TRANSCRIPT OF PROCEEDINGS

IN THE MATTER OF:)
)
MINE SAFETY AND HEALTH)
ADMINISTRATION DIESEL)
TECHNOLOGY WORKSHOP)

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U.S. DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION

IN THE MATTER OF:	)
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ADMINISTRATION DIESEL	)
TECHNOLOGY WORKSHOP	)

Auditorium
Frances Perkins Building
200 Constitution Avenue, N.W.
Washington, D.C.

Wednesday,
January 23, 2019

The parties met, pursuant to the notice, at 8:10 a.m.

PARTICIPANTS:

MR. DAVID ZATEZALO, Assistant Secretary of Labor for Mine Safety and Health, MSHA
JOHN PIACENTINO, Associate Director for Science, National Institute for Occupational Safety and Health, NIOSH

Context Panel:

EDWARD GREEN, Senior Counsel, Crowell & Moring LLP
JESSICA KOGEL, Associate Director for Mining, NIOSH
SHEILA MCCONNELL, Director, Office of Standards, Regulations, and Variances, MSHA
PATRICIA SILVEY, Deputy Assistant Secretary of Labor for Mine Safety and Health, MSHA
DAVID WEISSMAN, Director, Respiratory Health Division, NIOSH

Engine Controls Panel:

GEORGE LIN, Global Regulatory Affairs, Emissions Regulations and Conformance, Caterpillar
DAVE DUNNUCK, Executive Director, Research & Engineering, Cummins

PARTICIPANTS: (Cont'd)

Engine Controls Panel: (Cont'd)

PAUL SPARENBERG, Senior Sales Manager, Construction & Agricultural Engines, MTU America Inc.
MARC ANDVIK, Senior Engineer, Donaldson Exhaust/Emissions
TIM FRENCH, MODERATOR, General Counsel, Truck & Engine Manufacturers Association

Emission Reduction/Exposure Reduction Panel:

REN RAMER, Mining Engineer, Carmeuse Lime & Stone Inc.
JAMES NOLL, Senior Research Chemist, NIOSH
BRIAN HUFF, Chief Technology Officer, Artisan Vehicles
JEFFREY WELSH, MODERATOR, Acting Associate Director for Science, NIOSH

Current Barriers to Deployment of Technologies Panel:

DORIAN PIA, Regional Manager, Dry Systems Technologies
STEVE COCHRANE, Maintenance Analyst, Blue Mountain Energy
ARTHUR BROWER, Electrical Engineering Manager, Commonwealth of Pennsylvania Bureau of Mine Safety
TERRY ZERR, Vice President, Operations, Mississippi Lime Company
TIMOTHY WATKINS, Administrator for Enforcement, MSHA
MARK ELLIS, MODERATOR, President, Industrial Minerals Association, North America

Strategies and Path Forward Panel:

RASHID SHAIKH, Director of Science, Health Effects Institute
ALEKSANDER BUGARSKI, Senior Research Engineer, NIOSH
WILLIAM FRANCART, MODERATOR, Director, Directorate of Technical Support, MSHA

I N D E X

P R O C E E D I N G S

(8:10 a.m.)

MR. ZATEZALO: Thank you. I went out and checked, and I think everybody's finally through the security line. I appreciate you all not bringing your guns.

(Laughter.)

MR. ZATEZALO: Welcome to D.C. Welcome to the Frances Perkins Building. Welcome to the Department of Labor. We're here today for the diesel workshop. Very good to see everybody here. I do appreciate you coming.

We have a full day, a very substantial discussion ahead of us. This is the fourth meeting of the Partnership since it was created in a little over two years ago now. I'm glad to see that it continues to fulfill its mission to bring together MSHA, NIOSH, industry, and labor to share information and best practices regarding diesel exhaust exposure.

Our aim is to collaborate and to learn how we can harness the latest knowledge and technology to ensure that miners are protected.

I want to thank everyone here for making this Partnership meaningful, and I'd like to especially acknowledge Mark Ellis of the IMA and Ed

Green of Crowell & Moring who were key organizers of today's event.

I'd also like to acknowledge Sheila McConnell and Pat Silvey of MSHA who continue to give this initiative their attention and will be speaking later today.

Health has not always enjoyed the same problems as physical safety where the effects are much more immediate, but it is no less important. In recognition of that, we at MSHA are increasing our focus on miners' health, especially lung health.

I'm pleased to let you know that virtually every one of our sampling criteria last year was increased. We've had more samples for respirable dust, more samples for quartz, more samples for DPM, more samples for radon, and, in nearly every case, that exposure has lessened.

We're now at a point where we frequently expect to see over 99 percent compliance on sampling, and we're generally seeing that. And that's good news, that's great direction, but it's not really quite enough yet.

I think we can all agree that the air that miners breathe should not make them sick or kill them, whether it contains particles from coal, quartz, silica, diesel exhaust, or anything else. That's our purpose, and that's the purpose of this symposium.

There are known ways to minimize miners' exposure to diesel particulate matter. We need to make sure that all mine operators and miners are aware of them and make use of this information.

It is those discussions will lead us forward in that direction, and I look forward to hearing from all participants, and to our continued collaboration through this Partnership.

I think it's especially noteworthy that in this time of divisiveness, turbulence, and other trouble, it's especially noteworthy to see that we can get all interested parties together for a workshop in January.

It's very important, it's very encouraging, and I really believe that there aren't any problems that we can't eventually overcome and solve, and it's important that we do because people's lives are dependent on what we do.

Has anybody seen John? There you are. John, come on up here. They've got tired of hearing from me already.

MR. PIACENTINO: Thank you. Thank you. Good morning, everyone. I'm John Piacentino, the

Associate Director for Science for NIOSH. Unfortunately, Dr. Howard can't be here this morning to welcome everyone himself; however, he did want me to convey how important workshops like this are for NIOSH.

NIOSH depends very heavily on establishing collaborations and partnerships. The work that we do is inherently collaborative and the way that we try to administer an applied research portfolio really causes us to look to partners and give us a perspective that we would not be able to gain if we were to just work independently in our facilities, whether they be located in Pittsburgh, Morgantown, or some other location.

Partnership. I like to think about it at NIOSH as being baked into our DNA. Our scientists often think how they can provide information to solve technical challenges. These challenges are faced by, as Assistant Secretary Zatezalo said, are faced by workers, they're faced by employers.

They're difficult challenges, and they're nothing that we can solve overnight, and so I appreciate the fact that many of you have come today to share your perspective and help us fine tune our scientific programming.

We think about these challenges at the beginning when we plan our research, we continue to experience them as we try to conduct, or implement, our research and scientific activities, and then, of course, there's an exceptionally important transition point when we do develop new knowledge, that it can actually transition into practice.

It really is important for us to make sure that when we spend our money, our time, and our resources, that we're examining issues that are relevant to everyone.

And so today, in my opinion, is a really exceptional program, designed to help people think through what are the -- what is the current status of controlled technologies, and what are the challenges, or barriers, to moving these strategies into practice?

And so I'll look forward to listening to everyone today as people share their perspective, and I hope that we all have an opportunity to learn something that we haven't heard something.

So, with that, Ed, I think I'd like to turn it over to you to get us started, and thank you very much for this opportunity.

MR. ZATEZALO: Thank you.

MR. PIACENTINO: Sure.

MR. ZATEZALO: Good morning, everyone. If we can have the context panel come on up here now, that would be appreciated. And the only reason I'm up here is it would take me 10 minutes to get here otherwise, so we'd immediately be out of the schedule.

MR. GREEN: Good morning, officially. Boy, it's great to see this crowd here. Not an easy thing to get here for those of you from out of town. Deeply appreciate it, that you could make it. Hope you didn't have any trouble getting through the TSA lines at -- whichever every airport you came in from.

This is a very, very important meeting. As Dave and John said, it's an outgrowth of the MSHA, NIOSH Diesel Health Effects Partnership, which, in turn, is an outgrowth from the MSHA Request for Information that we'll talk about.

So to move ahead quickly, we are going to be having five panels, one of which is divided into two groups, and I think you're going to find them all very, very significant, with experts in your field. When I look at my colleagues on this panel, you couldn't ask for a more important group of NIOSH and MSHA officials to talk about this.

But before I get too far down the road, I particularly want to give a big shout out to Mark

Ellis. Great job. If anything goes wrong, don't blame Mark. Whatever goes right, Mark -- it's because of Mark's hard work. There's a lot of elbow grease in here, pal, and you did a great job. Thank you so much.

So there's the five panels that we're going to be listening to today, and I want to give you some background in terms of how we got to where we are. It's a long history. I venture to guess there may be some people in this room who weren't even born when this all got started.

But you basically have two sort of parallel, but separate, proceedings. One is the MSHA rulemaking that began at the -- sort of at the beginning of the Clinton Administration, so you can see how old it is.

In fact, there was a lot of activity going on with regard to diesel exhaust prior to that. We could write a book on it, but we're not going to because no one would buy it. Even my daughters and my wife say, "What the hell are you doing here"? No. But, in any event, it is interesting, and it's got a long, long history.

And the other key line of thought is the NIOSH and National Cancer Institute Diesel Exhaust in Miners Study. We'll talk a little bit about that.

So as far as the MSHA DPM rulemaking is concerned, as many of you know, and for those who don't, there were two separate rulemakings, one for underground coal mines, and one for underground metal/nonmetal mines.

They proceeded pretty much at the same time. They were both published together as proposals. And for those of us who are participating in the rulemaking, it was really kind of interesting to see how it all went on.

The coal rules, of course, you know, when you try to figure out what is coming out of diesel exhau -- diesel engines in underground coal, it's virtually impossible to measure because you're surrounded by carbon, and carbon is the key factor of exhaust that you have to measure.

So the coal rule is basically one that generates from testing via the Approval and Certification Center and EPA testing as well. As far as the metal/nonmetal rules are concerned, it's a tailpipe measurement, and that was very, very controversial, as we'll briefly discuss.

Both rules were published on the very last day of the Clinton Administration, hence the moniker Midnight rules. There's a *Federal Register* citation here if you ever want to go back and look at it.

Industry was very unhappy that they were published, and, virtually overnight, the mining industry challenged the regulations in the United States Court of Appeals for the District of Columbia. Industry parties were Kennecott, now Rio Tinto, AngloGold North America, followed by separate suits by the National Mining Association, and a group of mining companies called the Methane Awareness Research Group, MARG.

As I say, the litigation was filed very quickly after the new George W. Bush Administration came into power, and those folks signaled very quickly that they wanted to talk about settlement discussions as opposed to litigating it, which was very good for the industry.

We talked, literally, if I remember correctly, Mark, about four years before things fell apart. It was maybe the longest settlement discussions ever.

And, to the extent there was any good news about it, that period of time when there were discussions between the industry, the steelworkers intervened as labor union representatives, NIOSH, to its credit, came in as sort of anonymous broker --

very helpful -- and the discussions enabled the underground metal/nonmetal industry in particular to sort of get acclimated to the regulations.

Filters were almost a brand new -- I won't even call them a science. They were a brand new art. Trying to figure out what worked and what didn't was an ongoing struggle, along with all the other controls that were new to the industry, and needed to be implemented in order to meet what was a PEL of 160 micrograms of total carbon per cubic meter of air, as I say, as measured at the tailpipe.

Long discussions. A very favorable settlement agreement was created, at which time, I'm disappointed to say even now, that -- the MARG group walked away from it for reasons that remain murky to me, and MSHA said to itself, and to us, well if we can't settle with everybody, we're not gonna settle with anybody.

And what that meant, miners' death cases were briefed, argued before the D.C. Circuit -- in fact, there were two arguments -- and, certainly not to my surprise, the Court rejected the industry's arguments, as well-crafted as they were. I'm gonna talk about why that happened later on.

I always said to my clients -- and as those of you who know me know well, I'm a great believer in finding compromise and a pathway through things. Sadly, that didn't happen.

I kept saying to folks, we really don't want to litigate these rules, because on the morning of the oral arguments, you know, one or more of those three Judges are going to be coming in to work and will get stuck behind a Metro bus fuming diesel exhaust, and they're gonna say to themselves, what the hell? And whether that actually colored their outcomes or not, I don't know, but I always remained concerned about it.

On the other track, the DEMS study, Diesel Exhaust in Miners Study, began in the early 1990s, around the same time that the rulemaking did. It was an effort between NIOSH and the National Cancer Institute to do a large-scale epidemiological study of underground nonmetal mines. Eight mines were voluntarily participating.

It was a good effort to begin with, but communications problems took place, along with really substantive disagreements between the mines, and NIOSH, and the National Cancer Institute.

Not surprising, another fist fight broke out, the industry obtained a temporary restraining order that was in effect for the better part of nine years before it was finally dissolved, and the DEMS was published in 2012. You can see the findings of the two major authors on the screen there.

One mine, a client of mine, decided to, as they said, reset the button with NIOSH. Mark and I actually went over one afternoon to visit with John Howard and company and we had a very cordial meeting -- I think NIOSH was anxious to make peace, too -- and it turned out to be an exceptionally valuable relationship that goes on to this day in terms of that particular operation.

And what was coming out at that time was something that was very worrisome to the companies, and that was to -- NIOSH and NCI were jointly crafting a letter to the involved miners, explaining what DEMS was all about.

And there was a high degree of anxiety among the companies as to what the agencies would say, whether it would result in tort liability issues, just like you see, advertisement by plaintiffs' lawsuits on mesothelioma. And now you see them about glyphosate. We were concerned about advertisements by plaintiffs' lawsuits, saying if you were ever exposed to diesel exhaust, call us, et cetera, et cetera.

Well, happily, with a lot of hard work on the part of everybody, the letter turned out to be a nothing burger -- that's a legal phrase, by the way -- and so it all -- that part all worked out.

But then came IARC, a very, very important piece of work. IARC is shorthand for the International Agency for Research on Cancer, a component of the World Health Organization, in turn, part of the United Nations.

IARC, based in Lyon, France, took all the recent studies, including DEMS, as well as a massive study on truckers and a study on railroad workers, and put it all together in a very unpleasant, but scientifically-sound, discussion, wrote a monograph, basically concluding that diesel exhaust is a known human carcinogen.

Very, very problematic finding, you know, whether you agree with that or not. I can't speak for anybody other than myself. I think it's overstated, but it is what it is.

That, in turn, led to MSHA publishing a couple of alerts in 2012, and, finally, in 2016, in the middle of the year, MSHA published a Request for Information, which I hope everybody in this room has read -- if you haven't, you should -- and a comment period ensued. It was a very, very complicated

Request for Information, asking what I thought were terribly difficult questions.

I was concerned that by the time this all happened the knowledge base of the industry had shifted. It was almost a generation since the original rules had been published, and, from my observation post, I was -- I thought that all of the expertise that had existed at the time of the rulemaking were retired and enjoying warm sunshine in Florida and other places.

So the comment period took place. There were some excellent comments that were submitted. Mark and I talked about what might be the next step, and we went over and we visited with Pat Silvery and John Howard and suggested to each of them separately that a partnership be created to help work our way through this Request for Information on the notion that collegial discussions of industry, academia, labor, manufacturers would be a smart thing to do, and we've had a couple of comment periods come and go, with the comment period now extended to I think March.

I urge all of you to take a peek at that, and urge all of you to comment on the RFI, if you haven't already.

This meeting, I think, is going to be

transcribed, Mark, and the transcript, I'm confident, will find its way into the RFI docket. And I am also confident that parties will ask for the RFI to continue to be open for additional comment. We'll talk more about that later.

The bottom line is that this workshop is one of the outcomes of the Partnership, and so, with that background, want to just briefly say look at the wonderful people up here. And I'm gonna sit down and get ready to throw spit balls at them if they don't behave themselves. So thanks very much.

MS. KOGEL: Well good morning, everybody. Excuse my voice. I'm working on a little bit of a cold here. I'm Jessica Kogel. I'm the Associate Director for mining at NIOSH. I'm gonna take a minute here to try to figure out how to get to my slides, and hopefully I can do that, but I may need some help.

So for the next 15 minutes or so what I would like to do is to kick off today's workshop, as well as this morning's panel discussion, by giving you a brief overview of the two decades of research that NIOSH has been engaged in around diesel technology.

So 15 minutes isn't enough time for me to talk about it in depth, so this really is going to be high level, and to kind of set the context for our later discussions.

So before getting into that discussion I thought it would be useful to talk a little bit about how we do research at NIOSH. At NIOSH we have, really, two kind of types of research that we engage in.

One is our Extramural Research Program, and that program is comprised of contracts and grants that we award to other government agencies, academia, and industry for carrying out research that complements what we're doing intramurally within NIOSH, or it may be research that we choose not to do for a variety of reasons -- we perhaps don't have the facilities or the capacity to do that research -- but all of it is aligned with our strategic plan.

And this research, I should mention, is also driven by the National Occupational Research Agenda, also known as NORA.

The Extramural Research Program, as I mentioned, complements, oftentimes, the intramural Research Program. And what I have listed on this slide are -- and that's shown there in the orange text -- are current or recently current projects that have taken place around diesel research at NIOSH.

So let me move to the Intramural Research

Program. You can see that there are five divisions within NIOSH that currently have active projects going on in this area. They focus on one of two sectors, the mining sector or the oil and gas sector.

If we think about the NIOSH mining research program, which is represented on this slide by both the Spokane and the Pittsburgh Mining Research Divisions, most of the work that's taken place in these two divisions under this program have been related to intervention.

I should also mention that the projects institute-wide focus on a number of different areas, including surveillance, exposure assessment, risk assessment, toxicology, and also identifying interventions for reducing workers' exposure.

The intervention research includes research in the areas of controlled technologies, and I'll give you some specific examples of some of the work that we've done in this area. We also look at work practices, different training solutions and approaches, as well as monitoring the mining environment.

And the way we approach monitoring the mining environment very much is around the idea of giving miners the -- empowering the miners, I should say, to identify and correct conditions that lead to overexposure. And you're gonna see that theme throughout some of the work that we've been doing over the last two decades.

So the remainder of my presentation really very much focused on the work that's being done at NIOSH through the mining program.

So I thought I'd just begin by reminding everybody of what our mission is, and that's to eliminate mining fatalities, injuries, and illnesses through both relevant research and impactful solutions, and really coming back to what John said in his introduction, and that's the very important aspect of our research, which is research to practice and delivering that research to the miners where it can really have an impact.

So the research is guided by three strategic goals. Those are listed on this slide: To reduce occupational illness and disease, to reduce injuries and fatalities, and then disaster prevention and response.

Within each of these strategic goals there are a number of different research focus areas that are listed here, and you can see that the scope of our research is quite broad. The diesel assessment and control work that we do falls under Strategic Goal No. 1.

We would not have accomplished what we've accomplished in the last two decades without partners and partnerships, and that comes back to this idea of, you know, collaboration being in NIOSH's DNA.

Our industry partners have very generously opened their minds to us so that we can come to their sites and do our research, do field investigations, and that's been very important for making sure that our research has credibility, and also relevance in the mining context.

We've been able to carry out research both domestically and internationally. We've partnered with 17 mines within the U.S. and six mines in Canada and Australia.

We've also had ongoing partnerships throughout the last two decades that have helped guide and inform the research. The first one was formed in 1999, and that's the Coal Diesel Partnership. Shortly after that, in 2002, we launched the metal/nonmetal diesel Partnership, and then, most recently, the Diesel Health Effects Partnership, which is what's responsible for today's workshop, as Ed just mentioned.

So in the spirit of summarizing, this is one slide that's gonna capture kind of the high level 20 year history.

So, as I've alluded to already, this work started in 1999, and the idea was for NIOSH to launch a research program that would investigate how to reduce miners' exposure to diesel particulate matter and gases in underground mines.

So the focus was very much to assist both the regulators, as well as the mining operators, in how to select, implement, and accept the existing and emerging control technologies, and so we worked in partnership to evaluate technologies that were available, and also to develop new technologies, and also to assist with the use of improved strategies and practices.

So the solutions that we came up with through this research effort really fall into one of four categories. One is around improved sampling and monitoring methods, and I'll talk a little bit more in detail about that. The other is we've done a large amount of work in engine exhaust after-treatment technologies.

We've also taken a very hard look at the use of alternative fuels in reducing exposure, and then filtration systems for enclosed cabs.

So, briefly, the results are that we've published over 100 peer-reviewed publications, conference proceedings, and presentations. I highlight two publications in this slide. I wanted to call your attention to them because these are very practical guides that summarize much of this research, that are very much aimed towards helping mine operators reduce miners' exposure to DPM.

We've also held a number of workshops, 40 workshops since the inception of this program, and those have been held both internationally, as well as domestically.

We've also partnered extensively with MSHA to improve compliant sampling protocols. These are based on NIOSH Method 5040. And also, we have developed a number of different new interventions and strategies, which I will give you some examples of starting with this next slide.

So the first one that I wanted to describe is the development and commercialization of a wearable, real-time elemental carbon monitor. So in order to reduce exposure we have to be able to measure DPM, and, preferably, we would like to be able to do this in real-time.

So the standard method is to collect a sample, and to collect that sample over an eight hour or longer work shift. This method determines the DPM con -- an average DPM concentration over this extensive sampling period, and what it does not do is it does not give real-time results.

However, real-time results are necessary because real-time results, again coming back to this idea of empowering mine workers, allow miners to make critical decisions in the area by identifying the major factors that contribute to their overexposures, and then, with that information, making decisions about how they can implement very quickly engineering controls that would then reduce those exposures.

So because there was a gap here, and there was a need, NIOSH decided to develop a real-time DPM sampling device. And so the technology was developed, and then it was licensed to a manufacturer, and then commercialized as the Airtec. And you can see that device here, on the slide.

We've continued to do work in this area. The Airtec measures elemental carbon, and then it estimates organic carbon. In cases where there is a high level of organic carbon in the sample, that can impact the accuracy of the results, and so NIOSH has just started a project, and this is in the early research phases, of looking at alternatives to help improve what we've already developed.

Currently, we're looking at two methods. One is FTIR, and the other is LIBS -- that's laser-induced breakdown spectroscopy -- to determine whether or not these analytical methods are capable of measuring both EC and OC, and, you know, preliminary results show that both the FTIR and the LIBS are capable of measuring the elemental carbon.

The organic carbon is still a challenge, but you can see from the two graphs that the FTIR is producing better results than the LIBS in terms of its ability to measure organic carbon as compared to the organic carbon measurement that's done with the NIOSH Method 5040.

So another technology that I wanted to mention is the work that we did around the ability to be able to directly measure DPM from exhaust being emitted from a tailpipe.

This work is important because mine operators can use this method to determine which vehicles in their fleet are the highest DPM emitters, and they can also evaluate how well intervention technologies that have already been installed in their fleet are working in terms of reducing DPM.

One of the problems, though, is that doing a direct measurement from diesel exhaust is difficult because diesel exhaust, as you know, is hot, and it has a lot of moisture, and so you can't take a sample directly from the tailpipe into a sensitive analytical instrument without damaging that instrument, and so what we developed was a probe that reduces the temperature of the exhaust and removes the water, and then, once that's done, the sample can be directly measured using the Airtec device, for example.

Another example of a technology that we've developed is this handheld electrostatic precipitator. It's a handheld particle sampler, and NIOSH developed this sampler which uses a high voltage electrical field to simultaneously charge and collect the sample, and then electrostatically precipitate it on a sample substrate. In this case, this shows a TEM grid substrate.

The device is capable of collecting particles that range in size from tens of nanometers to tens of microns, and so it can collect a representative sample.

It's used by industrial hydra -- hygienists to do field surveys, and it's also used in research to do things, such as collect samples, so that researchers can look at the morphology of the diesel particulate matter, which is very important when you're doing health-related studies, trying to understand toxicology and other things related to human health.

I mentioned that NIOSH has done some work to improve the compliant sampling methodology, and two things that we've done to help improve that is introduce the use of a dynamic plank for correcting absorption of vapor phase organic carbon in the DPM-compliant samples, and also in introducing a conversion factor that's used during each sampling event.

So NIOSH has done a significant body of work around after-treatment technology, and one of the drivers for that was that when MSHA promulgated the DPM rules, diesel particul -- particulate filter systems at that time were thought to be one of the most promising technologies for reducing particulate emissions.

NIOSH then started looking at some of the commercially-available technologies that were -- technologies that could be possibly used to retrofit mining equipment, and they found that, in fact, they weren't suitable for doing that. A lot of that was because of secondary emissions of nitrogen dioxide.

So NIOSH then undertook a study looking at a number of different technologies -- this work was done at our Lake Lynn experimental mine -- and through that work determined that there were a couple of systems that were suitable for retrofitting equipment in the mines. These were the wall flow monolith filtration elements and sintered metal elements. So this was important work to help mine operators determine which technologies were the most suited for their operations.

And then another strategy for reducing miners' exposure to diesel exhaust is to use alternative fuels, things such as ultralow sulfur diesel, bio fuels, as well as gas diesel blends.

However, there's a real research gap here in understanding how these alternative fuels behave in terms of human health and what the effects are, and so we've been engaged in a number of different studies, both intramurally and extramurally, looking at this question.

So, you know, much of the work has been around bio fuels. We've demonstrated that the bio fuels that we've evaluated are a potential control strategy for reducing exposure. That, when compared with ultra-low sulphur diesel, they have reduced DPM and total carbon, as well as elemental carbon mass concentrations.

But then when we did some follow-up laboratory studies looking at toxicology, the toxicity of aerosols produced by some of these bio fuels is higher than that produced by the ultra-low sulfur diesel.

And then a study that was done by Burgess, et al. -- and this was through our extramural research program -- also looked at the health effects of bio diesel, and their result showed that it's not conclusive. That we need to continue to do some more work in this area. So that's another body of work that I think has been important for tackling this problem.

So, finally, this is my last slide. Normally at this point I would ask you if you had questions, but I thought what I would do instead is ask a rhetorical question, and that is what is -- what about the miner?

This slide shows the total carbon diesel concentration in underground metal/nonmetal mines from the time period between 2008 and 2017. The concentration has dropped about 54 percent during this time period, and although we cannot directly attribute this drop to the 20 year research effort that I've just described, we can say, and I believe with confidence, that this trend does reflect combined efforts and dedication of the government agencies, the industry, academia, the equipment manufacturers coming together to address this.

These are very challenging problems, and it really does take this kind of collaborative effort and this broad research community to come together and answer these very, very difficult questions, and so I think it's a real testament to the power of partnership, and that's why we're all here today.

With that, I would like to just encourage us to continue this process, both through this Partnership and through these workshops. And, also, I would like to thank you for your attention, and I'll introduce David Weissman, who's our next speaker.

MR. WEISSMAN: So I'd like to start out just by thanking the organizers, by thanking Mark and thanking Ed for the opportunity to be here at the diesel technology workshop. I'm going to provide a very brief update on diesel health effects as part of our context panel.

So here's an outline of what I'm going to talk about. First I'll do a brief overview of diesel health effects, then I'll talk a bit about the IARC 2012 evaluation for carcinogenicity of diesel exhaust that Ed talked about in his talk -- I'll expand a little bit on that -- and I'll provide some follow-up information about ongoing work related to the diesel exhaust and miner study, the DEMS study, also expanding on what Ed spoke about.

So here's a table that I pulled from a recent summary of health effects of exposure to diesel exhaust that was published by Health Canada in 2016. You can see there are three columns here, in this table. The first one are the type of health outcome, the second one are whether it's an acute or chronic effect, and then the third one is Health Canada's determination of level of evidence for causality.

And I don't have a pointer here, but as you look at the table you'll see that there are two rows where Health Canada felt that there was sufficient evidence for causality. One is lung cancer, at the very top, and the second are acute respiratory effects, so irritative things, like wheezing and asthmatics, or coughing, or other irritative kinds of symptoms.

Then there were a couple of things that were rated as being likely, which was the next level of causality, and one of those were chronic respiratory effects. And their review talks about things like loss of lung function over time -- there's very limited data about COPD -- and, also, asthma in children, for example.

Another thing that was rated as being likely were acute cardiovascular effects, and there are volunteer studies that were mentioned where people were exposed, and there were effects like heart rate variability changes. So this gives you an idea of the sorts of health effects that are out there, in the literature.

So what I'd like to do now is sort of change gears a little bit and talk about the IARC determination because lung cancer is the health effect of most concern to most folks in the group, and the IARC study is really important.

I cut this text from the IARC report, from their conclusions, just so that folks can see what's actually in the report. And so cancer in humans, they say there is sufficient evidence in humans for the carcinogenicity of diesel engine exhaust. Diesel engine exhaust causes cancer of the lung.

And they felt that the evidence was less strong for cancer of the bladder. They say that a positive association has been observed between level of exhaust and bladder cancer. So lower level of evidence for that.

And in terms of their overall evaluation, they found that diesel engine exhaust is carcinogenic to humans, or group one, okay? So that's what's out there.

Now there was a companion publication put out by IARC that was in *Lancet: Oncology* which talked a little bit about the types of studies that were most influential.

They say from that that the most influential epi-studies assessing cancer risks associated with diesel engine exhausts investigated occupational exposure among nonmetal miners, so the DEMS study, railroad workers, and workers in the trucking industry, so just like Ed had presented earlier.

I've listed here the specific studies that were cited as being the most influential by IARC. So the two DEMS studies, the cohort mortality study showing a relationship between exposure and lung cancer mortality, the case control study that looked at exposure/response relationships, and then also the trucker and railroad studies by Garshick, et al.

Now a couple of years after the IARC report, and after the DEMS report, the Health Effects Institute published a report, *Diesel Emissions and Lung Cancer: An Evaluation of Recent Epidemiological Evidence for Quantitative Risk Assessment*, looking at the potential usefulness of the literature that existed for risk assessment.

Again, I snipped this from the executive summary. These were sort of the bottom line points. They say that this report's a careful review of two major epi-studies of historical exposures to diesel exhaust.

The word historical is really important because these were cohorts that were followed over long periods of time that were exposed to old technology, before the measures that Jessica spoke about. But, basically, that -- they reviewed the Diesel Exhausted in Miners study and the trucking industry particle study to assess whether they could form a basis for risk assessment.

In the panel's view, both the trucker study and the DEMS were well-designed, well-conducted, and made considerable progress towards addressing then-current limitations in the literature. They found that the studies had many strengths, but any effort at quantitative risk assessment would need to acknowledge some key uncertainties and limitations.

Again, these were people that were exposed over a period of many years. Old technology diesel met the newer technology that's more recent. Also, mostly white men, aged. Questions about whether the exact quantitative relationships could be extrapolated to other ages, other groups.

The panel concluded, however, that both the DEMS and the trucker study provided results and data that provide a useful basis for quantitative risk assessments in particular to older diesel engine exhaust, okay?

So I'm gonna change studies a little -- change gears a little bit more and provide a little bit of information about ongoing follow-up to the DEMS study. There has been ongoing work with the DEMS study and its data since it was published in 2012. I see Tim French in the audience.

So one of the areas of work has been that after the DEMS study was published, we made the data accessible to outside investigators, and the largest body of work that involved re-analysis of the DEMS data was done by a group of investigators that were funded by the Truck and Engines Manufacturer Association, or EMA.

I've provided here a list of some of the key EMA-funded publications which raised criticisms of DEMS and present alternative data analysis. For those interested, I've also provided some references related to DEMS investigator responses. And so this is an ongoing area of work.

There's also ongoing work going on at the National Cancer Institute, and I've cited two publications here from 2018 that look at relationships between ischemic heart disease mortality and exposure to respirable elemental carbon and/or respirable dust in the DEMS cohort.

The two were sort of correlated with each other and they couldn't separate out the effect of one from the other, but they did see relationships between exposure to those metrics and risk for ischemic -- death from ischemic heart disease.

In addition, the NCIA investigators are working to do a follow-up of the DEMS cohort. So the original studies that were published in 2012 followed causes of death in the cohort through 1997.

A lot of years have gone on since then, and so they're currently doing a analysis that follows death experience through 2015, so adding 18 years. That will add power to the study and the ability to look at a range of potential causes of death. And probably we'll be securing results from that in a few years. So ongoing activity here as well.

And then, finally, I wanted to finish up on an optimistic note with some snips from a Health Effects Institute study from 2015, the advanced collaborative emission study.

That study looked at new technology diesel exhaust, and you can see that first yellow highlighted group, and they found that new technology diesel exhaust from a 2007 engine was not carcinogenic, unlike traditional technology diesel exhaust from older engines which is known to cause lung tumors in rats under similar conditions. So new technology with exposure to rats was less toxic, and that was their bottom line conclusion as well.

ACES results demonstrate, even after considering some inherent limitations in any such study, that diesel particulate filters greatly reduce PM from modern diesel engines, and the overall toxicity of exhaust from modern diesel engines is significantly decreased compared with the toxicity of emissions from traditional technology diesel engines.

So that really validates the work that's going on here, and it really validates the efforts of everyone to bring new technology to bear to reduce potentially harmful exposures.

So I'll finish up right there. We did a little bit of an overview of diesel health effects, we expanded a bit on IARC, and talked a little bit about ongoing work relative to the DEMS study. So thank you very much.

MS. MCCONNELL: Good morning. My name is Sheila McConnell. I am the Director of Standards, Regulations, and Variances at MSHA, and I would like to thank you all for coming today. I also would like to thank again Mark, and Ed, and -- for putting together this meeting together and the agenda, and I also wanted to thank all of you for participating.

I'm going to follow-up on a lot of the things that Ed said. As he noted, we did publish a Request for Information in 2016, and one of those -- one of the outcomes of that Request for Information was the formation of this Partnership.

Today is our fourth meeting, and I am heartened to see so many of our stakeholders in attendance today. It is from this type of participation that we can learn from one another, gather the needed information to better understand issues related to miners' exposures.

Again following on Ed's remarks, we did produce a RFI that was technical, which I believe is reflective of the issues at hand regarding miners' exposures to diesel exhaust. We did have 28 questions, and we broke those questions up into certain categories.

For coal we requested data information related to the feasibility of lowering the emission limits for non-permissible, light-duty, diesel-powered equipment to 2.5 grams per hour of DPM or less. We asked about the maintenance of diesel-powered equipment at underground coal mines and recordkeeping requirements.

For our metal/nonmetal mines we requested data and information related to alternative surrogates, other than total carbon, to estimate exposures, and ways by which we could reduce miners' personal exposures.

For all mine types we also requested data and information related to the types and effectiveness of after-treat -- exhaust after-treatment technologies in underground mines.

I think we had our first meeting, which was a quick meeting and shortly after publication of the RFI, in December 2016. I think our first substantive meeting was in 2017. At that meeting we provided a summary of comments that we received. We have posted that comment summary on our website. The comments are provided in a variety of format for ease of use by our stakeholders to be able to locate a comment on a particular question or a particular issue.

We also went through all of the studies that were submitted by commenters and provided a summary of those as well. All of these are posted on our -- their website.

Many of the comments and issues we discussed at our second meeting related to best practices for controlling exposures to DPM. At our second meeting we addressed -- NIOSH and MSHA addressed issues related to advancing strategies for controlling diesel aerosols, best practices for reducing DPM.

We provided an overview of our diesel inventory in underground coal mines, and we did a review of MSHA's metal/nonmetal exposure sample data and best practices identified by MSHA for controlling exposures.

I think today's agenda really follows up on that meeting, and -- with our panels on a -- mission control technologies and barriers of deployment to technologies.

More importantly, we are hearing from our stakeholders. It's not just hearing from MSHA and NIOSH. That really provides us with an opportunity to hear the -- to receive the necessary information for MSHA's consideration and to know how to move, hopefully, forward.

As Ed mentioned, we -- the comment period for this RFI will close on March 26th. We have extended the comment period in the past to ensure that all the proceedings that -- and all the information gathered through the Partnership are included in the docket.

We will do the same with this as well and extend it -- extend the comment period as well to -- making sure that not only this conversation, but future conversations, are a part of the docket. With that, I also hope that this is not -- you know, we have many more meetings like today.

So before I move off and pass the baton off to Pat Silvey, I do want to talk a little bit about MSHA's efforts to address the President's Initiative for Regulatory Reform, as you know that shortly after, the Executive Orders were issued charging federal agencies to go back and look at their standards and regulations to identify those which could be updated for tech -- new technologies, or new processes, or just outdated.

And we immediately took action, provided an email address for you to send your comments, provided a website for those to be posted.

Since then, we have added a coup -- two RFIs on our regulatory agenda, one related to regulatory reform, one looking at the petitions that we received as pro -- as potential for updating the code based on approvals.

So far we've received about 82 recommendations -- these are all posted on our website -- and we're reviewing those comments that we've received. We plan on -- hopefully this year, that we will hopefully publish something that will address some of the recommendations that we received.

They will be incremental, they will be -- we're not do -- maybe multiple proposed rules or direct final rules that will come out to address some of these recommendations, and hopefully that will be by the end of the year.

Again, I would like to thank everyone for coming. I look forward to hearing the information that's presented at our panels this afternoon, and if you have any questions, we can address those after Pat Silvey has provided her comments. Thank you.

MS. SILVEY: Good morning. And everybody has thanked you, and so I won't take any time and do that. I do thank you, but I think all of our panel members have appropriately thanked everybody, the people who were so generous and charitable with their time in putting on this conference, as well as all of you for being in attendance.

First of all, though, I would like to ask an important question, and that is: is anybody in here from Louisiana? Nobody? Are there any Saints fans in the crowd? My heart is with you, too. And, you know, I have to say that.

And I could go all day without saying the next thing: especially so -- I had to be a Saints fan, and now look what happened to me -- but especially the way Alabama fizzled out. I could go all day without saying that, but I'll say it and take my -- so now let's get to our business here.

I want to first reiterate some of Assistant Secretary Zatezalo's comments, and that is that we, at MSHA, have placed an increased emphasis on health sampling.

While I am heartened to hear some of the positive results that have come from some of the new technologies, I mean that's why we engage in more and more research and we develop better and better technologies: we hope to reap the benefits. And I think we're seeing some of those when it comes to the control of diesel exhaust.

But at MSHA, for each and every one of our staff meetings, our assistant secretary and our top staff, we look at -- particularly at certain ones of our health samples, and for each one of the health samples -- each one -- including diesel particulate matter, that exceeds the PEL, then we talk about it.

I mean, what was the cause? That's really where the bottom line is, where a miner is overexposed to the standard, and what was the cause? What can we do to control it?

And I know you're gonna see some more of that later on today, but while Jessica showed you that great slide that showed the downward trend in exposures of DPM, we still know -- we at MSHA know that we are -- we do have some exceedances.

And that's one of our challenges, and that's what we have to communicate back to the mine operator, and that's what we have to work with our field enforcement staff on, and do all the kinds of things that we need to do to make sure that the exposures are with -- are controlled appropriately.

And one of the reasons that's so very important, because, as Assistant Secretary Zatezalo said, the health effects -- when you talk about safety effects, they're immediate. With health effects, it's a latency period.

We see that a lot, and we see that in a lot of different areas. I mean I wouldn't want to leave this room without knowing -- continuing to know some of the challenges we are facing with respect to coal mine dust. So when you're talking about that latent exposure, that's why prevention is so important; and, therefore, controlling the exposures.

And also -- also -- significantly, knowing what they are, because even if you -- you know, you -- we are not at that perfect place now, so we know we are probably not gonna be able to control 100 percent of exposures, but knowing that when there's an overexposure you know you can immediately do something about it and make the mining workplace safer.

So I sort of made these kind of disparate sort of notes, maybe, but I'll try to put them together in terms of I already talked about the greater emphasis on sam -- on health. And what does that mean? That we're doing more sampling, we're finding more samples in compliance, although significantly, as I mentioned earlier, some are not in compliance. And that's our challenge. That's all of our challenge.

We are providing more compliance assistance from our own people in terms of more outreach, and we are seeking more input from you. That's what Sheila talked about, and that's part of the purpose of this Partnership.

I want to go down now out of the order of what I -- these notes I had made, but I want to follow on to Sheila's and Ed's comments -- remarks about our RFI. That it was -- I was first gonna pick up on Ed's, but that it was -- but to mention Sheila's -- had technical and difficult questions.

That may be true, but I look out here, in this audience, and I see that's why we have all the -- all you out here today. That's why we have all these smart people in the mining industry. I know that you all have, and can continue to contribute to answering the questions in that RFI.

Now when I made that comment nobody smiled, but that was supposed to be a little humor because I was calling you all smart.

(Laughter.)

MS. SILVEY: Got to have some humor. Shoot. Okay. Now where am I?

When the IARC finding came out in 2012 we did, we, at MSHA, took a new look at things, and that's what generated some of the actions that -- I don't have to go over them, they've appropriately been over -- some of the actions that resulted in the reason that we are here today.

But, in the process, we looked at regulatory and non-regulatory actions that we could put in place to help control miners' exposure to diesel exhaust, and some of those -- you've heard a lot of those today, and you will hear more of those -- sharing best practices, new technologies, mine site challenges.

And I think the two things with mine site challenges -- and I say all the -- say this for people who are on the ground, the boots on the ground people -- the maintenance with respect to the equipment, as well as training for your mines, for our mines.

So I think that we can -- and those seem like rudimentary, simple things, but sometimes I think it's the simple things. We look sometimes for esoteric and high end things, and sometimes the simple things can get us -- help get us to our goal as we continue to work on innovative -- more innovative approaches.

I probably am -- we're -- in ahead of ourselves, but -- you all might have some questions, but I think, as we move on into the parts of this panel, we can all agree on one thing here, and that is our goal is to reduce miners' exposure to diesel exhaust in all forms, and all of the particles of diesel exhaust.

I was gonna say all. We talk about DPM, but we talk about other outcomes of diesel exhaust, too. We are going to, I believe, and with seeing this audience here today, collaboratively continue to work together to achieve that goal.

So, with that, I think then since I'm last, I can sort of, kind of do what I want to do, but I will see if you all have any questions. Or maybe I took over the role of the chair, didn't I? No, I can't do exactly what I want to do because Ed was the moderator. I'm wrong. I'm sorry.

MR. GREEN: Well, I've known Pat for going on 40 plus years now.

MS. SILVEY: Too long.

MR. GREEN: That's the first time she's ever told me she's sorry, so --

(Laughter.)

MR. GREEN: Thank you, Pat. Those were some very useful comments.

(Applause.)

MR. GREEN: Now we do have some time for -- in fact, we have plenty of time for questions. We're ahead of ourselves in terms of the schedule. So if anybody has any questions on stuff so far, now is the time to ask them. Do we have a microphone roaming around somewhere?

So if you have a question, come down to one of the mics.

