Diesel Emissions Control Strategy at Inco

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Diesel Emissions Control at Inco

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Introduction

- In the last decade Inco has operated up to 15 underground mines in the Canadian Division. Presently 9 are operating with others on standby
- These operations are some 365 miles west of Montreal, and 225 miles north of Toronto

Underground Diesel Equipment at Inco

- The first diesel powered machine was put into operation in 1966,
- The number of diesel machines underground was increased to: (J. Stachulak, B. Conard, 1997)
  - 360 units in 1971
  - 550 units in 1977
  - 880 units in 1995
- Majority of the LHD and trucks are equipped with electronic fuel control engines. Many of the secondary equipment are using indirect fuel injection. They emit about one half as much carbon monoxide and particles as do older engines with direct fuel injection. The formation of nitrogen oxide is also reduced (Waytulonis, 1992)

Underground Diesel Equipment

- During the last three decades of diesel operation at Inco, a significant amount of research and improvements were made in the area of work environment and effective diesel operation, namely:
  - Implementation and use of modern engines
  - Improved fuel quality
  - Improved exhaust control technology
  - Ventilation design and practices

Control of Diesel Exhaust

- The control (reduction) of diesel emissions can be realized by:
  - Proper engine maintenance
  - Engine design modifications
  - Improved fuel quality
  - Use of exhaust technology
  - Good ventilation practices

Diesel Engine Maintenance Practices

- **Preventative and predictive maintenance scheduled repairs and adjustment are all parts of a basic maintenance program**
- **Each piece of diesel equipment is scheduled for inspection and service every 250 operating hours**
- **The inspection of complete machine includes the following components that control the exhaust emissions:**
  - **1. intake air system**
  - **2. exhaust system**
  - **3. engine**
    - **stall speed at full load, rated speed**
    - **valve clearance**
    - **electrical systems…**
  - **4. fuel system**

Diesel Engine Maintenance Practices

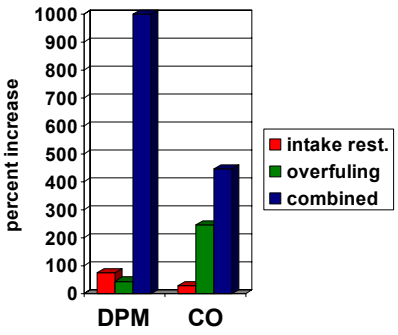
- The first line of maintenance is the vehicle operator
- At the beginning of each shift, the operator makes an initial check using a checklist, which is completed, signed and submitted to supervision
- Particular attention is paid to **intake air filter** system, machine condition, lubricants, brakes and fire suppression system

Diesel Engine Maintenance Practices – Control of Emissions

- An important factor in maintaining a clean-burning engine is regular maintenance of the intake air cleaners.
- A blocked air filter results in an increase in fuel/air ratio, hence an increase in tailpipe diesel particulate concentration.
- Similarly, dust-laden air causes engine wear and leads to an increase in DPM (diesel particulate matter)

Synergistic Effect of Air Intake Restriction and Over-fuelling on Diesel Emission – (Courtesy of USBM/University of Minnesota)

- If a correctly adjusted engine has an intake air restriction of 50 in W.G., **particulate emissions increase 75 % (CO, 28%)**
- If engine is over-fuelled, and otherwise adjusted properly, **particulates (DPM) increase by 44% (CO, 247%)**
- If, however, the two fault situations are combined, **particulate matter emissions increase by more than 1000% (CO, 446%) above the baseline value.**



Control of Diesel Emissions – Engine Technology

- Electronic Controls
  - fuel and air are optimized for low emissions
- Modified Engine Seals, Rings and Pistons
  - greatly lowers lubrication oil consumption, a major contributor to organic particulate emissions
- Turbocharging
  - optimizes power, emissions and performance
- Fuel Injection System in excess of 1500 Atm.
  - critical element in controlling engine emissions

Diesel Engine Maintenance Practices

- All of the ore handling machines at Inco are de-rated engines. De-rating results in significantly lower emission levels and longer engine life
- Some 75% of large ore handling machines are electronically controlled turbocharged units
  - The emissions from these engines are significantly lower than those from conventional, indirect injection, naturally aspirated engines:
    - on average 50 % reductions in DPM emissions
    - on average 20 % reductions in NO_x emissions

