals upholds DPM Final Rules

Current MSHA MNM DPM Rule

- Permissible exposure limit (PEL) of 160_{TC} µg/m^3 (shift weighted average full shift personal sample, analyzed per NIOSH method 5040)
- Mine operators may apply for Special Extension of the PEL based on technological or economic infeasibility (1 year duration, renewable)
- Exposures controlled via engineering and/or administrative means. If compliance infeasible using engr/admin controls alone, supplemental respiratory protection required
  - Respiratory protection program, medical evaluations
  - Medical transfers with pay retention
  - Job rotation <u>not allowed</u> as a means of compliance

Current MSHA MNM DPM Rule

- Low sulfur (500 ppm) fuel required and fuel additives must be registered with US EPA
- Engine maintenance
  - Approved engines in approved condition
  - Emission-related components to manufacturers' spec
  - Emission controls in effective operating condition
  - Maintenance tagging
  - Mechanic qualifications
- Engines either Approved or meet EPA PM limits
- DPM training annually
- DPM exposure monitoring
- DPM recordkeeping

DPM Regulations Outside the US

- EU Member States
  - Engine emission standards similar to US EPA
  - Occupational exposure limits (OEL) established on state-by-state basis
  - Germany - 300_{EC} µg/m^3 for tunneling/non-coal mining
    - diesel particulate filters mandatory
- Non-EU European states
  - Switzerland - Engine emissions based on EU limits
    - OEL of 100_{EC} µg/m^3 for mining/tunneling
    - diesel particulate filters mandatory
- Canada
  - Engine emission standards harmonized with US EPA
  - Several Provinces have adopted 1.5 mg/m^3 (RCD)

US EPA vs. EU Non-Road Diesel Engine Emission Standards

US EPA (Tiers 2, 3,and 4)		EU (Stages III and IV)	
HP	g/hp-hr	KW	g/hp-hr
25-75	0.22 (2008) 0.022 (2013)	19-37	0.45 (2007)
50-100	0.30 (2004)	37-75	0.30 (2008)
50-75	0.22 (2008) 0.022 (2013)	37-56	0.019 (2013)
100-175	0.22 (2003)	75-130	0.22 (2007)
75-175	0.015 (2012)	56-130	0.019 (2012)
175-750	0.15 (2001-2003) 0.015 (2011)	130-560	0.15 (2006) 0.019 (2011)

Available Control Strategies

1. Ventilation
2. Environmental Cabs
3. Administrative Controls
4. Diesel Engines
5. Engine Maintenance
6. Biodiesel Fuel
7. DPM Exhaust Filters

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(Items 1–3: Exposure Controls)

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Items 1–3 → Exposure Controls

Items 4–7 → Emission Reduction

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(Items 1–5 →) Most MNM mines were able to attain consistent compliance with Interim DPM PEL

Available Control Strategies

1. Ventilation
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(1–5) → Most MNM mines were able to attain consistent compliance with Interim DPM PEL

(6–7) → Additional controls will be needed at many mines to meet Final DPM PEL

Available Control Strategies

1. Ventilation
2. Environmental Cabs
3. Administrative Controls
4. Diesel Engines
5. Engine Maintenance
6. Biodiesel Fuel
7. DPM Exhaust Filters

Almost all mines will require a <u>combination</u> of controls to attain compliance

Effectiveness of DPM Controls

- Ventilation – DPM reduction depends on nature of upgrade - improvement roughly proportional to airflow increase
  - Doubling airflow ***could*** cut DPM conc. 50%
- Environmental cabs 50 - 80% reduction
  - *800 µg/m^3 reduced to 400 - 160 µg/m^3 in cab*
  - Some workers ***can't*** work inside cab
- Administrative or work practice controls - DPM reduction depends on mine conditions and work practices employed