AUDIENCE MEMBER: I'd like to hear this from each of the panelists. What are the top three recommendations you would have to lower DPM?

MS. KOGEL: So I'll start. So I think it's just continuing to -- I think Ed actually summarized it pretty well, and that was controlling exposures and knowing what they are. And so I think I'll count that as two, if I could.

So I think we have to continue controlling, and we also have to continue doing the science, so that we really understand, you know, what exactly is it that miners are being exposed to, and what are the health impacts.

And, you know, David talked about the health work that's been done around these things. You know, I mentioned that we don't really understand toxicity of the alternative fuels, for example, and so some of the strategies that we're using maybe aren't having the effects that we believe they are because we haven't completed the science.

So I think that's another area, is continuing to understand. That would be my third, is the health impacts of things, such as the alternative fuels.

MR. GREEN: Let me go next because I've thought about this a lot. Dave, it's a great question. You know, I think there's an interesting advertisement on daytime TV that is done by Alex Trebek. Talks about an insurance company, and he says there are three things that you have to remember about insurance: price, price, price, which is a terribly boring advertisement.

I would say that there are three things we need to worry about in this issue, too, and that's maintenance, maintenance, and maintenance, in terms of underground engines. I agree with Jessica, the science is -- it needs to be explored further, but I think we know enough about health effects that the argument about whether or not diesel exhaust is carcinogenic is over. We can talk about the details.

I've always said to folks that if God wanted us to breathe diesel exhaust, he would have put it in the atmosphere and we'd be breathing diesel exhaust instead of oxygen. So it's not good for you, it is harmless in doses that are controlled. So maintenance, maintenance, maintenance, for me, is the key to the issue.

MS. SILVEY: Okay. Well I would say that -- and I'm gonna kind of sound like a broken record because I'm gonna kind of repeat myself, and that is it kind of does, I think, end up being some of the basic industrial hygiene, general industrial hygiene precipice that we have all learned and studied about.

And I'll say this as an American. I drive a Nissan Rogue, and my husband swears that -- and you wonder, what relation does that have to what I'm gonna say? But he swears that you can keep a car forever by changing the oil and changing the filter. You know, I guess, to some extent, he may be right because my Rogue is '09 and I -- it's never been in the shop. So -- and I don't want to start something here.

But I think that goes to a couple of things

I said, which were maintenance. And now I'm redoing -- making sure that the equipment is properly maintained.

Dave, I think making sure that miners are trained and have the information that they need, and then I think that -- and kind of, you know, this is where we come in the picture -- making sure that over exposures, if we find over-exposures, that they are appropriately controlled, and part of that is our interaction with the mine -- and I'm talking about MSHA now -- our interaction with the mine operator and the mine.

So I would say -- and that, you know, that's not so complicated, I don't think.

MS. MCCONNELL: Well to provide some anecdotal support to Pat's comment about maintenance, I currently have a 2005 Subaru --

MS. SILVEY: She sure does.

MS. MCCONNELL: -- and it's running just fine. And prior to that I had a Honda Civic for almost over 15 years. So I'm not trying to support foreign cars, what I'm trying to support is the fact that just basic maintenance, you can keep a car for a long time.

But I don't know what the solutions are, so

I'm from a -- I'm taking a different perspective, from a rulemaking perspective. What are the best strategies for reducing exposures? Do any of those strategies require rulemaking? Can they all be done through best practices, sharing information?

If they do require rulemaking, what are the costs associated with those strategies? What are the cases avoided? All those things, MSHA would need to address in any type of rulemaking action. Is that data out there?

That's what is the benefit of this Partnership, that if there are strategies that do require some kind of change to the code, those are the questions we would need to answer: the cost and the benefits, and those are significant issues that would have to be addressed.

MS. SILVEY: And if you would allow me, I would like to modify my comment a little as a follow on to Sheila, Dave. I think that's significant for us, the regulatory: better data. I probably should have start, "more", and better data. The best data that we can get, the better position you're in, and I'll say that to everybody in attendance here.

MR. WEISSMAN: And I'm the last one, and sometimes there's a benefit to going last because I really don't have anything to add.

(Laughter.)

AUDIENCE MEMBER: I find it curious that none of you mentioned bio fuels.

MR. GREEN: You know, I'll comment on that. I'm not a technical expert on bio fuels, but I know from the feedback I've had from clients that bio fuels are a mixed blessing.

When they work, they're wonderful, but they're subject to climate issues, particularly in terms of wintertime and the mining regions of the country which are usually pretty bitter, and then you have to start dealing with the effects of cold weather on bio fuel. It's problematic. I think they're useful, but they're not the answer.

AUDIENCE MEMBER: Part of the solution.

MR. GREEN: Part of the solution, right? And to the credit of the folks at MSHA who crafted the current regulations, if you look at them -- and they begin at 30 C.F.R. Part 57 -- 5060, and they go on for a bit, and they cover all the topics that we'll discuss today, including maintenance, and training, et cetera, the -- to MSHA's credit, they did a good job.

The agency did a good job of crafting regulations that attempt to cover all the issues of significance, not one size fits all. Thank you, MSHA, for not forcing that. So the regulations, in my humble opinion, are useful, they're being implemented effectively. We're gonna talk all about that during the course of the day, I'm sure, and going forward.

But it's a very worthwhile job, and I'll stop. Do you know what, by the way? I just noticed Tim French.

I didn't see you before, Tim. Sorry. We need to give Tim French a shout out, too, for his work in organizing the workshop, particularly in terms of reaching out to the engine manufacturers for speakers. Thank you, Tim.

Pete, you're on.

AUDIENCE MEMBER: Yeah, thanks, Ed. I just want to support what you said about maintenance, and, at the risk of showing our age, if you remember, you and Mark, Pat and I were intimately involved in the Secretary of Labor's Advisory Committee on Diesels.

In that process, the committee spent a lot of time talking about maintenance, and, in doing that, there was a lot of information presented by MSHA's Technical Support and the Bureau of Mines.

If you remember, we talked about the Bureau of Mines had done some work where they looked at engine faults, and what the discussion centered around was in order to detect a fault in a diesel engine, that, really, you had to test it. Your routine, weekly test had to be under-load. And, as a result, in coal there's a requirement for a weekly loaded repeated engine condition test.

Now after that rule went into effect, MSHA, along with the United Mine Workers and the National Mining Association, did a very good video of -- talking about conducting the test and the benefits. Now that's something that -- that's done in coal on a weekly basis, and it's been very effective in lowering exposures. Then it's not required in metal/nonmetal. And I don't know how much of it's done in metal/nonmetal, but probably not much.

In fact, to show you, you know, what impact that has, there's equipment out there where the manufacturer, if a piece of equipment is going to a coal mine, their maintenance manual will tell them about the benefits and how to conduct that weekly loaded repeated engine condition test. In fact, many of them even put ports that make it easy to get a direct exhaust sample.

That same equipment, when it's shipped to a metal/nonmetal mine, that manual does not include that weekly test, and the ports aren't there. Now that's up to the legal folks to determine, if those manufacturers may be at risk somewhere, but there's a rule that something that's a very simple maintenance item that has been employed in coal for quite a long time, and it has reportedly, you know, resulted in significant improvement in exposures.

MS. SILVEY: And I want to just follow on. As Pete correctly said, as somebody who was there when that all happened -- I appreciate what you said, Pete, and I appreciate your observation on that, but I'll just add a comment. As somebody who was at MSHA, there were real reasons why the coal standard and the metal standard are different, and I'll just let it rest right there. Real, legitimate regulatory reasons.

MR. ELLIS: Mark Ellis with the Industrial Minerals Association. I just want to remark that it's just after 9:30 and I've already learned something today. I'm really pleased to see that MSHA is taking a look at overexposures because I think, while we all want to see exposures lowered, the ones that you really have to look at are that low-hanging fruit of the overexposures.

Maybe it's a request that I'm offering here.

That as we move forward with the Partnership, that MSHA make available, in some way, what lessons you've learned from the overexposures you've found so that others can benefit from what steps were taken to reduce those overexposures so that it's no longer a problem.

I mean part of the challenge that we all face is that we're all trying to comply with the rule, and we're trying to reduce exposures to the lowest levels possible, but if we can find out where people have had challenges and overcome those challenges, that's the kind of thing that we want to share with others as part of the Partnership.

MS. SILVEY: Okay. Yeah. Thank you. We can do that.

MR. GREEN: Okay. That's a great idea.

Pete, thank you for the comment. You're sitting down again.

Gentleman -- I don't know your name, sir, but go ahead.

MR. BUGARSKI: Aleksander Bugarski, NIOSH.

MR. GREEN: I can't see that far.

MR. BUGARSKI: Ed, I know that sight is getting worse.

I would just like to comment on something what panel brought: maintenance. Maintenance is very important, and we agree on that. We did a lot of research in the past on maintenance.

But I think one message we need to convey is that it's necessary to embrace new technology, because maintenance is important, but keeps us on our existing levels. So, basically, I think it's very important that -- to emphasize this impor -- the fact that we need to embrace new technology.

And now I would like to bring one next question, is how we do that, and how we generate economical environment in which we can bring this technology, because we all know that it's cost, cost, cost. But, unfortunately, I think what we are failing to understand, and put amount of the dollars to the -- of the -- on health and safety of the miners.

And, on top of that, we are failing to link how this expensive technology can help us to become more economically viable and a more sustainable industry. So if you can propose some ways to do that, I would appreciate it.

MR. GREEN: So, well said, Aleksander, and that goes back to Dr. Weissman's comment about the ACES study, and I think we'll probably talk more about that during the course of the day. To say that it's a difficult problem would be an understatement. But you're absolutely right, Aleksander, and thank you for that very salient comment.

MS. KOGEL: I don't have a solution, but I really appreciate you bringing that comment up. I'm gonna speak to this question from being a previous mine operator.

You know, what we're facing here is that there's huge capital investment in these diesel fleets, and so the reality is that despite how well you've articulated the positive benefits of moving to new engine technologies, companies are really, I think, confronted by a huge challenge in today's mining industry.

You know, profitability is very much a very thin margin of profitability, and so companies have to make those fleets last as long as they can, and so all of these things that we've talked about, and where -- why I think our after-treatment technologies and all of these other alternative strategies that we've talked about, besides replacing the fleets, come into play, because the reality is I think it's going to be very difficult for mining companies to quickly turn over their fleets to these new technologies.

So I know that's not an answer to your

question, but I just wanted to say that it's a critical, critical question. And I don't know how we, as this group -- and I know there are many operators in here who are faced with this economic reality.

Yeah, if there was a way we could come up with a message, or some way that -- to help promote that, I think that would change this conversation we're having here.

MS. SILVEY: Thank you.

MR. BUGARSKI: Yeah.

MR. GREEN: Anyone else?

MR. FLORES: Daniel Flores, NWP, Carlsbad, New Mexico, WIPP site, and I've worked on the ground, Potash maintenance man, for 38 years. Been doing emissions testing 38 years.

Who sets the procedure for doing emissions testing? I've basically moved up to systems engineer. I'm trying to figure things out here. I'm trying to devise a new emissions test, but I'd like to know where it developed from. Who developed it? Who set it? Does anybody know?

MR. GREEN: I'm not sure if there's any specific methodology set out. It may well be that -- depending on the engine, maybe the manufacturer's specifications, most likely. I mean the end outcome is what is critical for the MSHA regulations to achieve the PEL.

MR. FLORES: Okay. The thing is we've been following the same procedure for years, not just out at WIPP, but in the mining side of it, and I just wanted somewhere to start, and, so far, I guess this is the closest way, here, what you're telling me? Okay.

MR. GREEN: Good question. Thank you.

MR. FLORES: Thank you.

MS. SILVEY: And we can look further into it also. Just give one of us your card or your information. Okay.

MR. GREEN: Okay. Matt, go ahead.

MR. STEWART: Yeah, Matt Stewart with RT Vanderbilt. We've been mining for a long time, over 100 years, and we're what I would call a relatively small manufacturer, but we've survived many recessions.

I would say Jessica's really hit on something, as has Patricia. You know, these things, these -- mining equipment will run forever, so we've got to encourage operators to use proper maintenance. You know, I think that's something that we could work on, is how to make it clear to operators, the importance of routine maintenance.

When MSHA's out at the facilities, when NIOSH is doing their research, really try to understand where the struggles are and how some of those roadblocks can be broken down. Even the manufacturers of equipment in the room, reaching out to your operators to help them understand how important maintenance is.

I've done diesel particulate monitoring myself. I've done it within the last four months. The reason our site didn't do as well as I wanted them to was just some basic, routine maintenance.

Question, Jessica. The bio diesel toxicity issue, do we know -- do you know what the toxicity issue is?

MS. KOGEL: So I could give you some more information around that. That was work that was done in our health effects laboratory division, and so I don't have the details of the study, but I'd be happy to follow-up with you and give you some more detailed information.

MR. STEWART: Okay. And I counted. There might be like 29 operators in the room here. How many use bio diesel? Because, like Mr. Zatezalo said, I think that's an incremental value. We use it.

Hopefully there are -- there's 29 operators in here, so maybe a third are using bio diesel, or the other two-thirds are too shy. If you're using it, please raise your hand. We do. So it seems to me like it's not a mainstream.

Does that comport with what MSHA and NIOSH says? How prominent is bio diesel in the fix? That's my last question.

MR. BUGARSKI: We, at NIOSH, looked in all possibilities, you know, for the mining industry and propo -- we propose bio diesel as one of potential solutions to the problem, but, of course, we are not encouraging anybody to use bio diesel to the point it's the only solution. We always believe that the best solutions are related to controlling DP emission at the source, but using bio diesel is one of those.

Of course, it has its advantages and disadvantages. In particular, bio diesel is good for somebody who doesn't want to embrace this latest and the greatest engine and after-treatment technology, cannot do it from technical -- other technical reasons.

If you apply bio diesel as a control for the whole fleet -- that means light-duty, heavy-duty vehicles -- you can reduce your exposures to the total carbon and elemental carbon. And we proved over and over with a number of the engines we tested in number of the fleets that that's doable.

Of course, it has -- downside of it is, for example, Tier 4 final engines. If you're switching to the newer technology engines, bio diesel is not option for you.

So, basically, if you are, you know, trying on -- latching to the use of bio diesel, you might not be able to implement this latest and greatest technology. So there are advantages and disadvantages of applying this technology, but they're not absolute.

Regarding toxicology, I was part of that study. I supplied the samples to the health. We looked in increased toxicity to the oxidative stress, you know, because bio diesel carry oxygen with it. So, basically, it's a better, I would say, by definition, stressor than the regular alter -- also sulfur diesel. And we also showed some effects on reproductive -- on all reproductive organs.

So I can share with you publications, if you want, and you can read in detail. Again, I'm not toxicologist. They're a way to give you more insight in that.

So take all these proposals from NIOSH with a grain of salt because we don't know specifics about the applications. And we cannot really guide you to using something, but we can show you data to show advantages and disadvantages of these technologies.

MR. GREEN: Okay, one more question, and then we'll take a break.

MR. FLORA: My name is Jason Flora. I'm from the WIPP facility with -- just like Mr. Flores. My question has to do with the reduction standard for NO2.

One of the things that we're having great difficulty with at the WIPP facility is, because we are operating under low air flow conditions because of an event that occurred in 2014 which requires us to go through filtration, the PEL for the NO2 was significantly lowered, and one of the impacts that we're having is the short term exposure limit with the diesel -- the operation of diesel equipment underground.

For NO2 with low air flow in our underground we are moving toward an electrical mining facility. In other words, we're looking in the future to try to get rid of much of our diesel, which is a significant impact.

Do you have any advice on the NO2 control and how that plays into the DPM or the operation of our equipment?

MS. KOGEL: I think that man behind you can answer.

MR. BUGARSKI: So just a short comment, I think this is a, you know, very complicated issue, and we stumbled on this issue, trying to reduce and -- DPM exposures, actually.

And introduction of DPFs and catalyzed devices brought this issue because catalyzed devices by itself not only convert CO and hydrocarbons to CO2 and water, but they also oxidize NO2 and O2. So over the time, I think manufacturers and -- you know, get smarter, and now we have, basically, formulations which can also do this CO and hydrocarbon conversions without conversion of NO2 and O2 using different type of catalyst formulations.

So what I would suggest, that you look in a catalyst, what's inside your systems. Maybe you have some DOC and some DPF which has, I would say, unfavorable catalyst formulation, and you might experience this NO2 problems. But we -- I personally tested a couple DOCs and DPFs which have these NO-suppressant type catalysts, and I have that available from a number of manufacturers. If you talk to me later, I can suggest couple.

MR. FLORA: Sure. I'll do that.

MR. BUGARSKI: So, basically, you need to look into these products which are most suitable for underground mining industry, because we inherit this technology from on highway market, and they typically do not think about NO2 clearly as we do.

MR. FLORA: Okay.

MR. BUGARSKI: So I think it's a matter of using wrong product in the wrong place.

MR. GREEN: Thank you, Aleksander.

We're ready for a break, I think. Let's try to be back here right around 10:00 and we'll pick up. We're pretty much on schedule.

(Whereupon, a short recess was taken.)

MR. FRENCH: All right, this next panel -- we are gonna try to stay on time, so I'll just keep rolling along as people come back in. My name's Tim French, and I'm General Counsel with the Truck and Engine Manufacturer's Association. It's a great pleasure to be here. As others have said, thanks very much to Mark and Ed for helping to coordinate this. Thanks very much to NIOSH and MSHA for conceiving of, and putting the Diesel Partnership together.

We've been members of the Diesel Partnership for about two years now and have appreciated the opportunity to submit information to the docket about some of the health effects relating to diesel engine exhaust, the history of how we've come to understand those health effects, what the industry has done to ameliorate those health effects, and now, trying to noodle on the problem of how do we get clean diesel technologies into the minds.

I think one thing we'll all discover is that it's going to require some significant incentive dollars to help accelerate the turnover of this mining equipment fleet, and it's something that can, and should, be done.

If you consider the priorities from some of our congressional programs in terms of incentives for diesel technology, almost no better place to deploy those dollars than in the underground mining situation where you could have, potentially, high concentrations from old what we call traditional diesel exhaust.

In that regard, when you're thinking about some of the health effect studies that we've just touched on and that others presented about, for example, the Diesel Exhaust in Miners Study, that was a study that looked at health effects through 1999 in underground mine workers.

If you assume a latency period of cancer that might go back 20 years -- the common assumption is that it takes 20 years from exposures, or chronic exposures, to the manifestation of cancer -- that means you're looking at diesel exhaust exposures that were occurring in the '70s and the '80s, and those exposures would have been caused by diesel engines manufactured in the '70s and '80s, if not before.

We have come miles and miles since diesel technologies of the '70s and '80s, and this panel is here to talk to you about those advancements. In summary, we've reduced particulate emissions from diesel engines by 99 percent or more from uncontrolled baselines that would have been in existence in the '70s and 80's for non-road engines.

We have reduced emissions of nitrogen oxides by 95 percent or more from unregulated baselines, including those engines that were studied in the DEMS program.

A representative of the Health effects Institute is here today, Rashid Shaikh, and he'll talk to you a little bit more detail about the ACES program that you heard about, and that looked at and profiled in detail the exhaust emission signatures from diesel engines that comply with current emission standards and showed those significant 99 percent, 95 percent reductions in diesel emissions.

What you'll see is the tox -- the potential toxicity of those emissions has been reduced dramatically. The PM signature has changed from an organic carbon element to something that's much more elemental -- excuse me -- from an elemental carbon element that could have had additional chemical absorbed onto that elemental carbon element to something that's predominantly organic carbon, has a completely different signature, and is no longer carcinogenic in animals.

Anyway, point is today's diesel, substantially clean, substantially ameliorated potential health effects, and the question is how to get those technologies in underground mines.

So, without further ado, this panel's here to talk to you a little bit more in detail about the advancements in diesel engine exhaust systems and controls, where current emission standards are, and how we can deploy these technologies in underground mines.

They'll talk to you a little bit more about current products. We have a representative from Donaldson in after-treatment -- a leader in the after-treatment market. They'll talk to you a little bit more about specific components of after-treatment technologies. And then, once we're done, hopefully we'll have a robust discussion of some of these issues and any questions that arise as these gentlemen speak to you.

So thanks very much for being here, and our first speaker on the panel -- their bios are in the materials that were submitted to you -- our first speaker is George Lin from Caterpillar.

MR. LIN: All right. Good morning, everybody. Before I get started, I am just wondering who here went to MDEC this year. I didn't go, but who here went to MDEC? All right. All right. Thank you. And in the audience, I'm wondering, how many of you are Canadian?

AUDIENCE MEMBER: I'm sort of Canadian.

MR. LIN: All right. All right. Are you half Canadian?

AUDIENCE MEMBER: I lived there for 10 years.

MR. LIN: Okay. All right.

AUDIENCE MEMBER: Yeah.

MR. LIN: So earlier on Ms. Silvey came up talking about the Saints. I had no idea who the

Saints are. I had to pull up on my phone to understand they're a football team.

And part of the reason, I think, is because in Canada we really don't have any real sports teams, right? We have the CFL, which I'm a little embarrassed about because it's kind of like NFL, except we changed the rules a little bit, and we have hockey, but, you know, hockey is a religion in Canada, it's not really a sport, so we try not to get into arguments about it. And it's true -- the stereotype is true. We give babies ice skates and a hockey stick before they learn how to walk.

But, with that, I'm gonna -- I'm told I need to keep this under 10 minutes, so I'm gonna move through the slides very quickly.

MR. FRENCH: You've got 15. You can have 15.

MR. LIN: I have 15?

MR. FRENCH: Yeah.

MR. LIN: Okay. All right. I'm gonna talk about our emissions solutions for underground equipment. For existing equipment, we have this thing called a ventilation reduction package. If you were at MDEC my co-worker, Trink Peen (phonetic), talked about this a little bit, but the ventilation reduction package is essentially a re-calibration of the engine that lowers the PM. We have this on a lot of products. It's generally available.

And then from there we have -- we can add a flow through filter. A flow through filter is something that's easy to add. It adds about a 50 percent additional PM reduction. In addition to that, or another product we have is, really, the ventilation reduction again. It's a re-calibration of the engine, plus a wall flow filter.

Now a wall flow filter is like a 99 percent or more reduction in particulates, but it is a little bit more involved, and it is harder to add. It's only available on some select configurations of machines.

And then we have -- the EU Stage 4 and Stage 5 engines are coming out on non-road products. We're gonna introduce that more and more. We have a few machines that currently have this now. And then, finally, just a brief mention at the end here about battery electric. So it is something that we're field testing right now.

All right, I talked about this on the previous slide, but, again, the idea of the ventilation reduction options is to lower PM, so -- either through engine re-calibration or engine re-calibration with a flow through filter, or engine re-calibration with a wall flow filter.

This is the EPA emissions requirements and the EU requirements kind of summarized on a slide. So for underground mining for metal/nonmetal, we're around the Tier 1, Tier 2 range that's required, that's mandated as a minimum for underground mining. For surface products, or above ground, we're at that light blue box, that's at the bottom left there, Stage 5, or Tier 4, essentially. So there's a difference in the minimum requirements that's required in order to put product out there.

Now the Stage 5 products or the Tier 4 products that we have on surface, that technology is being introduced into underground, and so the Stage 5 products -- and I say Stage 5 because these products don't always get U.S. EPA approval.

In European Union, Stage 5 is required for underground, and so you'll see -- my guess is that you're gonna see manufacturers typically certified to -- for underground -- if it's an underground-specific product, it's gonna be Stage 5. It might not necessarily have Tier 4 because that Tier 4 approval isn't necessary. Stage 5 products will have a wall flow filter bringing PM down very, very low, and it will have the SCR catalyst with diesel exhaust fluid.

Now underground, you're all aware that, you know, there are additional safety requirements that apply, and so things like Stage 5 technology and some of the performance requirements for coal, the low exhaust temperature, those are inherently incompatible, and so Stage 5, when I talk about Stage 5, it's coming to metal/nonmetal, but it's not really coming to coal. Not in the foreseeable future.

I guess for folks that operate mines, do any of you use diesel exhaust fluid right now in underground applications? Okay. And what's the range of temperatures? Are you deep enough that high temperature is a concern? No? Okay.

So I know our equipment goes in mines where the temperature is actually very, very high. You're so far underground that the temperature actually rises, right? And so with diesel exhaust fluid, the concern here is that if you're above 90 degrees Fahrenheit, the decomposition rate of DEF is actually fairly substantial. It'll degrade in somewhere between six months to a year that -- you can't -- you know, you won't be able to use it, or it wouldn't be quite as effective.

And then the other thing with the SCR

catalyst in DEF is that it emits traces (sic) amounts of ammonia. The limits for EU I believe is around 10 to 25 PPM, kind of in that range.

So the table here shows the various Caterpillar models. The displacement is on the left. So, for example, a C1.5 would be a 1.5 liter, C18 would be an 18 liter. The table is kind of a summary on what sort of emissions technology you'll see on engines. The 56 to 560 kilowatt range is the power category that has both a DPF and SCR catalyst, so it's gonna require the diesel exhaust fluid.

Just kind of a quick picture -- pictorial of the different engine configurations. You'll see that the after-treatment on the 3.4 there, it's that silver piece in front, on the C4.4 it's that silver piece on top, and the C7.1 you'll see it's painted in yellow but sitting on top of the engine. But kind of the relative sizes of the after-treatment to give you an idea.

And so currently we have the R1700 loader that's available with a Stage 5 engine. This can be purchased. Some of you folks might be using this now. There are other Stage 5 models coming in, so some trucks and a larger loader.

And then, finally, my last slide, we do have a battery-electric loader that's being field tested right now, and so that should be available in the near future. I can't give a date for that, but it should be relatively soon. And that is all I have. Thank you.

MR. FRENCH: So as I said, I think we'll hold the questions until the end of the panel. Our next speaker is Dave Dunnuck from Cummins.

MR. DUNNUCK: All right. Good morning, everybody. I'm gonna talk about enabling technologies. Really, the evolution of the diesel engine technology as we moved all the way into what George has been describing as Stage 5.

So as we look through the growth curves and the evolution, there's been many years of different stages of bringing in technology, where we came in with after cooling technology in the late 1990s that helped reduce NOx levels, electric fuel systems that come into play, bringing in a Tier 3 type environment, which, as George showed on the regulatory landscape, is almost half the PM and half the NOx levels from where a relevant tar -- Tier 1 base engine would be.

As we've evolved, we've introduced cool EGR technology into diesel engines, and then in 2007 the introduction of the DPF, and then 2010 we introduced

SCR acrossed -- in combination with the DPF technologies.

In order to accomplish these technology evolutions we had to drive lower and lower sulfur and fuels. So we drove, initially, the first step into 500 PPM sulfur fuel, ultimately into what we call ultra-low sulfur fuel at 15 PPM.

As we worked through this, we still had to maintain focus on fuel efficiency improvements, reliability improvements, as well as a total cost of ownership, so as we introduce new technologies, we want to continue to progress in the improvements in reliability, improvements in fuel economy, and, as I just said, the overall total cost of ownership.

From an off highway, non-road perspective, as we introduced the Tier 3 engines in 2006, there's no after-treatment involved with the Tier 3-based engine. It's electronic controlled technology.

In 2011 we introduced what we called Tier 4 interim, and this is where we introduced the first phase of after-treatment on our off highway products. We had some models with just a diesel oxidation catalyst, known as a DOC, and then other models where we actually introduced the DPF as well for particulate control.

Along with this came EGR control in the products, but there were a lot of challenges around the notification oper -- operator notification. So we have when is the DPF regenerating, the ability to inhibit the regeneration, how do you maintain and manage when, and where, that can happen. This goes into forced rate (phonetic) applications indoors, and some forklift type operations.

So not just confined to one market, a broad spectrum of markets, that really brought some complexity that went into notifications, communications, documentations, training, and education.

A Tier 4 final was introduced, and we saw a wide spectrum of technology at Tier 4 final. Some of them came in with filters, and some -- in some instances within Cummins we were able to develop Tier 4 final technology that did not contain a filter on some products.

As we moved into our model year '19 products, also known as Stage 5, it's the full DOC, DPF, and SCR technology. We've removed the EGR from the system, and I'll talk about that a little bit in the future.

We're starting to bring in more advanced technologies. We're focused now on start-stop technologies that can help with idle time, idle fuel consumption, diagnostics that help from a repair perspective, know what's happening with the system, you know, real-time through telematics (phonetic) and data electronics, and then even looking at hybrid options as well.

As we look into the future, 2022 plus, don't know if Tier 5 --- when Tier 5 will come along and what it will include, but we're actually looking at increased enabling technologies as start-stop, hybrid technologies as well, as well as more electrification in this market.

So in order to really be successful in this, it really boils down to what we just consider total system integration. It really is an integration and a marriage between fuel systems, electronic control systems, the after-treatment, all the way through filtration, and within Cummins, that's what we focus on, is how all of these systems interact to provide the solution that's necessary for the given market that we're trying to address.

And so what this boils down to, and I think George talked about, there's different technologies in different markets. The right technology matters.

As you can see through the applications from Tier 3 all the way through European on highway regulations, North America on highway, into our Tier 4 and Stage 5 emission regulations, there's different technologies where the emission controls are met through in cylinder technology only.

In some cases we've brought in cooled EGR to manage the NOx levels and the PM levels out of the engines. In some cases we've introduced NOx absorbers, in various pickup truck-based applications.

And then, predominantly in the SCR and the PM space -- and you can see at the bottom in the Stage 5 -- you know, we're really focused on putting more heavy lifting into the after-treatment of the system, and it'll drive more reliability and fuel economy up on the engine side.

So as we look at what do we get as we move in the phases of emission regulations, on carbon monoxide, at a Tier 3 level, this is in -- about 3.5 grams per kilowatt hour.

So how much work is the engine producing, and how many grams of CO is it putting out? As we move from Tier 3 to Tier 4 interim, Tier 4 final, we saw almost a 99 percent reduction in carbon monoxide from the technology. And I think we talked earlier in some of the discussions, that's predominantly around the diesel oxidation catalyst can accommodate that.

The flip side what we've talked about is the nitrogen dioxide. As you go from a Tier 3 engine -- and this plot can be somewhat complicated, and I'll try to simplify it. The gray bars are the NOx levels. Many people talk about emission NOx levels out of the engine. The red bars are the NO2 that's coming out of the tailpipe. And so in a Tier 3 application, that's the pure NO2 coming out of the engine. Nothing to do with after-treatment.

As we moved into Tier 4 interim where we brought in the diesel oxidation catalyst, brought in the DPF, the catalytic conversions created more NO2. It's necessary for the function of the DPF to operate properly, but we don't consume everything that's converted through the oxidation catalyst. So you -- we saw an increase in the NO2 at Tier 4 interim.

But if we move forward to Tier 4 final and Stage 5 when we introduced SCR technology with DEF, the SCR technology consumes that NO2 to create the reactions to eliminate NOx from the system. Therefore you see, as it moves through time, almost a 99 percent reduction in NO2 as we move into Stage 5 and Tier 4 final technology. So while it's an increase at Tier 4 interim, it was a significant decrease as we bring in Tier 4 final technology and SCR technology.

I think this will be talked about. It's been mentioned already here today. I thought I would share this from a PM perspective from the ACES study and HEI. You can see the difference between 2004 and 2007. That prior to a DPF and after a DPF, a significant reduction in the mass emissions of particulate matter.

But then also what we focused on a lot, and is predominantly controlled in Europe, is particle number. In that particle number you see a significant reduction as well by the full wall flow filter technology. And there's a difference whether it's with regeneration or without regeneration, and it has to do with how the soot and the carbon is actually packed inside the filter.

The chart on the right's kind of interesting. While it shows that transition from elemental carbon, organic carbon, and sulfates actually transition more to sulfate, the size of those bubbles are relevant to the reduction in the mass. So the filter technology by itself is a significant transformation in diesel particulate matter coming out of the tailpipe.

I like this chart. One Tier 4, or one Tier 1 level engine is the equivalent of about 25 Tier 4 engines. So when you think about trying from a pure emissions to emissions standpoint, this is what it really boils down to on emission levels coming out of the products.

Moving forward though, from an emissions standpoint into the cost. We've talked a little bit about the cost. You know, how do you do this in this type of a market with the margins that you're dealing with? From a Tier 3 perspective, this is a comparison of moving from Tier 3 to Tier 4 final, to what we call a model year '19 where we've adjusted technology.

What you can see in this is the total cost itself, the operating cost, has actually come down with each stage. As we introduce new technology, we're trying to drive reliability and efficiency in with the systems. You know, along with the advanced added cost of the technology, the total cost of ownership reduces.

In addition, though, the maintenance cost is a significant improvement as well. We actually look at this on like to like maintenance cycles. And so there's a tremendous effort that goes into bringing in new technology that meets the regulatory requirements and the health and safety requirements that we try to live by, as well as bringing in advantageous packages from a total cost of ownership.

When we move this to the next stages, we look forward. The level of emissions that we've reduced to is pretty close to zero. It's gonna be challenging to make significant step changes in the constituent levels coming out of the tailpipe.

The next focus is, really, how do we reduce CO_2? What are the enabling technology, because CO_2 is fuel economy. Idle reduction, start-stop technologies, low carbon fuels, looking at hybrid technologies. How do we incorporate the electrification?

High efficient clean combustion -- we (sic) continuing to research in the combustion space -- waste heat recovery, and as well as advanced development in low temperature catalyst technology. How can we get catalysts to operate at a much lower temperature? As the engines become more efficient, the available temperature in the exhaust gets much, much lower.

As we look forward, from Cummins' perspective, we're focused on trying to be the powertrain supplier of choice. That ranges from

internal combustion engines with motor generators, all the way through power electronics, into full hybrid -- sorry
-- from hybrid, to range extending, to full battery-electric vehicles, as well as now investing in fuel cell technology as well. We want to be able to provide whatever powertrains necessary for the market that we're trying to work in.

And this is just an image from an overall site. The world's vast. We want to be able to provide power. What's the right market? Where do we need electrification? Where do we integrate with the drive train itself? Where are we with connected solutions? How do we understand how to get the data from engines, from systems, evaluate it -- you can have prognostics, pro-active approach to diagnosing systems -- as we move forward?

But it's a changing world. We're in this changing world, and we're trying to adapt. We're investing in the right technologies to continue to move us forward. With that, I thank you.

MR. FRENCH: Thanks very much, Dave. Our next speaker is Paul Sparenberg from MTU America, and he's here to expand on some of these topics.

MR. SPARENBERG: Good morning. I'll take

just a second to echo everyone in the previous thanks to everyone in the entities that brought us together here this morning. So we certainly -- I certainly appreciate the opportunity to be here and speak to the group about some of these subjects. Since you have the bio, I'm gonna skip that.

I think it's important, as we talk about the technologies and where diesel engines have come over time, to understand where we started. My colleagues here have already touched on this to a certain degree, but it was not uncommon at all for me, growing up on a family farm, to see the tractors in the spring and the fall plowing through the field with a cloud of black smoke puffing out of them, or drive by a construction site, or see a bus like this, you know, driving through the city.

We still see the ill effects of that in places like Los Angeles, you know, Beijing, New Delhi, et cetera, and so it's important that we understand that. So you've seen a chart like this already, or something similar, but what I wanted to illustrate here, going back to even pre-tier, call it Tier 0, if you will, engines, how high of particulates and NOx we were actually putting out, and, as we've come through these stages over time, what the significant reduction has been.

The bars for the Tier 4 interim, and Tier 4 final, and Stage 5 illustrate what the regulation is, not necessarily where the engine manufacturers are. As you know, we have to meet, or exceed, those, which we do.

And so in just over the last 20 years -- and I guess keep in mind the diesel engine was invented in the late 1800s. So there's nearly 125 years of compressed engine technology out there, but only in the last 20 to 25 years we have made tremendous strides in reducing the NOx by 97 percent, and, as already mentioned, reducing the particulate matter by around 99 percent, and that's all with in engine or on engine integrated technology from each of the engine suppliers.

But there are challenges that come along with that. We've mentioned the acquisition cost. There's no doubt about it, the Tier 4 engines are more expensive up front. Not only are they more expensive up front, but it does cost the equipment manufacturers more to re-design their equipment, make the changes necessary to accommodate that.

And then, of course, for the mines, they have infrastructure for DEF storage, if that's the case, or particulate filter management and re -- and, you know, replacement, if that's the path they chose. So certainly that's -- that can be viewed as a negative.

Complexity. We've added electronics, extra sensors, particulate filter, SCR, extra fluids, extra maintenance. Again, there's no debating that. It is more complex than a Tier 2, or even Tier 3 engine in a lot of cases.

Space claim. When we add those things it takes up more space. Again, going back to the equipment manufacturers, where do they fit these in? We all know that space in underground mine is limited as it is, so where do you start putting these technologies on the machines and not block visibility or not create other unsafe atmospheres within with you operate that machinery?

And then there's a perception about operating cost, which that's part of my discussion. I have to say, Dr. Bugarski, you actually were leading into my discussion here perfectly with your talk about getting into the new technologies, and then, you know, making the case for them in a business sense, as well as in the health and safety aspect.

But I would wager to say that as we move forward in this Tier 4 discussion, that there are a lot of positives to gain, and engine efficiency being one of them that I'll illustrate here.

Maintenance intervals. We talked a lot about maintenance, and I'll agree with everybody that said that maintenance is critical, and not just critical in old engines, but on the new engines as well.

Health and safety. I believe that as we go -- as we dig a little deeper into this -- and I'm gonna kind of try and put this back on the folks that are here from the mines themselves, to start thinking about some of these downstream effects of potentially switching to the Tier 4 engines beyond just the exposure to the particulates and NOx that are generally the focus of what we're talking about here for this state.

And then the last one is operational data. You know, we -- the comment was made earlier about getting more data and better data, and as we move into the world of internet of things, and connected machines, and all that, there's gonna be more data than we know what to do with.

Now that's a whole another day or two on its own topic so I'm not going to really dig into that one, but suffice to say that that is another benefit that's going to be coming with the Tier 4 and the Stage 5 engines. And so that's where I'm gonna focus my -- the rest of my discussion here this morning.

So one of the things I wanted to point out was fuel economy improvement over the tiers. So I started pulling data from our friends at CARB, the California Air Resources Board. With every Executive Order that goes out for diesel engines they publish various numbers.

When I got to actually crunching the numbers for the, you'll see the lines are for the average 100 horsepower engine, average 200 horsepower engine, or average 300 horsepower engine, there actually hasn't been a significant decrease in fuel economy like I initially expected, but what I did find as I went through that, though, is what happened to the displacements of those engines.

We have increased the efficiency of the diesel engine so much in the last 25 years, the displacement of the average 300 horsepower engine has gone down by nearly three liters. The same can be said for the average 200 and 100 horsepower engine as well.

You are getting significantly more work done out of a smaller engine package which, again, can potentially negate some of those negatives that are there when you talk about integrating after-treatment and things like that. So I thought that was an extremely interesting outcome.

And so how did we achieve those engine efficiencies? Well the primary driver is advancements in the engine combustion. We have higher quality oils and fuels. We mentioned the lower sulfur fuel. That helps maintain engine cleanliness and function of the internal components.

The oil is longer lasting. When you design -- you know, the actual design of the engine, and the pistons, and the cylinders, and the rings themselves also impact that. By keeping ash and things out of the oil you increase your maintenance intervals that we talked about before.

We have more precise fuel injections. You have injectors that instead of a single drip type tip point, you have six ports for spraying out, with up to microsecond control of the injections, for a much more precise, much more complete, and, most importantly, a much cleaner fuel burn.

Along with that is precise air management. You know, we've added turbo charging, variable turbo charging in some cases, to precisely control how the engine performs in terms of both power and torque output, but also emission performance. And so that's all absolutely critical to that.

And so what are the end user benefits? Well for the manufacturers or for the miners and the end users, you're getting more for less, like I already mentioned. You're running the engines at a lower RPM.

Almost every engine manufacturer now for Tier 4 final runs the engine somewhere in the neighborhood of 1,700, 1,800, 1,900 RPM versus 2,000, 2,100, 2,200, even up to 2,500 RPM in the past. That can significantly extend the life of the engines, again, reduce the maintenance intervals, and make these engines a truly beneficial addition to the equipment, and to the fleet. And then again, part of that efficiency is getting that high degree of emission control right in the cylinder.

So I mentioned the service intervals. They're getting longer. As one example, so the MTU Mercedes engines that we supply in the underground mining world, our Tier 2, 225 horsepower engine, at the -- with the heaviest grade oil that we recommend, in the heaviest duty maintenance class, our maintenance interval went from 500 hours to now 4,000 hours on the Tier 4 and Stage 5 engine.

So now I'm gonna reach out to the folks that are here from the mines themselves and challenge you guys. What does that do to your bottom line, all right? If I can cut your oil changes in half that you have to do for your whole fleet, how does that impact you?

And now, not necessarily even just in terms of cost, say cost of the filters, cost of oil, et cetera -- what about manpower? Can you reallocate, maybe, those people to a different production situation? Get more production out of the same people that you have there? You also limit their exposure to the oil, to the filter, to spillage. So you have health, safety, environmental, and, potentially, financial benefits from some of these as well.

Another positive aspect of the Tier 4 final engine is less noise. You know, we all know the noise causes fatigue, distractions, strains, et cetera, and the Tier 4 final engines are generally much quieter.

Most of you in here are probably not familiar with the Nebraska Tractor Test Lab but, in the agriculture market, every tractor over I think 75 or 100 horsepower is tested by the University of Nebraska.

Recently, the 11 and 13 liter MTU engines in an ag tractor set the record for the quietest engine ever tested there in almost 100 years of testing. Now that's obviously not just the engine, but that's a combination of engine, machine design, cab design, et cetera.

There's less vibration with Tier 4 engines. We talked about the combustion enfan -- enhancements earlier that reduces engine vibration, which we know vibration is a -- can degrade the operator experience and cause a lot of issues there as well.

So when you start to look at some of these other benefits you can end up with employees who are happier, healthier, more alert, more safe, et cetera. You get more loyalty, you have, potentially, less turnover.

You know, what does it cost to retrain a new -- or to train -- excuse me -- a new employee when they come into a mine? I'm sure it's significant, but only, you know, obviously, you folks know what that is for each of your operations. Again, so what -- when you start to think of the downstream benefits, there's a lot of potential there.

So just to summarize, again, I think there's a whole lot more to the smiley face list, if you will, versus the down sides, and we certainly look forward to answering any other questions that you guys have here as we go on through the morning. Thank you.

