Diesel Emissions Evaluation Program
Project Summary

The Relationship Between Diesel Engine Maintenance and Exhaust Emissions

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For the Diesel Emissions Evaluation Program (DEEP)

Complete Report
Maintenance Guidelines
Audit Plan

Executive Summary

In the first months of the DEEP program the Technical Committee solicited ideas for projects that would fulfill the 3-year mandate to provide a toolbox of technologies and information on control and reduction of diesel particulate matter in the underground mining environment. The third project to be proposed to the Technical Committee was one investigating the relationship between improved diesel engine maintenance and associated reductions in emissions. Noranda Technology Centre in Pointe Claire, Québec submitted a project proposal to conduct the project based on previous experience with related work at Noranda and Falconbridge mining operations. In early 1998 the Technical Committee approved the project proposal with stated objectives to:

1. Drawing on previous research and in consultation with industry authorities, identify the principal engine maintenance procedures and practices which reduce diesel emissions
2. Establish a maintenance review process to determine the current status of a maintenance operation and recommendations for improvements to reduce engine emissions
3. Test and evaluate this process in an underground mine(s)
4. Develop a model of good maintenance practice with an emphasis on reduced emissions
5. Perform before and after implementation sampling of exhaust gases and DPM to establish relationship between improved maintenance and reduced emissions and DPM
6. Educate and train maintenance personnel on the importance of effective maintenance on diesel engines and exhaust emissions

To accomplish these objectives a plan was laid out that would involve a wide range of resource participation from several mining companies, engine manufacturers, emission control manufacturers, and research organisations. The project plan was broken into major stages, which were:

- Construct a review model for engine maintenance and conduct reviews at 2 mines for selection of a suitable host site for the project
- Develop guidelines and best practices for engine maintenance that would serve as a foundation to implement improvements at the mine
- Begin field work by implementing emissions testing equipment and acquiring baseline emissions values for mobile equipment included in the study
- Implement an improved engine maintenance strategy through a combination of changes to process, tools and training
- Analysis and recommendations resulting from field work.

Auditing Engine Maintenance and Site Selection

Based on an existing audit framework, an audit model for diesel engine maintenance was constructed that could be taken to a mine site and conducted over a one-week period. Common maintenance practices such as condition based and scheduled maintenance activity were built into the evaluation along with focus on the 6 systems of diesel engines identified from previous research. The completed model became an easy to use tool that proved effective in identifying strengths and weaknesses and providing instant value to the host site for the audit even before any corrective actions. By the end of the summer two mine sites had participated in the site review process. The 5 day audits were conducted at Hudson Bay Mining & Smelting's Ruttan Mine in Leaf Rapids, Manitoba and Falconbridge Ltd's Strathcona Mine in Onaping, Ontario. From the final reports of both reviews based on a combination of strengths, weaknesses, opportunities and threats, the Technical Committee approved the recommended selection of Strathcona Mine as the most suitable site to host the project.

Guidelines and Best Practices for Diesel Engine Maintenance

In parallel to the review model and selection process the guidelines and best practices for maintaining engines was put together. Once again the 6 system approach to diesel engines was followed along with the other categories in the audit model. By doing both in parallel the results from the audit could be directly applied to the guidelines and best practices and solutions easily identified. The foundation for the guidelines and best practices was laid down by a five person technical panel of specialists in the field of diesel engine maintenance in the mining industry. Through group brainstorming and compilation of reference information materials from all members the document was built in time to be used for the

implementation stage of the project against the results from the audit.

Acquiring an Emissions Baseline

The first phase of the field work at the mine was to move the emissions testing equipment into the shop on 3900 level at Strathcona and begin training and testing with the group of mechanics. The emissions test equipment consisted of a gaseous emissions test system from Noranda Technology Centre called the Undiluted Gas Analysis System (UGAS) and a particulate emissions test system from CANMET called the Undiluted Particulate Sampling System (UPSS). The two systems were integrated into one package situated on the shop floor as a tool for the mechanics to use. In total 13 vehicles were tested and 16 mechanics and leaders were trained over the baseline period of 3 months. Each of the vehicles was tested at least once but in most cases several times over this period. This also permitted enough time for every mechanic to go through the emissions training aspect of the project and at least one mechanic from each of the 4 crews to be trained to an advanced level where he could take emissions tests on his own on shift.