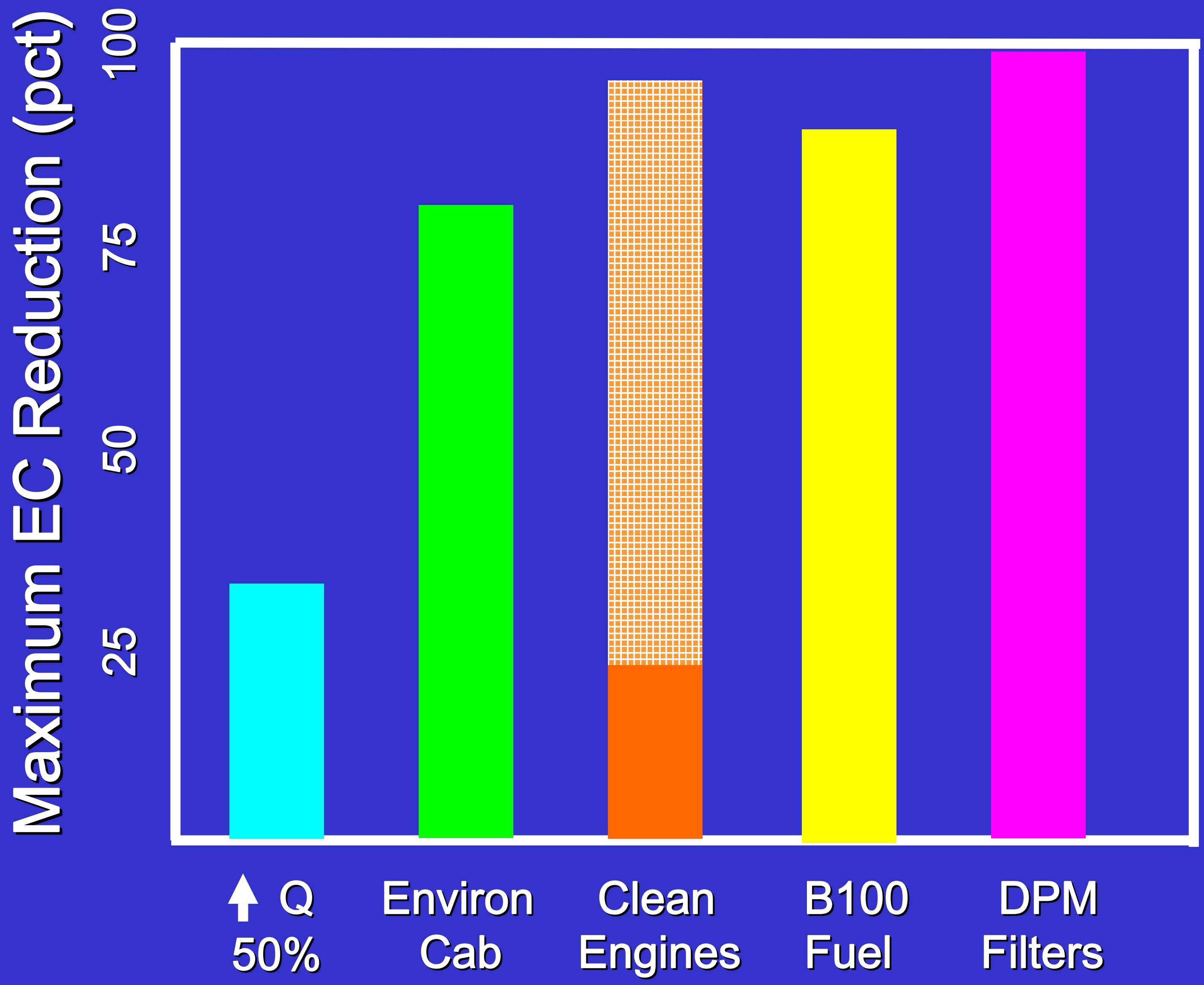
Effectiveness of DPM Controls

- Low emission engines - effect depends on engines - 95+% reduction ***possible***
  - Example: Pre-"Tier" engine replaced by Tier 2 engine could reduce DPM ***up to*** 95%
  - 800 µg/m^3 reduced to 40 µg/m^3
  - Reductions of 25% to 40% ***more typical***
- Engine maintenance – depends on many factors - results vary widely
  - A few mine operators have implemented "emissions-based maintenance"

Effectiveness of DPM Controls

- Alternate fuels - effect depends on fuel blend, engines, etc. - results vary
  - 50% bio-diesel fuel reduces DPM 20-40%
    800 µg/m^3 reduced to 640 µg/m^3 to 480 µg/m^3
  - 100% biodiesel fuel reduces DPM 50-80%
    800 µg/m^3 reduced to 400 µg/m^3 to 160 µg/m^3
  - OCC recommended to reduce OC
- DPM exhaust filters - 80 to 99% efficient
  - 80% efficiency reduces 800 µg/m^3 to 160 µg/m^3
  - *99% efficiency reduces 800 µg/m^3 to 8 µg/m3*

Summary Comparison of DPM Controls



MSHA Compliance Sampling
Comparing Results From ’03-’04 to ’07-’08

Total Carbon Concentration	Percent of Total Samples Obtained	
	July ‘03 to July ‘04 N = 811	May ‘07 to May ‘08 N = 608
< 100 µg/m^3	28.1%	44.6%
< 200 µg/m^3	55.7%	71.8%
< 300 µg/m^3	73.1%	86.3%
> 400 µg/m^3	15.6% (49 mines)	8.1% (29 mines)
> 600 µg/m^3	5.1% (25 mines)	3.6% (12 mines)

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Thank You

United States Department of Labor

MSHA

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