MR. FRENCH: Thank you, Paul. Our final technical speaker on some of these Tier 4, Stage 5 technologies is Mark Andvik from Donaldson, an after-treatment supplier.

MR. ANDVIK: So today's presentation, I'll give you a brief overview of Donaldson. We've talked a little about emissions, but I'll go into a little bit more depth on some of the technologies, and then we'll talk about five different technologies, two of them that are used in the mining community today, and three that could be used in the future.

So Donaldson is a 100 year old company. We specialize in filters. We're a global company, and we have a wide portfolio range. We make filters that are as small as hearing aids and would go in your cell phone, and we make filters that are large enough to go into the air filtration systems of power plants.

We also have a wide range of engine filters, including air, lubrication, and fuel. We make mufflers. We've made those since the 1950s. In the 1990s we got into the emissions business, and we've made emissions devices for on-road, off-road, and retrofit applications. In 1991 we worked with the Bureau of Mines to create the first underground exhaust filter. That can be seen here, in the picture on the right.

So a general emissions overview. The heavy-duty truck industry has led a lot of the changes from the late '80s until 2010. A major focus is reducing NOx and particulate matter, and these guys have talked a lot about changes on the engine and after-treatments that have allowed them to meet those regulations.

The off-road community has made similar changes. The timeframe for implementation lagged so their changes occurred from roughly '96 to 2014, and they followed the same technology path that the on road community used.

Here's the same slide that George had shared earlier that shows how NOx has been reduced, and particulate matter has also been reduced. So we're operating in this yellow box for off highway applications.

One other way to look at the particulate matter would be with these three different vials. The first one is for Tier 1, the second one is for Tier 2, and the third one is for final Tier 4. So this shows the amount of particulate matter that an engine could produce in grams per horsepower hour. So we're reducing the amount of particulates so we're not getting that black cloud of smoke that was mentioned earlier.

So there's three different emissions technologies we'll talk about. I'm not sure how familiar you are, so we'll just give you a general overview.

The first one is a diesel oxidation catalyst, or a DOC. This will oxidize some of the particulate matter. It will also oxidize CO and hydrocarbons. They're typically a flow through substrate so there's different channels. Once the exhaust gets in one of the channels it will stay in that channel until it exits the DOC.

The next system would be a diesel particulate filter. These trap the particulate matter. It has a similar structure to the DOC, except every other channel is blocked off in either the front or the back.

So once the exhaust comes in it'll follow that channel and it will be forced to go through the wall of the filter and out through an adjacent channel. As it goes through that wall, it will trap the particulate matter, so you very high efficiencies in particulate matter. These systems do need to be re-generated with heat. That can be either done actively or passively. I'll talk about that more later.

And then the last system is selective catalytic reduction, or SCR. These use another fluid called diesel exhaust fluid. Gets injected into the exhaust, it breaks down into ammonia, and the ammonia reacts with NOx on the SCR to get rid of the NOx. With the SCR we can reach very high reduction levels in NOx, as you've seen on some of the previous slides.

Here's an example of one system. So the exhaust comes in from the bottom, there's a DOC, DPF in the connecting tube, there's a urea injector, and then there's a mixer, an SCR, and then the tailpipe.

So the next two technologies that we're talking about are technologies that are used in permissible and non-permissible applications today. The first one is a dry scrubber. This uses a heat exchanger to lower the temperature of the exhaust, and then the exhaust goes through a filter to take out the particulate matter.

So in this example you can see the exhaust manifold. It goes from the exhaust manifold through some catalytic converters. That is vehicle manufacturer-specific so you may, or may not, need the catalytic converters.

From there it goes to the heat exchanger, the temperature will drop, goes through the tube to the filter housing. And then there's an example of the filters that are inside of the housing. The particulate matter will collect on there, and then go out the tailpipe. As the particulate matter builds up, that filter will need to be replaced. So to use this kind of system you need a special heat exchanger and a filter housing.

Some of the benefits here would be very low surface temperature and exhaust. It's also allowable in permissible applications. Some of the cons would be, since we're taking the heat out of the exhaust, there is going to be a higher cooling load on the engine, the soot built up on the heat exchanger will need to be cleaned periodically, and then we have the cost of replacing the exhaust filters and the maintenance involved with that. There are no barriers for using this today because it's a current technology.

The next system is a wet scrubber. This is very similar to the dry scrubber, except, instead of a heat exchanger, we use a water bath. So exhaust comes in, goes through this water bath, the water will turn into steam and reduce the temperature of the exhaust, some of the particulates will also get dropped out in that water bath, saturated exhaust will go through a filter housing and get filtered out.

With this system the water in the scrubber housing does get consumed, so we have a water make up tank that will need to refill the housing. So this requires a special housing to be used.

It has the same benefits as a dry scrubber, and then a couple of the cons would be you need to refill the water tank, clean the scrubber housing, the weight of the water that you're carrying would be additional payload on the vehicle, there's kind of a -- when you clean the scrubber housing, there's kind of a wet sludge that gets produced from the soot so that needs to get cleaned out, and the humidity can effect the life of some of the filters.

So some options that we can talk about for future use. Some of these are used in non-permissible applications today. If we want to use them in permissible applications in the future so we can expand where they're being used, we'd likely need to make some modifications.

So the first one is a passively re-generated ceramic filter. This would be a DOC and DPF. So you can see the engine here. The exhaust comes out, goes through a DOC, through a DPF, and then out the tailpipe.

With this type of system we typically have temperature sensors and a delta *P* sensor. In a passive system, the exhaust temperature is elevated so we can regenerate while the engine is running. So exhaust temperatures can reach 600 degrees Celsius. And then we would need an electronically-controlled engine for this.

Some of the benefits would be lower operating costs -- you don't have the need to constantly replace filters like you do on the wet and dry scrubbers -- you get very high particulate and CO reductions, and there's no break in period. With the wet and dry scrubber, you put in a new filter, there's a small break in period where your efficiencies are a little bit lower. And then with a passive system there's no downtime for regeneration.

Some of the cons would be the exhaust gas is not cooled. It does require that higher duty cycle. If you don't get the higher duty cycle to keep the temperatures up, you may need to take that DPF off and regenerate that in a separate location. You can have a different DPF to put in so you can continue running.

These parts are ceramic so they are a little bit fragile. They're used in off-highway environments today. So when they're installed in the vehicle it's not a concern, but if you take them off for maintenance of the after-treatment or other components, you've got to be careful when you're handling them so they don't break. And then there's a potential for NO2 production in these systems.

So the barriers for using these in the future would be surface temperature, and then, if we're in a permissible application, there would be some concerns with electronics that would need to be overcome.

The next system is an active system. So this uses the same components that we had previously talked about, with the addition of a hydrocarbon injector, shown here in that black box. I guess instead of a hydrocarbon injector you could use an electric heater if you wanted to. It has the same sensors and electronically-controlled engine.

The main benefit of using an active system versus passive is that we can control when that regeneration occurs, when the additional heat goes into the system. So if you're in a permissible application you could wait until you're in a non-permissible or outside of the mine before you regenerate the system.

Some of the cons would be additional energy needed in the exhaust, and the downtime needed for stationary regenerations.

The last system we'll talk about is DOC, DPF, SCR. So this gives you all of the benefits. It does require additional components. So we've talked about the diesel exhaust fluid. That will need to be housed in a tank, so a DEF tank. You'd need a pump, heated lines, and an injector. Also, you'd need the SCR device at the end, along with a NOx sensor for some controls.

So the benefits that everybody else has talked about would be the very high NOx reduction and particulate matter reduction. There are some cons. So we have additional components. The DEF will freeze. Someone had talked about the -- at higher temperatures it will degrade.

When it gets below minus 11 degrees Celsius, it will freeze, so probably not an issue in your mine, but you're probably gonna store the bulk fluid above ground. If you're in a cold environment, just need to make sure that it's maintained property so it doesn't freeze.

With these systems, as you inject urea, if you're injecting at low temperatures, or if you have poor mixing, you can form deposits. Those can be cleared out by running at elevated temperatures, but it's something to be aware of.

And the system does produce ammonia to react on the SCR. Most of that should be consumed on the SCR, and there is a -- typically a oxidation -- ammonia oxidation catalyst after the SCR to consume any of the ammonia that might have gone past the SCR, but there could be some current conditions where ammonia could still go into the environment.

And then another drawback would be the expense with all the additional components that we've talked about.

So, moving forward, we can make changes to existing technology that's out there today. Some discussions that the mining community would need to have with the vehicle or after-treatment manufacturer would be are we wanting to target increased life, increased efficiency, or lowering the operation cost?

Should also have some discussions of whether this is in a permissible application or a non-permissible in case the -- there would be some validation testing that would be needed. And if we'd like to increase the efficiencies of NOx and particulate matter reduction, we can use some of the existing technologies today.

Some discussions that the mining community would need to have with the vehicle manufacturer or after-treatment supplier would be are we retrofitting existing equipment, or are we going to install a new engine? And the paths there could be a little bit different.

With these new technologies you'll want to talk about surface temperature and exhaust temperature. I believe some of this is covered in 30 C.F.R. And then there could be some special requirements.

So low sulfur fuel is needed for these. I know that's available on-highway and off-highway. I'm not sure what you guys use at your mining facilities, but there would be some special requirements that you'd want to review. And then you should have some discussions whether it's a permissible or non-permissible application.

So, in summary, Donaldson has been there since the exhaust filters in the underground mining community were used.

We can help improve the existing technology today, and we need some of your guidance on what targets we need to achieve, or we can help implement the new technology that's used on Stage 5, Tier -- final Tier 4 today, and then we'll have to work together to make sure there's a clear understanding of what your specifications and requirements are, and there would probably be some modifications or a validation that would be needed for your specific application.

So thank you very much.

MR. FRENCH: All right. So we have a good amount of time, which we had hoped we would, for questions, feedback, conversation about some of these technologies and opportunities, so anybody out there? If not, I'll try to instigate a quarrel amongst the panelists.

MR. BUGARSKI: I'll try to encourage the others to comment. I don't want to be the only one asking, but I think that you guys did great job in showing us technology, and I would maybe propose a couple other benefits of using this technology. I think the biggest saving and biggest economic drive could be savings in ventilation requirements. So that's a big cost for the mining industry, and you should use that extensively to market your engines because I think that can help your sales.

But what has struck me while you guys were talking about Stage 5 engines, since they are not EPA-approved, and we know that MSHA regulates, at least for coal mining industry, that engines have to be approved by MSHA, or for the metal/nonmetal industry they have to approve by MSHA or EPA, if this Stage 5 engines are not EPA approved, I think we are in a little bit of peril, how to use those engines.

Maybe MSHA can offer an answer if they would be allowed in underground mines. But that's one question.

The other question would be, you know, how you guys perceive bringing these engines to the mining industry. Because you have to go through this -- particular to the coal side of the industry, you need to bring these engines through the approval process, and seems to me that engines are just trickling down through that process, and we don't have enough of the offerings in the market.

So I guess between MSHA and you guys, if you can offer some of these answers.

MR. DUNNUCK: So, first of all, Aleks, thank you for the questions. I will comment from a Cummins perspective. Our Stage 5 products are also being certified at Tier 4 final. The same technology, the same product. So we have our original Tier 4 final products; the Stage 5 technology is also certified to Tier 4 final.

MR. BUGARSKI: Caterpillar?

MR. LIN: So EPA doesn't certify Tier 1 or Tier 2 engines. So for the 30 C.F.R. Part 57 PM equivalency -- it's PM equivalency, right? So, there isn't an EPA certification that you can get today, right, so it relies on manufacturers to state that they're equivalent to EPA Tier 1 or Tier 2, depending on the power category.

Now the other question you have about Stage 5 and coal, maybe it wasn't exceedingly clear in my presentation, but those -- right now those two are, you know, largely incompatible because of the surface temperature requirements. So I am not expecting Stage 5 products to enter the coal underground environment in the near future. Just for metal/nonmetal they will.

MR. SPARENBERG: And for the MTU Mercedes, Stage 5 will also be cross-certified to U.S. Tier 4, as well as the MSHA, CANMET regulations.

MR. BUGARSKI: Any perspective from MSHA

side on this issue?

MS. SILVEY: Not at this time.

AUDIENCE MEMBER: Again to support Dave, all our Stage 5 will be Tier 4, but also, we're going to go through the MSHA *B* certification in the first half of this year for our Stage 5 products, for our mid-range -- I mean some of our products are already Tier 4, Stage 5, on the higher end, but on the lower end, we're gonna go through the MSHA process.

AUDIENCE MEMBER: I don't really have a question, I just had a comment. I would echo what Aleks -- Aleks --

MR. BUGARSKI: Bugarski.

AUDIENCE MEMBER: -- said on the ventilation requirements. I work for Martin Marietta. We operate 14 underground mines.

Years ago we took the approach of, you know, more ventilation, better fans and everything else, and B99 bio fuels and everything else, to settle our DPM issues, but as we've come to the fleets getting newer and more and more tier -- higher percentage Tier 4 fleets when we're doing ventilation upgrades and everything now -- you now, historically, we'd try to design to 100 CFM per running horsepower.

Not that we were required to, that's just what we tried to hit, and we kind of found that that was a number that really helped us out a lot.

Now we have mines that are probably in the 60, 70 percent fleet range of all Tier 4 machines now, just over time, and what we're seeing is that number has significantly come down from a design perspective. We're not really having to hit 100 CFM per running horsepower anymore, it's more like probably 70 to get to compliance levels and -- at the face.

So it's a huge difference, and it -- it'll just get better as the older engines get phased out and newer engines get phased in. So I would again echo ventilation costs is also a big, big, big, big savings that is kind of -- we won't put a Tier -- a non-Tier 4 engine underground anymore in at any of our mines, but -- just by a decision that the company made so -- because of that. So, anyway, yeah, ventilation's a big problem cost.

MR. LIN: Yeah, thank you. Thank you. And I do want to add that the EU Stage 5 standard is more stringent than the Tier 4 standard for PM. So it does have -- you know, the NOx limits are the same, but the PM levels are a tad lower.

MR. FRENCH: So I have a question for the panel. If we have still these constraints about surface temperatures and other temperature constraints in coal mining application, what's the state-of-the-art, or state-of-the-art in the next two years for deployment of technologies in coal mines?

I mean is it the Donaldson scrubber systems? Is it just a pass through filter where you don't have to worry about re-gen? I mean what are we -- what are those solutions?

MR. ANDVIK: So if you want to use in after-treatments a DOC, DPF, SCR in a coal mine, you could take approach similar to what John Deere has done with their combine applications. Combines are very sensitive to surface temperatures due to all the dry crop debris that's in their environment. For their final Tier 4 product they created a housing for their after-treatment system with a blower to blow cool air over top of it.

So in the mining application, depending on what your requirements are, something like that could be considered. It doesn't need to be a direct copy of that, but there could be more elaborate systems going over top of the after-treatment to protect it in that environment.

MR. FRENCH: And that's something, though, that would certainly require separate MSHA certification at some point to ensure those temperature constraints, right?

MALE VOICE: Yeah. Just for coal mines it requires MSHA approval.

MR. FRENCH: Yeah. So I mean maybe one take away to think about is, you know, what kind of collaboration we could have over the next little bit to streamline some of the acceptance *A* of duly-certified Stage 5, final Tier 4 products for metal mining installations, and then work towards other certification parameters for coal mining applications.

MR. LIN: Yeah, but I'll add that solution -- I'd -- and I'd be interested in looking at it, but my first reaction is that I don't think it meets the requirements for coal just because like all exposed surface temperatures to air, you're using the air to cool something, right, and heat shields. I just, I mean that, initially, doesn't strike me as something that would work.

MR. ANDVIK: So it doesn't need to be that, necessarily. That's just one example where another application is very sensitive to surface temperatures, and it took an existing technology and they added something to it to try and meet their requirements.

MR. LIN: Yeah, yeah, it's not -- you know, so don't get the wrong -- I mean I think all manufacturers have looked at this for underground coal. I mean it is very challenging. The surface solutions, or the surface requirements, I -- I've -- again, I'm not familiar with ag products. I do know the folks at John Deere quite well. There is a strong technical challenge there, and I'm just skeptical that it's actually something that simple.

MR. FRENCH: So, again, faced with those temperature constraints, I don't want to monopolize this discussion, but if that's still a problem, what technology solutions are left in coal mining applications to reduce DPM?

MR. LIN: Yeah. So the one that I'm familiar with for coal is the disposable filters. You know, you have these filters on. So they don't go through the re-generation process. You use them, then you throw them out and you get another filter.

MR. FRENCH: Okay.

MR. ELLIS: One of the risks when you step up to a mic is it -- the advantage is everybody gets to hear what you have to say. The disadvantage is that you really reveal how ignorant you are about some subjects. So, but this is an awesome panel, and, because you're here, I'm gonna ask you some questions to help me and maybe a few people in the audience.

What's the difference between stage and tier? Can somebody explain that?

MR. LIN: Yeah. Stage is what we -- well, what the European Union regulations refer to. So European regulations and the U.S. regulations are similar, and they mirror each other, but tiers refer to the -- refers to EPA -- U.S. EPA regulations versus stage, which is the EU regulations.

MR. ELLIS: Great. Thank you. Okay, I'm just gonna -- I'm not gonna monopolize the mic too long. You know, a couple of the issues that you even brought up had to do with these trade-offs in terms of the capital costs and moving to improved engines.

I know that when I worked on these issues early on, one of the big challenges was the technology that's there for over the road and the market for mining is small, and the ability to downscale those engines to the size that is needed for mining environments.

Can you speak to that and talk about the differences between new equipment and retrofit? Basically taking engine packages and putting them in existing equipment. Can that transition be part of reducing exposures?

MR. SPARENBERG: Well, I mean, number one, it definitely can. You know, the advantage of using an integrated engine when it has the technology directly from the factory is that, as the equipment manufacturer, they have the ability to then package it as neatly and compactly as possible.

And for the MTU Mercedes offerings, you have some flexibility on how that installation is done, as I'm sure all the other engine manufacturers do as well, so that it does give the equipment manufacturers some ability to do that.

But, most importantly, when you do that with the engine manufacturer or -- excuse me -- with the equipment manufacturers, they know their customers, they know the operations. They know where there are pinch points, where there are lines of sight, things like that that can directly impact how that machine is operated, and get that feedback directly from the customers.

So the retrofit options are fantastic, especially for some of the existing machines that are out there, but to go build a new machine with say a Tier 2 or Tier 3 and then put the particular filter on it, that's definitely gonna bring, in terms of installation and finding a good place for it on the machine, some greater potential challenges than with the integrated systems that come directly from the engine manufacturers.

MR. DUNNUCK: And I think, from a diagnostic standpoint, when there is an issue from a functional standpoint, being able to diagnose and understand what's going wrong, what's failing in the system will be far more challenging with a retrofitted system than with an integrated electronic system that's self-diagnosing itself.

MR. ANDVIK: Guess one benefit for retrofit application could be lower installation costs for existing equipment rather than completely changing out the engine. So depends on your situation, on what you need.

MR. LIN: But it is challenging to fit the after-treatment. Like on surface products I would say it's easier because you don't have the same space constraints, right? I mean you have space constraints, but underground mine you have space constraints in all four directions, right?

Even at that, on surface products, you know, I think about the Cal -- there was a California rule to retrofit off-road equipment with after-treatment, but the problem was that they had to mount those things somewhere on the vehicle, and it became a visibility issue and so they rescinded that requirement. I think in underground mining it would be even worse because the space requirements are even tighter.

MR. DUNNUCK: And I think a lot of it depends on where you're coming from on where you go. So if you had a Tier 1 level engine or Tier 2 level engine, at a minimum, moving to Tier 3 with electronic controls is going to significantly reduce the emissions coming out of that engine compared to that Tier 1 level. You saw two colleagues up here share those charts. So, at a minimum, moving to at least Tier 3 is a significant step forward.

MR. LIN: Well, except for underground, right? So underground, generally you go from like the -- again, it depends what the goal is, right? If the goal is to reduce PM, then it's really moving from more of a Tier 3 to a Tier 2, because although the emissions limits -- the requirements are lower for Tier 3, in reality, the PM is lower on -- you know, can be lower on Tier 2 engines.

Some of the re-calibrations, they lower -- if the goal is lower PM, then they lower PM, but they may have slightly higher NOx -- same, or higher, NOx, right?

MR. DUNNUCK: Okay.

MALE VOICE: Yes?

MR. MONNINGER: Jeff Monninger with MSHA. Just wanted to maybe clear up some confusion I heard earlier on the underground coal mining and the surface temperature regulations. That MSHA does have the surface temperature requirements for permissible equipment, or permissible diesel, but that doesn't apply to underground coal mining as a whole.

The majority of the non-permissible side makes up the majority of the fleet out there, and they don't have those surface temperature requirements, so those, like the Stage 5, Tier 4 engines that you're talking about, those after-treatment devices could be evaluated and granted MSHA approval without having the worries that you were talking about earlier. That's all.

MR. LIN: Jeff, just -- I'm just curious. You had mentioned something about there the -- about the equipment split, right? So can you give like maybe an idea of what percentage or type of equipment is permissible versus non-permissible for coal?

MR. MONNINGER: Well, generally what we refer to as permissible is -- and -- by the last open cross-cut where the coal is being mined. Not having the numbers in front of me, just off the top of my head, I'd say about 10 percent of the fleet is permissible, while 90 percent of the fleet is not. Or explosion-proof.

AUDIENCE MEMBER: And those numbers will be covered later today.

MR. FRENCH: Okay. Great.

MR. LIN: Thank you.

MR. FRENCH: All right. Well that's very helpful.

MR. BUGARSKI: I have one more question. If I put myself in a position of the operator, you know, there is a matter of when you jump into the game -- for example, we have few -- current state of the mine in metal/nonmetal mines is Tier 2, Tier 3. So there were Tier 4 interim engines around, there are Tier 4 final engines, and there are battery-powered vehicles coming onboard.

So there's all -- never good moment to jump onto the market, so, basically, you need to kind of generate little bit of motivation for people why to jump now in a diesel market when battery power is -- battery-powered vehicles are coming.

And which generation of the engine should I use now? You know, I don't like to hear that we should at least use Tier 3 engines because they should not be sold at this time in the United States, I think, because that's past.

So how we get ahead of the time, and how -- because we need to count that these engines will be in the vehicles for 20 years. If you judge by 3306, they might be 40 years in the engine bay. So when is good time?

MR. SPARENBERG: I mean, you know, being the salesperson up here, I'd say now. But, seriously, I mean in reality right now, when you look at the Tier 4 final technology that's been implemented now since 2014, and you look at the Stage 5 technology, it's really just a small evolution to meet the Stage 5 requirements, and so that technology now is in the market, it's proven.

And when you talk about when is the good time to jump in, I mean, really, from that standpoint, I mean when is the best time to go buy a new computer, or go buy your next TV?

The technology's always changing, it's always evolving, by the day, by the hour, and so at some point we just have to say, you know what, we've cut the emissions by 99 or 98 percent, in most cases, this is a pretty good time to get a diesel engine now, and start making that move, if you're going to do it.

Now the other part of that is, of course, you know, when you look at the surface off-road equipment world, they were mandated to do it by regulations. Nobody wanted to go redesign every machine across their entire product offering.

No customer wanted to buy the same 400 horsepower engine but pay, I'll just say 25 percent more for it and still only get 400 horsepower, okay? You didn't exactly want to necessarily do that, but the regulations drove you to do it.

And while I'm -- I don't want to speak for my colleagues, but I would firmly believe that regulation is not one of our favorite words because that immediately means millions and millions of new dollars in research and development, and testing and all that, but, in my personal opinion, until there is a regulation or some path forward to drive that into the industry, the adoption will continue to be slow no matter how much we sell on ventilation, in reduced emissions, and the other benefits that we've all talked about up here.

MR. LIN: Well I'll partly agree with that, and then I -- so part of it is that, you know, it's not like *Field of Dreams*, right? If we build it, it doesn't mean that someone's gonna buy it, and so there has to be a market out there, right?

So with -- not with surface products, where we were regulated, the structure was such that it encouraged, and almost like required, manufacturers to start with their highest volume product, right?

Now in underground mining there isn't a regulation, but manufacturers will do the same, right? They'll start with the product that has the most demand -- now -- because if they build it, then they feel like they'll get, you know, some sort of market out there and market return for that.

So I think, to answer your question, it's -- it requires some market dynamics, right? People need to want these machines, and then manufacturers will build them.

MS. SILVEY: But at the end of the day, everything is what you look at it. I mean, you know, we sit in a regulatory agency, and our goal is improved safety and health, and that's whether it be today, tomorrow, and the next day, but at the end of the day -- and we are -- we believe in new technologies.

Because I think when Mr. Zatezalo says

regulatory reform, people look at re -- that was one of my points, but, you know, I had -- I told you all I had disparate points written everywhere.

But what I want now is an opportunity for me to make it, because when we talk about regulatory reform, everybody -- I've been around a long time -- everybody instinctively thinks about lessening regulations. No, it's not lessening regulations, because many of our regulations, you all know that, in 30 C.F.R. are outdated. They refer to the third -- 72 ACGIH book, TLV book.

So it means that technology is going to come. A lot of things drive technology, and, in many ways, technology can be good, but at the end of the day, you've got businesses, too, and you all rep manufacturers.

So people aren't looking at -- sort of looking at -- they're looking at research, good research, but I think they're looking at a return on investment, too, and that's what's gonna drive a lot of things.

MR. LIN: Yeah. Yeah. And so I agree with your statement. I mean the regulatory reform is to make the process more efficient, not less regulated, right, at a high level.

But in terms of, you know, regulations, so I just -- I guess my caution would be that the regulations have driven a lot of things in -- the EPA regulation has driven a lot of things on the surface product, but they've also put certain markets just out of business, right?

Because manufacturers look at the market there and they decide, hey, you know what, we will lose money here, so that product is just gonna be discontinued, right?

MS. SILVEY: And that was Ms. McConnell's comment this morning about we want all of your information, we want all of your data. The more specific you are to us, if you have a recommendation, the better it is, the more rationale that would support it.

And that includes the cost of that, too, because that's one of the arguments we have to make when we pass our proposal to the reviewers, when it goes up the line.

MR. LIN: Right, right.

MS. SILVEY: And that consideration is even included in the Mine Act. We have to do economic and technological feasibility considerations. Those can't be lost either. So, which means we can't regulate in a vacuum.

MR. LIN: Yeah, yeah. And we're happy to work with you. And, you know, EMA works with you all on that.

MR. FRENCH: So one other quick point in terms of when is the right time to jump in the new diesel technology pool. I would say, not surprisingly, now is a great time, and there are a couple reasons.

One the technologies that we're talking and presenting were -- have been developed for and proven out in the heavy-duty, on-highway market. The SCR technologies were first mandated effectively in 2010, diesel particulate filters in 2007.

Manufacturers credits, that is, they got credits if they substantially over performed vis-a-vis an existing standard, they banked enough credits that, really, the SCR systems didn't become more fully deployed until the 2013/2014 period.

Since that time initial catalyst formations that may have increased NO2 have been addressed, deterioration of catalytic systems that may have not been anticipated have been addressed, so now we have a fully mature product that can transition to the non real (phonetic) world in a meaningful way, in a fully reliable way, and in a very fuel efficient way.

And it's coming -- we're in a status now where we may see, in the on-highway sector, activities in California that actually, you know, make fuel economy worse. In this situation right now, with this product, it's sort of an optimized product, so it's a good time, if you are thinking about quasi-compulsory requirements, to get this product. It's a good time.

I would also say, though, that if there's a way to incentivize the purchase, that's the better way to go. Sometimes when you have a regulation, that may, or may not, preclude the utilization of incentive dollars. If I'm mandated to do it, why should the government subsidize me to do it? So we need to be careful about that, too, because, at the end of the day, I think we all need to really scurry around and find incentive dollars to make this happen.

MR. DUNNUCK: I think the only thing I'd add to that, Tim, is I do think this technology's proven in all five ways well. It was -- clearly has been proven in on-highway, but there's 100,000 plus systems running in off-highway environments. It's very viable, capable technology.

MR. FRENCH: If I wasn't clear, that was my point, this is --

MR. BUGARSKI: One more comment on George's comments about going after only profitable part of the market. I would like your opinion how we're going to address, for example, 3304s and 3306s for the grams for brake horsepower -- for the grams per hour engines which we currently use in coal mining industry in the future.

Because it's a small market, nobody wants to get in it, and we are using like 40, 50 year old technology and nobody wants to jump in.

MR. LIN: Yeah. So I'll tell you what sort of things I've seen, right? Where there's changes, for example, the -- like I said, the Association of Occupational Health, or Hygienists --

MALE VOICE: Oh, ACGIH.

MR. LIN: Yeah, ACGIH. I mean where they have set new exposure standards, human exposure standards that has driven changes in vent rates that has then driven mines to, you know, look or ask for different products. And, again, there's -- we have some ventilation reduction products, right, depending on the level of reduction that can be applied.

But otherwise, I think what you're suggesting is how do we -- how do you get rid of those engines, right?

MR. BUGARSKI: How we address permissibility market.

MR. LIN: Sorry, say that --

MR. BUGARSKI: Those engines which are used in permissible pieces of equipment which are requiring all these surface temperature and exhaust temperature. That's example of the small market, small niche, where nobody wants to go in, and it's a lot of risk and few benefits. Would, for example, engine manufacturers step in and somebody pony up the money and help this process? Because, you know, we're using awfully old engines in those vehicles, and there's no light in the end of the tunnel.

MR. FRENCH: That's why you need a DERA-like incentive application process. Kind of marry, you know, match yourself up with a bid, with a manufacturer, and go get the money.

AUDIENCE MEMBER: I would caution you to draw conclusions based on either on-highway surface operations or off-highway surface operations that you would in turn use to extrapolate the success in underground operations. They are significantly different.

My responsibility is both to sell these advanced technologies, but, more importantly, to maintain them underground in an operational status once they're deployed. And I can tell you that there are significant obstacles to maintaining this technologically-complex equipment that are unique to an underground setting that do not exist in a surface setting.

I was concerned as I -- each of you did your presentations that nothing was really mentioned about the enormous infrastructure training and maintenance burden -- I'll call it a burden, you would probably call it an opportunity -- that comes along with these technologies.

I would caution you against glossing over what is a significant obstacle in the real world underground, as opposed to the off-highway surface.

MR. LIN: Yeah. Thank you. Thank you. And, yeah, so I think we did gloss over that, but the training, we've kind of taken that for granted, because on-highway surface, that whole service network has been trained over time, and it does -- as the commenter made, it does take some effort to make sure all your service personnel are trained to service this new equipment.

AUDIENCE MEMBER: Well first comment I would like to make is I don't work in the coal environment, and I'm really glad that I don't because, you know -- coming from limestone, because it was mandated on surface, a huge percentage of our fleet came from surface mining and we just take it underground. So that's good for us, and we don't have -- but I'm really glad I don't have to operate under the coal restrictions.

But I guess the comment I was gonna make about, and kind of a cautionary tale on, the whole retrofit, and I think kind of Aleks' comment about the old engines, in our experience, it has not been very successful at all.

And, as a matter of fact, we don't do it, as far as retrofitting new engine packages in the old 3306s or whatever, because of the electronics and all the associated, you know, infrastructure that the frame has to have, that the machine has to have to support that engine.

In our experience, it has not been successful at all, so we don't even go down that road. We just run them out and replace because it's just not cost-effective.

MR. LIN: Yeah. So you're specifically talking about retrofits of after-treatment then?

AUDIENCE MEMBER: Retrofits of anything.

The whole -- not after-treatment, but retrofitting an old Tier 1 engine to a Tier 3 engine --

MR. LIN: Oh, okay. So just swapping the engine. Okay.

AUDIENCE MEMBER: Swapping engines. It is not successful, in our experience, and we don't even do it. After-treatments, you know, that's -- we don't go down that road anyway. But the true upgrading the engine and the whole system is -- it has not been successful or cost-effective so we don't even do it.

MR. LIN: Okay. Thank you.

MR. FRENCH: All right. Well we're almost pushing against the lunch but let's get these last two questions.

AUDIENCE MEMBER: Well, given the last speaker, I might be sort of saying the wrong things, but I was just supporting Dave in terms of selling Tier 3s, to Aleks' point, we shouldn't be. But the retrofit option, I think if you work with the engine manufacturer it can be a lot more successful. If you're trying to do it on your own, then it's difficult.

So I think you need the engineering team and the application engineering team to come in and support that because I have seen it successfully done.

You know, even EPA, on the surface, allow Tier 2 engines still to be sold because you're allowed to replace light with light. So they're not actually improving their emissions either where they don't have to.

Some miners are. Some want the latest and greatest. So I mean underground, I mean if you can go from the older emissions to zero, if there are any still underground, to Tier 1 to something like a Tier 3, it would certainly help with the emissions package.

So I would suggest if you're looking at retrofitting, don't try doing it on your own. If you're going to upgrade into the latest electronics, it isn't easy.

I fully appreciate that, but I know we've done it successfully going from mechanical to electronic engines, and so try and get the engine manufacturer and the equipment manufacturer involved so it can be a -- sort of a neater package and help you get through that.

MR. FRENCH: Aleks, do you want the last word?

MR. BUGARSKI: No, no, I'm not standing --

MR. FRENCH: Oh, I thought you were in line.

You're just holding up the wall. Okay.

MR. BUGARSKI: You're the last.

MR. FRENCH: All right. Well thanks for your attention for this panel. We're going to adjourn now for lunch. We're gonna reconvene at 12:30. I think lunch is upstairs in the cafeteria.

MALE VOICE: Sixth floor.

MR. FRENCH: Sixth floor? And, thanks. We'll reconvene in about an hour. Thank you.

(Whereupon, at 11:35 a.m., the meeting in the above-entitled matter was recessed, to reconvene at 12:30 p.m. this same day, Wednesday, January 23, 2019.)

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A F T E R N O O N S E S S I O N

(12:30 p.m.)

MR. WELSH: I think we'll get started because we have a full agenda this afternoon. My name is Jeff Welsh. I am with the NIOSH Spokane Mining Research Division, and I'll be the moderator for the next session. The title of this session is emission reduction/exposure reduction, and we have three speakers who will look at that topic from different perspectives.

First we have Ren Ramer, a mining engineer with Carmeuse Lime and Stone, and he will talk to you about that topic from an operator, mining operator, perspective. Next we have James Noll, Senior Research Chemist with NIOSH, and he will talk about enclosed cabs and exposure reduction from that aspect. And our third speaker is Brian Huff, Chief Technology Officer with Artisan Vehicles, and he will talk to you about battery-operated vehicles and the transition to battery vehicles.

So with that, we have a short, 45-minute session. I'll start off with Ren.

MR. RAMER: I just want to cover what Carmeuse is experienced with, our use of biodiesel. There is a number of other people out there using biodiesel, different levels of it. They may have different perspectives than what I possibly will share today, but this is just our snapshot of what we have. Wrong way, okay. So we're just going to go through some -- the good points. We'll have some bad points, and then we're going to have some really difficult scenarios as well, too, and where we're kind of projecting forward as well.

So just to give a little background on Carmeuse, basically, we have five underground limestone mines. The Black River and the Maysville ones are in Kentucky. They are our largest operations and our heaviest consumers of biodiesel at the time, when we were doing the regulations, and they're strictly, totally underground. A couple of our other facilities haul their material to surface so they get a little break from having the diesel trucks underground at the entire portion of shipping stuff like that, whereas we're down there.

So what we do solely -- all mines do rely on diesel mobile equipment to meet their stone production needs. You know, Maysville does have, you know, conveyors, crushers, and things along that lines, and electric powered, but diesel is the way we carry out our work.

Basically, both mines are, you know, underground, standard room-and-pillar mines. We have a benching operation that goes in with that, so we get full height, full recovery of the reserves. And then we utilize a various array of diesel equipment and stuff like that. And it is pretty much the standard off-the-highway equipment, you know, 988 loaders from CAT are 72-haul trucks, some Fletcher face drills. Those are unique to the mining industry, I guess you would say, older burnt-powder rigs, along those lines, and then some various support equipment, which are, you know, like CAT-725, water trucks, and service trucks as well, too, so a lot of it is pretty much your typical off-highway equipment.

For us, I mean, just to give a little background, I mean, how do we, you know, go into using, you know, biodiesel. You know, basically, you know, we needed to make some changes when the rulemaking was coming out, like a lot of other people had to. So, you know, we put a team together, and we looked at our different options, you know, you know, trying to provide more ventilation, you know.

I had an old professor who says that the solution to pollution is dilution. So, you know, if we got enough air in there, you know, we're going to cut -- you know, we're going to cut the emissions down and get us within, you know, the workable limits of stuff. Also, we know the DPM exhaust filters was pushed very heavily at that time. And we -- you know, we're -- we've had concerns with that. Our alternative fuels was there, you know, engine upgrades, you know, better-enclosed cabs as well, too.

So, you know, low-sulphur diesel was mandated. You know, we switched to that. That was relatively, you know, easy, straightforward, and everything like that. But, you know, looking at the other options as far as, you know, trying to put in larger shafts, you know, more ventilation, you know, it was major capital investment, also with the filters. You know, we felt at the same time it was another large capital investment to put them on all of our pieces of equipment there at the time, and we wasn't sure about the operating and the maintenance costs.

You know, engine upgrades, they were cost prohibitive at the time. We knew they would come as we were able to get new equipment, so then our strategy was, you know, what could we do in the interim until we can get the new equipment coming in. We'll have the newer -- you know, newer engine technology. And the same thing was the enclosed cabs. You know, we'd encourage the guys, you know, take real good care of your cabs, you know, make sure if you're having problems, you know, we get them sealed up, you know, we repair any issues where we're starting to damage cabs, from -- you know, keeping that better environment. What we also knew is we would get newer equipment. We would get the, you know, better cabs as well, too.

So the alternative fuels then for us became, you know, the best scenario. You know, we had relatively simple implementation with it other than, you know, educating our people on it, you know, contacting and getting set up with the right vendors and things along those lines. And also we knew there was going to be some performance issues we'd have to work through, some changes in our operating costs, and in -- but we knew we would get the decreased emission right at the source of it, the engine, you know, not putting out in the DPMs, and we're not having to do a lot of work with the ventilation to dilute down what is not being generated.

And this was way back in 2000 when we were looking at this, just some estimates on where we were at as far as capital dollars goes. So for us, the alternative fuels was definitely lower. This Lubrizol is another alternative fuel product we used just for a period of time. I've got it in there because it was part of our data, and kind of part of our history as well, too, and then also the operating costs. We can see that the annual costs for the bio was going to be, you know, somewhat more expensive for us, but I think really even these improved ventilation fans is slightly low as I go back and look at the numbers and stuff with the horsepowers they were wanting to increase there to get the air flow up.

So fuel selection definitely, for us, was the biodiesel. There was a lot of different products out there for us, or sources. You know, we had recycled yellow grease. We had stuff made from virgin soybean oil and, you know, animal fats, related ones, and other sources as well, but different seed stocks and stuff along those lines.

We used the yellow grease because we had a local company that had got into it, Griffin Industries. They were making the biodiesel at the time, and we partnered up with them to do it. And you can see there is varying degrees of purity of it, you might say. This is biodiesel, B99, and that's what we're burning with and that's what we eventually went to, which was really unique for our employees because they thought they were putting water in the engines, you know, it was so clear and stuff like that. They actually asked us to dye the fluid. You can't get these people to dye it. You know, we've been burning, you know, dyed fuel for 30 years, you know. We need to see red going in the tank.

(Laughter.)

MR. RAMER: But so just an aside, now, we did get them some red fuel. We did use Lubrizol PuriNOx, this emulsified diesel fuel. That made me a lot of friends there for the couple years we used it. We had quite a bit of problems with it. But, you know, it did help us with our emissions at the time. I mean, it did lower down the emissions, so it made that objective.

So we tried -- you know, we tried B20, we tried B50, you know, soy-based, PuriNOx, and then, you know, basically began going on to the B99. And that's where we went to with it after the PuriNOx was, is because we wanted to get the most bang for our bucks to make sure we were in compliance and as low as possible with our emissions.

A couple of things with the biodiesel. You know, one, we have migrated to, you know, distilled only. The products that have a lot of alter filtering, filtering, and stuff like that have not proven to work for us. But if somebody has the distillation process during their manufacturing of it, it seems to work the best, and it makes that nice, clear looking biodiesel that -- you know, that has worked well.

This just shows a quick graph of how -- where we've emerged from, you know, early on, starting off with this regular diesel, transitioning into some biodiesel, touching the PuriNOx, thinking that we had some -- enough newer equipment in there that we could go back, which we couldn't, and then finally sticking with the B99s and, you know, running on out in here as well, too, is B99 and some ultra-low sulphur diesel running in our Tier 4 engines, so these last few are Tier 4s.

And these are just basically from our exhaust shaft. It's just one steady point that we can sample over and over again. You know, it's pretty common for us, and we don't have to worry about, you know, was the person in a different place, those kind of things. I do got to admit, you know, with a little -- a grain of salt in some of these lower numbers. In recent years, you know, with, you know, the reduction in coal-fired power plants, you know, Maysville is a coal-fired lime producer for the scrubbing and stuff like that. So our production numbers have to decreased off and stuff like that. So some of that will be the fact that, you know, we're not running quite as hard as what we had been in years past.

But still the shifts are there. We're just not running, you know, the six days a week like we had been, but four days a week are still there. So we're still sampling. You know, later in the week when we do that, and we had the guys in there running this as much as possible as well, too.

The good side from the biodiesel was that, hey, it got us into compliance. I mean, you know, it brought us down where we needed to be. You know, we're high. We did have, you know, slight performance reductions and stuff like that, but, you know, the engines had, you know, enough horsepower and stuff. You know, they pretty much powered through that. You got the guys with the learning curve, got them to accept in on the product and stuff, and they made it work.

We did -- you know, we got reductions in -- and I will take a side note that I had gone to another operation for a short period of time and stuff like that. We were having some emission issues there. I got hold of the biodiesel supplier, got us some biodiesel in there, and put those, you know, behind us and stuff like that until we could, you know, do some ventilation work along those lines and stuff like that. So it was a quick bullet for that situation, too.