Implementing Change to Process - Tools - Training

At the completion of the baseline stage a meeting was held with the project team and mine management to discuss the implementation of change to the existing engine maintenance system. the results from the audit were presented once again and a short list of the most implementable items yielding the most significant potential was outlined. from this a plan was put together to approach the problem from three directions. changes would be made to the existing process such as the structure of preventive maintenance with respect to engines. this would be a process with considerable planning and intervention on the part of the mine and would be ongoing through the rest of the fieldwork in the project. the implementation of new tools was immediate and produced both a change in engine performance and positive feedback from mechanics. the mechanics were introduced to the new tools through a training strategy that was the third component to the implementation. the primary level of training was done on a one to one basis between the mechanic and the project leader. to complement this, group training sessions were conducted as individual case studies where a specific vehicle was used for a one-day hands on training session with a small group of four to five mechanics. training was provided by service representatives from the engine manufacturers. during each case study the mechanics were also shown how to incorporate the new process and new tools along with the training to improve performance and reduce emissions. it was the case studies where the impact to emissions was measured and qualified from a before and after perspective.

Evaluating the Impact of Improved Maintenance

The most effective way to evaluate the effects of the improved maintenance process was through the results in the four case studies. For each case study the vehicle emissions were measured at the start of the day session before any changes were made or maintenance activity. As the session progressed emissions were measured with a final set of tests once the case study was complete and the vehicle was ready to return to work. This gave a comparison of emissions values from when the vehicle arrived at the shop for the study to when it was released back to production.

Results from the case studies showed that gaseous and particulate emissions could be reduced significantly depending on engine design technology and condition. Gaseous emissions reductions (carbon monoxide) as high as 65% were proven and particulate emissions reductions as high as 55% were seen as well.

Conclusions and Recommendations

With the fieldwork and testing behind the focus shifted to analysing the considerable emissions data gathered over the seven-month period at the mine. When looking back to the original project objectives in the proposal the work would appear to have satisfied these and more. Each stage of the project all the way back to the audit model proved to be very effective in application and in educating not only the mine personnel but every person involved with the project at every stage. The modular approach to the project also leads well to succeeding in transferring the knowledge gained through deliverables, such as the *Guidelines and Best Practices for Diesel Engine Maintenance* and the *Diesel Engine Maintenance Audit Model* included as part of the final report.

As the first level of control in reducing diesel exhaust emissions, the following recommendations for improved diesel engine maintenance can be adopted as the first steps in achieving reduced emissions.

1. Build a team focussed on implementing an improved maintenance strategy. The team should have members including mechanics, operators, supervision, planning, and management from the mine. Responsibilities can be delegated according to an implementation plan and followed up through a report and meeting structure. Ensure that sufficient resources are made available to the team with respect to time, tools, and training.
2. Construct an engine maintenance audit program using the model provided in this report as a template. Select an auditing team from both internal and external to the mine maintenance system. Sometimes it takes an unaccustomed eye to uncover what is obvious and overlooked by someone closer to home. A good audit program has follow up mechanisms built in to it and should be conducted at least annually.
3. Utilize the Guidelines and Best Practices included in this report along with the six system approach to engine maintenance as a foundation in building a strategy for improving existing maintenance practices.
4. Put a program together for testing undiluted tailpipe emissions on underground vehicles. Integrate the program with a structured Maintenance Management record and planning system - preferably computer based. Set action limits on emissions within the system to ensure response to problems. The critical factor in the emissions testing program is not so much in the technology used to measure but in the structured protocol in taking the tests. In order to be useful the emissions must be compared against a known baseline at a known operating state consistently.

5. Make use of the suppliers of diesel engines and related equipment for training and follow up with new tools and other developments. The best way for an engine supplier to improve the relationship with the mine is to provide solutions to problems. The best way to do this is to have service representatives come to the mine and provide hands on instruction with small groups or one on one as described in the case studies for this project.

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