Diesel Engine Maintenance Practices - Exhaust System

- All diesel engines at Inco are equipped with a diesel oxidation catalyst (DOC)
- DOC oxidize CO and HC, diesel odour, as well as the volatile organic fraction of DPM are also diminished – but they (DOC's) have no effect on the reduction of solid carbon core of DPM
- At every schedule inspection, the complete exhaust system is checked for leaks, cracks, holes and loose connections – since dented/plugged exhaust pipes results in engine overheating which leads to an increase in emissions

Diesel Engine Maintenance Practices – Fuel system

- The important emission-related fuel properties for controlling diesel particulate matter emissions are sulphur content, cetane number and aromatic hydrocarbon (HC) content
- Currently, Inco uses the fuel with sulphur content of less than 0.05%. This was found to result in:
  - reduced emission of sulphate fraction of DPM, and SO_2
  - prolonged engine life
  - better fuel economy
  - reduced corrosion of exhaust components...

Diesel Engine Maintenance Practices – Fuel System

- Higher cetane number, reduced aromatic hydrocarbon content and lower distillation temperature of the fuel result in lower emissions of nitrogen oxides and total particulate matter
- The fuel used at Inco meets the following criteria:
  - Aromatic content of less than 20%
  - Cetane number more than 40
  - 90% dist. temperature is less than 288 ^{o}C
- The purity of the fuel supplied to injection pump and injectors was found to be essential, since even very small quantities of dirt in the fuel can damage the injection system leading to an increased emissions

Diesel Engine Maintenance Practices – Operator and Mechanic Training

- Operator and mechanic training is essential to safe and efficient operation of trackless equipment
- A heavy duty equipment mechanic apprenticeship program comprising 2 years of post secondary school education (graduates are HDEM Technicians) including exposure to classroom “hands on” training, and 7500 hours in the field training, is in place at Inco
- All successful applicants that are hired as incumbent trades people pass a series of aptitude and behavioural tests as well as a hands on demonstration of skill

Diesel Engine Maintenance Practices – Concluding Remarks

- **The research done by USBM (1992) indicates that exhaust emission quality does not degrade excessively during the initial 4000 hours in service.**
- **After 4000 hours, CO, HC's and DPM increase due to increased engine component wear**
- **Furthermore, induced fault tests revealed that intake air restriction, fuel injection timing, and over fuelling had the greatest effect on emission rates**
- **A certain faults were found to have synergistic effects.**

Diesel Engine Maintenance Practices – Concluding Remarks

- In general, properly maintained diesel engines can be expected to run several thousand hours with minimal degradation of exhaust pollutants and performance
- The successful use of diesel equipment in underground mining operations necessitates a commitment to a well-planned inspections and maintenance program
- Close cooperation and communication between operators and maintenance is required for the successful implementation of a such program

Ventilation Practices

- In hard rock mining, mines must be ventilated to control the working environment with respect to heat and humidity, dust created by mining operations, emissions from diesel engines and fumes from blasting operations
- These requirements have always been understood, the specific criteria have become more stringent with the passage of time

Ventilation Practice

- The volume of air required at each diesel unit is regulated by Ontario Occupational Act and must be at least 100 cfm per hp of engine as operated in work place
- Inco practice is to design 125 cfm per hp to assure that the legal requirement are met
- Ore body ventilation layouts are made to avoid ventilating work areas in series, with the same airflow

Ventilation Practice

- To conclude, the trend in metal mining during the last 30 years toward mechanization and high tonnage production methods has greatly increased air flow requirements.

References

Stachulak,J.S.,Conard, B.R., 1997. Diesel exhaust: control strategy and measurement at Inco mines. Proceedings of the 6 th International Mine Ventilation Congress. Pittsburgh,Pennsylvania. p. 134-139

Waytulonis, R.W., 1992. An overview of the effects on diesel engine maintenance on emissions and performance. IC 9324. Bureau of Mines, Pittsburgh, Pennsylvania, p. 113 120

Waytulonis, R.W., 1992. The effects of maintenance and time-in-service on diesel engine exhaust emissions. IC 9324. Bureau of Mines, Pittsburgh, Pennsylvania, p. 103-112

Questions

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