The bad is really, you know, none of this technology -- nothing is free. Any time you're trying to make these changes like that, it costs us stuff. So with our biodiesel, you know, we had, you know, increased fuel prices, consumption, you know, storage and handling issues and stuff there as well. We started going through a lot more fuel filters in the early trial stages and stuff along those lines. Also, until we realized that, hey, you need to use this type of biodiesel and stick with that, you know that worked as well, or was part of the hurdle we had to get over, you know, the injectors, the hoses, you know, some increased production costs with unplanned down time, you know, the lost production, which I wanted to balance that out because I knew, man, I'm painting a really bad picture of this fuel, you know.

But at the same time, as we've transitioned into our non-Tier 4 engines now, I mean, they're not, you know, the easiest thing in the world, either. You know, we have the DEF that we have to put there, maintain those systems. The truck systems are much more complicated. We have re-gen issues at times and stuff along those lines, getting people to understand about the re-gening process, you know, and then also unplanned down time for those units and stuff like that, too. So neither one, you know, has totally been the cat's meow, you might say, you know, 100 percent problem-free, so there was a balance there for us with it.

The ugly side of the product, you know, for us was, you know, was the fuel plug -- you know, fuel lines and fuel filters and stuff with the injector replacements. You know, the problem was is, you know, after you started having some issues with your filters plugging and the cooling of the nozzles wasn't occurring for the injector, so the next thing you know, you've shortened the lives of the injectors so you're having to go back in there. You know, I had to replace those.

Also, just the varying quality of the diesel particulate -- or not the diesel particulate, but the biodiesel, you know, finding good feed stocks, good sources. You know, everybody will tell you their product is the equivalent of everybody else's, but, you know, in reality, that's not always the case. So you've got to have good product.

You know, we did see some increased fuel costs. You know, there is a little bit of BTU performance with it, and also some limited supplies at times, and pricing sometimes is -- you know, it depended on the commodity of the yellow grease stock.

We did have gelled fuel lines earlier on one time in the winter time, just to learn about it, you know, and then we learned you had to get it underground as quickly as possible. Don't let it -- you know, don't let it sit up there. And then our other mine at Black River, they ended up having some equipment early on over by the air intake, and that gelled up a lot of stuff like that in one winter's time frame, too, so, you know, there are some learning curves to go through as well.

Kind of where we're going right now. You know, the Maysville site is currently the only site right now burning the biodiesel product. And, you know, to be honest, as we transition into more Tier 4 engines, we'll probably move off the biodiesel as well, too. There is, you know, advantages with it.

And that was one of the things. I know we joked about the graph scene with the little square. I remember years ago seeing that, and I was like, yes, if we can just let the equipment manufacturers get there and stuff like that, we'll get down to this stuff, and we won't have to use this fuel and stuff like that. So it was a matter of working with the guys to say, you know, there is possibly something better coming along, but we have to use this at this time, you know, to keep us in compliance, to keep us safe, and everything like that, and then move on into it and stuff.

So -- and really, we have not experimented with any biodiesel in our Tier 4s and stuff like that. The guys are very adamant that that's not going to happen as well, too, and stuff like that. So that's it.

MR. WELSH: Is that it? Okay.

(Applause.)

MR. NOLL: Good afternoon. This afternoon I want to talk to you about using enclosed cabs for reducing DPM or diesel particulate matter exposures in mines.

As many of you know, a lot of pieces of equipment have enclosed cabs, especially the large ones that you see in stone mines. And many of these cabs have pressurization systems in them. So what I mean by pressurization system is that the air that is outside is mechanically drawn through a filter. A filter cleans out or captures the DMP and puts cleaner air to where the miner is working. And it also causes a positive pressure so that the outside air doesn't come into the cab.

Now, if these systems, if these enclosed cabs are used properly, we have seen over 90 percent efficiency in reducing DPM. Now, if we look at this chart here, the Y-axis is the percent reductions. That's the reduction between what is outside and inside of the cab, and the just a random number there for the number of vehicles because we did a number of vehicles in the field. And these are in the field, actual cabs being used when they are properly functioning and sealed. We got over 90 percent efficiency in reducing diesel particulate matter.

However, not all cabs initially got us that kind of reduction. In fact, many of you out there might say that some of your cabs -- like we don't get that kind of reductions in our cabs. What we found out throughout the years of research, that there is two main components that help make an effective cab.

One is filtration, and the other one is cab integrity.

So let's look at the first one, and then we're going to what -- effective filtration. And there is two types of effective filtration. There is your intake filtration and your recirculated air. So once again, let's look at the intake. This is very crucial. Your intake filter has to be able to capture your sub-micron particles, which is the size range of the DPM.

Now, we've seen many types of cabs that didn't work, and this was one of the main reasons. They didn't have efficient enough filter to capture the sub-micron particles. So we would recommend that you have at least a MERV-16 rated filter in order to capture the sub-micron.

Also, usually around 40 to 140 CFM is the flow rate that these pressurization systems run on. A good rule of thumb is to have at least 25 CFM per worker that's in your cab so that you can dilute the carbon dioxide that can be exhaled by the worker.

Now, the second part of the filtration is recirculation. Now, not all cabs have recirculation, but it does help the effectiveness of the cab. What I mean by recirculation is the air that's inside, so you go in the cab, you close it, you're sealed. The air that's inside that cab now is run through a filter and then back into the cab. So you're recirculate or you're cleaning the air that's in the cab.

Now, in all honesty, for the best benefit, it more benefits your exposure to dust than it does diesel, but it does help with diesel because dust can get on your clothes, it's on the seat, it's on the floor. You get in there and you shut the door, and you're just retraining this dust. And you can have a high cost concentration, actually, of dust exposure from this re-entrainment.

The recirculation filter then cleans that out. Now, with DPM, you don't usually get as high, but you will get DPM as you open and close the doors or windows, and it recirculates and it cleans the air out quickly so you have less exposure to that.

Through a lot of research, what we did find out is that usually you want the flow rate of your recirculation filter to be at least three to four times that of the intake. That gives you your best efficiency. It's not required. You can even have it at one-to-one. It's still going to give you some protection, but to get the best, it's usually three to four times, is what we found out.

Also, again, you want your filtration to be able to collect. So we recommend usually between a MERV-14 and 16. If you're dealing with these particulate matter, though, I would edge towards the MERV-16 filter for your recirculation filter.

Now, the next thing -- we just talked about filtration, so we're getting to the point you need good filtration to capture and clean the air that's coming in from the outside. Now you need to be able to have it so that you don't allow the outside air to contaminate into the cab. And one way of doing that is cab integrity. Here is another function that needs to be done in order to have an effective cab because if cab integrity is not there, and you have leaks, you're going to have the air coming in.

Now, of course, with brand new or the newer cab, it's going to be easier to have cab integrity. What we've also found out, though, through the years of research that even the older cabs can be made, put new gaskets in, sealing holes, sealing cracks, going over the cab to make sure that there is no leaks in the cab. And you can make an old cab actually have good cab integrity to get your positive pressure.

Now, after you do all this, and you get your cab working well, and you have your cab filtration going, you got your cab integrity, you got it all sealed up, you're getting a good positive pressure, how do I know continually that my cab is working properly? If I'm going to use this to protect my miners from DPM, how do I know that they're being protected throughout the years or months or in time?

Well, one thing that will be helpful in this is to have a monitoring system, like a pressure monitoring of the cab. So you're going to have a positive pressure inside the cab, and you want to make sure that that positive pressure is there.

Now, you seal your cab, you get the filtration system going right, and you look at the positive pressure. If that positive pressure changes drastically, then you know something is wrong. So say the positive pressure just skyrockets up. You probably have a hole in your filter. But if the positive pressure goes way down, then you probably need to change your filter, or possibly you have a problem with your cab integrity. You have some kind of leak somewhere.

So this is really modern. You can tell what is going on with your cab. Now, there is different manufacturers. This is just a picture of one that is made by Cyclone. Here is another one from Dwyer that we've used in the field to look and measure the pressurization that's coming inside the cab. But this can be very helpful.

Now, after you get the cab working properly, we can see from a few of these pictures here that sometimes another thing that can affect safety and, in this case, your efficiency of your cab is work practices. So we want to look at some work practices that affect your effectiveness.

So let's look at -- one of seeing this, let's look at -- we did some measurements of two vehicles in a stone mine of a loader and of a haul truck. Now, if we look at the data that is on the right, and that is the -- right over here, the haul truck -- we see that every day we got over 90 percent efficiency, and we had one operator in that haul truck.

Now, we don't see the same, though, when we look at the loader. We see that from day to day in the same cab, the same filtration, we're getting different efficiencies. It can be as low as 40 percent. It can be as high as 90 percent. And if we look at that now, we look at the different operations. We had four different operators here. We could see, though, that Operator 3 here is -- he seems to be always in the lowest spot, and other operators are always in the high. So we're looking at -- it's operator-dependent. And we find that a lot of it is from the door or window being open and closed and how often that is that gives them the efficiency.

So let's take a look more of how these work practices can affect the efficiency of your cab. So we did a study where we looked at two pretty new cabs a boulder and a drill at a stone mine.

And they had a pretty good system. The way that their cab system worked and design was, is that the air would go through an initial filter, which was a MERV-16, and then through a final filter, which was another MERV-16. Then it also had a recirculation where at the bottom of the cab the air would go through a filter, an initial filter, and then back through the final filter. So we were getting good pressurization and good reductions in these cab systems.

So I want to take a look at it when they were being used to see what kind of work practices would affect. So we measured the pressure inside to see when it was positive pressure. We measured elemental and total carbon inside and outside of the cab using NIOSH Method 5040. And we measured elemental carbon in real-time using the air tech outside and inside of the cab.

And if we look at the results, the Y-axis is the percent reduction, and the numbers on the X is just random numbers of the time we do it. And we could see, though, that we got low numbers. We got mostly above 80 percent, but still we got days where it was 70 and some even below 50 percent reductions, with the same piece of equipment.

So if we look at some of the real-time data, we can kind of get an idea of what is going on. The dotted line here, this is the pressure. So when there is a positive pressure, that means the doors are shut and the windows shut and everything is sealed. When you see it at low to zero, that means there is a window or door or something being opened. And if we look at the results, when -- right here, if we look at this one right here, when it is positive pressure or the doors and the windows are sealed, we could see outside.

This is the outside. We're reading DPM, but we're not reading much DPM in the inside. Now, I take the opposite, and that's when we have no pressure here. That means that some doors or windows are being opened, that we have outside air. We're measuring DPM. But we're also measuring DPM inside. In fact, to some times, the inside was just as equal as the outside.

So we're getting this different types of efficiency because of this window/door being opened and closed. Again, let's take a look at this chart. This is again the different types of reductions we got. If we take a look now -- if you look here at these low ones, the 50 percent and 45 percent, now let's just take the times where we know that the door was open. So we look at the real-time data, and we look at when it's positive pressure.

So the times when we know that the doors and windows were sealed, we look at the real-time elemental carbon, and we determine the reduction. And if we do that, it goes from 50 to 45 percent up to over 90 percent. So if we look here at the orange, the orange dots now are when we're just looking at when it's sealed. We can see now except for one day they were all above 90 percent, and one day we had 85 percent. But we can see that when it's sealed, we can usually get above 90 percent efficiency in removing DPM.

Now, one thing I did want to add to that, too, though, is that one thing this tells us now -- because let's face it, most of the times we can't just always have the doors closed and sealed and the windows. Sometimes during your work day you may have to open the window. You may have to open the door to go do something.

So it's not always going to be sealed. But we can see for most days that we were sampling that you could at least get over 80 percent efficiency even with the work practices. Even with the times you may need to get out and in and open the windows and doors, we still could get over 80 percent efficiency in the cab from DPM.

Now, there were times again like we saw at 45 and 50, but those days probably -- you know, you probably could have had work on the work practices and be able not to have it open the door or the window as much because it looks like in most cases, they could have functioned with their work practices and still have over 80 percent efficiency.

Now, of course, with any kind of control technology, you have some limitations. One limitation is maintenance, right? You have to change the filters. You have to make sure you keep you cab integrity. Again, I want to mention that this is a time where you really could have a monitoring system like measuring the positive pressure that's inside the cab, and that would help you determine when you need a filter change or when something is going wrong with your cab integrity. So it could help you monitor the condition of your cab.

Now, not all vehicles have an effective cab or even can have an effective cab system, some due to size, some maybe due to visibility problems. When you put a cab on, you may not be able to have a good effective cab on them. So in some cases you can't do it. And not all miners can work in side cabs.

Just for example, in the stone mine, you have ANFO loaders or you have blasters and you have scalers and maybe some surveyors who may not be able to work inside a cab. So in these cases, we're going to have to look at different control technology to protect them.

And then I'd like to thank you for your time.

(Applause.)

MR. HUFF: Hi. My name is Brian Hoff. I'm the Chief Technology Officer of Artisan Vehicles. I want to thank you guys for allowing me to come day. And this is a diesel technology workshop, but I'm here to talk about a complete alternative to diesel and alternative to engines altogether. You know, and it hasn't been mentioned too much. I know there was a couple of references from CAT and some of the other suppliers here that are working on this, but this actually not as new as you might think.

So I first want to -- I also want to make sure -- and I'm going to rush through this pretty quickly. I want to make sure there is enough time for some questions so that we can do it more dynamically rather than me just, you know, giving you a more technical spiel here.

So this really kind of started in northern Ontario. I know there has been battery electric equipment in mines for even longer than that, but the latest push with lithium batteries and the real latest technology started in late 2010 and early 2011, and in northern Ontario. And now, after eight years or so of vehicles proving themselves, pretty much all of the major mining companies, especially in the Sudbury Basin in Ontario, have committed to going battery electric for all of their production going forward.

There have been statements that they're never going to buy another piece of diesel gear. And I think that kind of attitude is really going to start to penetrate into more and more markets as you go because -- and one thing that is interesting about that is -- I was just on a panel last week with mostly Sudbury Mining Company's Glencore, Vale, Gold Corp -- and I asked all of them who was doing this for health and safety reasons, and every one of them is doing this for economic reasons. And I think that's really going to be the key factor, is that this is -- the main motivation for this technology is financial.

One also can kind of give an example. This is one mine, the one that we started working with in 2011. This is from the KL Gold Macassa Mine project. They had a new ore body mine that has been in production for a long time, near 100 years, I think. But they had a new ore body that they wanted to access, but they didn't have enough ventilation out there. So they were faced with the idea of spending $100 million on a new ventilation shaft in order to access this ore body, or take a leap on new technology and go after it with battery equipment.

And basically, there was no way they were going to be able to make that project a success unless they did battery equipment because they just couldn't get the finance part of it to work out. And so that's why they took this leap, basically because they had to.

Now, they've got 34 machines, and they've already decommissioned some machines. I think there are probably six or seven machines that have, you know, exceeded their useful life and have not been decommissioned. So overall, they've had close to 40. They have 38 charters, 80-plus batteries. They have well over 187,000 operating hours, and 80 percent of their overall production now comes from their battery electric equipment.

So even though they're not 100 percent battery electric, the vast majority of their production comes from battery. And they've seen over time that their availability is 85 to 90 percent in some cases. I've listed there some of the stuff -- the equipment that's there. A lot of equipment is from us, but some of it is from Epiroc and RDH. But all of those machines have battery supply and electric motors and systems that are supplied by Artisan. So we kind of learned in the early days, and we started making equipment, though, in just the last few years.

So as I mentioned earlier, kind of why are they using battery-powered equipment, and this is where the top reasons here are all financial. You know, the regulations are out there for how they're going to -- what ventilation they have to provide for certain installed horsepower, but once you had no engines on board, now the regulations are really just about blast gas clearing, dust reduction, heat, and those kind of things.

So now, their ventilation reduction is really driven by these other factors. And the cost savings are immense for ventilation reduction, not only capital costs for expansion, but power costs for running the vent fans as well.

So and one thing I wanted to note here, too, I've been doing some studies on heat generation, and that's -- you know, once you take particulates and the exhaust emissions out of the equation, dust and heat are going to be the next one. And I've done some analysis to show that the heat reduction is really kind of down to one-ninth the heat generation for battery equipment versus the diesel equipment.

The other thing is once you've reduced your ventilation, you have less heating and cooling costs, right? If you're moving less volume there, you have to put less power into heating. Your cooling plant doesn't have to work as hard. And so it's a compounding benefit from an economic standpoint.

Another thing is I mentioned that one of the reasons that Kirkland Lake Gold did this was tied to production. Even if they were able to make the financial model work out to dig a new ventilation shaft, that's going to take time, and that time is time we're not moving that ore. So that time for production, that time value of money, is really a big impact. The other thing they really found is that there is actually a faster permitting process to get these projects permitted because you don't have to go through all of the diesel and ventilation requirements that you did.

Another side effect -- and this is kind of something that wasn't even really forethought from the mine standpoint for doing this is that your productivity goes up with battery-electric equipment. When, you know, diesel manufacturers, diesel equipment manufacturers are designing these machines, they know that especially in Ontario, ventilation is decided by the amount of installed horsepower.

So for a given piece of equipment, the smaller the engine they can put on it, the less ventilation costs are for the customer, so the best economic benefit. So all of these machines tend to have the smallest engine that they can get away with. With battery equipment, there is no restriction on that, and we put three times the horsepower, which significant improves your ability to haul, to fill your bucket. The machine is just all in all more powerful, and that increases your productivity.

Then the last few things on the list are the health benefits. You know, less dust because you don't have an exhaust pipe kicking up dust behind the machine or blowing it off the walls, less noise. That one is considerable. We find often people are like, wow, what is that really loud noise. That's the hydraulic pump that has been there the entire time, and that's now the loudest piece of -- the loudest thing on the equipment. And vibration -- and that's another one that I think was mentioned today, too, that there is pretty significant benefits to getting rid of that engine vibration.

And then, of course, as new regulations come along, you hopefully will be sidestepping those by using battery technology.

There are some complications, right? This is a big change. There is impact on infrastructure, logistics, personnel, training. All of those things kind of come into play. I want to try and go pretty quickly. I have five minutes left. Is that where we're at? All right. Go as quickly as possible here.

But there is a big choice with battery equipment, right? You have to figure out how to refuel it. You know, and you can either try and quick charge, or you can swap batteries. Those are kind of the two competing technologies at the moment. And we kind of enable both with our products, but we've focused more on swapping systems then on rapid charge. You know, rapid charge rates are going to require significantly more electrical power and electrical infrastructure to support that. Plus the heat generated from a charging system goes up with a square of the current. So the faster you push it, you're going to generate heat at the square term rate, so doubling the current is going to give you four times the heat generation, and that means your product development gets more challenging. You have to use more copper in your system. You have to add active cooling.

This battery swapping allows you to charge over a one- to two-hour period, which is shorter than the time that the battery runs. So you can run on it on a two-battery system with a quick changeout, and it has much less impact on your overall logistics, and you use your batteries half as much.

The operators need new training. They need to understand that they no longer have a fuel gauge, and there is no longer a guy with a -- you know, a truck that can come by and add fuel to the thing. If you're out of charge, you're going to either need a tow or somebody is going to have to drop off a much more significant batter to swap out in place.

So there is some training there. Technicians have a whole new kind of responsibility. Most of the -- it's mostly electricians because a lot of this assumes there are high voltage electrical that you have to work on. The supply chain is a little different as well. There are different parts you got to keep in stock. There is less parts from a maintenance standpoint that get consumed. There is really not a lot of wear items other than the typical hydraulic system components. So that's kind of a different thing.

My management has to figure out how to land the logistics of batteries and parts and equipment and understand better what the -- you know, how to work with this because it has new PM cycles and everything. And then there is kind of a new personnel type, and this is really what we've been struggling with over the last eight years, is getting people trained to understand how to diagnose problems with battery systems and electrical systems on these machines.

Here's another example of some of the

infrastructure stuff. The picture on the right is an underground battery shop. This allows people to work on the batteries and replace modules and other sensors and systems underground. The item on the right, that is the charger. The one on the left is kind of a charge bay. So that is actually just an old stope or a remock that they added some ventilation and put electrical at the back of it and put a charger there.

So that's kind of the easiest implementation. You see a lot of loaders can handle this kind of thing if they've got enough down time during their shift that they can charge and they don't have to do any battery swapping.

This is a swapping station. You can kind of see the hoist chains hanging from the top, but this services two machines. There's the charger in the background there, and that's the back end of one of our machines. You just hoist the batteries out and put them in the empty spot to put the new battery.

This, you know, usually needs a little bit more infrastructure. You have to have the high back heights. There is a little bit more development, but -- and it's a little more purpose-built cutout. So quickly I want to go through our products, and we can get to the Q&A. We've got a 4-ton loader pictured here. This one has a swappable battery, but it swaps through a crane, a hoist. But it's about a 3,500 pound battery, so it's a relatively easy process.

Here is a video of the machine running. We don't have any audio, but the sound of the rock is actually the loudest part of the operation. I wanted to give you a sense of seeing the thing in motion. This is in at the Macassa Mine in Kirkland Lake. And then we have a 40-ton haul truck. This is a low-profile haul truck, so you can obviously see the visibility issues. We've got seven cameras around the machine to replace that view to the right side so that the operator can see what is going over there, and they have proximity sensors as well to help keep them from getting too close to the walls.

And this is our newest product, which is a 10-ton loader. This one, as well as the 40-ton haul truck, have a self-swapping system, so the truck can drop its own battery off, pick up another battery, and then continue on. And this one the interesting thing, too, about battery technology is because we can install so much more power, we have a drive line flexibility. You notice here the front wheels are larger than the rear wheels, and that's because all the load, when you're loading, is on the front, and on the back it's just carrying a never-changing weight of the batteries and the rest of the machine.

So we have 10-ton loader wheels on the front, and 8-ton loader wheels on the rear. Because we have a split electrical drive frame, we can get away with that, and that really kind of enabled better packaging density. And this 10-ton loader is actually the same size as an equivalent 7-ton loader.

Another thing to announce that's been in the news just yesterday is that Artisan is being acquired by Sandvik, so we'll be expanding our production quickly and really excited about that transition. And then I'll leave this. This is an image of the battery-truck swapping system. To give you an idea, this whole process takes a little over eight minutes. But I think we can start with Q&A. But you can the process happening here at least.

MR. WELSH: Okay. Thank you.

(Applause.)

MR. WELSH: Okay. We have time for a few questions, and anybody that has a question, when you come to the mic, would you please state your name and the company you work for. Do you have any questions for our panel?

AUDIENCE MEMBER: My name is Charles Kocsis.

I am a professor at the University of Nevada. You know, I have a question for Brian. Why Macassa?

MR. HUFF: Why Macassa? It was really -- I think there was -- someone made a reference to that earlier. You know, if you build it, they will come, right? We weren't going to build it, but it was demanded. And so they were the first ones that were willing to take that leap because they were between a rock and a hard place, right? They were not going to be able to access their ore body without it, and so they took a chance on it. So that's why Macassa, because they were willing to try it.

AUDIENCE MEMBER: The second question is have you looked at how reliable these batteries are with respect to catching on fire, like if they are damaged, ruptured, they are punctured? I mean, we are underground, right? And if a battery is damaged, you know, and catches on fire, what are we going to do? How are we going to put it out? Is that because it's kind of a different fire, right?

MR. HUFF: Yeah. So I'll stop you there because that's a very good question and comes up very commonly. We use a lithium iron phosphate chemistry, and that chemistry is considered kind of a safe chemistry because shorting, puncturing, overcharging, crushing, anything you can do with it doesn't generate enough heat to ignite the flammable materials.

So it's a really safe chemistry. We take a bit of a hit in terms of energy density because of that, but for underground mining, that's really the right choice. There are some companies working with NCM, nickel, cobalt, and manganese blended cathodes. And those have a high volatility. If you short them out or puncture them, you have the risk of explosion. And so we're staying away from that for our chemistry, but it is a concern, and -- but it also from an overall energy content -- I did some analysis for our batteries, as an example. It's essentially the same rate of heat creation or rate of energy release as burning firewood.

So if you burned our batteries, it's like burning wood instead of a steel box. So relatively speaking, it's a low risk.

AUDIENCE MEMBER: The only problem is that modules come from all over the world, right? So modules built in the USA versus modules elsewhere in the world. So, you know, how are we going to --

MR. HUFF: From a regulation standpoint, I agree with you.

AUDIENCE MEMBER: Regulation standpoint,

yes.

MR. HUFF: That is a challenge. You know, we're taking a hard line on that from our own product standpoint, and that's our big focus, right? And we know, you know, giving -- when we first were approached with this, we had to imagine delivering a high-voltage, volatile batter system to a bunch of guys who had never seen this before, a mile under the surface, in far northern Ontario, Canada, and we designed the battery system with that in mind, right?

We know that there is no such thing as a non-serviceable anything in mining. Anyone who is going to take it apart to try and fix it if needed, they're going to hit it with a wrench. They're going to do whatever they're going to do. And so we designed the system to be resistant to that and-- to minimize risk as much as possible.

AUDIENCE MEMBER: So far have you looked at battery-powered equipment as a means of reducing ventilation, saving flow, as a result of operating cost? For the first time, you mentioned about economics, which is interesting to hear that.

MR. HUFF: Yeah. Like I said, I was on that panel, and there is multiple programs that have been -- you know, there is ore bodies that have been identified, and they like Onaping Depth, which is a Glencore property. That has been planned for I think 20 years, and they've never been able to get out of feasibility until battery equipment. So now it's moving forward because they found a way to do it economically, and it's really because of battery technology that that's possible.

And you see that in actually multiple projects, especially as they go deeper. And a lot of these mining properties are going deeper and deeper because they're seeing more and more ore as they go. So it's becoming more economical as existing identified ore bodies are already mined out.

AUDIENCE MEMBER: Thank you so much.

MR. WELSH: Tom, do you want to ask a question?

AUDIENCE MEMBER: Sure. A couple of questions. Do you have onboard fire suppression agents, and what type they might be?

MR. HUFF: This is for me, I suppose, yeah?

AUDIENCE MEMBER: Yeah.

MR. HUFF: Yeah, we do. We use Ansul products for addressing the risk of the hydraulic system catching on fire, but we also don't have any real heat sources. So there has been --

AUDIENCE MEMBER: For the battery.

MR. HUFF: There has been some debate about whether fire suppression was even needed in the machine. In the battery, we also have fire suppression in the battery pack. And it's an atomized particle system that is really there to suppress fires caused by anything else in the battery. We have had a couple of fires in our battery packs over the years, and one of them was caused by electrical connection that the nut wasn't tightened. It was serviced by the customer and not properly serviced by the customer.

And that really caused no damage. It caused damage, but it didn't make too much of a problem. It burned some of the insulation on the cabling and then went out on its own. It did melt the cells, and we even had electrolyte release and a few other things like that, but no catastrophic events from that.

AUDIENCE MEMBER: Right. So with the phosphate, the thermal vent was fairly benign maybe relative to some other chemistry.

MR. HUFF: Yeah. That is definitely a topic. I'm part of a global mining guideline group and a couple of other organizations in Canada trying to make sure there is some consistency in the safety systems for these battery technologies, but one thing that's really difficult in the battery industry is preventing these internal shorts that are caused by dendrite formation over time, like high-cycle lives and high charge rates tend to cause solid lithium to grow these whiskers that will eventually penetrate the separator material in the cells. And when that happens, you can get an internal short, and those are the toughest thing to address.

The way that most manufacturers that are contemplating NCM or some of the more volatile chemistries are looking at containment, right? At that point, you're just trying to keep it from propagating to the cell or getting out of the battery itself. Our systems, we've had that happen because we've had these batteries that have, you know, been there for so long, and it's really kind of uneventful. You know, you get some melting of some plastics, and some of the electrolytes get boiled and off-gassed, but no fire, in fact, from that event.

AUDIENCE MEMBER: So with the phosphates, the prevention of the cascading event is a little bit more straightforward, it sounds like.

MR. HUFF: It is. Well, even if it does cascade, it just causes electrolyte boiling and smoke, but no flame.

AUDIENCE MEMBER: Okay. But you did mention there are some other manufacturers who may be looking at some of the more reactive chemistry, such as NCM.

MR. HUFF: Yeah.

AUDIENCE MEMBER: What might be done?

MR. HUFF: It just -- it all has to be considered, right? As long as they've done a failure mode and effect analysis, and they can show through testing or whatever else that the system is contained and doesn't pose a risk, then you've met the burden to keep it safe. So, you know, I think at this point, you don't want to be too -- you don't want to put barriers to innovation and prevent technology or developers from coming up with solutions. You just need to put the basic safety guidelines in place, saying it has to be safe, and you need to demonstrate that it's safe, not tell them how to do it.

AUDIENCE MEMBER: Okay. Agreed. Yeah, just one more thing. Any plans on developing permissible equipment?

MR. HUFF: You know, we've been approached a couple of times for that. I think there is some distinct advantages to the technology for that, in terms of the hot surface requirements and some of the others. But the market is relatively small, and the work is relatively large to do that. And so we aren't really looking at that too much right now.

AUDIENCE MEMBER: Okay.

MR. HUFF: But I think it is a good -- from a technology overlap standpoint, it's definitely a good possibility from that, but it's just the electrical system protections are onerous.

AUDIENCE MEMBER: Okay. Thank you.

MR. WELSH: One more, Alek.

MR. BUGARSKI: I wanted to congratulate Brian on a great presentation. I'm just curious if you can bring a little bit of a discussion of what needs to be changed in the mining industry to adopt this battery-powered technology, and how we would transition in that new year.

MR. HUFF: Yeah. That's a big question. There is definitely -- there is changes to mining method that I think you might be touching on a bit there. One thing -- and this is something that Glencore has put forward for their Onaping Depth program. You know, one of the key capabilities for battery equipment is the ability to regenerate potential energy in a battery pack, right? And so one approach for that -- to elaborate on that a little bit. When you have a truck at the top of a ramp, and you've got a certain amount of mass, it has got potential energy associated with that mass. And has it goes down the ramp, you can turn that potential energy either into heat in the breaking system, or you can use the electric motors to slow the truck and put that energy back into the battery pack.

So by that means, if you are mining in a way where you're hauling ore down-ramp, you can actually capture the potential energy of the ore and use that to fuel the truck. And if the ore weighs -- if the payload weighs more than the truck, you can produce more potential energy from the down-ramp then you need to go back up. And so you could effectively create a system that doesn't need to be charged.

And even if it's a not a one-to-one or 100 percent, where your payload is more than your truck weight, you can decrease your amount of charge requirements significantly. Maybe you only need to do it between shifts. That's one, and then there is a million others.

MR. BUGARSKI: I understand. One more followup question. Why innovation is currently happening in Canada, not in the United States?

MR. HUFF: That's also a very good question. There is definitely a lot of hard rock mining up there, and they have -- from my -- I think they do have a good focus on the health aspects up there. But I think it's just when the opportunity arose, they needed to do it. You know, it starts with the need, and that's what motivates people to do things. And, you know, in this case, and for industry in general, that economic needs is the one that puts it over to the edge to make it happen.

But I'm not sure why, is the answer.

MR. BUGARSKI: And one more if I can. Yeah. Can you touch a little bit on other ways of using electrical-powered vehicles beside battery powered in the mining, and what are the advantages and disadvantages of using battery-powered versus tethered or trolley vehicles.

MR. HUFF: Yeah. Tethered machines have been around for a long time, as have trolley-system machines, since the '80s. And the maintenance and other requirements for the system, I think, are what really drives things toward battery. You need the freedom, you know. Most mines are not mining the same exact location consistently over and over and over. They're mining it out, and then they're expanding. And they need to be able to develop the ramp further without all the additional costs and more infrastructure. Some of those systems are difficult to scale to that level.

Trolley systems have issues with road bed maintenance requirements and other system requirements to keep their machines reliable, whereas battery really, for all intents and purposes, operates exactly like a diesel machine, with more power and less emissions. So it makes it a lot easier to sustain the existing mining methods, and, yeah, I think that's really the core, is infrastructure and maintenance costs are better.

MR. BUGARSKI: Thanks.

MR. WELSH: Well, thank you very much.

(Applause.)

(Pause.)

MR. ELLIS: All right. So this is the next panel, and -- no, I won't go there.

(Laughter.)

MR. PIA: Okay. Now you all ate lunch. That doesn't mean you can go to sleep, right? I'm Dorian Pia. I'm with Dry Systems Technology. It's really interesting being here. I want to tell you all thank you very much, and I've actually learned quite a bit myself just in the short period here.

But I want to, fresh from the topics that --

it's very unique, every mining operation and applications. And a gentleman said don't assume what works in one place is going to work in all others. You know, in my experience, before I get started on this -- in my experience with diesel, with battery, with these different after-market or after-treatment systems, you know, one thing I always keep in mind, I'm in a mine. I'm in a tunnel. Yes, we all want to reduce exposure. We all want to reduce the risks. But one thing I've always tried to keep in myself in my mind is what is the bigger picture.

You know, when you talk about regen systems, I come from coal. Even in the hard rock stuff, I've spent quite a bit of time. I always want to look and see what are the potentials of each system and how it's going to work, or what the catastrophic end may be. And so we always try to find a balance, right?

You know, in the applications that I'm speaking of, you know, heat is a big thing, especially in coal. We have to be real careful. A lot of these systems create a tremendous amount of heat, you know. Each mine is different again. Uncontrolled regen, I mean, I don't know how many times I've -- on surface mines I've been to they've had issues with this, fires. On our own vehicles, our three-quarter-ton and one-ton trucks, when they go under regen, sometimes it's not controlled.

And I think about that stuff underground in a contained environment, how many fires, you know, on surface areas, going through canyons. You know, we get these forest fires. Has anybody really looked or know what really causes all of them or some of them, or a portion of them?

So I really try to keep all that stuff in view, you know. When you get into tier or phase, one of the big obstacles we run into as an equipment rebuilder manufacturer for many of our customers is they do ask, they do approach us. They want to try to contain a lot of their DPM. They actually do make the step forward and want to do the right thing. And some of the barriers, if you want to call, or some of the obstacles we run into -- and I hope, you know, after listening to some of the engine manufacturers, is one thing that we ran into -- I hope there is a clear up on this, but one thing we ran into is the package for the EPA or the package of the engine is somewhat or has been -- and it kind of sounds like it might be maneuverable or movable now, some of the exhaust components.

Well, in a lot of mining application of

these machines, well, you're going to grow. We don't have that room. We don't have that flexibility. You know, one thing they've always come across to do is to swap out to a newer, cleaner engine, or able to do what DST does very well with hundreds of machines out there that we've done, built, and/or converted over to reduce the exact same things that we're trying to prevent.

And as you guys were saying, maintenance is everything. I've been in maintenance my whole life, so it's kind of easy for me to say that, right? But, no. I mean, production, maintenance, all these things have to come inside. But I want to say is if we're able to tackle the big polluters within a lot of our mines, some of these smaller ones may just fit into some of the applications that we're doing by reducing these emissions.

Dry Systems Technology -- maybe it might help. Dry Systems Technology, we're the world's leading manufacturer of diesel-powered packages underground. We hold multiple approvals within MSHA, not just on engines, but also on equipment. Our main offices are in Woodridge, Illinois, facilities in Vienna, Illinois and Price, Utah.

The Dry Systems Technology team, we've

developed the Dry Systems emissions treatment in a low temperature exhaust filtration technology. So instead of going up on temperature, we actually go down. We actually cool the exhaust down. Diesel power packs incorporate the most efficient methods to reduce the particulate emissions from existing and new diesel engines used in underground mines. Diesel power packages are also safe, user friendly, and low maintenance, comply with stringent MSHA diesel regulations.

And what we've done is a lot of our -- our system is really quite simple, and we'll get into some of that, and a lot of maintenance personnel really like it because it is friendly. It is not complex. There is not a bunch of sensors. There is not a lot of electronic type stuff going on.

And the other key thing, too, it will outlast diesels throughout multiple rebuilds and are exclusively available through us. Prototypes have been coming in since 1987. The page is kind of crumped together there. Continuous -- has been in continuous mining since 1992.

This number is actually inflated. We have actually more than 850 systems out there right now. The diesel power package approvals are currently operating in more than 175 tunneling projects in North America. We actually do quite a few in tunneling. We brought some tremendous amount in coal, some of your bigger projects, even your small, little tiny mines as well. Diesel power packages have been in successive agent -- excuse me -- accident-free operation and combined of -- it's closer to about seven and a half million hours without incident, catastrophic, anything of that event.

Again, we cool down our exhaust to keep everything within the control. Diesel power packages are available for a wide range of new and existing engine models, and we've ranged horsepower between 50 and 350 horsepower, you know, and that's within, you know, some of your bigger hard rock vehicles. They are a higher horsepower, but the technology is also still available there. This is just the main focus of what we've done so far to date.

So what we do is basically -- there was a slide earlier today. It kind of showed a little bit of the same concept. We do some very different things within our oxide catalyst that we especially work with the manufacturer to get some of this control. We also do a little bit different in our heat exchanger as well. Basically, it's that simple. Our DPM filter, we're able to capture 96 percent DPM reduction, 90 percent carbon monoxide reduction. And also keep in mind, even though we're low-drill (phonetic) sulphur, there are some other markets that still use the higher sulphur, and we're able to capture 90 percent of the sulphur.

This is one of the very early vehicles that were done in Colorado. Excuse me. This is actually in Illinois. This is back in 1992. The current situation on after-treatment -- now, these numbers, again dilution by ventilation. One of our last guys, you know, kind of hit that on the mark, the way it has been in the early past. Scoop limits the operator's view and contaminated air. And what we basically do is we take the small particles. By cooling them rapidly, they form a larger particle and we're able to capture that within our particulate filter.

Excuse me. So this is just within reference of an engine with just ventilation requirements. That's with no treatment at all. This kind of gives you an idea of the CFM to get it within your .15 milligrams per cubic meter, so 117,000 typical clean, you know, 20,000, and we'll go to another slide here to show you after our treatment what we're able to get that ventilation requirements down, reduces particulate matter by 96 percent, like I was saying, seal them, carbon monoxide. Again in the sulfur area there is reference to other markets again, and we don't want to take that -- a lot of consideration for the states because we use the ultra-low sulfur (phonetic).

It reduces diesel odor as well. And one thing you ought to keep in mind, it reduces on fuel-based hydrocarbons 85 percent. So after -- with our treatment in line with the system, we're able to take that same engine and we're able to reduce the ventilation. Again, this is just for reference for an engine requirement with the regulations. We'll get down to basically 7 -- 4,700 CFM, and typical clean engine down to 777.

And this is typically again our system where we go about tackling such DPM reduction, 90 percent CO reduction, and it kind of goes through our catalyst that we have a few different catalysts, depending on horsepower, depending on the package that we work with. And again, some of our components and the way that we do our system.

We were able to use control of gases and particulate emissions in diesel engines are required. You know, the big thing that we caught -- that we specialize in is principal requirements. We also have done a lot and quite a bit for other markets, tunneling in the West for a lot of the subway systems going in for those requirements because they're deemed gassy.

Explosion prevention systems use the power packages in coal mines, gassy mines. But one thing that we want to keep in mind through all of this is the way our particulate filter works. It's kind of -- we were passing through the center and coming out each side. You know, we kind of act as a filtration with a lot of requirements of CFM of this engine.

One thing that we've done for a lot of our -- for some of our customers is both those machines there, the CAT machines are permissible right now that we've converted over to for some tunneling projects, and we also build and manufacture new, which is the LHT up in our left-hand side with our package as well, again MSHA compliant for permissible use.

We were able to retrofit older, dirty engines as well as newer, clean engines, and we get that reduction across of the 96 percent, whether it be an old, dirty engine or a newer, cleaner engine, providing the best ambient environments for the miners that we can offer. Dry Systems will last again several times of the rebuild, and very, very routine maintenance.

If you ask a lot of our larger customers, you know, one thing they really like about the DST system is it's just simple. There is not a whole lot of maintenance required, you know, and that's one thing that I keep in my mind is availability, ease to work on, and customer agrees that the simple, easy tactic for permissible and for the maintenance personnel is pretty key.

One thing that we're able to do quite well, not always in every application, but we do quite well even in small skid steers is we're able to fit our system on most of all machines with not too much modification. Some are pretty challenging, I'll be honest, some of the smaller machines. But, you know, one thing that we're able to do well and we've done very, very good at for a majority of the customer base is exactly that, to meet those needs of the customer.

But like -- you know, one thing that -- excuse me. One thing that really stands out to me when you get into the regen type systems and you get into some of these other roadblocks kind of so to speak, especially underground coal and some of these gaseous type applications is the regulation, you know.

I don't want to say our hands are tied, you know, but again we have to follow regulation, which is -- and is agreeable to across the board for the other manufacturers, is it's such a niche market, and it is tough. But again, it's the familiarity with the system. It's familiarity with the application and having the know-how to do so. But like I said earlier, I always try to keep in mind all the potentials for hazard for the big issues that may be coming with some of these other alternative systems.

One thing I'd like to know, how many people here are actually from like coal or gaseous type mines? Because I was just looking around. I know three or four of them myself, but, yeah, see, there is quite a few here that are, you know. And when you're talking about all these other applications for hard rock and for these other mining type, it's really interesting to me to see how much and how different the systems may be.

But any questions, I guess I'll taken them when we're sitting over here. I appreciate your guys' time, and thank you.

(Applause.)

MR. COCHRANE: Thank you for having me. My name is Steve Cochrane. I'm a Maintenance Analyst for

Blue Mountain Energy, Deserado Mine. We're located in Rangely, Colorado. I've been a Maintenance Analyst for about 12 years now, and I was asked to come and represent the underground coal industry about the topics that have been discussed today, a little bit about the mine.

Like I said, it is in Colorado. We are an underground longwall mine. We've been in operation since 1987. We produce about 2 million tons of coal. We deliver it to our power plant by an electric train. It's about 34 miles away. Our power plant produces about 460 megawatts per hour.

On the topics that I'm going to talk about are the current underground technologies for DPM, light-duty, which is our pickup trucks versus Tier 4 technology, DPM and underground coal, and the cost of Tier 4 technology.

For coal anyway, all of our diesel equipment has to be approved by MSHA. We cannot just take any diesel equipment underground. It has to be approved. A lot of our after-treatment devices are also approved, and there are standards already put in place for these.

Our first piece of equipment is our permissibility. These are Wagner scoops. Our scoops have Dorian's Dry System Technology on it. I'm not really going to go into that because he kind of covered it.

Our second category is heavy-duty. These things are like ASV skid steers, haul trucks, boom trucks, graders. These systems have an air flow catalyst system on it. The exhaust goes into that filter, gets separated. Over time, that filter will become plugged, and we are able to break that filter down, and in our shop, we have a bunch of ovens that we can bake that filter. Our ovens back about 900 degrees. Once that is done, we can reuse that filter.

Like I said earlier, all of our engines and all of our after-treatment devices are already approved with DPM in mind. All of our permissible and heavy equipment has a 2.5 grounds per hour standard. As Dorian was talking, these systems are very efficient. We have to do weekly exhaust tests. And you can tell instantly when there is a problem with that system. Very, very easy to maintain for both operators and maintenance personnel.

Operators, when the back pressure gets too high, they change the filter out. Maintenance-wise, just like Dorian was saying, you got to flush the system out occasionally, but we are doing it maybe once a year. I mean, that's how efficient these systems are.

Our light-duty category, as our pickup trucks and our welders -- I'm going to talk a little bit more about our pickup trucks. At our mine, we use Dodge Rams. They do have an approved engine. We use the Cummins Engine. We have 5.9s and the 6.7-liter engines, and these are also approved by MSHA.

So when you start talking about the whole Tier 4, that exhaust system always comes with it, and the regen process. You kind of got two different regens. You got that passive regen that during normal operating times, that DPM filter will try to keep itself clean, but over time that filter will become plugged, and that's when that active regen needs to take place. That's when the fuel gets dumped in there to get the higher temperatures up.

So with our pickup trucks, we started thinking about this process. These engines are already approved, and they are De-rated from MSHA, and they are also governed at 25 miles per hour per manufacturer request.

So we also started thinking about, well, because of this, how much load are we actually using. Are we getting the full load out of the engine? So we were able to pull up some diagnostic stuff through our troubleshooting stuff, and we found that 35 percent of the run time of that engine, we're only at zero to 10 percent load.

So with the loads that we put on these engines, the De-rate, and the governor at 25 miles an hour, we have a feeling that we are going to be always in that active regeneration mode. We are going to constantly going to be fighting that filter. Also with that 25 miles an hour, we're not going to be able to get that truck up to highway speeds, highway temperatures. So we're going to have to come up with some way of bypassing that system.

The technology also -- it was brought up earlier, these exhaust systems are very computer-dependent. They have sensors. They have computers monitoring this. And if that computer does not like what it sees, it's going to throw that truck or piece of equipment into lit mode or even shut the vehicle down.

So we are going to have to come up with some way around these systems. And it was talked a lot about in that second panel with all the engine manufacturers, temperature is a huge issue for us. I was able to find a study that the Forest Service did.

They were concerned about this, that these exhaust systems were -- had the potential to start fires. And so they did a study. They took six trucks that had -- one of them had a non-DPF system. And their goal in the study was to find out what is the exhaust temperature, and what is the various surface temperature throughout that exhaust system, and also what their ignition point is.

And these are their findings. You got anywhere from 497 up to 1,000 degrees, so pretty high temperatures. But we asked the same question. Where do we need to start thinking about temperatures with coal? And there was a study done by Clete Stephan from MSHA. He wrote a paper on all the elements that were required for coal to burn coal for having explosions. And in his paper, he had some temperatures here for the coal dust layer.

And as you can see, they're pretty low numbers, depending on seam and grade of coal. MSHA already has standards for surface temperatures. You can go throughout the law book, and this number of 302 comes up everywhere. It's just not the permissible equipment, it's all of the equipment. You can see it in -- you know, I just put up a couple here, electric motor-driven equipment. That surface temperature is always that, 302, that we have to stay below. Just a review of what the Forest Service found.

So with these numbers here, we are definitely -- one, they're higher than what MSHA currently already has, and two, we're higher -- we're going to start lighting coal on fire. Not a good situation on the ground.

So DPM in the underground coal, we've already got standards set by MSHA. On the heavy equipment side, 2.5 grams per hour. On the light-duty side with pickup trucks, 5 grams per hour. One thing that we couldn't find when this was kind of presented to us was -- the first question I had was how much DPM do we actually have in the mine? And we were not able to come up with any answers for that. We asked our local district MSHA for help. We kind of reached out to NIOSH.

It was kind of brought up today it doesn't seem like there is a lot of data actually inside a coal mine of how much DPM is actually there. Also, in underground coal, we ventilate the whole entire mine. And during MSHA's approval process for the engines, is they are setting that ventilation rate of how much air that we need to have going over the top of that engine. And these are just some of the numbers that we have at our mine. Just for example, the pickup trucks need to have 8,000 CFM of air.

On the cost, I can't even put a number on if we have to redesign all of our permissible equipment and all of our heavy-duty equipment. A lot of these equipment already have MSHA approvals. I've done enough field modifications in my time to know if you have to restart doing MSHA approvals, it gets really expensive. It gets a lot of time consuming. So I can't even really kind of throw a number at that, but I have a feeling it would be very high.

On the light-duty side, with pickup trucks, I kind of went out on the Internet to see, is there any kind of retrofit to go from old technology to newer technology, and I really didn't come up with a whole lot of answers. There is a lot of products if you want to take your system off your pickup truck, but nothing to put it on your pickup truck.

So that would mean like for our fleet, with our pickup trucks, we'd have to replace the whole entire fleet, and we're looking about $2.8 million. Now, we are a really small organization compared to even the mines that are around us. That number could be really big for a lot of mines. Maintenance -- we talked -- a lot of people have been talking about maintenance.

I see this Tier 4 technology with the exhaust system for coal being a very high maintenance. From operators, we might have to hire just people just to do the regen process, however that process comes about, if we get forced to do that. Parts -- I just kind of jumped out on the Internet and kind of looked at a couple different ops, you know, how much does stuff cost. And that was just the DPM filter.

And training, kind of went around our organization. We don't have one single person that has any kind of Tier 4 and the exhaust system training. So we would have to train all of our people, and there is always a cost associated with that.

Just to summarize, the permissibility in heavy equipment, we've already got approved engines. We already have approved after-treatment, and they work. They work very well. They're very efficient. On the light-duty side with the pickup trucks, we just feel that this is going to be a very high maintenance ordeal for us. And the real big one is those temperatures. We cannot have those temperatures underground.

Lack of data -- like I said, maybe we need to start first. Let's actually see how much DPM is actually in the coal mining, in a coal mine. And then the cost associated, there is always cost with new technology. As far as underground coal, it's no secret, we're kind of a struggling industry right now. It's a lot better than it was a couple of years ago, but I guarantee you every coal mine in this industry right now is counting their costs.

And that's all I have. Thank you very much.

(Applause.)

MR. BROWER: I wanted to thank the organizers for having us here with such late notice. A lot of good presentations. This won't be one of them.

(Laughter.)

MR. BROWER: But it will be short. My name is Arthur Brower. I'm with the Bureau of Mine Safety in Pennsylvania. I'm familiar with some of the faces out there. I'm going to talk a little bit about how Pennsylvania is set up to help promote newer technologies. I think I got the right button.

This is basically an overview of our program. We have the law. The latest edition is 2008. We have an equipment approval process. All equipment used in Pennsylvania goes through that process. And one of the key things that helps us is we have a technical advisory committee that deals with diesel engines.

We have a dedicated diesel equipment inspector, which is something we started recently to get an expert on this kind of thing and have some kind of consistency in the program. We know the mines need to see that. And we also have a diesel training instructor certification program where these people can go -- after they're certified, they can go to the mine and teach operators, teach maintenance people, and so forth.

One of the reasons I think our law is adaptable, it was developed in conjunction with industry. It came about after a court case, and there was a stipulation of settlement, and the law was developed. And we try to work with industry to keep it that way, a cooperative environment. And the law allows the TAC to evaluate alternative technology or methods for meeting the requirements for diesel-powered equipment, as set forth in this chapter.

Now, we rely on MSHA for the base power unit, but the emission controls and everything are described in our law, either prescriptively or performance-wise. And that's basically the chapters of the law, and a couple of ones that apply to the diesel stuff. This is the chapter for -- it's pretty extensive, but the training and general requirements is an important one, and 424, which is where the technical advisory committee is defined.

The approval process is pretty straightforward. We have two types of approval. We approve the piece of equipment in whole for the fire suppression system safety shutdowns, breaking systems, those types of things. And we have an approval called BOTE-DEEfs, which is for the engine and emissions package. If somebody gets an engine and an emission package approved, they can put it in any piece of equipment once it's approved.

We also have a BFE, which is for face equipment. But as someone mentioned, there is very little of that. There might be 10 pieces in Pennsylvania. It just seems to be maintenance-intensive, and the mines find other ways to handle that. And the process is they'll submit a technical package, ISO charts, filter cut sheets, basically everything, calculations on particulate matter. And then we'll do a review, and then we'll go out and actually test it onsite, and we'll do emissions tests. We have our own ECOM, and we'll work with the mine to get that done.

Now, this is the part that gives us a lot of flexibility, technical advisory committee. They're involved in all aspects, legislative, technical guideline standards, equipment approvals, the whole deal. And they meet basically monthly. And if a manufacturer or a mine or somebody wants to introduce a new technology, all they need do is bring it to the technical advisory committee, TAC, and submit it.

At that point, we'll work with TAC to give them the technical support they need to evaluate that. And the TAC is appointed by the governor. It's two members, one from industry, one representing the miners. And currently, one of the gentleman is here, Ron Bowersox, from the UMWA, and Paul Borcheck, who is recently retired. They work well together. I haven't seen a conflict. And again, they're allowed to look at new technology.

So if somebody brings something in, a new catalyst, filters, surface temperature treatment, whatever, they're allowed to look at that and make a recommendation, and then nine times out of ten the bureau will adopt it.

Now, this is something new here. We have a dedicated diesel equipment inspector. We were finding that under our law, the mine inspector was responsible for diesel equipment, but he didn't have the right skill set to do a good job doing that. So we picked somebody out of our electrical group who had a lot of experience with diesel equipment, and we've made him our diesel inspector. And he'll basically rotate through the mines, sampling the equipment. He can't get it all. There is 650 pieces. And in Pennsylvania, it has to -- each piece is supposed to be inspected twice a year, but that's not possible with one gentleman.

But he'll go through there and work with these guys, and rather than looking for citations, we're looking for compliance. And we found if the guys understand what they need to do to comply, they'll do it. So our inspector is more of a teacher, or we'd like to think of him that way, as he is a cop. We equip him with an ECOM, IR temperature sensors, whatever he -- you know, wax pencils, the whole nine yards. And as someone mentioned, all equipment has to meet the surface requirements, 302 degrees, not just in by equipment.

Now, training, there is basically three major areas of training: operator equipment-specific, mechanics, and diesel instructor. We call it train-the-trainer. Once somebody gets that certification, they can train people in all aspects of the diesel equipment. And to the right is the procedure you need to go through. There is a couple of different methods. You can do it by training, experience, and methods seized basically by petition.

Somebody will take a look at your résumé and what you've accomplished, and if it looks good, you'll be certified. You do have to do a training session witnessed by one of the instructors from the Bureau, then he'll sign off on you.

Back to the TAC committee. We've had a couple of different requests. Some of them have been -- silly might be the wrong word. Pennsylvania adopted a standard where you had to have two connection points on a battery. And this came from the federal law for scoops, but it had been adapted all the way to a starting battery on a piece of diesel equipment.

Well, the battery technology has changed, and they weren't able to do that. People were drilling into the posts and doing stuff like that, and we didn't want to do that. So one of the operators came to us and said, what can we do, and we basically -- the TAC took it upon themselves, took a look at it, and they basically changed it, saying you only need to have one connection on there. Put a GM nut or a lock nut, and you're good to go.

Another one a little more substantial was the bureau had de facto used surface coating as our temperature control method. Polyamide, I believe that's a brand name, but that's what they were using. And the mines are having a problem with that because when you take it off and put it back on, you can damage it. It gets damaged by heat, contamination. Around bolts it's hard to do much with it. And an operator came to us and wanted to start using blankets.

Well, we had a bad experience with blankets because people were just basically wrapping stuff around it, using piano wire to secure it and tie wraps. Well, the TAC took a look at it, and we came up -- in conjunction with the bureau came up with some standards to be able to use this. And this whole process took about a month, which is pretty quick for most regulatory processes.

And it has to get a custom-fit piece, and typically the way that works, they'll send a piece to the manufacturer, or they'll send them a CAD drawing. It has to have a part number on it, so if it's damaged, the guy -- the mechanic can look at the part number and order it without having to try to figure out what he needs. They need to just put the cut sheet in their equipment log books so they know that piece has been changed, and it has got to meet the 302-degree limitation.

This kind of shows what we can do, and we can do it with anything. That's the nice thing. And now, some agencies have gotten rid of their TAC committee or whatever they call it because they felt it was a burden because it placed limitations and that sort of thing. But it's an advantage in our case because somebody can bring something in. These two gentlemen can look at it, work with us, and within a period of a couple of meetings are allowed to make that kind of change.

So that's mine. If you have any questions, I'll be here. Thank you.

(Applause.)

MR. ZERR: Well, thank you for the opportunity to share a little bit of our story today. I'm going to spend a little time talking about who we are, what we do, what we've learned, and how we're getting better. And I can honestly say after listening to a bunch of really good presentations today, there is not a lot of new information that I'm going to share other than a little bit of a different perspective as an operator.

So a lot of you probably haven't heard of Mississippi Lime, and we're a St. Louis-based company. So, Patricia, we were not rooting for the Saints. We were rooting against the Rams, and we still felt your pain. I understand your perspective.

So we are based in St. Louis. The name actually comes from the river. It started as the Alton, Illinois Sand and Gravel Company. Our founder, Harry B. Matthews, moved into the lime industry a little over 100 years ago, and so we've been there ever since. Very diversified in what we do. My background is actually chemical engineering and process engineering, so I came out of the specialty chemical business. I've really only joined mining in the last four, so, you know, today was good because I've learned a lot about stuff that I should know more about, which is always good.

We are privately held. We're still owned by the Harry B. Matthews family. We're working with the third and fourth generation family owners, and it's a wonderful experience. I'm very happy to be there, as are many of our employees, who are in some cases third- and fourth-generation employees.

We have a set of core values. We actually run our business still like a family business, and we follow our values, and we're very focused on safety. I'm going to touch upon that a bit more.

The picture you see here is half of the surface operation at St. Gen. It's the north half, the old half. There is a southern half of that operation as well. And then what I'm going to talk about a bit later is our underground mine.

This is just real quick, but I want to make sure people understand -- sometimes I think we forget why we do all this, right? And so on average today, you use five -- you used indirectly or directly five ounces of lime in what you did, everything from for your -- from the steel in your building and your car, to the tires, to the water you drank, to, you know, even the power, how you're getting power because we scrub a lot of acid gases out of power plants. And in a couple of weeks, when you're celebrating your Super Bowl party and you've having corn chips, you can think of us again because our product is in corn chips.

So underground mine, yes, but as you can see in the first picture, the difference is we drive into our mine. We're not a shaft. We drive into a bluff, so to speak, and that's the way, you know, those mines were developed in St. Genevieve. Because we've been mining out of this existing spot for about 70 years, we have a pretty large footprint. So over three square miles of developed mine, and really unlimited resources based on reserves that we have acquired.

The other big difference is unlike a lot of underground mines where you have limited space, we have 90-foot seams. So we mine in two passes. We take out a heading, and then we do a big bench, and so our limitations on space is really between our pillars, between the 50-foot pillars and the physical dimension there, not so much in height.

Spent a lot of time focused on safety. That's one of the things I brought from the process chemical industry. From a process safety management point of view, we look at things very systematically. There is still a human touch. We have been recognized five times since 1980, most recently in 2015, with a Sentinels of Safety award, and we're very proud of that, so -- and we keep working on that.

So part of our complexities -- and this kind of gets into why this is hard to make some of these changes. We operate equipment from 32 -- I counted them up the other day -- 32 different manufacturers.

So the practical side of making all these changes is you've got a maintenance group. You've got outside vendors, but you're operating 32 different pieces of OEM stuff.

Now, could we consolidate a bit more? Yeah. Does the local vendor figure out when you're only buying brand X versus brand Y and their prices go up? Sure. And so we like competition, and so we maintain a diverse fleet. We have some standardizations, obviously. So that's a challenge for us. I'll talk a little bit more about where we're at in our Tiered engines. And, yes, I apologize, I should have capitalized tiered.

We move a lot of air, and it's because the footprint is so big. And this is actually a misprint. We're slightly under a million cubic feet per minute of air that we move through up to 60 ventilation shafts. Now, they're not all operating at the same time, and that's part of the mindset that we're bringing in terms of operating the mine like a controlled process as opposed to kind of everything wide open all the time. But we're adding technology to where we're monitoring conditions and turning on systems on and off to maximize or optimize how we move air around the mine, and our operators are really the ones that are doing a vast majority of that.

And so continually monitor. Our supervisors, our crew leads, our miners, our mine rescue team are the folks that are actually monitoring the air quality and making changes as needed down in the mine to keep the air quality where we want it to be.

So -- did I skip one? Yeah, sorry. So this is part of the why, and this is part of why I think we've got asked to speak. We were one of the mines that volunteered for the DEMS study back before my time. And so as you all well know, a large number of mines that were selected, we were selected for various reasons, but one of the reasons was because our ore body is very pure at 98-1/2 percent calcium carbonate, very low other contaminants, not a gaseous mine, low in silica, and so that was one of the reasons we were selected.

And so our 2,000 employees or data grabbed from them, and all those results were shared. As you all well know, in 2012, we had a lot of followup conversations and meetings with all of our employees about what that meant, offered health screening. And as Ed said earlier this morning, it was pretty much a non-event for us, but we continue to ask the question because we value our employees, and it's the right thing to do.

And so part of the reasons that we were asked to talk today was, you know, what our mine looked like and what it was like then versus what it is like now is dramatically different. And if you don't believe, you can ask some of my employees' grandfathers, and they'll tell you what it was like when they worked in the -- you know, in the '50s and '60s.

So obviously, we introduced diesel into our plant in 1947. As you all have heard today from lots of manufacturers, lots of change, new regulation, new technologies. One of the things that we do -- and it came up over and over again, the maintenance. Our predictive, preventative maintenance program is very much valued. We put a lot of time and effort into that. We track all of our individual pieces of equipment. We do a lot of our PMs. Our intent is to get the maximum efficiency for good business reasons, but also impact what the emissions will be.

Also, in 2008, we put in a new crushing and spinning plant. The so what of that is we moved what was from the surface or near to the front of our mine back into the mine a couple of miles, so we eliminated about half of our haul trucks and installed nearly two and a half miles of conveyors and electric motors. And so, you know, we eliminated a bunch of diesel particulate matter.

We have been using bio blends for over 10 years. And, yes, sometimes it's difficult. We have multiple tanks, and our delivery trucks that drive out to our equipment blend out of them, so there is more -- our trucks are more sophisticated. It takes, you know, a higher level of operator than just the normal person going up there and squeezing a nozzle and filling a tank. But that has worked pretty well.

Recently, I will share the assistance of CAT we were rebuilding one of our large loaders, and asked them to do some additional analysis on that engine to look for additional wear and tear because of the concern about biodiesel. And I think they were as surprised as we were that they basically said if you didn't tell us that was a biodiesel engine, we couldn't tell. There was almost no distinguishable difference. So that was a CAT 990 loader after 22,000 hours of service going through its first rebuild. And so we actually had some more hours left in that machine.

The presentation of the group before -- a vast majority of our operators now work in climate-controlled cabs. You know, we check those cab filters weekly. That's a weekly PM. If they need to be changed, they're changed. We maintain our cabs. Sometimes I get a little bit upset by how much dirt we get in the cabs, but beyond that -- a lot more use of water not only on our roads to maintain our roads so that we're not beating up our trucks, but to keep the dust down.

And a lot of the newer equipment, especially the drills, have a lot more, you know, dust-suppression systems, so we just -- you know, we just have a cleaner mine, so you just don't have as much going on there.

Well, the purpose of the conversation was to talk about the barriers or deployment. And from a practical point of view, you've already heard one of them. Well, actually, I'm skipping ahead. Sorry. Because we maintain our equipment so well, we have stuff that lasts five and ten years. And so part of the issue is how fast do we change them over. And some of our initial changes and moves into the Tier 4 and Tier 3 -- not so much Tier 3, but Tier 4 engines didn't go very well. We had issues. And so being the beta test site for some things is fine. This one probably wasn't so much.

The stuff that we bought most recently has worked very well. We're not having near as many issues. And we're learning how to handle all the different technologies and the different manufacturers. But it's a challenge again. You got 10, essentially 10, guys down there maintaining equipment, and it's just a lot for them to learn and keep up with.

The DPM filters are expensive. They take time to change, but we're figuring it out, right? The multiple fuel sources, biodiesel on two, three, and before, now that you're in to Tier 4, straight diesel -- okay. So again, you know, we just have to change out our delivery systems to look like -- to make sure we keep all that straight, which is a bit of a challenge, but all handled -- you know, all things that could be handled.

Then one of the conversations from the mine, yeah, we had pickup trucks. We have 25 pickup trucks down there, and when we blew up or burned up our first engine and couldn't figure out what happened, the vendor came back and said, well, you never drive it over 25 miles an hour. That's not going to work.

So we had to license -- because we're a

drive-in, drive-out mine, we just literally licensed all of our pickups so they could go over the roads and like once a month one of them gets used to go to pick up parts. So we get it out at highway speeds, and it runs the highway speed, and that seems to have worked for the most part. We haven't had as much problem. But we had to get them licensed to get them out on the highway to get them up to highway speeds so that we could get them to the regeneration.

And the same way with idle time on trucks, which was not necessarily a good thing that we learned that we figured out that we had more idle time than we thought, so we added some new -- with the use of the vendors, you know, if the truck idles too long, or if it's cooled down, you know, we'll get them -- we'll shut them down so they don't just sit there and idle.

So that was -- you know, that was something that we learned that we didn't even know that was -- that we corrected.

In terms of continued progress, in one of the first presentations this morning, when we looked at our data for our DPM exposure, it has dropped from 2007 through 2017 very similar to the data that was presented this morning. We're less than a third of what we were in 2007. And we're only 10 percent of our fleet at Tier 4. So I'm optimistic that's going to drop more because, you know, as we clean up our emissions, that will move along.

We already talked about making our control networks under ventilation systems smarter, treating it like a process instead of just a big on/off switch, keeping track of where we're at. The machine -- the data we get from the machine, the use of machines to minimize exposure -- we talked about scaling. I saw a presentation on scaling. We're getting into more and more mechanical scaling. And the other thing that we've just implemented last year is a lot of CAT and lots of the big equipment manufacturers have the satellite uplinks where they collect data from machines, including condition monitoring, which is indicative of how well the machine is running. You know, bad machines mean probably more emissions.

We have actually installed a piece of software based out of Canada, Symbotic, where we're collecting data from all of our big pieces of machines. Now, it's not continuous, so our haul trucks go by nodes. We've installed nodes in our mine. They go by the node. It downloads the data, goes into a central place where we can monitor and look for conditions.

We've actually included not just equipment, but seatbelts, are the seatbelts on, if they're driving more than 25 miles an hour. All of those alerts come in to our control system, our control center, if you will, which is where the supervisors -- one of the supervisors sits. And so, you know, it's a safety, environmental equipment monitoring system. So we're applying some of the things we've used on the surface for years in controlling continuous operations into the mine to better optimize what we do.

So that's all I have.

(Applause.)

MR. WATKINS: Good afternoon, everyone. It's an honor and a privilege to be here today. I've really enjoyed the presentations. Hats off to Mark and Ed for putting the program together. Really enjoyable, and I learned a lot. We appreciate it.

My biggest job for today is to get us back on schedule, and I think I can do that. Got a fairly short presentation, three or four slides to get into. I'm going to change gears a little bit, pun intended. The presentations today that we've heard, you know, like I said, they've all been great, and they've all been geared towards, you know, reducing diesel particulate matter, whether it be in a coal mine or metal/nonmetal mine.

I guess I should start off by letting you know I am with MSHA. My name is Tim Watkins. I am the Administrator for Mine Safety and Health Enforcement. And as you can see from the bio, most of my experience, you know, has been on the coal side. I am quickly learning the metal/nonmetal side. I got a lot of people helping me do that. But, you know, some of the examples that we have going forward and that I'm going to give you, maybe talking more about the coal side just because that's, you know, a bit what I'm familiar with more.

But nevertheless, one of the questions came up this morning, and it also came up, you know, with light-duty, heavy-duty, and permissible equipment. One of the charts that we've shown at these meetings in the past, you know, both those numbers, you know, add a little bit. It's included in this presentation simply, you know, due to the fact that we have given this, you know, information out before.

But again, on the coal side, there is approximately 5,000 pieces of diesel equipment being used. You know, 6 percent of that equipment is light-duty. Okay. Permissible makes up about 7 percent of that equipment, with, you know, heavy-duty being around 25 percent. And we have another category that makes up the rest of it.

So I know those numbers -- those questions came up before, been floating around, about how many pieces of diesel equipment we have, and so I wanted just to throw that out there real quick so people would -- so each of you know at least on the coal side the number of equipment that we're dealing with.

The slide that you see on -- you know, on the screen now, I think actually reflects, you know, the industry as a whole, not MSHA. It's not -- you know, not any one person. It's the industry as a whole and what they've done to embrace new technology and to reduce, you know, diesel particulate matter in mines.

The first slide, you know, deals with coal. Of course, coal, we don't measure diesel particular matter per se. We actually take samples and measure the CO and NO_2. So what you see on the slide goes back, you know, five, six years, back to 2013, and it actually has the number of samples that we have collected on the left slide, and you'll see a slash, then you're followed by another number.

Well, the number on the right side of the slash refers to the number of citations that have been issued in this timeframe. So you go back and you look at this relatively low number, especially percentagewise, number of citations that have been issued over the years. And again, I think that's a testament to the industry as a whole.

One of the things that you've probably heard just this morning was a little bit of the fact that we're increasing our samples. So the first slide that I put up shows that that, you know, we have a decrease in the number of samples that was taken from 2017 to 2018. So I want to talk about that just briefly.

You know, with coal there isn't a set number of samples that's to be collected. We take a representative number of samples, you know, throughout the year. We try to achieve around 10 percent of the samples -- back up -- 10 percent of the equipment out there being sampled.

So year to year, it's going to vary a little bit. We have achieved -- we have maintained that our sample is at 10 percent. We have at least 10 percent of the equipment being sampled, but last year we did sample less than we did, you know, the previous year. I don't expect that number to continue to decrease. You can expect that that number will rise, and we will put more emphasis on getting out and sampling more on the coal side.

I think this slide is one that you've probably seen the very presentation when Jessica put it up. It has been referenced two or three times after. Again, this goes back to the job that the industry has done in reducing the DPM. This slide is actually for metal/nonmetal. And you can where we were 15, you know, 16 years ago back in 2003. You know, with -- and now and then, we'll have a blip and we'll have, you know, an increase in the average concentration. But, you know, the line that you're looking at, whether you're looking at elemental carbon or total carbon, you know, it's got a good trend, that one -- we always like to see those trends going in that direction -- but also a pretty good -- a pretty significant, you know, decrease.

So again, that goes back to what everyone in the industry is looking at, what needs to be done, taking -- you know, looking at their samples, and whether it be retrofitting or new equipment or whatever the case may be, you know, after-market stuff, what you're doing is working.

And this slide is very, very similar to what you saw in the first slide. For this one, this is the sample they exceeded, the 160 micrograms per cubic meter of dust and -- diesel particulate matter rather -- in metal/nonmetal mines. Again, this is the number of samples that we've taken. On the left you see last year we did increase the number of samples that were taken at metal/nonmetal mines, and on the right side, you know, there is a number of citations that were issued.

Again, the number of citations -- well, the number exceeded for metal/nonmetal, you know, percentage-wise is more than what it was on the coal side. Again, you're not really taking the same comparison. But even at the -- you know, at the low-right, 2018, you know, 731 samples were taken and only 49 exceeded above the limit.

One of the things that metal/nonmetal have done in 2018 that kind of drove that number up a little bit was for the first time we actually sampled every underground mine in metal/nonmetal for diesel particulate matter. That's not to say -- I'm not going to tell you we sampled every piece of equipment, but we did sample every underground mine in metal/nonmetal. At least one piece of equipment was sampled.

So I think that's the biggest increase, the biggest cost of that increase that you see on this slide.

One of the good things about going this late in -- I guess in the presentations is a lot of the topics that -- you know, for example the challenges of ventilation and maintenance. How many times have you heard ventilation and maintenance mentioned today? You know, it's quite a few times. By far the vast majority of the citations that were issued were due to ventilation issues. You know, so that's where the correct, you know, upping the ventilation. We had numerous speakers talk about the cost of increasing ventilation.

So by far -- I'm like everyone else. The easiest and best solution to lowering the diesel particulate matter in the mine is to reduce it at the source. You know, if we can reduce it coming out of the engine, that's just less we have to deal with, whether it be by ventilation or by maintenance.

And from -- let's see. For the last 10 years, going back 10 years, at least on the coal side, and looking at the number of issuances that we -- the citation that we issued due to maintenance, we average about 13 citations per year on maintenance of equipment. That's different than the first slide that you've seen.

So for the last 10 years, you know, we've had 130 issuances on maintenance. You know, it makes the math pretty easy to figure out. That's roughly 13 citations per year that we've issued on maintenance of equipment. You know, we talk about training a lot. You know, people talk about training of the mechanics, training of different folks in the mine.

But also going back to training of our examiners. You know, when we're looking at ventilation controls, making sure the ventilation controls are installed correctly, make sure that they're maintained correctly, no holes in the tubing, and so forth. Maintenance of our equipment, you know, getting our mechanics, getting our folks trained on maintaining that equipment. It all goes to reducing the -- you know, the diesel particulate matter that's being produced.

So with that, I'll close.

(Applause.)

MR. ELLIS: Okay. We got about 10 minutes for questions, so why don't we start with questions from the audience? And if you would, please state your name and your affiliation, just for the court reporter.

MR. TURCIC: Is it on? Yeah. Pete Turcic.

I'm with Eagle Research. Mark, I just wanted to point out there was a lot of talk about things that are, you know, an impediment to getting new equipment underground. And I just wanted to point out that when we originally wrote Part 7 for the diesel equipment approvals, we had a -- we put in there the particulate index.

Now, the particulate index today really has no valid use anymore. I mean, I don't think anybody uses the particulate index. And the reason it was in there was we wrote part seven before there was a standard, so we didn't know what the standard was going to be. And so that's why we put the particulate index, and there is a lot of effort that goes into that, you know, maintaining that and testing to that.

So more manufacturers may come in if you reduced, you know, a standard like that that there is just -- it's not even used anymore.

MR. ELLIS: Or maybe give it a different basis in fact rather than one that's --

MR. TURCIC: Well, exactly. What could you do, the information -- really, if you just looked at what the standards are in Tier 4, you can easily convert, you know, what the minimum -- the maximum DPM is, convert to -- you know, and see what the particulate index would be.

MR. ELLIS: Okay. Thank you.

Other questions? Don't do this to me because if you don't ask a question, I've got to come up with one.

(Laughter.)

MR. ELLIS: All right. So, Art, you know, this technical advisory committee -- and Ron Bowersox is in the audience. There you go, Ron. When you were describing it, it sounds a lot like MSHA's petition for modification process, you know, and that's an internal mechanism within MSHA to deal with things that vary from the standard. And you're dealing with this as more of a collaborative kind of approach between an industry rep and a labor rep that offer recommendations to you as the agency. How do you find that working?

MR. BROWER: I've been involved with it for about seven years, and we haven't had any issues with it. I don't think we've had a conflict or anything that hasn't been resolved.

MS. SILVEY: Excuse me. This is Pat Silvey. For the court reporter -- it's a lot different. You know why? Because he gave one example that happened. They reached a decision in a month. MSHA's petition for modification process, all due respect, couldn't happen in a month.

MR. ELLIS: Well, they got the right answer, though, in a month, you know.

(Laughter.)

MS. SILVEY: They got the right answer, I'll give them that, right? I'll take my hat off. We're going to try to expedite it.

MR. ELLIS: Point taken. Yeah. I mean, part of what we're doing here in this workshop is having a dialog. You know, we want to have give and take with everybody so that we find out what issues are left to be explored. And that's really part of what this Partnership is about. Let's identify the issues that are unknown so that we can bring some certainty to what we're trying to do in terms of keep people safe and healthy.

So again, just offering different ideas.

MS. SILVEY: As a follow-up to Tim's presentation, I'd like to add we will not forget the question you raised after our panel this morning. Some of the -- and particularly, I think in metal/nonmetal area, where we had exceeded above the limits on DPM, diesel particulate matter, and when we will be sharing with everybody some of the things, even if just in a summary, generic way, some of the best practices that were implemented. Some of the information controls, changes, those kinds of things because most likely, if anybody, whatever mines, if they had experiences with their exceeding since they can benefit from that information, and the mine.

MR. ELLIS: Thank you for that.

Ed.

MR. GREEN: Thank you, James. Ed Green with Crowell & Moring. Further to Pat's comment and Arthur's comment about the way they resolve issues in Pennsylvania, I was taken aback by the data that Tim showed in terms of the number of samples taken of those out of compliance. They seem to be a pretty significant number that were out of compliance.

MALE VOICE: I was surprised by that, too.

MR. GREEN: And I was particularly taken aback by it because going back to the experience of the coal mining industry with regard to the respirable dust standard and MSHA's touting of -- touting is, I guess, a loaded word -- but MSHA's demonstration that the data that it has shows that the industry is in virtually complete compliance with the new standard. So you've got a fairly substantial percentages of samples out of compliance. What does MSHA do to fix them, or what does the operator do to fix them? I think that's probably related to what we're talking about.

That, I think, would be very valuable in terms of aiding MSHA as well as stakeholders to do a better job.

MR. WATKINS: Well, I think the vast majority of those corrections were, as we mentioned before, ventilation issues. Okay. So whether it be, you know, adding more air, taking care of what you got as far as the ventilation controls, the vast majority of those were corrected with ventilation.

Now, I'm sure there is probably others that we've done case studies at and had -- actually had tech support come out and do some other studies. But like I said, the vast majority of those were corrected by ventilation. I'm sure maintenance, you know, of the filters and the after-market, you know, filters played a role as well, but by far the vast majority was the ventilation.

MS. SILVEY: You know, not to disagree, but I guess I can. I would say -- this is just my gut feeling because we're going to get the results from the data. I think Tim is right when he's talking about coal. I would say -- my gut tells me that in metal/nonmetal, we are probably talking about a combination of things in terms of training, maintenance, probably -- and I don't know what mines. I have not a clue what mines we're talking about. But probably some of the mines had the greatest problem from the beginning, and you all know one or two of those. And so you're probably talking about a little bit older equipment, so for metal now, the mine.

So you bring all that together, the combination, and that's probably why you've got a little bit higher percentage. But what we're going to do is we're going to dig into the numbers, and we're going to give you a summary of the predominant reasons. But like I said, I think Tim is right about on the coal side. But on the metal/nonmetal side, it's probably a little more complicated than that.

MR. BROWER: I'd just like to add, when you look at --

MS. SILVEY: I'm sorry we keep blocking you, James.

MALE VOICE: That's okay. I need the exercise.

MR. BROWER: When you look at the percentages, for example, for the coal/non-coal or the metal/nonmetal, it's 7 percent last year. But that doesn't really tell you a lot. If they only exceeded the limits by 1 percent --

MS. SILVEY: Right.

MR. BROWER: You see what I'm saying? It's only partial context there.

MS. SILVEY: No. That's true.

MR. GREEN: Just another comment. Terry, congratulations on the work that you guys have done at Mississippi Lime. You know, being familiar relatively speaking with the data from DEMS, Mississippi Lime was the outlier in many respects. And I guess you have to be Saul before you can become Paul, and you guys have done a great job based on your presentation of really turning the operation around. Congratulations. Well done.

MR. ZERR: I will thank you on behalf of all of our employees. But, yes, we work at it every day.

MR. ELLIS: I'm going to ask one last question because load came up a couple of times, having to do with clearing particulate filters. Terry, you have a unique situation because you're able to take your vehicles out on the road. And I know you had to go through some highway approvals to get them able to do that.

MR. ZERR: Right, right.

MR. ELLIS: How about some of your situations, Steve? You know, I mean, you're operating maybe at 10 percent of what your load would be to clear the filter out, and you're not able to do it. I mean, what kind of problems does that present?

MR. COCHRANE: Well, with the Tier 4 technology, it's going to create a real bad problem because, you know, with the engine being governed and everything else, we're not going to be able to do that on the ground. We're going to have to take that truck out on our haul road and do that, and then you've got pickup trucks driving around with haul trucks. You're just going to create a massive disaster here.

Now, this 25 mile an hour comes from the manufacturer. And from my understanding of where that came from was the engines are built outside the country, and the government was worried about, you know, these engines coming into the U.S. and not having any of the after-treatment systems on there. So that's where this 25 mile an hour came from. And it's going to cause a lot of problems. We just -- we cannot -- we're going to have to turn that system off somehow. And if you know anything about coal miners, as soon as they know that there is a way to turn something off, they're going to turn it off.

So we can't have just a toggle switch to flip the system off either, so --

MR. ELLIS: Good. Thank you.

AUDIENCE MEMBER: Yeah. My name is Ryan Bender. I'm with Martin Marietta. And we have large room-and-pillar limestone mines as well, and that has been my primary experience. And we've got a lot of -- all levels of engines, the early Tier models and, you know, stuff from the late '90s even yet, all the way up through the very modern, brand new equipment with just a couple of hundred hours on it. And we've actually had an experience where some of the new Tier 4 engines can go into a work area and clean the air up, working adjacent to some of the older equipment.

Now, obviously not a permanent solution, but in certain cases, you know, if you're running a little older haul unit and all of a sudden the air gets better, I was wondering if you had had a similar experience.

MR. ZERR: No, but we now it's possible. I mean, I know the math and science you're talking about based on the exit. In fact, the engine manufacturers can talk about that even better. In our environment in a Tier 4 engine, likely what is coming out the exhaust is cleaner than what is going in the intake, air intake, because of what it does.

Now, that's a pretty expensive air filter. So I'm not going to run around a bunch of trucks to clean up the air. We're going to focus on keeping it clean to start with.

AUDIENCE MEMBER: No, absolutely. That -- I wasn't trying to suggest that that's a permanent solution, but it was kind of a benefit we didn't really see coming out of the gate. We bought a new loader, and all of a sudden, the three trucks that were running with it, the air improved.

MR. ZERR: Yeah, no. We've seen that, too.

MR. ELLIS: All right. Well, we'll consider this panel concluded. Thank you.

(Applause.)

MR. ELLIS: We're on break right now, so if you would, please try to be back by 3 o'clock.

(Whereupon, a brief recess was taken.)

MR. FRANCART: Okay. We're ready to start the final panel discussion of the day. Thank you for hanging in there with us. We really appreciate the attendance and the attention you've paid today, much appreciated by all the panelists.

This panel is entitled Strategies and Path Forward. We were scheduled to have three panelists.

Unfortunately, Faye Swift, who is an employee of the EPA, could not be here because of the partial government shutdown. And her presentation was to discuss incentives that the EPA provides for the deployment and implementation of technologies for improving air quality for diesel engines. So she will not be here.

We do have with us Rashid Shaikh, who is Director of Science with the Health Effects Institute, a nonprofit agency. He has a PhD from MIT. And Dr. Aleksander Bugarski, who is a research engineer with NIOSH, a PhD with the West Virginia University.

I have to tell you I'm a Pittsburgh native, and I cheer for the Pittsburgh teams. Of course, they're terrible this year. I'm just happy it's hockey season finally, get out of football. I'm a Penn State grad, and we lost to Kentucky, and I just can't do anything right this year.

But we do have --

AUDIENCE MEMBER: It's hockey season now.

MR. FRANCART: It is hockey season. And if you're a Capitals fan, can you raise your hand? I'm sorry about last night's game. It was really a great win for the Sharks. If you didn't see the game, the Sharks scored with one second left in the game to tie the game, and then won in overtime. So Penguins fans are happy today.

So without further -- pardon?

AUDIENCE MEMBER: We still got a point.

MR. FRANCART: A point. I'm glad you're happy.

(Laughter.)

MR. FRANCART: But without further ado, we will go ahead and get started with Dr. Rashid Shaikh.

Rashid?

(Applause.)

MR. SHAIKH: Thank you, Bill. So I come to you from Boston, and I have to confess that I'm not into sports. If I were into sports, I would have colorful stories to tell you about all the teams that we have in Boston. But I'm sorry. I can't do that. Actually, I live in Cambridge, so I guess I'm absolved from being too much into sports just for that reason.

But I'm glad to be here, and I'm actually honored to be speaking in the Cesar Chavez Auditorium. It's a nice -- it's a very nice touch to this day. Let's see. What I'm going to do today is I'm going to tell you a little bit about the Health Effects Institute and the work that we support on and what we have done on these engine emissions. I'll tell you about who we are. I'll tell you about a couple of the studies that we have been involved in, and then I'll tell you some of the conclusions and some useful information.

You know, one of the advantages or disadvantages of being at the end of a day of speakers is that many things you wanted to say have already been said. So you can cut your presentation short or you can prolong it, hoping that people have forgotten things that were talked about in the morning, so that this will be reinforcing them.

Nevertheless, the Health Effects Institute, what is it? It's an independent, nonprofit institute that provides high quality, impartial scientific information for the last about 40 years. It gives balanced core support from the US EPA, the government, and the automotive industry, the worldwide automotive industry. But we also have additional partners from time to time, including support from DOE, Department of Energy, oil industry, and from foundations.

The way we are governed is that we have an independent board of governors -- of directors, so the representatives of the sponsors don't serve on it. And a lot of our work is done through expert scientific committees that develop, oversee, and in terms of the peer review all of research. We have published some 350 scientific reviews, re-analysis, and various other studies that are all available on our web site. We do not advocate public policy positions. We are a scientific research organization.

And our activities include, as I mentioned, a lot of original research, as well as re-analysis that we have done in a number of areas. We have re-analysis of clinical studies. We also do authoritative literature reviews from time to time, and we have a very global program in global health, where we look at issues in middle and low-income countries, and very recently we have started an energy research program that are looking at pressure exposures and from unconventional oil and gas, otherwise called fracking.

So that's a little background. Now, let's see. Why won't this move? I cannot advance my slides. Oh, there we go.

So you've heard about this during the day today. On the right-hand side, I show how diesel emissions have gone. The diesel emissions regulations is for highway trucks and lighter vehicles -- have gone down tremendously, really precipitously, from the 1960s and '70s to now, where we are in 2018, somewhere there. And this has happened in large part due to health effects studies. And the health effects studies have shown from in vitro studies that PM extracts have mutagenicity. Inhalation studies with PM, diesel PM, have shown carcinogenicity and epidemiology studies have been suggestive of lung carcinogenicity. And as you heard earlier today, the IAPRC, International Agency Panel for Research on Cancer, which is part of the WHO, declared in 1988 that the diesel exhaust is probably carcinogenic, but in 2012 upgraded that, so to speak, to say that diesel exhaust is a known carcinogen.

And we have heard a lot about this today earlier. And these kinds of things led to a number of national and international bodies to implement a number of regulations having to do with exposure to diesel emissions. This is what we have been talking about today.

What HEI has done most recently has been two major pieces of work. One is called the ACES, the vast collaborative emission studies. It's the most rigorous and comprehensive investigation for new technology diesel engines that have DPF, SCR, meeting 2007 and '10 EPA regs. This involved emissions characteristic of four 2007 engines and three 2010 engines, it should say. I'm sorry there is a typo there -- a health effect testing in animals from emissions for a 2007 engine.

And then we have also done some recent work on diesel emissions lung cancer epidemiology, including the DEMS study, about which I will talk very briefly, and you have heard about that earlier today, too.

The rationale for the ACES study was that we need -- we wanted to confirm that the new -- this was in 2004 or '05 when this was being planned -- that the new technologies that were being introduced, after-treatment technology, was in fact going to do what it is supposed to do in an impartial kind of a setting using engine from different manufacturers with the best available methodology that could be used. And also, we have some -- not a concern, but we wanted to show that all the most pollutants would be decreasing, that no new species of pollutants were being formed in those technologies that you could detect.

The design, as I mentioned very briefly, was to emissions characterization in phases one and two. We were using the FTP cycle, which is a federal transport cycle. I don't know what it's called exactly. It's a cycle that the EPA uses with certification testing, but we also used a 16-hour cycle that was more rigorous than the standard federal cycle. We used four 2007 compliant engines that -- so these engines had DOCs and DPFs -- and three 2010 compliant engines, so these had both DOC, DPF, as well as SCR.

And you saw a version of this earlier today. Basically, what you're seeing here is that compared to all engines, like here for 2004, the mass emissions go down very significantly, by 90, 95 percent or more. In fact, just so that you could see this, I have enlarged that here so you can get a little sense of the 2010 emissions were lower, although the emissions had not changed.

So this is the standard -- the standards based on mass emissions. So you see that we were -- that these four engines were meeting, actually exceeding, the 2007 and 2010 standards.

PN, which was mentioned again earlier today, the particle level emissions also went down very significantly, really about 95 to 99 percent, when the 2007 and 2010 engines were tested. And -- oops -- this slightly -- with this slide, let's talk -- let's go through this one at a time.

So this is about research in NO_x emissions.

So remember that 2007 of phase one year did not really involve the testing of -- or the decrease of NO_x emissions, but 2010 standards did. And you can indeed see that the levels go down. This is the standard, and this is where the testing for the three engines in this case was. And the same thing is true for 2007. These are four -- these are the average of four things.

Just comparing 2007 and 2010 engines, you can see on the right-hand side how everything was kind of going down, NO_x, NO_2. CO was going down even compared to 2007 engines. In the 2010 engines, PM and soot and everything else was going down. CO_2 was about -- was a slight decrease, so what it says is that using SCR did not have an impact on fuel efficiency to any great degree. It was a very small effect, if at all.

And this slide, this graph here shows how the composition of the particulate matter changed, going from an old engine to a 2007 and '10 engine. And someone mentioned this morning that you -- I think Tim mentioned this morning that you see a lot more OC and a lot less of some of the other things. But keep in mind that you're now talking about a tiny, tiny mass. It's not a lot of mass that is coming out of

2010 engines. In fact, you have to really look for it very carefully.

So these after-treatment technologies are highly effective by lowering PM and PN by 95 percent and more. NO_x was lowered by more than 90 percent. All regulated emissions exceeded -- actually, the emissions met or exceeded the standards. And there were some other toxic compounds -- this is an important point -- such as the VOCs, SVOCs were lowered by 80 to 99 percent, and PAHS and nitro-PAHS were down by 99 percent.

These lighter compounds, polycyclic aromatic hydrocarbons and nitro polycyclic aromatic hydrocarbons are important because a lot of the carcinogenicity of diesel particulate emissions resides in those compounds. Not all of it, but a substantial part of it. And no new compounds were detected, so it's not like some new thing was coming out of the tailpipe all of a sudden.

There are some limitations of these that we should keep in mind. These are laboratory testing, of course. By design, it's not real-world testing. We have heard some issues about DPF, old DPF, and when vehicles have gone 500,000 miles or so, begin to show some problems in small numbers of trucks. SCR has problems under certain conditions. This has been well discussed and well studied. We haven't talked about it today, but in operation, especially at low temperatures, their SCR will not work as effectively as in other places. But this really is just to convince you if you needed any convincing that the after-treatment technologies work extremely well.

So the ACES phase two -- here, the hypothesis was that so all diesel engine, when you expose animals to it, gives rise to cancer. That has been one of the reasons that car -- I'm sorry -- IARC has been pursuing this issue so vigorously. The question was whether the new -- emissions from new engines would also produce any health effects, especially cancer.

So we went out -- we looked to -- we developed a study to test this in an animal model. Here, the hypothesis was that emissions -- these emissions will not cause an increase in tumor formation in the lungs, although you may see some other effects because you'll be exposing animals to high levels.

The design was to give as high a dose as possible to these rats. These are called Wistar Han rats, which are susceptible to lung cancer, and we exposed them for 30 months, which is really about the end of their lifetime, their lifespan. The exposure was to a 2007 engine for 30 months at 16 hours a day for five days a week. So it was really pretty high level of exposure.

There was too little PM coming out of the tailpipe, so the emission levels were tailored to NO_2 levels, and there were four levels, high, medium, and low emissions, plus clean air, and there was extensive monitoring and sampling of exposure, and those animals were sacrificed at 1, 3, 12, and 24 months, and terminally at 28 to 30 months.

And this is just a little picture to show -- this is not the right chamber, but chambers like this is where you expose these animals. And you cooled the room because there's a lot of heat coming out of the diesel engines. But the major findings is that there was no increase in tumors in the lung or at any other site in these rats. There was some minor effects on the lung, but these were believed to be caused by NO_2 exposures, and we are pretty sure of that based on observations, one-year observations, in studies where pure NO_2 was given to animals. And some hundred or so endpoints were studies in these studies, but very few showed any changes, and these changes were related to mild pulmonary inflammation and oxidative stress, generally observed at the highest dose, and generally observed in only one sex.

This was a major difference from studies with old technology diesel emissions where you always saw a lung and other -- not always, but in most of those studies, you saw lung tumors and other effects. We also did a number of ancillary studies that showed no genotoxic effects or cardiac or vascular changes. So this confirmed the study hypothesis that exposure to new technology diesel did not cause an increase in lung tumors.

And just to show you that I'm a bit of a biologist by training, I had to show you some histopathology slides. These are sections of rat lungs. You section them very, very fine, a few micron, and then you stain them so you can see the cells. And when you do that, you find that ACES clean air control and the ACES high exposure were almost the same. There was really no difference. But if you had taken a look at old diesel exhaust, you see extensive changes in the lung. You see a soot deposit in these black kind of alarm rates or a soot deposit. All kinds of other things are going on in the lung. So this was a major, major change.

So more recently, as a number of people have mentioned today, we were involved in -- we looked at the DEMS study that had been published by NIOSH and NCI investigators. These studies, as was mentioned earlier, overcame a number of limitations that characterized the older studies. These new studies, especially the DEMS study, looked at more than 12,000 miners who work in nonmetal mines, and the data were made available by NIOSH and NCI, which was really fantastic because then a number of people could look at them very carefully.

HEI set up a panel of experts to look at that, and the panel concluded that the exposure from -- well, just to keep in mind that these are exposure from old technology diesel engines, and they go back a long time when exposure levels were relatively high. The DEMS study carefully worked over an extended period of time to develop historical exposure profiles. But the panel basically found that the association between exposure and lung cancer reported can be replicated and are found to be robust, but many uncertainties remain, and these have been studied by Silverman, but also by HEI, and also a lot of other investigators.

And these other investigators, as was

mentioned earlier, include very good work by people like Kenny Crump and Suresh Moolgavkar and their colleagues that were asked by the EMA to look at these studies, and a number of these people have -- four or five of these people have been published in the literature in the last many years.

So where does this leave us? I think, clearly, the old technology diesel emissions have a lot of problems with toxicity, including animal carcinogenicity and human epidemiology studies that show an association, and many national and international bodies have taken action based on that. New technology engines are highly effective at reducing emissions of PM and toxic compounds, and do not produce cancer in animal tests. And it's an ideal way to reduce air concentration exposure.

Now, so this is in a way sort of a repeat -- some of this is repetition of what you have been hearing all day today. But I hope this background in health effects would give you some more fodder, if you needed any, to understand why it is so important to reduce these emissions.

But before I leave you, I want to tell you about something else that is not from the diesel world but from ambient emissions. So this is basically what you -- what all of us live and breathe in, and these levels are very low in the U.S. and most of the industrialized countries. This is a paper that was -- this is based on a paper that was published in 2012 by a group of Canadian investigators, and the main finding is on this right side here, where you see with a true curve showing relative risk versus PM 2.5, and the numbers are very small. This is 15 micrograms per cubic meter. Here's 10, and here's 5. The current U.S. standard is 12, and the WHO guidelines are at about 10.

But what you see here is that a large -- in Canada, half the population lives below about 10, but the risk curve keeps going down, suggesting that there is a risk to people who are living even at very low levels of emissions -- of ambient air, ambient air pollution.

There were a lot of questions about this study, and some years ago, we -- a couple of years ago, we began funding three massive studies, one in U.S., one in Canada, and one in Europe, and the goal was to rigorously test whether these low levels of emissions -- these low-level effects are quite real.

These studies that we are funding are not complete, have not been completed. I hate this thing.

Okay. But there are two major papers that were published by Harvard investigators, one in *JAMA* and one in *New England Journal of Medicine*. And I'm just showing you one graph from the *New England Journal of Medicine* paper. And I want to tell you that HEI is currently reviewing this study, so at least although this is published in *New England Journal*, we still take a look at it very carefully to make sure that the findings are robust and appropriately expressed and that we can reproduce them as much as we can.

But what the investigators find is that -- is evidence for concentration response relationship for PM to very low levels, maybe -- I wouldn't -- I don't think this is as quite robust, but certainly below the current standard of 12. They're looking at 66 million Medicare enrollees, so the confidence intervals are very narrow. Here, this is ozone, and this also goes down quite a bit below the current standard, although the confidence intervals here are quite a bit wider.

They're doing additional analysis and more detailed work in Medicaid database, where a lot more covariant information is available. But I show you this only to make the point that new evidence is emerging that suggests that we might be seeing health effects at levels far below even our current ambient levels. And that's an important message. And if these studies at all turn out to be robust and well-supported by other evidence, this will be a big challenge for us over how we think about air pollution control.

But, in the mining environment, I think this is an added incentive, if you needed any, that exposures should be decreased, and there is very strong evidence from health effect studies, not just these studies but the other studies we have been talking about, that it is important to do that.

So let's see. Well, there's just some acknowledgments, but I'll stop now. Thank you very much.

(Applause.)

MR. BUGARSKI: My name is Aleksandar Bugarski, and I'm with NIOSH, Pittsburgh Mining Research Division. I really enjoyed today's meeting. I think we had pretty good discussion and we covered a lot of stuff. I still think that there is a little bit of misunderstanding what we are dealing with. I think complexity of the problems we have within mining industry controlling diesel emissions are much higher than, you know, it was even painted today. And the reason for that, we have a wide variety of engines and vehicles used in underground mining. And it's almost that we are facing little bit more of trouble than probably EPA faced with on-highway vehicles because almost any particular application in a mine has its own kind of quirks we need to deal with, so we are dealing with very extensive problems which need to be really micro-targeted.

So I'm going to talk a little bit about something, what we kind of typically neglect when we are talking about diesel emissions. It's light-duty vehicles, because most of the people and efforts and money is invested in controlling emissions from heavy-duty vehicles. And the reason for that, because they are big, nice, yellow, orange, and they're showing at the work sites. And people think because of the vicinity of those vehicles to us, to the operators, basically, that they are primary source of exposures.

They are, but, of course, something what is neglected because of the size of these are aerosols, and we are talking about sub-100 nanometer aerosols which are floating through whole mine. Then basically every diesel vehicle operated inside the mine is a potential contributor to the exposure of operators.

So we cannot neglect the contribution of other vehicles in a mine and focus only on nearby vehicle to the operator. And I think that's mostly obvious to the mines which do not have very good ventilation, particularly do not have very good local ventilation. And I think, if anything, DPM regulation showed that we might need a little bit second insight into how we are ventilating metal/nonmetal mines because there is no really prescriptive solution like there is one for the coal mines. And I think most of the DPM over exposures are a result of the lack of adequate ventilation.

And then, of course, something is changing over the time, particularly in the past two decades. We put a lot of effort in heavy-duty vehicles. So these engines are there because of high output, high utilization factors, and role of, you know, production righteously addressed. And medium-duty and light-duty vehicles -- those are all kind of support vehicles we see in underground mines in large quantities -- are typically neglected.

And then, over the time, you know, our efforts were on heavy-duty, so, basically, now at this point, you know, 15 or 20 years down the road, we need to start thinking about light-duty vehicles.

So what's the definition of light-duty,

heavy-duty, or medium-duty vehicle? There is not one, you know. For the coal, that's very well defined. You know, anything what is moving, cuts or moves rock, perform drilling or vaulting, that's heavy-duty. And then, of course, light-duty are all the other support vehicles.

In metal/nonmetal, when I ask people around what do you consider light-duty or heavy-duty or medium-duty, I never get the right answer because people think in terms of engine output. People usually think that small engines are light-duty. You know, they also think that vehicles which are used frequently are light-duty, or vehicles which are used over light-duty cycle are light-duty.

So there is no real definition. So I'll try to kind of put a little bit of light on that because this fuzziness actually puts us in problems even with writing regulations or demanding controls.

So, as we know in the coal mining industry, you know, MSHA also took kind of easy, you know, approach to their light-duty vehicles because we have 2.5 grams per hour DPM emissions for the heavy-duty vehicles, inby and outby, and permissible and non-permissible. And we have high, 5 grams per hour, for the light-duty.

So I guess understanding was and misunderstanding was translating EPA regulations, which said small engines cannot meet high standards, so we give them a little bit of a leeway. But I'll show you that we are not talking about small engines. And since, you know, we have heard this in a previous session, since there is no monitoring of personal exposure to DPM, we don't know if this approach even worked, you know. The fact is, if somebody tried to find piece of information, as it was discussed earlier, about exposures of underground coal miners to DPM, we are not going to find any number out there because really there was no measurements, and I understand that there are some concerns about accuracy of measurement to DPM exposures in the presence of coal dust. But that's a minor issue. It should not prevent us to know with plus/minus 10 percent accuracy what it is.

And then, of course, when metal/nonmetal comes in place, we have outdated basic requirements for diesel-powered vehicles in underground mines. Basically, the requirements are based on MSHA-approved engines or EPA-approved engines from tables shown below. And I dare you to find something like this on the market these days. These are all engines which are phased out like a decade ago. They are all very old, you know, Tier 1 and Tier 2 engines, which are basically, you know, requiring something like this. It shows that prescribed occupational exposure regulations have expiration date. And if you don't update this, this is pretty much, you know, shameful, I would say.

And then about light-duty vehicles, you know, a misconception is -- and, you know, it's like kids would imagine, you know, mines, that we have LHDs and trucks. That's pretty much what we heard today, and that was pretty much what was discussed at MDEC conferences for past several years. Everybody is focusing on that, you know, G 1700 or, you know, HD-30, but nobody is really thinking about that there is much more of other vehicles in underground mines than just haulage trucks and LHDs.

And so let me just show you this. So, basically, there is a diesel inventory for underground coal mines in the United States. MSHA has pretty good grasp on how many vehicles is operated. And as of November, I counted 4918 vehicles in underground coal mines. And, you know, this is a division. So, basically, 3,261 or 66 percent of those vehicles are basically light-duty vehicles. And just recall that all those vehicles emit much more, and they're in the background, and all the DPM emitted by those vehicles eventually get to the face where people work.

And, you know, I looked even by state, and it appears that, you know, it's relatively consistent except with some, you know, states which have very few or a lot of vehicles. So what is important also when, for example, we're talking about that same inventory list that we have 103 different types of the -- and models of engines used in these almost 5,000 vehicles.

So -- and each of those vehicles is -- some of them are similar, but there's a lot of dissimilarity between these vehicles. So addressing emissions from every of -- any of those, it's kind of complex. And then, of course, what is important, that we have broad spectrum of vehicles, assuming that about 20 percent of those vehicles have engines about 130 kilowatts, which is about 175 horsepower. And if you see on this plot, you know, you cannot tell which one is light-duty, which one is heavy-duty by engine output.

So we are not translating EPA decision not to address small engines because -- and light-duty based on that concept because there is no really distinction in the size here. There are technologies to address emissions in these vehicles too.

And then, of course, in metal/nonmetal, you know, I couldn't find it. There was no inventor, you know. Everywhere appreciate an inventor of coal mining industry, but somehow regulations do not require metal/nonmetal mines to compile their inventories and submit to MSHA, so MSHA doesn't produce one, and it's not in the public domain.

I think, you know, for somebody who'd like to know what's operated and what type of action needs to be taken, it will be interesting to have that inventory available. I tried to reach some of the operators I know, and, basically, there was a little bit of confusion about what I'm asking, you know, and one of them is what is light-duty.

And, you know, there are a lot of categories of vehicles which are basically forgotten in a light-duty group, like personnel carriers, side-by-side utilities, you know, and then, of course, there is something probably you never heard of, shotcrete trucks, ENFO loaders, scissors trucks. All those vehicles are there, you know, not only LHDs and trucks, haulage trucks.

So we need to look into these and see how much they contribute, and since they make, even in the metal/nonmetal mines, over 60 percent of the fleets, that would be really important to look into.

And now look, you know, at issues with light-duty vehicles, you know. We heard today about all these potential pathways operators can take where they're resolving their DPM issues, the acquisition of new or repowering existing vehicles with advanced engines and exhaust after-treatment technologies. Science has a perfect solution, and if you look at it from perspective of LHD and haulage truck, there's plenty of options. I'll discuss a little bit what's available for lightduty.

Retrofitting existing EPA Tier 2 and Tier 3 engines with viable DPF systems. If you look at any piece of research done lately on the DPFs and retrofit system, it's explicitly done on heavy-duty pieces of equipment. And they're targeted because they are low-laying fruit. The reason for that is because they have engine operating conditions which favor use of these devices.

Substituting petroleum-based fuels with cleaner-burning fuels, I'll mention that. And maybe that's the one of those control technologies and strategies which can be applied equally on heavy-duty and light-duty vehicles.

And then, of course, improving quality of existing acquisition of new environmental enclosures. That's again where heavy-duty engines and vehicles have much more, you know, effort was done in equipping them with much better enclosures than on a lightduty.

And then, of course, we heard from Brian about substitution of selected vehicles with electric-powered vehicles. And I'll try to address that a little bit to see which of those vehicles is going to have a better chance.

And then about acquisition of new and repowering. There is a lot of space for improvement. This is coming again from the inventory I mentioned earlier. This is a typical representative engine in coal mines these days, beyond the level of Tier 2 or Tier 3, you know, here and there. You know, there are some Tier 3. What is important, 43 percent of non-permissible light-duty diesel-powered equipment emit less than 5 grams per hour, which is legal limit, only 49 percent of that. That means that there is 50 percent of these vehicles which emit more than that.

Then approximately 24 percent of these really emit under 2.5. So that means there are vehicles out there. There are engines in light-duty vehicles which basically comply with 2.5. That means it's feasible. And then, of course, you know, a majority of light-duty vehicles which meet even 5 grams are very tiny engines, under 50 horsepower. So, basically, those engines really are favored by this grams-per-hour regulations because, again, when MSHA wrote these regulations, they gave some credit to light-duty vehicles focusing mostly on heavy-duty vehicles.

And then, of course, there is something what we need to understand. You know, we discussed how we can drive cars for 25, 30 years, and they're still running. There is something what EPA factored in addressing exposures of people in an environment, and that's that there will be attrition. And, you know, for example, 2008 economic crisis adversely affected their models. The reason for that is because they predicted that average American is going to exchange his vehicle in an eight-year period. Of course, economic crisis came in, so that period expanded on 11 and something years. So that definitely affected models and affected predictions about the length of the concentration in environment.

Same is with the mining vehicles or any vehicle, you know. I mean, it's good to keep vehicle on the road, but we have to understand that vehicle is built like 15, 20 years before this age, and, of course, emits much more than any particular vehicle which you would purchase today.

So when you look at it, 15,000 hours -- and I understand operators have these numbers, and, you know, they like to keep their haulage trucks, LHDs, and, you know, other pieces of equipment for as long as they can, and the reason for that is economics, you know. And then, of course, there is two sides of economics. One is keeping an engine running, and the other is controlling emissions.

So -- and then, of course, I also heard quite often, you know, when we are talking about repowering diesel-powered vehicles, quite often those thoughts go, oh, I would find somewhere, as already mentioned, Tier 2 engine because, if I already had Tier 2 engine, and it's easy to repower it with the same type of engine, same waste of effort and waste of the complexity, so people typically go after the same generation of the engines because retrofitting with more advanced engines brings all the technical issues which sometimes people do not want to deal with.

So that's the issue. And then, of course, you know, there's the upside of the whole story, is that there is a small light-duty vehicles which are purchased by mines to transport people around, like Gators or some maybe other pickup trucks. They really do not last that long because they are in a mining world and more like light-duty than really heavy-duty. So, basically, they expire before, you know, the emissions standards expire.

We discussed this today, you know, how much more improvement we can have, you know, and we have to really understand, you know, that you're talking about 90 percent reduction. That means if we would change at this moment all the engines in underground mines, and we are averaging now 80, we should be talking in teenths. That's technological visibility because we have also to understand that regulations which are brought in are visibility regulations. The 160 micrograms is not healthy for anybody. Maybe Rashid can tell me that, because he spent tons of money studying what's happening to the people at the levels of 10 micrograms per meter, and it's not that good.

So, when we think now, you know, why we need to adopt this technology, it's because 15 or 20 years later, after this regulation is introduced, we need to consider the technology advanced and visibility change. So maybe even levels which we are talking about these days are not what is feasible. Feasible these days is better than that. It should be better than that.

And then, of course, there's something what we discussed today, and that's stage 5, Euro stage 5. We're going, you know -- I think somebody was asking why we are talking about stage 5 now, why we are talking about European regulations, and the reason for that is because we parted with Europe. You know, EPA said there will be no more regulations after Tier 4 final, at least for time being. So Europeans kind of went together and they said, you know, we're going to force these regulations which are going to force engine manufacturers to put DPFs on all the vehicles. And the reason for that, because you can tune engine to emit low PM emissions, but, you know, still there will be particles emitted by that engine.

Since we have no real conclusion on that, how many particles is enough to cause health effects, they decided to limit those to a particulate number. Particulate number is regulated by stage 5. So, if you're looking at a perfect engine for this task, that will be stage 5 engine because it's not going only to cut your mass emissions but also going to cut number emissions.

And then, of course, there's something what has probably started and instigated this morning, is we have to think -- you know, I understand it's controversial to us from a mining industry to buy all these new goodies because they're expensive, and it's hard to justify throwing away, you know, a perfectly fine engine and maybe replacing it with new engine. And, you know, I always looked in example of a trucking industry. If a trucker is going to kill for 2 percent saving in fuel, why mining industry can operate 1970s 3306 and burn all the fuel available, you know. It doesn't matter. And then we are talking about, you know, low margins.

And I think what is important to show here, and that this is something what we discussed also -- there is different economic reasons why to do it, and one of them is probably -- and I'm hearing this from our Canadian friends because they're very concerned about how much money they put into the ventilation.

And, you know, when you understand that, you know, costs of the energy, it's going with the cube when it comes to increasing ventilation. That's why we need to look maybe if there is any economical model now to put basically mining industry on the same page with OEMs and ties this technology as something is beneficial to everybody. And this graph is showing basically -- this is what is right now, you know, in the mines.

But these are Tier 4 final. So you can see how much ventilation would go down when it comes -- if these engines would be implemented. I think that we heard today from the gentleman, you know, how much, you know, you can really save on ventilation. So, basically, if you have to put this additional tens of thousands of dollars in the engines, how much more that can translate over the year in a cost of savings in ventilation money.

And then, of course, this is similar, you know, based on CANMET data. You can see how theoretically these engines are very clean and how much less ventilation they require. In Canada, they have 100 CFM per brake horsepower hour. It's a common regulation. But if they would switch today on a Tier 4 final, that will go down to 30, you know, CFM per brake horsepower hour, so, basically, about a 70 percent cut in ventilation cost.

So that's why in Canada we see all these drive, because they have a high cost of the energy in north of the interior, so they were going about after the cost of ventilation. And that's why we see this -- all the initiatives about battery power. So we need to create such environment when everybody benefits from doing this. And then, of course, you have to understand, if you recall that table I showed you about EPA emissions, you know, you realize that EPA, they really didn't -- and I think I brought some of it here. You know, EPA really didn't think much about engines under 25 horsepower. You can see it's .3 grams per brake horsepower versus .01 grams for brake horsepower for engines between 75 and 750.

So, basically, there are still engines, particularly in the small size range under 25 horsepower, you know, which are really dirty engines compared to the -- so, basically, this Tier 4 final certification doesn't necessarily that they are going to get particle-free, particle -- a mass particle number of free engine. There will be still some particles coming out of them.

So, in this under 25, probably if you are planning to replace all your engines with Tier 4 final, then you might be best thing to do that because your John Deere or somebody else is not going to sell you any more of anything. He's not allowed to sell you anything like a Gator with a Tier 3 engine. They have to sell it Tier 4 final. But that Tier 4 final is not necessarily clean.

So that's something what needs also to look, and maybe battery-powered vehicles in this size range of the vehicles would be definitely most viable. Then, of course, what I mentioned earlier about these -- sorry, I lost my thought. So some people can do it, you know. We heard today very interestingly that, you know, there is, you know, according to the diesel inventory, there is 672 out of 3,261 light-duty vehicles in coal mines are equipped with filtration devices. And then, of course, all vehicles in Pennsylvania and West Virginia because they have special regulations, they are all equipped with DPFs or DFEs.

So we know that it can be done. You know, of course, there is a cost to pay for that. You know, I understand that, you know, but somehow it's doable in Pennsylvania and West Virginia, but it's not doable, you know, in other states for some reason.

And then, of course, when it comes to retrofit, we spoke about retrofits, and there is desire to keep your engine for as long as you can, maybe try to retrofit with DPF. And, you know, that's a noble, you know, you know -- this is economics, and you have to do it. But, of course, you have to understand that retrofitting a haulage truck or LHD is relatively easy because you have this temperature profile where a lot of hot exhaust is coming from that engine, so regeneration is possible.

You know, so there are these good concepts, and they will work, you know, so you'll be able to deal with your heavy-duty truck. But the problem is, when it comes -- and then, of course, that seeds, you know. I mean, I looked in detail. MSHA also has publicly available exposures.

And then I looked at specific groups of truck drivers and LHD operators, and as you can see over these years, where they have seen 2008 to 2017, we have seen general trend in average reduction in exposures. And, basically, I think because we've worried so much about truck drivers, that you can tell that there is a trend there. There's also a trend for LHD operators, of course, you know, and those numbers are relatively low, you know. You're talking about 33, 38, 39 micrograms per meter cubic. That's, you know, relatively normal and low.

Of course, we have to understand where these people operate. LHD operators, you know, might operate in a little bit more tighter quarters than truck drivers. But truck drivers usually operate in places with an abundance of the ventilation air.

Now there's a totally different problem with the light-duty, you know. If you have a duty cycle that generates this type of temperature profile, there is nowhere there to be seen any. Every T-30 under 300. It's very difficult to design any retrofit-type system which is going to work, except one which is going to require active regeneration, which by all experiences I have heard nobody wants to deal with. So, basically, people prefer passive systems, and if they don't work, they just don't do it.

And then, of course, you have to look at these people who usually hang around these light-duty vehicles and are exposed to their emissions, you know, in the tightest corner of our mines. These are the people, you know, which work with the least ventilation available, and they're on the very end of the ventilation circuit. So, basically, you know -- so, basically, you can see that there's no real trend here in reduction. We can see these average trends for the whole industry, but there's no average in the reduction of how the men shot the fire shooters, blasters, you know, scalers. That's kind of area where it's difficult to find one.

About cleaning burn -- cleaner burning fuels, you know, there was question how much you can expect, and, basically, we did studies at NIOSH, and we found, you know, really very respectful reductions in elemental total mass concentration and total number concentrations can be achieved with these fuels. But I would like to leave you with a note that this doesn't work all the time. On some engines, it works better than on the others. And then, of course, it's not universal solution. And DPFs by my standards are a better, you know, solution and a more universal solution.

Improving quality of existing acquisition of new environmental cabs, that's something what Jim mentioned today, and I think we need to look into that. But, in general, light-duty vehicles are those which do not have nice, tight, you know, cabs with the highest filtration and pressurization system, or they do not have cabs at all, like this one here. That's typical light-duty.

So we need to work on, you know, people -- it's not only truck drivers and LHD operators which need to be protected. We need to provide similar protection to the -- and then this is something along the -- what Brian Huff spoke with. We know we have long history of using battery-powered vehicles in coal mines. Of course, in metal/nonmetal, that's not true.

And then, of course, now we have reemergence of battery-powered, tethered-cable operated and hydrogen fuel cell-powered solutions, and, hopefully, that would come to fruition over next decade or two.

What we need also to look is how much this change from diesel-powered to battery-powered is going to change mining overall. And then, you know, there is a lot of benefits. I've listed some of them. And this is based on global mining. I think Brian mentioned that global mining group. And, basically, they have basically put something, again in Canada -- it's not in the United States -- something together just to start sprouting this work.

And then, of course, if you want to look at more, there's several good presentations in the GMG report which tells you basically the complexity of how to transfer that. I think that over the time we'll get there, but it might take some time. What might -- we might need a little bit of legal framework to start this development.

And then, of course, there's something -- what also we have to think is about sustainability of the mining and appearance of the mining, and definitely running battery-powered vehicles, providing clean environment, and would also help in recruiting new miners and leaving better picture of the mining industry overall.

At NIOSH, you know, we are focusing on several issues, and, currently, they're running one project, a project dealing with developing and evaluating technologies and strategies to prevent over-exposures, and we are looking definitely for partners. And I heard today that we might have opportunity to work with coal mine, which wants to know what the exposures is. And then, you know, we would like actually to have mining industry tells us what are the issues, you know, because, as a government agency, you know, and not really somebody who spent time in underground mining industry beside what I consider visits or short visits, you know, I do not understand what mining industry needs.

Mining industry needs to tell us what are the issues so we avoid this situation where we are presenting mining industry for the solutions for the problems they might not have. So we need to kind of get ahead of that.

And then we need to look in retrofits of Tier 2 and Tier 3 engines and, you know, or replacement with Tier 4 final engines. We are testing several of those, trying to figure out, you know -- I mean, we have heard about different technical solutions. And I can tell you that engine which is meeting Tier 4 final standards with SCR assistant is not the same as a stage 5 engine which meets the similar standards using DPF or DFE. So, you know, a different type of context comes out of the 2007 or 2010 engine, and all that depends on the technology which is applied.

And then, of course, we need to develop these filtration systems for the cabs, diesel exhaust filtration systems because exposure of filter elements are the same on the market for many, many years, so we need a little bit better products too. And then, of course, there's something -- what we need to improve is DPM monitoring methodology, including to develop one which allow us to reliably and accurately measure exposure of coal miners to the DPM.

And then, of course, we need to improve ventilation strategies because I think, if anything else showed up from DPM regulations, is that we do not have adequate ventilation in a lot of metal/nonmetal mines around the United States. And, of course, we are always searching for new partners, and if anybody is interested at this time, please approach me and we can discuss any potential work.

One more slide I would like to show. And, you know, I just want to tell you that these efforts are not unique. There's a lot of efforts around this country and the world, you know, where different organizations, including International Council on Mining and Metals, ICMM, is trying to address this issue on a level, global level.

There are 16 major mining companies joined with 10 of 30 major suppliers, you know, and some of the representatives of those companies are here. But this is on a global level. That means we are talking about curtailing DPM emissions across the globe. And then for major suppliers of the equipment -- and they're trying to come up with the same economical reasoning why mining industry would embrace this new technology and how that can bring that in the 21st Century or wherever they want to be.

So, basically, as of October 30, in Melbourne, CEOs of all these companies basically committed to reducing -- minimize operational impact of diesel exhaust by 2025. There was discussion that they are planning to see all the diesel-powered vehicles out of the mines across the world in the 2020s.

So that's something what we need also to try to do, is to get onboard with these, you know, major companies and try to get ahead of the curve. So, yeah, this will conclude my presentation. It was a little bit longer, and thank you to the EPA lady, I guess. I had a little bit more time. Thank you. If you have any questions, let me know.

(Applause.)

MR. FRANCART: So we have a few minutes if there are any questions for our two panelists.

(No response.)

MR. FRANCART: All right. Well, thank you again for your attention and your participation today, and, Ed Green, the floor is yours for the final comments.

MR. GREEN: Okay. Give me a minute or two to get up there, gentlemen. It takes me longer to get up there.

(Pause.)

MR. GREEN: Okay. Well, you've all been very, very, very patient today. Thank you very much. It's been a long day. Just a comment in terms of availability of the materials. Everything that we saw and heard today is going to be available at some date in the near future on the NIOSH and MSHA websites. I can't tell exactly when. I'm not suggesting you hold your breath, but it won't be all that long.

I don't know about you guys, but I thought this was a fabulous, fabulous day, well done. You know, you just think about the fact that this Request for Information again is open until March 26. Everything that happened today is going to be part of the docket, I'm sure. And, you know, just think for a moment. Sheila particularly, who's charge of all this stuff -- trying to get all this stuff in a comment form would be impossible.

So, instead, we have this marvelous combined panel of experts, certainly among the best in the world and the best in the United States, and the back and forth, I thought, was just very impressive, and I'm very proud of Mark and everybody else. The MSHA folks, thank you; the NIOSH people, thank you. And all the folks from the stakeholders, well done.

You know, as we close this, I thought to myself it's kind of like being the last wife of Henry VIII. I'm not going to do it, but can I make it interesting? So since we have a moment or two, and there's been absolutely not one lawyer joke today, I'm going to tell you guys a lawyer joke, so bear with me.

There were three fellows walking through the woods one afternoon, a rabbi, a Hindu minister, and a lawyer. It began to get dark. They lost their way. They finally came upon a clearing with a farm and a farmhouse, and they knocked on the door. Happily, the farmer came and said, can I help you gentlemen? And they said, well, we're lost. Would you mind if we just came in and had some water? And he said, fine, come in. And they invited them to sit down for dinner. They had a delightful dinner.

And by that time, it was pitch dark, and the farmer said, fellows, I know this is not going to happen. You're not going to get home tonight. Would you like to sleep here? It'll be fine. I've got -- I don't have any extra beds, but one of you can sleep in the barn, and it will be just fine.

So the three guys talked about it among themselves, and the rabbi finally said he would go out to the barn. So he grabbed a pillow and a blanket from the farmhouse, went out to the barn, and everybody kind of settled down for the night.

Knock on the door. It was the rabbi. He said, I'm sorry, I can't sleep in the barn. There's a pig in there, and as you sure know, you know, pigs are kind of anathema to my religion, so I need to come back in. All right, they said. More discussion. The Hindu said he would go out. He did, took a pillow and blanket. Everybody kind of settled down.

Knock on the door. It was the Hindu. I can't sleep in the barn, he said. There's a cow there, and, you know, they're sacred to my religion, and I'm concerned it may be an ancestor of mine, and it's very uncomfortable.

So the jig was up. The lawyer went out to the barn with his pillow and blanket. Everybody sort of settled down. There was a knock on the door. The farmer opened it up. It was the pig and the cow.

(Laughter.)

MR. GREEN: Now, with that lesson, one other last thing I wanted to say, and my good friend, Mike Wright, reminded me that I misspoke at the beginning. The metal/nonmetal DPM standard is not a tailpipe limitation, as I described it. It's an exposure limitation, a very important distinction. And, Mike, thank you for pointing it out. Again, the comment period is open until March 26, and -- if I have my pointer here or not. Yes, here it is. Thank you.

And so, as I said, the workshop proceedings are going to be transcribed, et cetera. I think -- I'm hoping that either later this year or maybe early next we're going to have another workshop. And I think we should discuss -- the Partnership should discuss it being a partnership on the health effects of diesel exhaust, something that we can do ourselves to have something that will be current and useful.

Thank you from HEI. Give Dan my best. Tell him that the Red Sox are doing great, God bless them. Go Patriots. I'm a Boston guy too, by the way, although you can't hear my accent unless I really get pissed off.

And we have to be mindful, folks, that in spite of our best intentions, the debate about diesel exhaust is going to continue. It's not just a safety issue in the mining industry. It's a public health issue. We hear about it every day. And that's not going to go away.

For mining in particular, we shouldn't forget, we haven't really talked about the law today. One of the reasons I think I'm here is to just remind us about the law. The legal bar for miners, protection of miners, under the Mine Safety and Health Act, is extraordinarily low and stringent. You can find it in section 101(A)(6)(a)(1) of the Mine Act. I'm going to just flash it up there for a minute.

It's a long provision, but I want you to look at it and be mindful of the fact that as you work through the legalese -- and, by the way, this is the same provision as you can find in OSHA virtually word for word. In fact, the reason this provision is in the Mine Act is because, when the Congress passed the 1977 Mine Safety Act, they basically lifted up the OSHA language and almost word for word put it into the Mine Safety Act.

There's lots of judicial precedent about what this means in the OSHA context and enough in the mine safety context to tell us that feasibility, whether it's economic or technological feasibility, is not the primary focus of this particular provision of the statute. The primary focus is to make sure that miners are protected throughout their careers. And I encourage everybody in this room to be mindful of that and to be mindful of the fact that our foremost goal is to protect the people who work for the industry, who toil in the industry.

I've grown over my five-plus decades in this industry to admire as a young lawyer who was totally unfamiliar with mining, to admire everybody in it, both operators and rank-and-file folks. It's a great industry with many success stories. Let's make this one of them, and thank everybody again for coming.

James, where are you? Is he over there? James, thank you for everything you did, buddy. We couldn't do it without you.

So, again, any questions, I'd be happy to try and respond, or I'm sure any of the panelists would. And if not, vaya con Dios, folks. See you sometime.

(Applause.)

(Whereupon, at 4:15 p.m., the meeting in the above-entitled matter adjourned.)

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REPORTER'S CERTIFICATE

DOCKET NO.: N/A

CASE TITLE: MSHA Diesel Technology Workshop

HEARING DATE: January 23, 2019

LOCATION: Washington, D.C.

I hereby certify that the proceedings and evidence are contained fully and accurately on the tapes and notes reported by me at the hearing in the above case before the U.S. Department of Labor, Mine Safety and Health Administration.

Date: January 23, 2019

David W. Jones

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MSHA/NIOSH Diesel Partnership
U.S. Department of Labor Auditorium
200 Constitution Avenue, NW
Washington, DC 20210

Wednesday, January 23, 2019

Introduction to the Workshop

- Context Panel
- Current Emissions/Control Technologies Panels
  - Engine Controls
  - Emission Reduction/Exposure Reduction
- Current Barriers to Deployment of Technologies Panel
- Strategies and Path Forward Panel
- Closing Remarks

How We Got Here?

- The MSHA Diesel Particulate Matter (DPM) Rulemaking
- The NIOSH/National Cancer Institute (NCI) Diesel Exhaust in Miners Study (DEMS)
- MSHA DPM Rulemaking
  - Separate Proposals for Underground Coal Mines and Underground Metal-Nonmetal Mines
    - Coal Rules – based on engine testing by the MSHA Approval and Certification Center (A&CC)/or EPA limit
    - Metal/Nonmetal Rules – Permissible Exposure Limits (PEL) as actually measured at the tailpipe by MSHA and/or operator
- MSHA DPM Rulemaking Published in the Federal Register on the Very Last Day of the Clinton Administration as a “Midnight Rule” (January 19, 2001, See 30 C.F.R. §§ 57.5060-57.5075)

How We Got Here? (Cont'd)

- Virtually Overnight, Mining Industry Challenges the DPM Rules (Kennecott, AngloGold North America, Followed by Separate Suit by National Mining Association (NMA) And the Methane Awareness Research Group (MARG); Labor Unions Become Engaged as Well)
- In George W. Bush Administration, MSHA Chief Dave Lauriski Seeks Settlement Discussions which Go on for Years, with Changes to the DPM Rules Along the Way Giving Operators Time to Learn About Exhaust Filters and Other Engine Controls
  - With Very Favorable Global Settlement Finally in Hand, Discussions Break Down as Result of MARG Objections; MSHA Takes View If Cannot Settle with All, then Will not Settle with Anyone
  - Metal/Nonmetal – At Heart of Rules is Permissible Exposure Limit (PEL) of 160 Micrograms of Total Carbon per Cubic Meter of Air as Actually Measured at Tailpipe
  - Litigation Ensues-
    - Briefs are Filed; Oral Arguments are Held; Three-Judge Panel of US Court of Appeals for DC Circuit Rejects Industry Arguments and Upholds MSHA Rules in Their Entirety

How We Got Here? (Cont'd)

- NIOSH/NCI DEMS Begun in Early 1990s; Around Time of Initiation of MSHA DPM Rulemaking; Group of Eight Underground Nonmetal Mines Voluntarily Participate (Trona, Potash, Salt, Limestone); Involves Over 12,000 Miners
- Initially Constructive Relationships Between NIOSH, NCI and Participating Mines, Communications Break Down over Real and Perceived Problems; Quarrels and Litigation Ensue
- DEMS Finally Published in March 2012; Concluding that Diesel Exhaust May Cause Lung Cancer in Humans (Silverman, et al.) and that Exposure to Diesel Exhaust Increases the Risk of Death from Lung Cancer (Attfield, et al.)
- One Mine Seeks Repair of Relationship with NIOSH/NCI, as Agencies Begin to Prepare Letter to Participating Miners and Families re DEMS; DEMS Mines Worry About Tort Liability Issues; But Letter to Miners and Families Turns Out to be a "Nothingburger"
- But then comes IARC

How We Got Here? (Cont'd)

- Based on DEMS and Other Studies, in June 2012,the United Nations International Agency for Research on Cancer (IARC) Decides Diesel Exhaust is a "Known Human Carcinogen"
- As result of IARC Finding, MSHA Issues Hazard Alerts in January and August 2013
- MSHA then Publishes a Request for Information (RFI) on Exposure of Underground Miners to Diesel Exhaust in Federal Register of June 8. 2016 (81 Fed. Reg. 36826)
- Industry Parties (e.g., Industrial Minerals Association-North America (IMA-NA)) ask MSHA and NIOSH to Form a Diesel Exhaust Health Effects Partnership (Partnership) To Explore the 28 Highly Complex Questions Posed by the RFI
- MSHA and NIOSH Accept Offer and the MSHA/NIOSH Diesel Exhaust Health Effects Partnership is Formed in 2016
- This Workshop is one Outcome of the Partnership

Introduction of Context Panel Speakers

- Dr. Jessica Kogel, Associate Director for Mining and Director Office of Mine Safety and Health Research, NIOSH
- Dr. David Weissman, Director, Division of Respiratory Disease Studies, NIOSH
- Patricia Silvey, Deputy Assistant Secretary of Labor for Mine Safety and Health Operations
- Sheila McConnell, Director, MSHA Office of Standards, Regulations, and Variances

TBD

Setting the Stage

Diesel Technology Research at NIOSH

Diesel Technology Workshop
January 23, 2019
Washington D.C.

Jessica E. Kogel, PhD

Associate Director for Mining

National Institute for Occupational Safety and Health

Safe mines - Healthy workers

Current diesel research at NIOSH

Extramural Research Program

- Academia, industry and other government agencies
  - ✓ Comparison of diesel and biodiesel emissions and health effects in underground mining (University of Arizona)

Intramural Research Program

Mining Sector

- Spokane Mining Research Division (SMRD)
  - ✓ Developing a Field- Portable DPM Monitor
- Pittsburgh Mining Research Division (PMRD)
  - ✓ Advanced strategies for controlling exposures to diesel aerosols

Oil & Gas Sector

- Health Effects Laboratory Division (HELD)
  - ✓ Fracking: Toxicological Effects of Silica & Diesel Exposure
- Western States Division (WSD)
  - ✓ Protecting Oil Workers through Enhanced Surveillance, Exposure Assessments, and Control Evaluations
- Division of Applied Research and Technology (DART)
  - ✓ Controls and Interventions for Hazardous Exposures in Oil and Gas Extraction

Safe mines - Healthy workers

NIOSH Mining Program mission…

To eliminate mining fatalities, injuries, and illnesses through relevant research and impactful solutions

NIOSH Mining Program research focus areas

Strategic Goals

Reduce Occupational Illness

- Diesel Assessment & Control
- Respirable Dust Assessment & Control
- Hearing Loss Prevention
- Thermal Stress
- Cognitive Workload
- Chronic Disease Surveillance

Reduce Injuries and Fatalities

- Health & Safety Management Systems
- Musculoskeletal Disorder Prevention
- Training Research & Development
- Illumination
- Ground Control
- Electrical Machine Safety
- Safety Culture
- Surveillance

Disaster Prevention & Response

- Atmospheric Monitoring & Control
- Refuge Alternatives
- Breathing Air Supplies
- Communications & Tracking
- Emergency Response & Rescue
- Explosion Prevention
- Fire Prevention & Control
- Ventilation

Reducing miner's occupational exposure to DPM has relied on extensive collaboration

- Industry partners - Completed field-testing in both domestic (17 mines) and international (6 mines in Canada and Australia) mines.

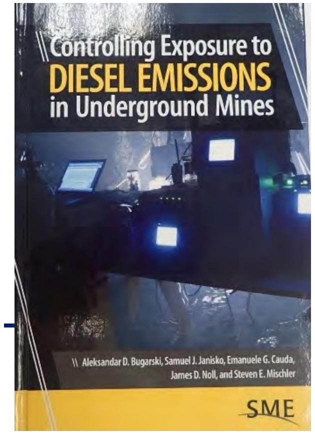
- Partnerships
  - Coal Diesel Partnership (1999) - UMWA, BCOA, NMA and NIOSH,
  - Metal/Nonmetal Diesel Partnership (2002) – USWA, NMA, NSSGA, MARG Diesel Coalition, IMA-NA and NIOSH,
  - Diesel Health Effects Partnership (2016) – MSHA and NIOSH Co-Sponsors.

A brief history....

- 1999 to 2019 - NIOSH investigates ways to reduce miner's exposure to diesel particulate matter (DPM) and gases in underground mines.
- Focus – to assist the mining industry and regulators with
  - selection, implementation, and acceptance of existing and emerging control technologies,
  - use of improved strategies and practices.
- Solutions include -
  - improved sampling and monitoring methods
  - engine and exhaust after treatment technologies,
  - alternative fuels,
  - filtration systems for enclosed cabs,

Results

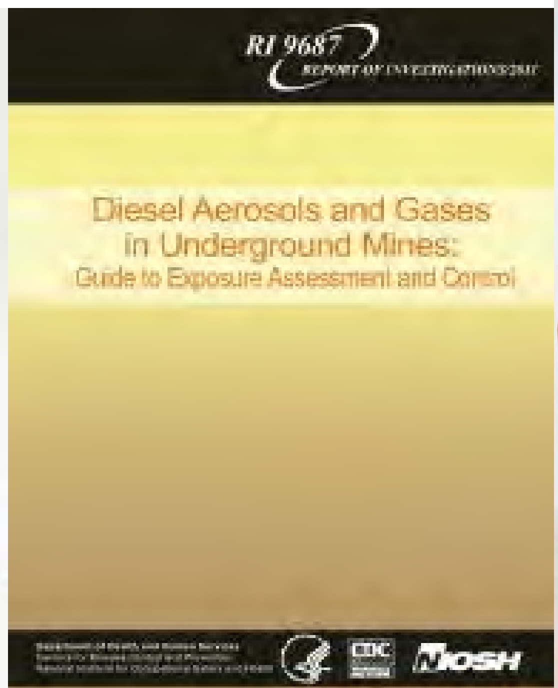
- Over 100 peer-reviewed publications, conference papers and presentations:
  - *Controlling Exposure - Diesel Emissions in Underground Mines*. Society for Mining, Metallurgy, and Exploration. 2012
  - *Diesel Aerosols and Gases in Underground Mines: Guide to Exposure Assessment and Control*. NIOSH RI 9687 Pub No. 2012-



- From 2008 to 2017 over 14 diesel workshops held in US, China, Australia and Canada (over 40 since inception).
- Improved compliance sampling protocols based on NISOH Method 5040.
- Developed new interventions and strategies

Development and Commercialization of a Wearable Real-time Elemental Carbon (EC) Monitor

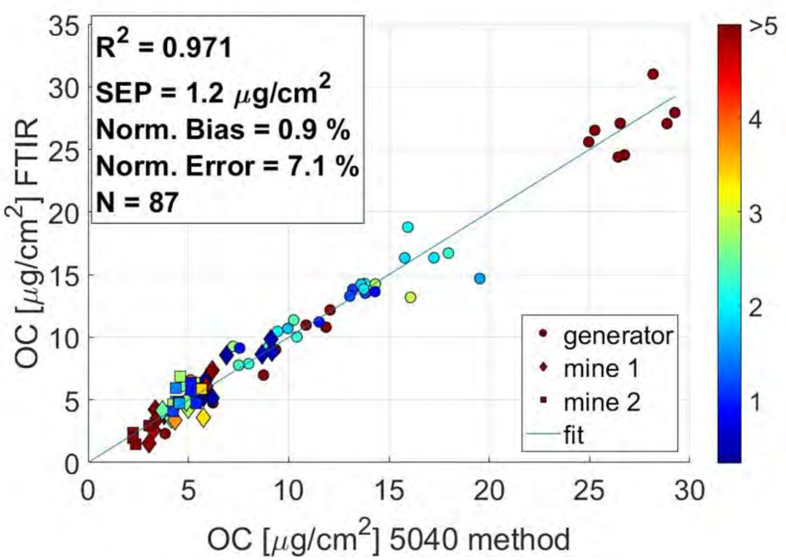
- Mines have incorporated Airtec into their DPM control strategy to
  - detect the presence of elevated concentrations of EC,
  - identify the shortcomings of engineering and administrative controls,
  - implement changes to reduce exposure levels
- Since initial commercialization, over 200 Airtec monitors have been sold worldwide.



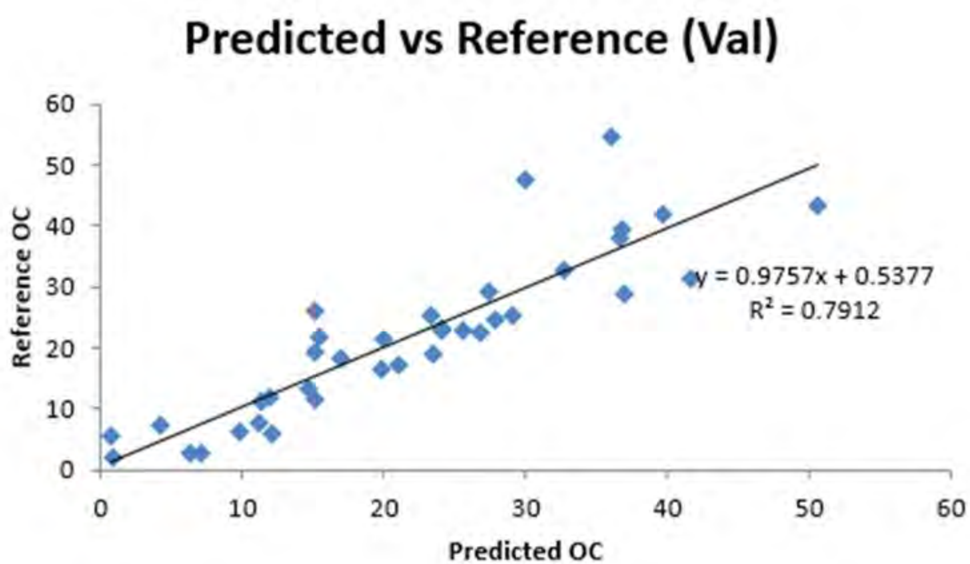
Research and Development of a Real-time EC/OC Monitor

- Airtec measures EC, then estimates OC from known EC/OC trends
  - accuracy of EC may be affected by high OC levels
- A new method is needed to mimic NIOSH 5040 measurement of both EC and OC
- FTIR and LIBS can both measure EC, and possibly OC as well
- Research is under way to refine these methods, and develop an EC/OC monitor

FTIR data (OC)



LIBS data (OC)



Development of a technique for direct tailpipe measurement of DPM

Direct tailpipe sampling of diesel vehicles in mines is used to

- identify the highest DPM emitters in a fleet of vehicles,
- determine the effectiveness of control measures
- BHP Billiton used the NIOSH-designed probe to evaluate its diesel fleet at several different mine sites.

Handheld Electrostatic Precipitator (ESP) Particle Sampler (ESPnano)

A sampling device used by industrial hygienists to characterize hazardous airborne particulate matter to investigate

- worker exposures to DPM and other airborne hazards [Tumolva et al. 2010; Saffaripour et al. 2015].
- engine soot morphology to evaluate the toxicity of engine-emitted particles [Saffaripour et al. 2015; Barone et al. 2012; Heejung et al. 2013].

Improvement in Compliance Sampling Methodology

Based on NIOSH research MSHA made changes to compliance sampling protocols including

- using a dynamic blank for correcting adsorption of vapor phase organic carbon in DPM compliance samples,
- calculating a conversion factor during each sampling event [73 Fed. Reg. 29058].

Aftertreatment Technologies for Diesel Emission Control

NIOSH evaluated diesel oxidation catalytic converters, particulate filters, and other systems to assist mine operators in the selection of exhaust aftertreatment systems

- Based on this research, diesel oxidation catalytic converters and other retrofit diesel particulate filter systems are being used in underground mines in the U.S.

- These systems are currently integrated into the diesel-power packages offered by major original equipment manufacturers

Alternative Fuel for Diesel Emission Control

- Studies conducted by NIOSH showed the potential of using fatty acid methyl ester (FAME)-derived bio fuels as a control strategy to reduce exposures of underground miners to DPM

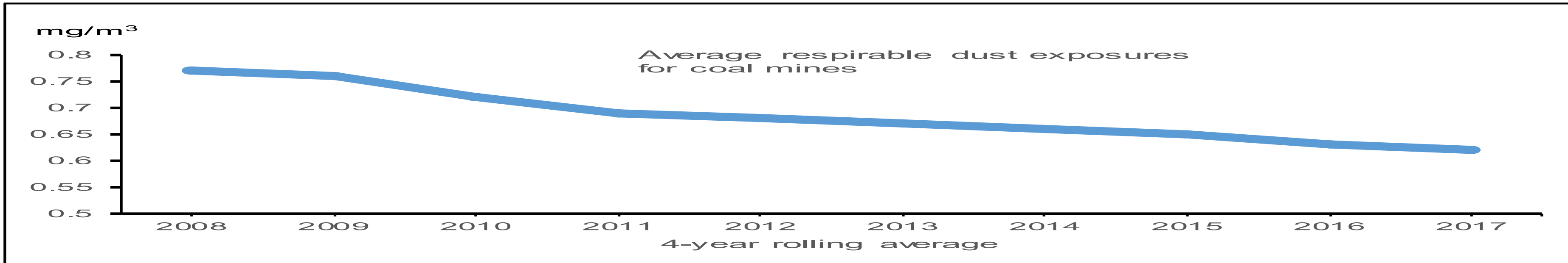
- NIOSH collaborated with Newmont USA Limited to evaluate the effects of several biodiesel blends and ultralow sulfur diesel (ULSD) on airborne contaminants in the underground environment

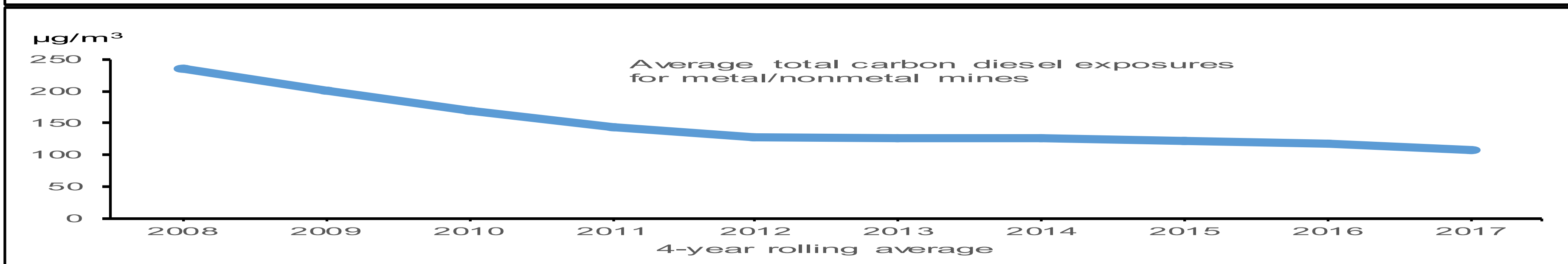
- The results showed that the FAME biodiesel, when compared with ULSD, reduced DPM, TC, and EC mass concentrations.

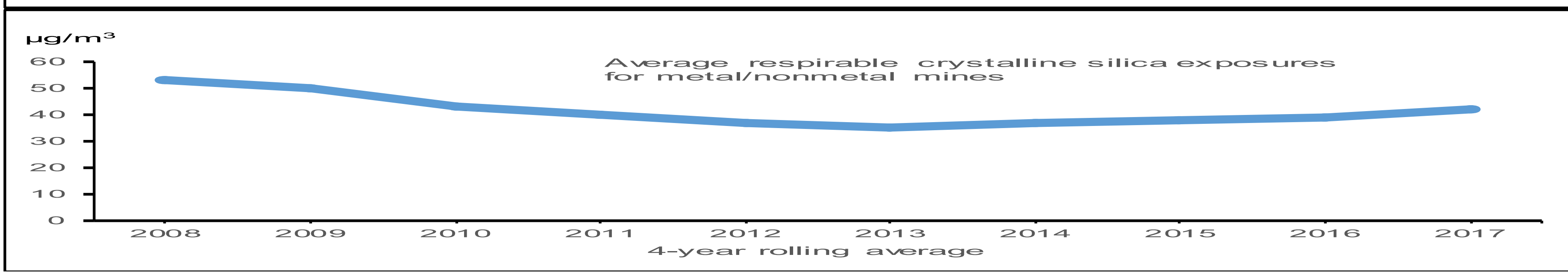
- Additional follow-up laboratory studies conducted at NIOSH showed that the toxicity of aerosols is higher when engine is fueled with FAME B100 than with ULSD

- Burgess et al. found that the use of biodiesel in an underground mine can result in variable changes in health effect outcomes as compared with diesel fuel.

But what about the miner?







Safe mines - Healthy workers

Brief Update On Diesel Health Effects

Diesel Technology Workshop
Washington, DC
January 23, 2019

David N. Weissman, MD
Director, Respiratory Health Division
National Institute for Occupational Safety and Health

Outline of Presentation

- Overview of Diesel Health Effects
- IARC 2012 Evaluation of Carcinogenicity of Diesel Exhaust
- Follow-up to Diesel Exhaust in Miners Study (DEMS)

Health Canada's Summary of Health Effects of Exposure to Diesel Exhaust

Outcome	Acute/chronic DE exposure	Causality determination
Carcinogenicity	Chronic	Causal (lung cancer) Suggestive (bladder cancer) Inadequate (other cancers)
Respiratory effects	Acute	Causal
	Chronic	Likely
Cardiovascular effects	Acute	Likely
	Chronic	Suggestive
Immunological effects	–	Likely
Reproductive and developmental effects	–	Suggestive
Central nervous system effects	Acute	Suggestive
	Chronic	Inadequate

Human Health Risk Assessment for Diesel Exhaust. 2016. Available at: http://publications.gc.ca/site/eng/9.810907/publication.html

International Agency for Research On Cancer (IARC), 2012

6.1 Cancer in humans

There is *sufficient evidence* in humans for the carcinogenicity of diesel engine exhaust. Diesel engine exhaust causes cancer of the lung. A positive association has been observed between exposure to diesel engine exhaust and cancer of the urinary bladder.

There is *inadequate evidence* in humans for the carcinogenicity of gasoline engine exhaust.

6.3 Overall evaluation

Diesel engine exhaust is *carcinogenic to humans* (Group 1).

Gasoline engine exhaust is *possibly carcinogenic to humans (Group 2B).*

IARC Monographs on the evaluation of carcinogenic risks to humans; v. 105

Basis for IARC Determination

- "The most influential epidemiological studies assessing cancer risks associated with diesel-engine exhausts investigated occupational exposure among non-metal miners, railroad workers, and workers in the trucking industry." Lancet Oncol. 2012; 13(7):663-664

- Studies cited as most influential:

Attfield MD, Schleiff PL, Lubin JH, et al. The Diesel Exhaust in Miners study: a cohort mortality study with emphasis on lung cancer. J Natl Cancer Inst. 2012 Jun 6;104(11):869-83.

Silverman DT, Samanic CM, Lubin JH, et al. The Diesel Exhaust in Miners study: a nested case-control study of lung cancer and diesel exhaust. J Natl Cancer Inst. 2012 Jun 6;104(11):855-68.

Garshick E, Laden F, Hart JE, et al. Lung cancer in railroad workers exposed to diesel exhaust. Environ Health Perspect. 2004 Nov;112(15):1539-43.

Laden F, Hart JE, Eschenroeder A, et al. Historical estimation of diesel exhaust exposure in a cohort study of U.S. railroad workers and lung cancer. Cancer Causes Control. 2006 Sep;17(7):911-9.

Garshick E, Laden F, Hart JE, et al. Lung cancer and vehicle exhaust in trucking industry workers. Environ Health Perspect. 2008 Oct;116(10):1327-32.

Garshick E, Laden F, Hart JE, et al. Lung cancer and elemental carbon exposure in trucking industry workers. Environ Health Perspect. 2012 Sep;120(9):1301-6.

Health Effects Institute (HEI), 2015

- Published *Diesel Emissions and Lung Cancer: An Evaluation of Recent Epidemiological Evidence for Quantitative Risk Assessment*

- This report is a careful review by an independent scientific panel of two major epidemiological studies of historical exposures to diesel exhaust, the Diesel Exhaust in Miners Study (DEMS) and the Trucking Industry Particle Study (Truckers) to assess whether these studies could provide the basis for quantitative risk assessment.

- In the Panel's view, both the Truckers study and the DEMS were well-designed and well-conducted studies that each made considerable progress toward addressing a number of the major limitations that had been identified in previous epidemiological studies of diesel exhaust and lung cancer.

- The Panel found that the studies have many strengths, but any effort at quantitative risk assessment will need to acknowledge some key uncertainties and limitations.

- The Panel concluded that both the DEMS and the Truckers study provided results and data that provide a useful basis for quantitative risk assessments of exposures in particular to older diesel engine exhaust.

Follow-Up to the Diesel Exhaust in Miners Study

- Access to data underlying DEMS were made available to interested investigators, including a team funded by the Truck & Engine Manufacturers Association (EMA)

- EMA-supported publications raising criticisms of DEMS and presenting alternative data analyses:

Chang ET, Lau EC, Van Landingham C, et al. Reanalysis of Diesel Engine Exhaust and Lung Cancer Mortality in the Diesel Exhaust in Miners Study Cohort Using Alternative Exposure Estimates and Radon Adjustment. Am J Epidemiol. 2018 Jun 1;187(6):1210-1219.

Crump KS, Van Landingham C, McClellan RO. Influence of Alternative Exposure Estimates in the Diesel Exhaust Miners Study: Diesel Exhaust and Lung Cancer. Risk Anal. 2016 Sep;36(9):1803-12.

Crump KS, Van Landingham C, Moolgavkar SH, et al. Reanalysis of the DEMS nested case-control study of lung cancer and diesel exhaust: suitability for quantitative risk assessment. Risk Anal. 2015 Apr;35(4):676-700.

Moolgavkar SH, Chang ET, Luebeck G, et al. Diesel engine exhaust and lung cancer mortality: time-related factors in exposure and risk. Risk Anal. 2015 Apr;35(4):663-75.

- DEMS investigator responses:

Silverman DT. Am J Epidemiol. 2018 Sep 6. PubMed PMID: 30192912.

Silverman DT. Diesel Exhaust and Lung Cancer-Aftermath of Becoming an IARC Group 1 Carcinogen. Am J Epidemiol. 2018 Jun 1;187(6):1149-1152.

Follow-Up to the Diesel Exhaust in Miners Study

- Ongoing studies based at NCI
- Suggested associations between ischemic heart disease and exposure to respirable elemental carbon and/or respirable dust

Costello S, Attfield MD, Lubin JH, et al. Ischemic Heart Disease Mortality and Diesel Exhaust and Respirable Dust Exposure in the Diesel Exhaust in Miners Study. Am J Epidemiol. 2018 Dec 1;187(12):2623-2632.

Neophytou AM, Costello S, Picciotto S, et al. Diesel exhaust, respirable dust, and ischemic heart disease: an application of the parametric g-formula. Epidemiology. 2018 Nov 27. PubMed PMID: 30489348.

- Efforts underway to extend mortality follow-up of DEMS cohort and case-control studies from 1997 (original studies) to 2015

Health Effects Institute (HEI), 2015

- Published *The Advanced Collaborative Emissions Study (ACES)*

- ACES set out to evaluate emissions and health effects from new-technology (MY 2007 and 2010) heavy-duty, on-road diesel engines.

- The results show that the aftertreatment technologies used in such modern diesel engines are highly effective and that they meet — and exceed — the reductions mandated by U.S. regulations. The study reports the effectiveness of diesel particulate filters in greatly reducing PM emissions and of selective catalytic reduction systems in reducing NO_x emissions; similarly, emissions of more than 300 other compounds — some with known carcinogenic and toxic properties — measured in the exhaust were also reduced relative to exhaust from traditional-technology diesel engines.

- Exposure to new-technology diesel exhaust (NTDE) from a 2007 engine tested in Phase 3 of ACES was not carcinogenic in the rat, unlike traditional-technology diesel exhaust (TDE) from older engines, which is known to cause lung tumors under similar conditions. A few NTDE-associated effects in rat lungs in ACES were observed; however, these effects were consistent with exposure to NO_2, a pollutant present in 2007 engine emissions that was further reduced in exhaust from MY 2010 engines, which deployed a selective catalytic reduction system.

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Outline of Presentation

- Overview of Diesel Health Effects
- IARC 2012 Evaluation of Carcinogenicity of Diesel Exhaust
- Follow-up to Diesel Exhaust in Miners Study (DEMS)

Thank you!

Carmeuse Biodiesel Experience

MSHA/NIOSH Diesel Technology Workshop - January 23, 2019

AGENDA

1. Carmeuse Usage
2. The Good…
3. The Bad…
4. The Ugly…
5. Close Out

Carmeuse Background

Carmeuse Lime and Stone, Inc. (Carmeuse North America) operates five underground limestone mines

- Black River Operation – Butler, KY
- Cisco Operation – Cisco, GA
- Ellijay Operation – Ellijay, GA
- Luttrell Operation – Luttrell, TN
- Maysville Operation – Maysville, KY

Carmeuse--Black River and Carmeuse--Maysville are the largest of the UG operations, with all mining operations carried out completely UG

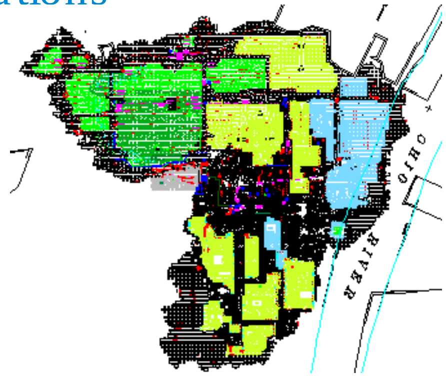
- The other operations utilize truck haulage to surface

All of the mines are solely dependent on diesel mobile equipment to meet the stone production needs of their plants

Maysville and Black River Background

Both mines use a staggered room and pillar mining configuration, with headings and benches mined

- Two to three mining fronts/panels are simultaneously advanced
- Multiple pieces of mining equipment are simultaneously used in the advancing panels, and split between heading or benching operations



Diesel equipment utilized:

- Cat 988 wheel loaders
- Cat 772 haul trucks
- Fletcher diesel face drills
- Cat track-mounted bench drills
- Oldenburg powder rigs
- Cat excavator-type scalers
- Fletcher roof bolters
- Various diesel powered support equipment
  - Water and service trucks, manlifts, personnel carriers

KY (MY and BR) Background

During initial DPM rulemaking, the mines were found to need to make DPM changes like numerous other mines at the time

Carmeuse formed a DPM Compliance team prior to the initial rules enactment date, and compliance options were evaluated:

- Additional ventilation (shafts and fans)
- DPM exhaust filters
- Alternative fuels
- Engine upgrades
- Enclosed cabs

Initial Compliance Background

Low-sulfur diesel (mandatory)

- Relatively easy change over (purchasing and communication)

Additional ventilation (shafts and fans)

- Large capital costs for shafts and fans
- Significant electrical operating costs for additional fan horsepower

DPM exhaust filters

- Large capital cost if used on all pieces of equipment
- Operating and maintenance issues and costs associated with using and regenerating

Engine upgrades

- Cost prohibitive based on cost and equipment ages at the time
- Would be done with new machine purchases

Enclosed cabs

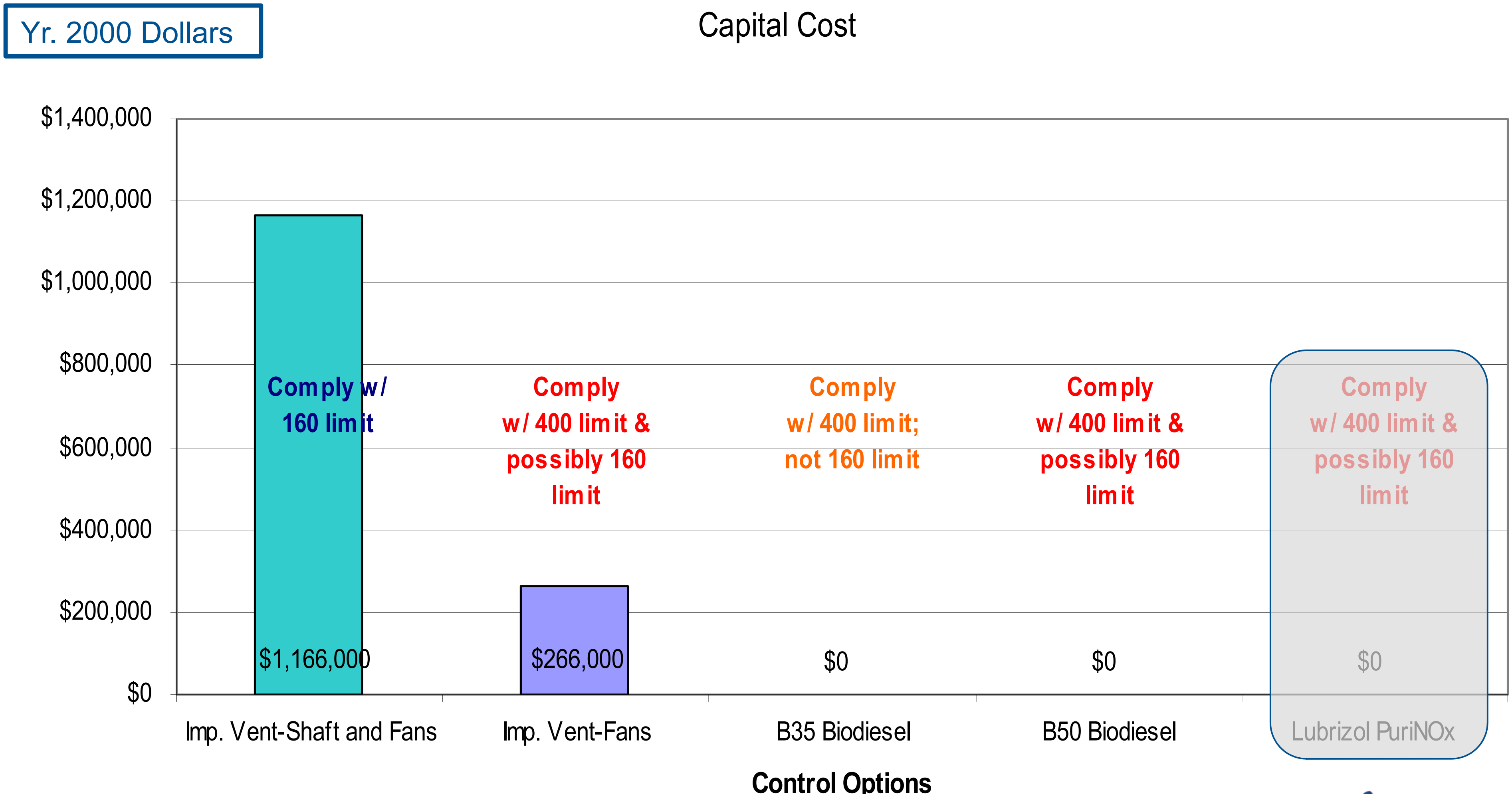
- Similar implementation reasoning as engine upgrades

Initial Compliance Background

Alternative fuels

- Relatively easy implementation (purchasing/scheduling/communication)
- Very minimal capital costs (if any)
- Possible performance issues to overcome
- Increase in operating/fuel cost
- Decreases emissions at the source - engine

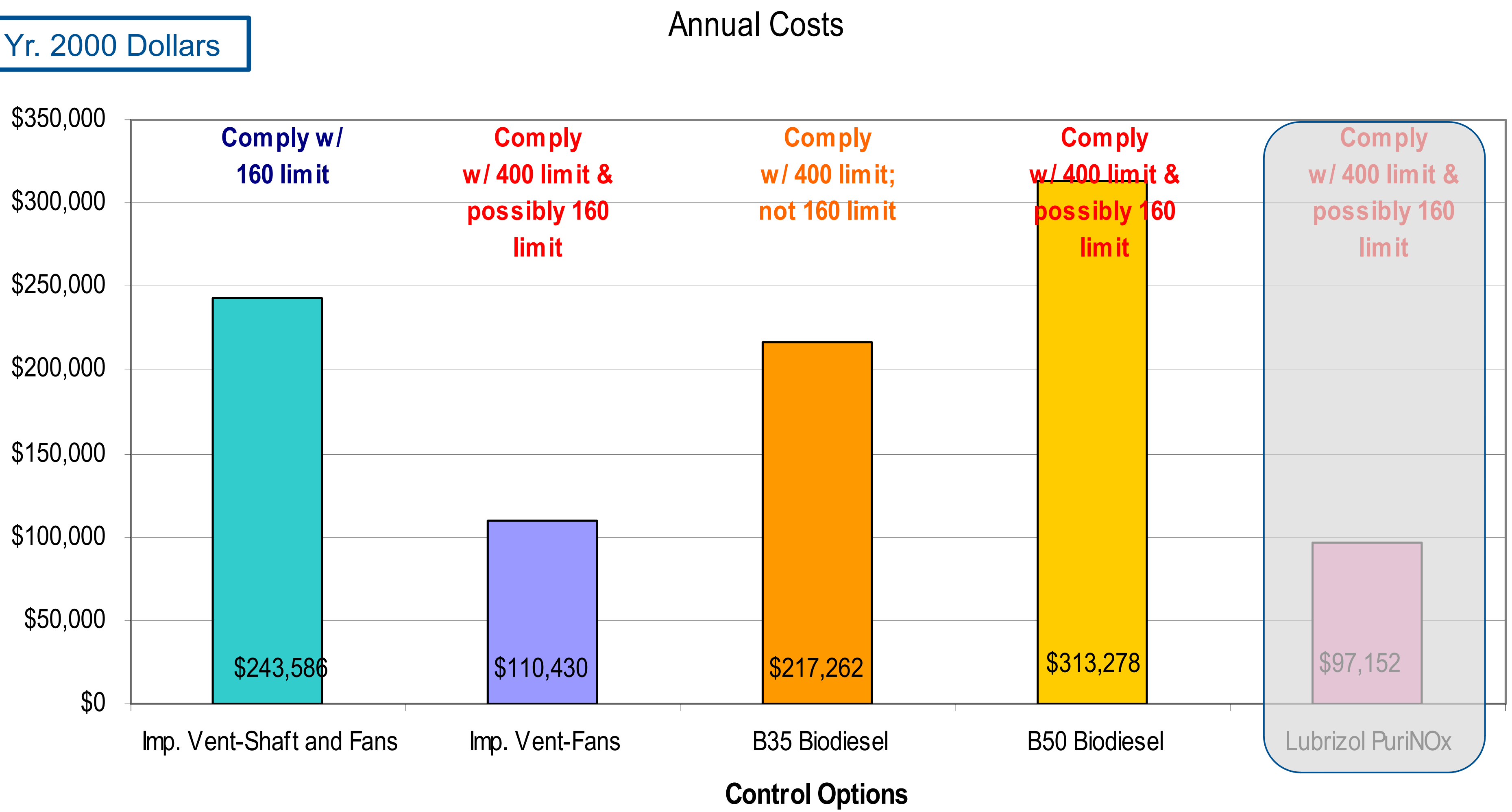
Initial Capital Estimates



CARMEUSE

Initial Operating Cost Estimates

Yr. 2000 Dollars



Fuel Selection

Alternative fuels selected as primary DPM control methodology based on cost and implementation

Biodiesel selected fuel choices available

- Recycled yellow-grease derived
- Virgin soybean oil derived
- Animal fats based
- And other sources

Yellow-grease based biodiesel initially selected

- Locally available
- Limited reported power loss issues
- Some comfort with fuel supplier

PuriNOx side note

- Water-Diesel fuel emulsion blend
- Deionized water, Lubrizol chemicals, and diesel fuel
  - Water molecules are encapsulated in diesel fuel
  - 10% water – winter blend
  - 20% water – summer blend
- Manufacturing phased out at end of 2006
- Ran the problematic fuel at various levels from 2004 thru 2006

Fuel Utilization

As required, switched to Low-Sulfur Diesel fuel (<0.05% sulfur)

Tested number of alternative fuel blends

- B20 Bio, B50 Bio, B50 Soy, PuriNOx

Used B35 Biodiesel for 7 mos. – middle to end of '03

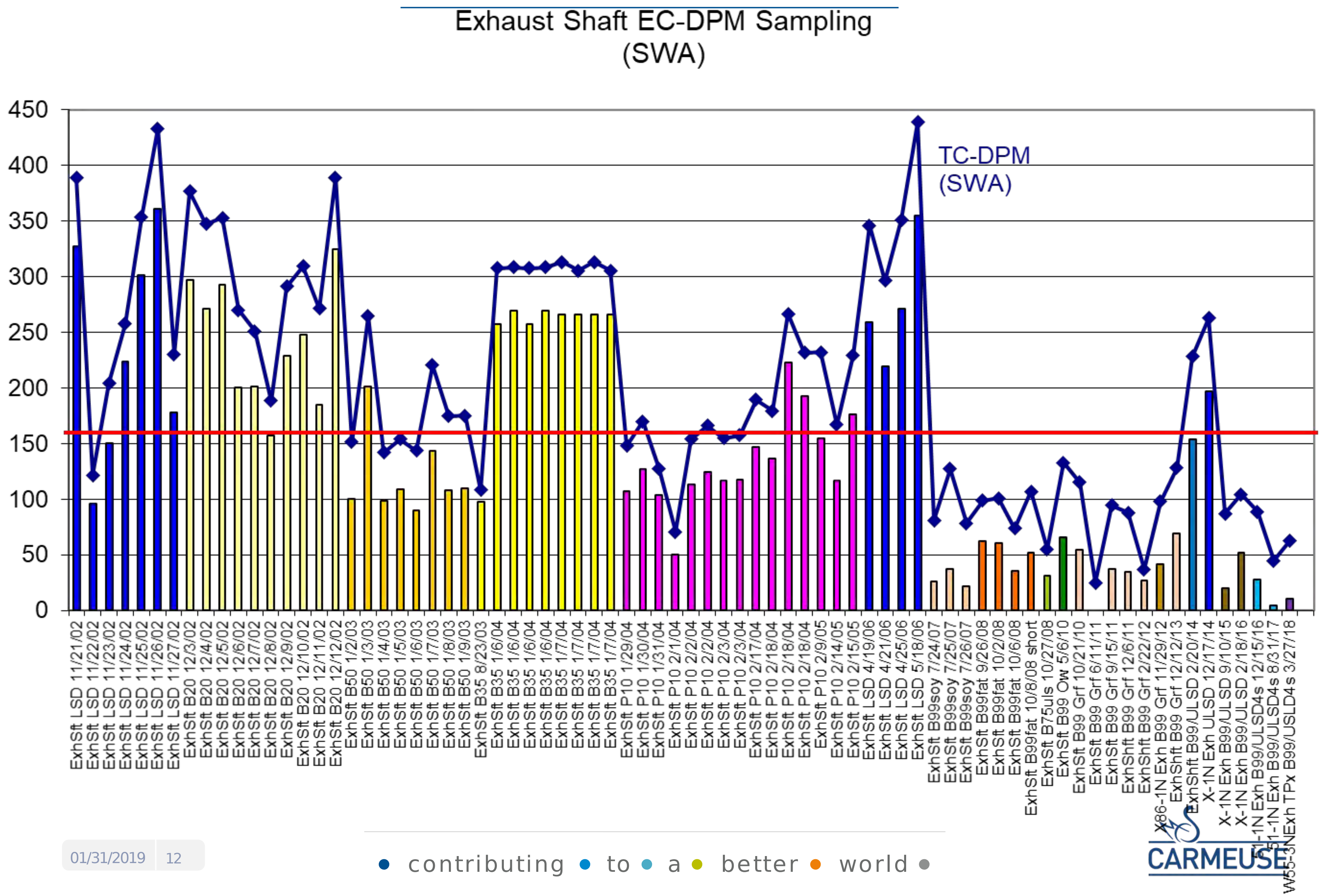
Tested and used PuriNOx

- 10% and 20% emulsion blends
- Majority of equipment operating on it from Jan '04 to late '05
- Select pieces still on it in mid-'06, but product phased out Dec'06

Switched back to biodiesel

- Selected B99 to meet PuriNOx performance levels
- Tried a few suppliers and feed stocks
- Migrated to distillation only processing of soy or yellow grease feed stocks

Fuels Performance



Carmeuse Biodiesel Experience

MSHA/NIOSH Diesel Technology Workshop

The Good

- Biodiesel brought the Carmeuse UG limestone mines into DPM compliance in the early days of the DPM regulations
  - Alternatives and recommendations had been considered, but biodiesel was selected as the best lead option
- Biodiesel was instrumental in keeping the KY Mines in compliance during the DPM limit changes
  - Other DPM controls were utilized as well, but Bio remained the lead (eliminate the generation of emissions)
- Biodiesel was a part of keeping the mines in compliance
  - Tier 4 engine technology usage increased, with Biodiesel remaining utilized in the non-Tier 4 units
  - Without additional DPM controls development and implementation, unable to remain consistently within compliance limits without Biodiesel
- Very limited issues with power and performance
- Significant emissions reductions
- Another site utilized biodiesel to quickly achieve compliance

Carmeuse Biodiesel Experience

MSHA/NIOSH Diesel Technology Workshop

The Bad

- Biodiesel has its disadvantages and limitations
  - Nothing is free; all of the DPM controls have costs associated with them

Biodiesel	Non-Bio DPM Controls (Tier 4)

• Increased fuel costs
  • Price
  • Consumption
  • Storage/handling
• Increased maintenance costs
  • Filters
  • Injectors
  • Hoses
• Increased production costs
  • Unplanned downtime (lost production)
	• Increased new equipment cost (new engine technology)
	• Increased fuel related costs (DEF Fluid)
	• Increased maintenance costs
	  • Regen system issues
	  • DEF systems
	  • DPM filters
	• Increased production costs
	  • DEF fluid procuring/handling
	  • Regen's
	  • Unplanned downtime

Carmeuse Biodiesel Experience

MSHA/NIOSH Diesel Technology Workshop

The Ugly

- Downed equipment
  - Plugged fuel filters
  - Injector replacements
  - Deteriorated hoses and o-rings
  - Paint removal
- Varying quality fuel supplies/suppliers
  - Distilled biodiesel production proven to be best
    - Works for Yellow Grease or Soy based bio's
  - Filtration based bio production still leads to filter plugging
    - On-site filtration system additions unsuccessful
    - Blend levels above B20 more susceptible
    - Yellow Grease more susceptible than Soy
- Increased fuel cost, and lower BTU performance (ton/gal)
- Limited fuel supplies, and commodity price fluctuations
- Gelled surface fuel delivery lines
- Gelling in equip near winter air intake areas

Biodiesel Close Out

Carmeuse Experiences

Within Carmeuse, Maysville is the only UG site still utilizing Biodiesel for DPM compliance

With Tier 4 engines (new engine technology) coming in the new equipment replacements, phasing out Bio was one of our recent KY plans

- Although sticking with less problematic, Tier 3 technology was considered at times as well ☺
- Black River has reached that point
  - Fuel additive (TPx HD) is in use at BR to enhance fuel burning and emissions
- Maysville is 23% B99 and 77% ULS Diesel
  - BR had been 15% B99 and 85% ULS Diesel

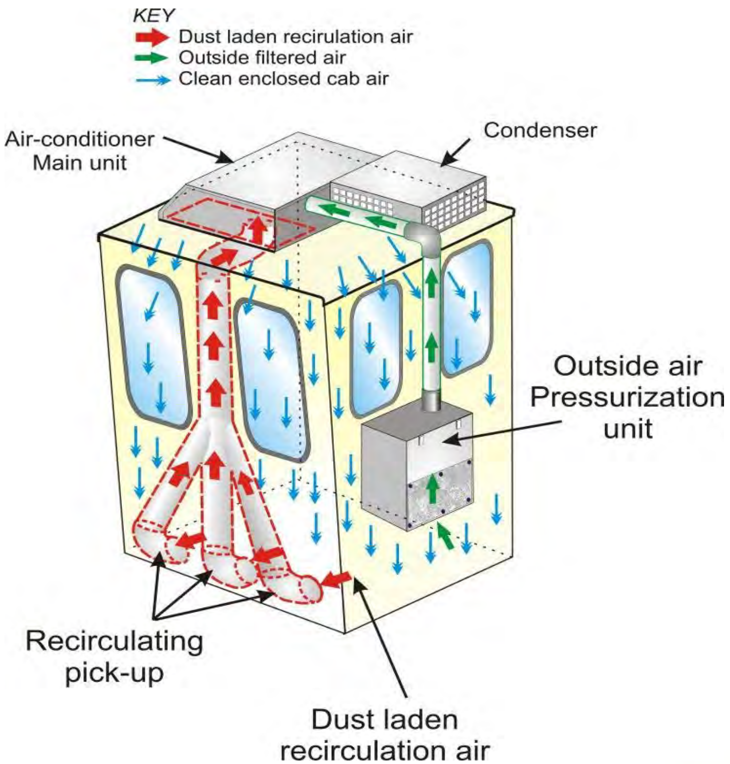
No Biodiesel blends have been utilized in the Tier 4 engines

- B20 is the known manufacturer limit; B5 can be common level
- Internally decided no Bio would be used in Tier 4's due to the unknowns

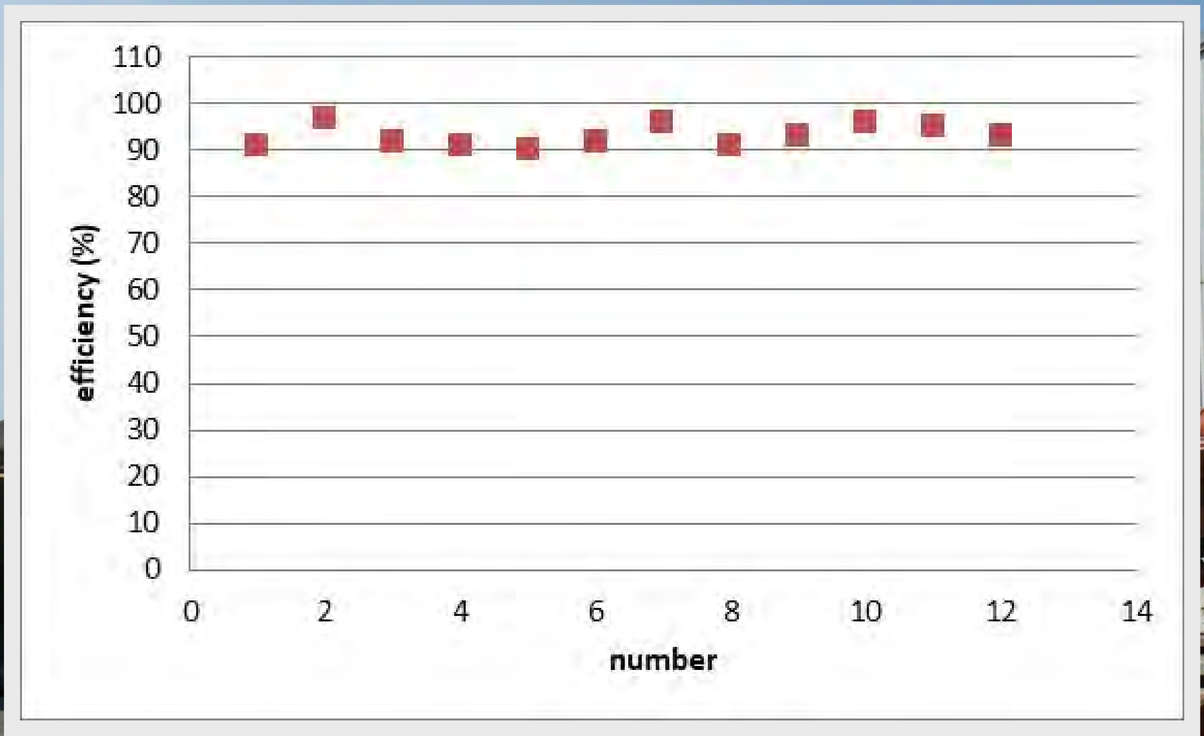
Using Enclosed Cabs for Reducing DPM Exposures

James Noll
NIOSH

Equipment can have pressurized cab



Cabs can be very efficient in reducing DPM exposures



Two Key Components

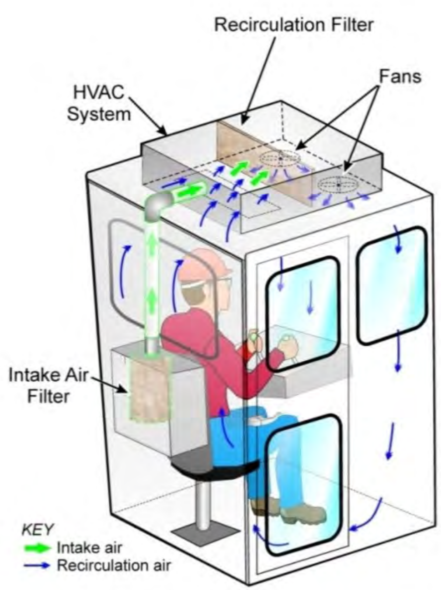
- **Effective Filtration**
- **Cab Integrity**

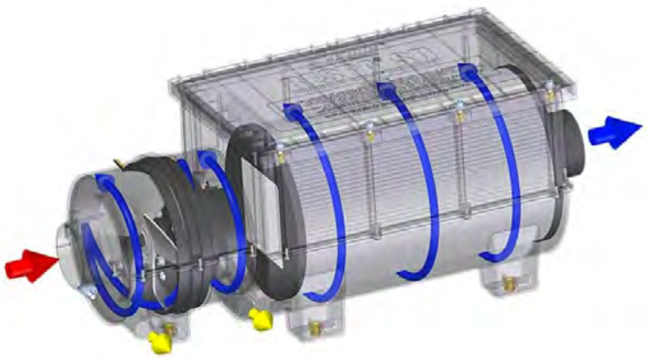
Effective Filtration

1. **Pressurized Intake**
2. **Recirculated Cab Air**

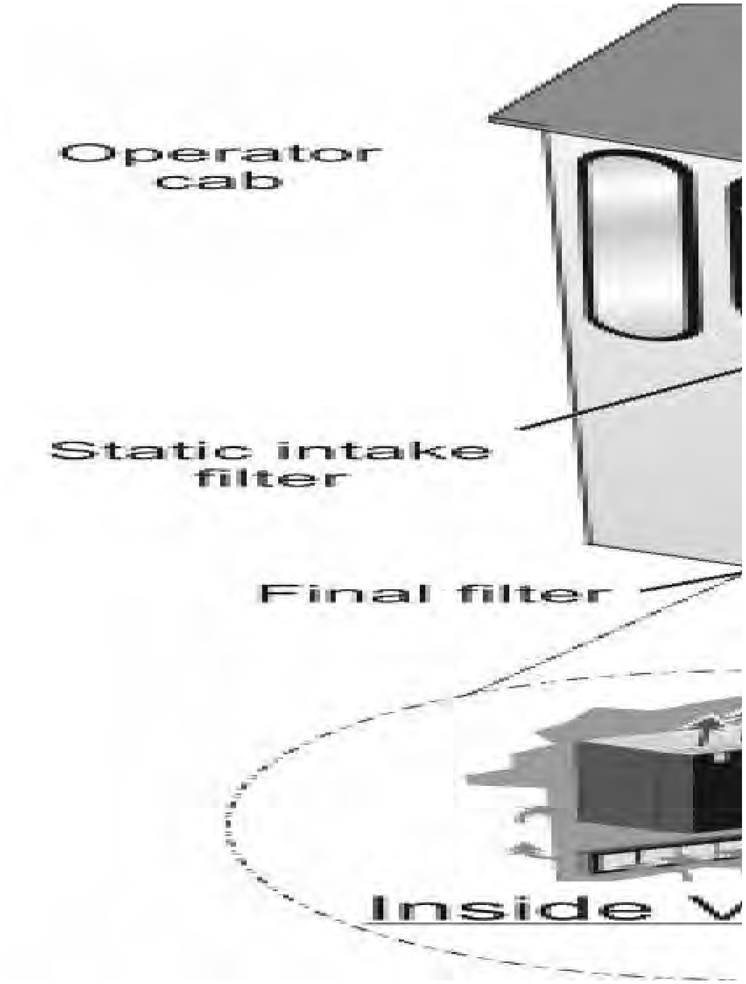
Pressurized Intake (Outside) Air

- **40 – 140 cfm**
- **At least 25 cfm per worker to dilute CO_2**
- **MERV-16 mechanical filter**
- **Powered Unit : Self-cleaning or centrifugal design**





Recirculated Cab Air



Recirculated Cab Air

- Effectiveness is by multiple passes through filter media
- Substantial reduction in cleaning time from in- cab dust sources
- MERV 14 -16 rated filter media
- 3-4 times the intake airflow quantity (200-300 cfm typical)

Cab Integrity

Installing new doors gaskets and seals/plugging and sealing cracks and holes

Pressure Monitoring Testing

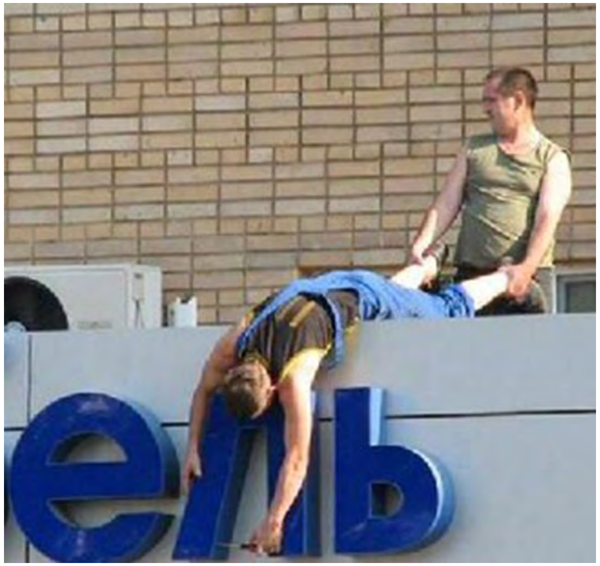
O **utside**

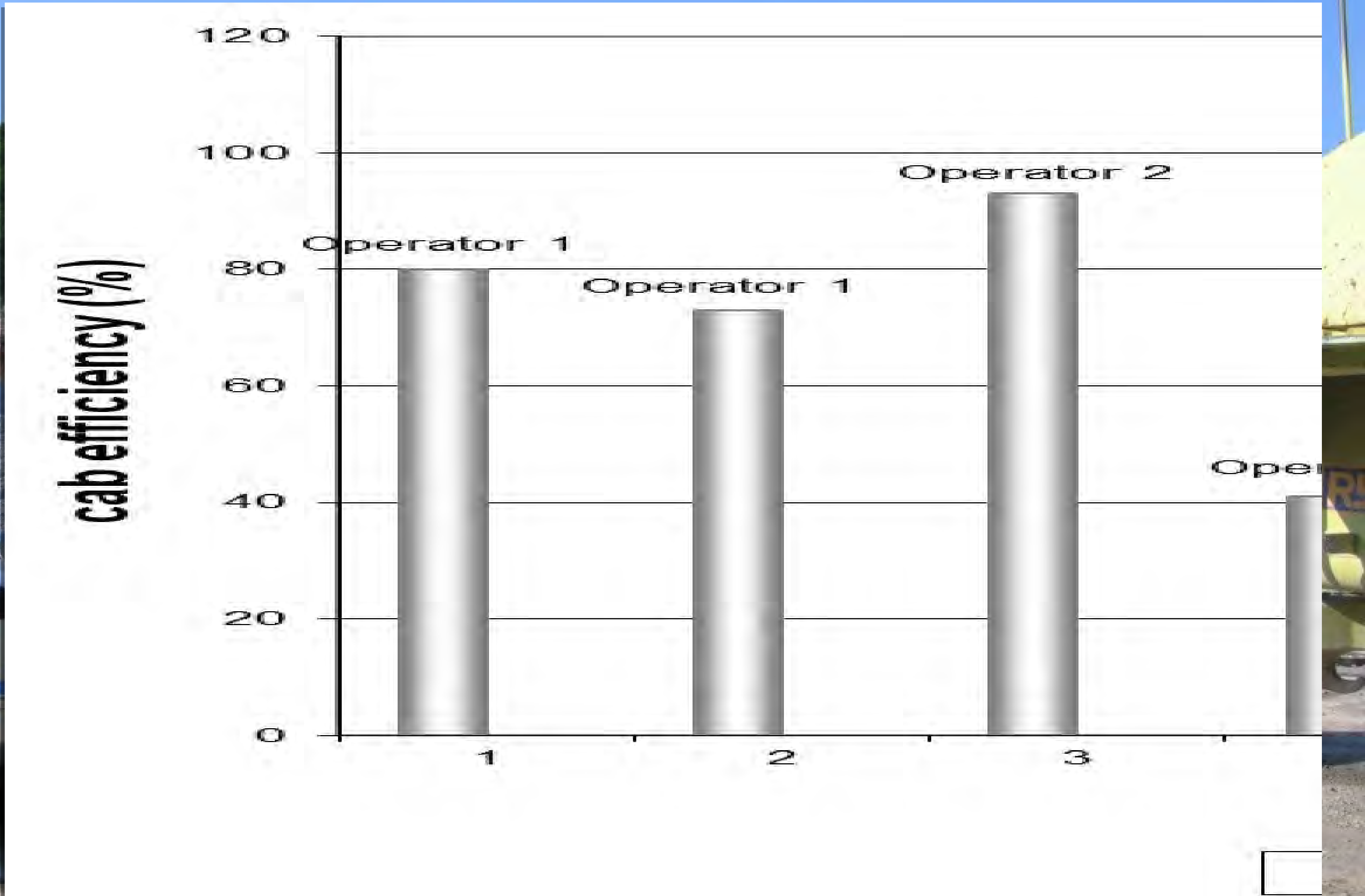
for pressure monitor

Data logger and Pressure Monitoring System


Dwyer
-.009
DM-2000
PRESSURE 1
ZERO
UNITS
OFF
RUN
EMERGENCY STOP
NO HYD. OIL
HIGH HYD. OIL TEMP.
LOW HYD. OIL
MUTED
IRON LIFE

Effect of work practices





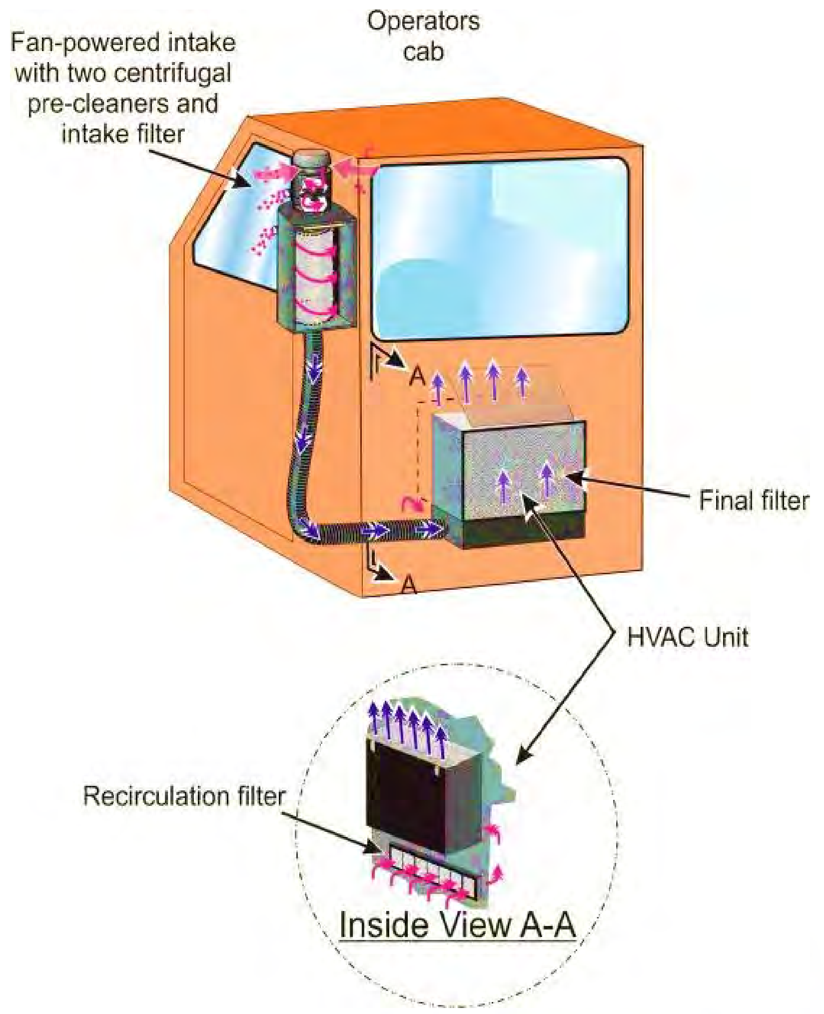
cab efficiency (%)
120
100
80
60
40
20
0
Operator 1
Operator 1
Operator 2
1
2
3

Evaluation of Enclosed Cabs

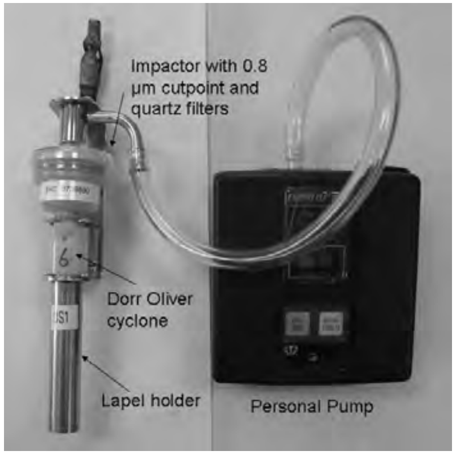
Bolter

Drill

Enclosed cab design

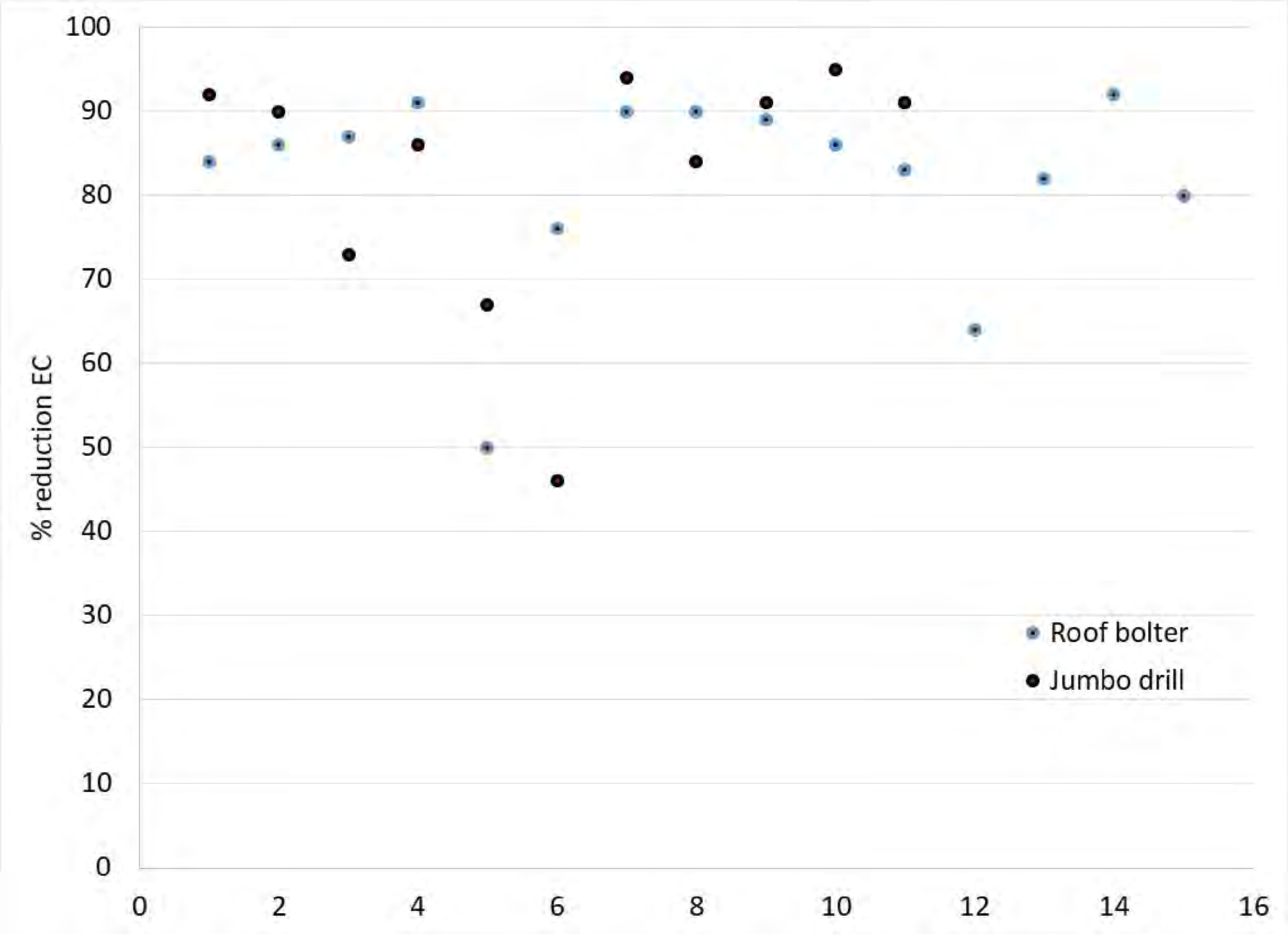


PRESSURE



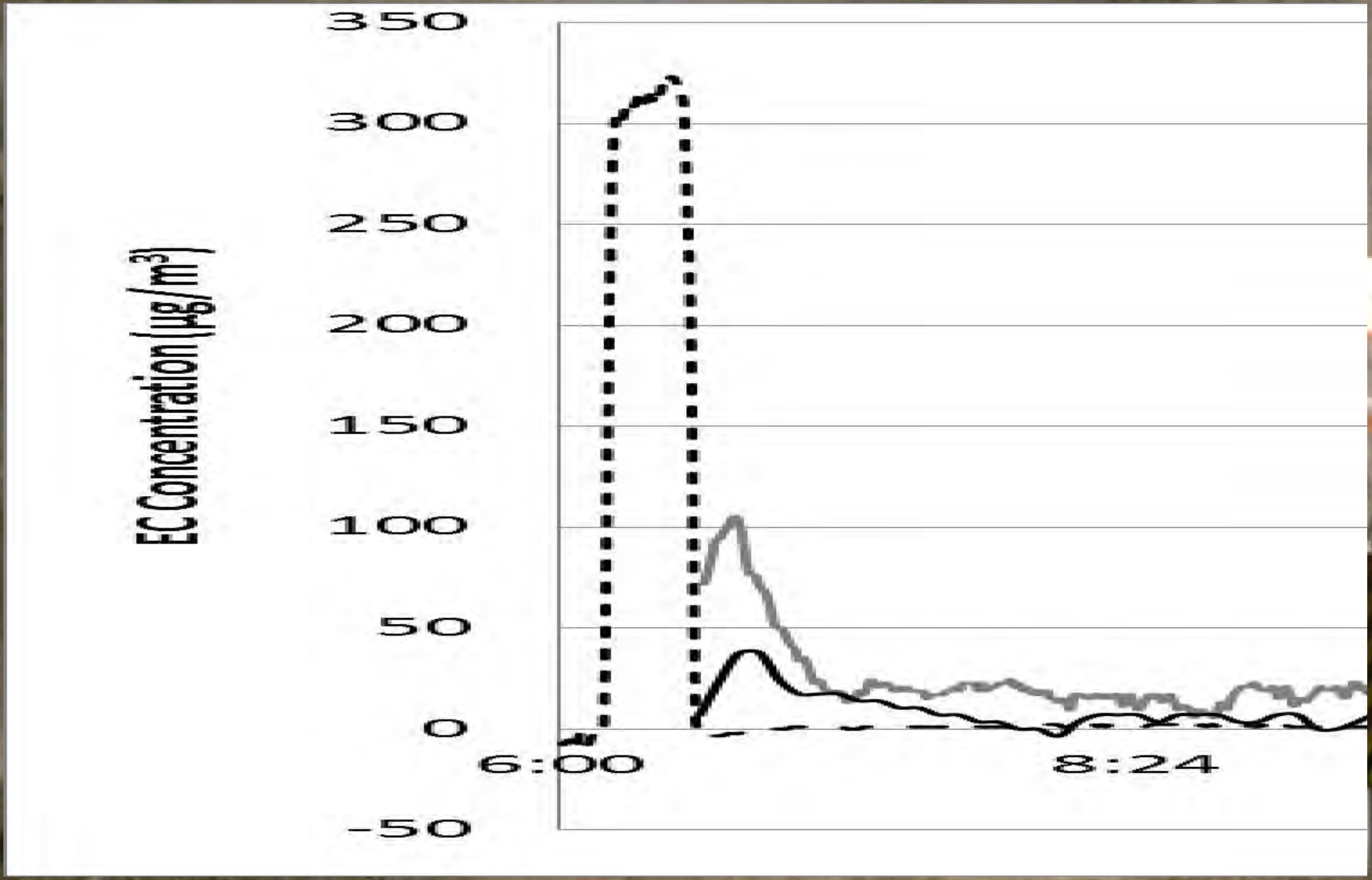
NIOSH 5040 EC/TC

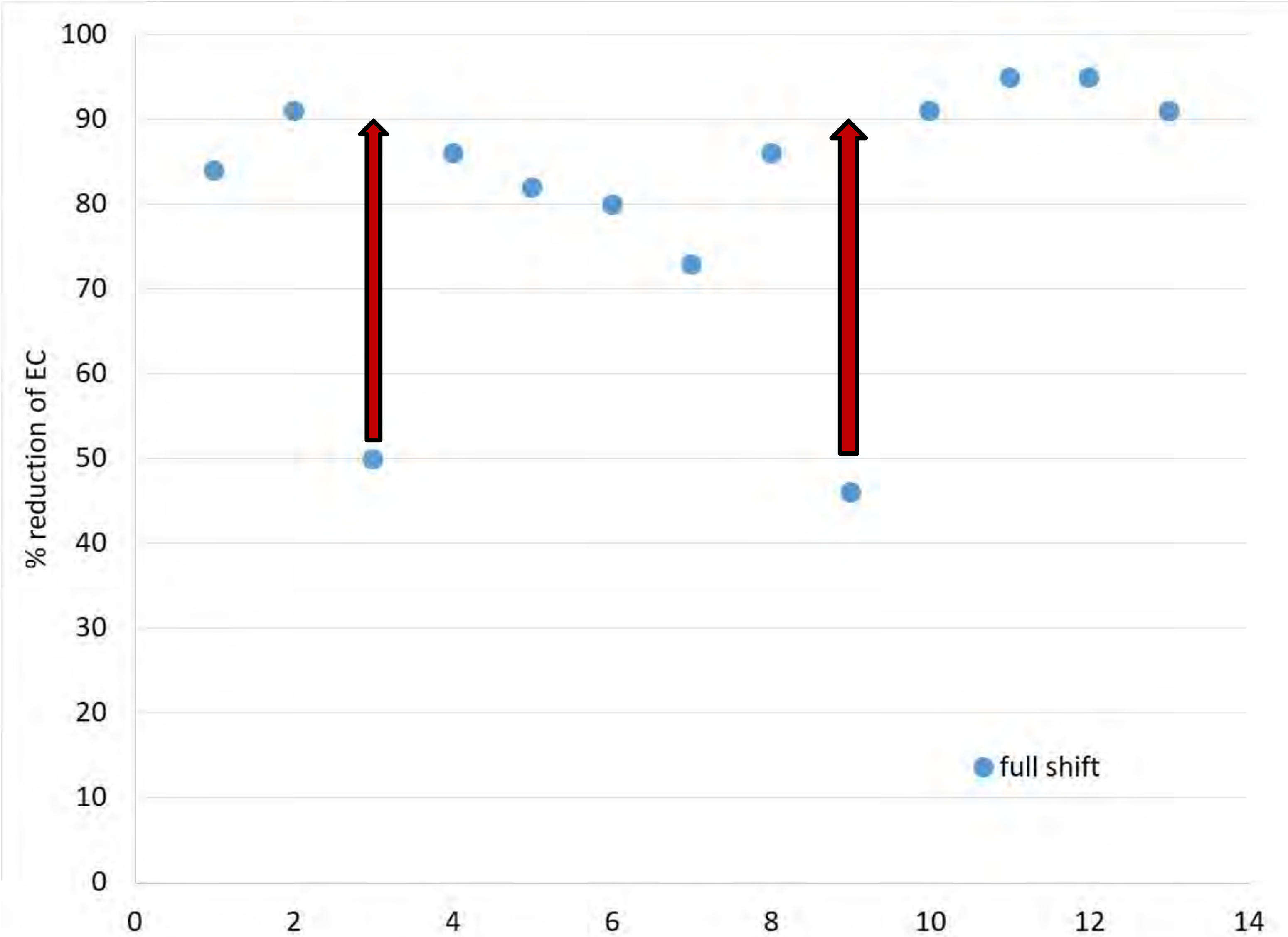
REAL TIME EC



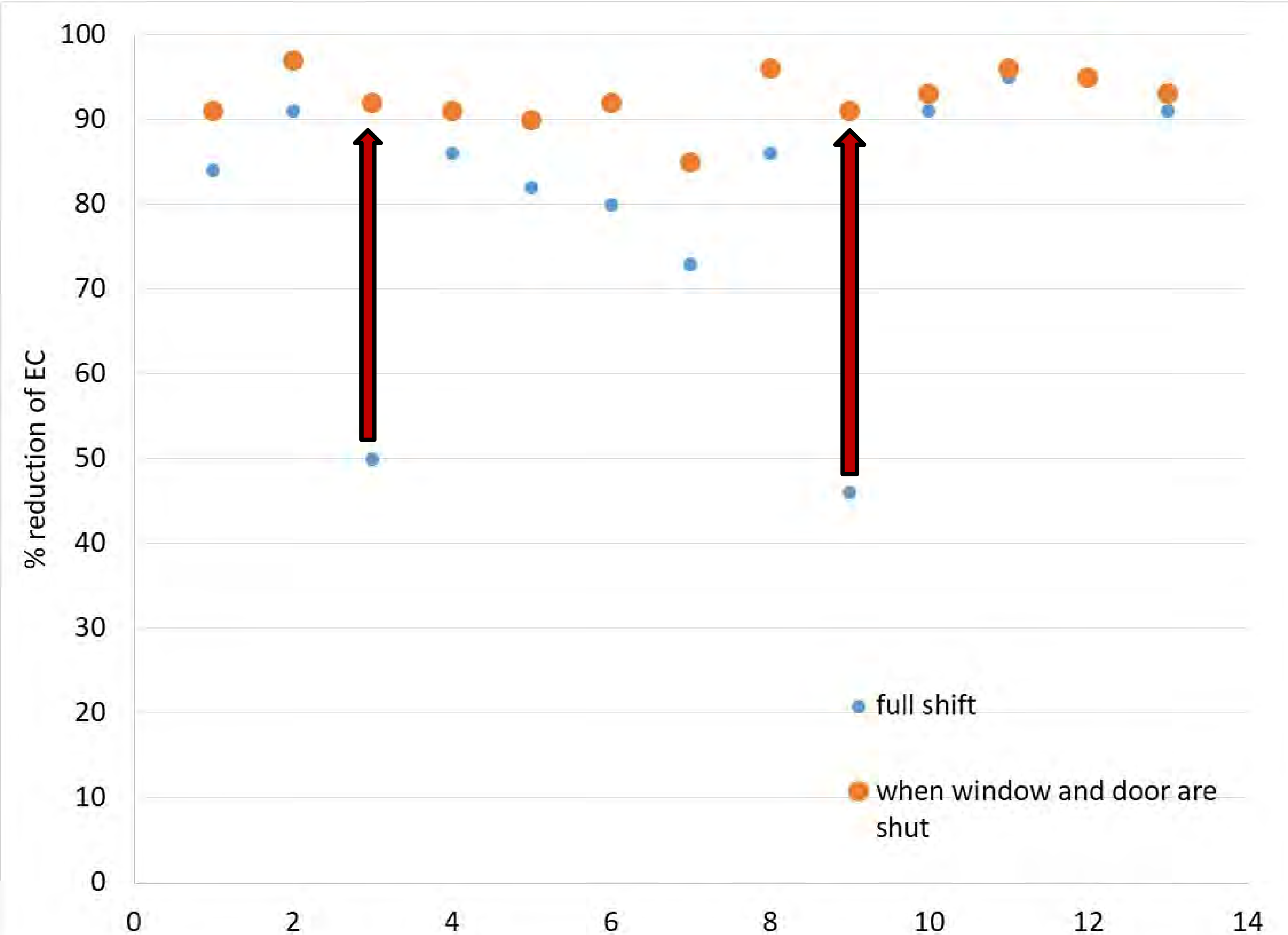
% reduction EC
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
Roof bolter
Jumbo drill

Cab Door Opening





OFFICE OF MINE SAFETY AND HEALTH RESEARCH


100
90
80
70
60
50
40
30
20
10
0
% reduction of EC
0
2
4
6
8
10
12
14
full shift
when window and door are shut

Limitations

- **Maintenance**
  - **Change filters**
  - **Cab integrity**

Limitations

- Maintenance
  - Change filters
  - Cab integrity
- **Not all vehicles have an effective enclosed cab**
  - **Size**
  - **Visibility**

Limitations

- Maintenance
  - Change filters
  - Cab integrity
- Not all vehicles have an effective enclosed cab
  - Size
  - Visibility
- **Not all miners can work in enclosed cabs**

Questions???

James Noll

jnoll@cdc.gov

412-386-6828

ARTISAN VEHICLES

TRANSITIONING TO ZERO-EMISSION EQUIPMENT

Brian Huff

Chief Technology Officer

Current Status of the Zero Emission Mine

- Very Active in Northern Ontario
- New generation lithium battery equipment in service since 2011
- All major mining companies in Canada are planning a full conversion to zero emission equipment underground

KL Gold - Macassa BEV Fleet - Since 2011

34 machines, 38 chargers, 80 batteries

187,000 operating hours

80% of production from BEV

85% availability

- Artisan 2.7 tonne LHD conversion
- Artisan A4 - 4 tonne LHD
- Artisan Z40 - 40 tonne HT
- Epiroc ST7 - 7 tonne LHD
- Epiroc ST2G – 3.6 tonne LHD
- Epiroc MT2010 - 20 tonne HT
- RDH 3 yd - 5 tonne LHD

ALL have Artisan's Powertrain

Why use battery powered equipment?

- Ventilation Reduction
  - No emissions (H_2O/DPM/NOx/etc.)
  - 88% reduction in heat
  - Less dust (no tailpipe)
- Cooling/Heating reduction
  - Less airflow = less cooling or heating
- Time to Production
  - Expand with no new shafts
- Productivity
  - Higher power and smaller
- Health Concerns
  - DPM/Dust/Noise/Vibration
- Possible New Regulations

Managing the Transition

Infrastructure

- Electrical Requirements
- Underground Shop Requirements

Charging Logistics

- Fast Charge or Swap

Personnel

- Operators
- Technicians
- Supply Chain
- Mine Management
- New service personnel type - Battery equipment technician

Infrastructure Transformation

Infrastructure Transformation

Facilities - Swapping Bay

- Purpose built cut out
- Swapping Bay requires:
  - Higher back height
  - Level floor
  - Overhead crane
  - Room for machine
  - Room for 2-3 packs
  - Room for charger


A4
ORE

Artisan Products

Z40

- Battery-Electric
- 40 tonne Truck

ArtisanVehicles.com/Z40

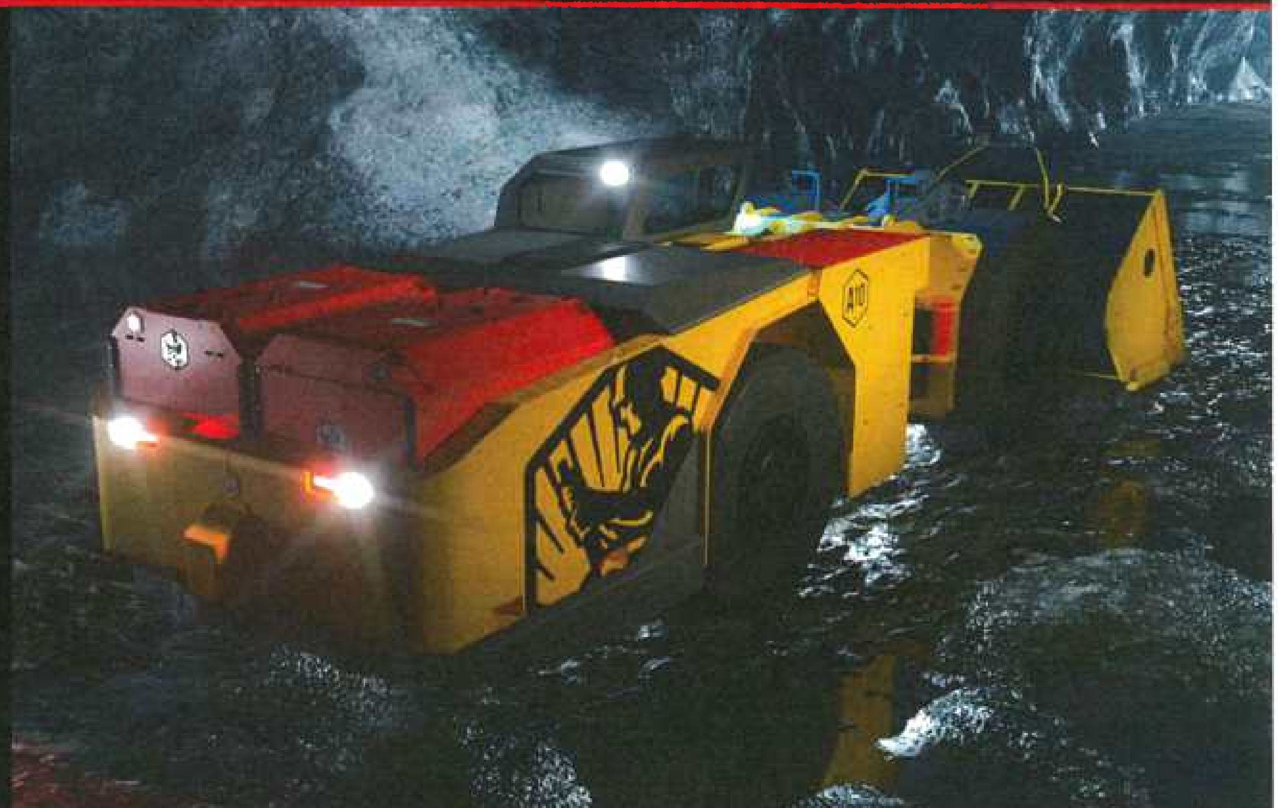
ARTISAN VEHICLES • 2385 PLEASANT VALLEY RD. • CAMARILLO, CA 93012 • 805-512-9955 • ARTISANVEHICLES.COM

Artisan Products

A10

- Battery-Electric
- 10 tonne LHD

ArtisanVehicles.com/A10



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Artisan announces that it is to be acquired by Sandvik

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Artisan Products

Z40

- Battery-Electric
- 40 tonne Truck

ArtisanVehicles.com/Z40

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ARTISAN VEHICLES

ENTER CHARGE BAY
DISCONNECT BATTERY
02:00

DROP USED BATTERY
01:30

DRIVE TO NEW BATTERY
01:30

PICK UP NEW BATTERY
01:00

CONNECT BATTERY
LEAVE CHARGE BAY
02:35

TOTAL TIME
00:00

DRY SYSTEMS TECHNOLOGIES®

Technology for a cleaner and safer Mining Environment™

Dorian Pia, Dry Systems Technologies

Who is Dry Systems Technologies®

- Dry Systems Technologies® is the World's Leading Manufacturer of Diesel Power Packages for underground Mines.
- The Dry Systems Technologies® Main Offices and Manufacturing are located in Woodridge Illinois with a state of the art rebuild and installation facility in Vienna Illinois and Price Utah.
- The Dry Systems Technologies® team invented and developed the "Dry System®" Emissions Treatment and the Low Temperature Exhaust Filtration Technology.

What is the “Dry System®”

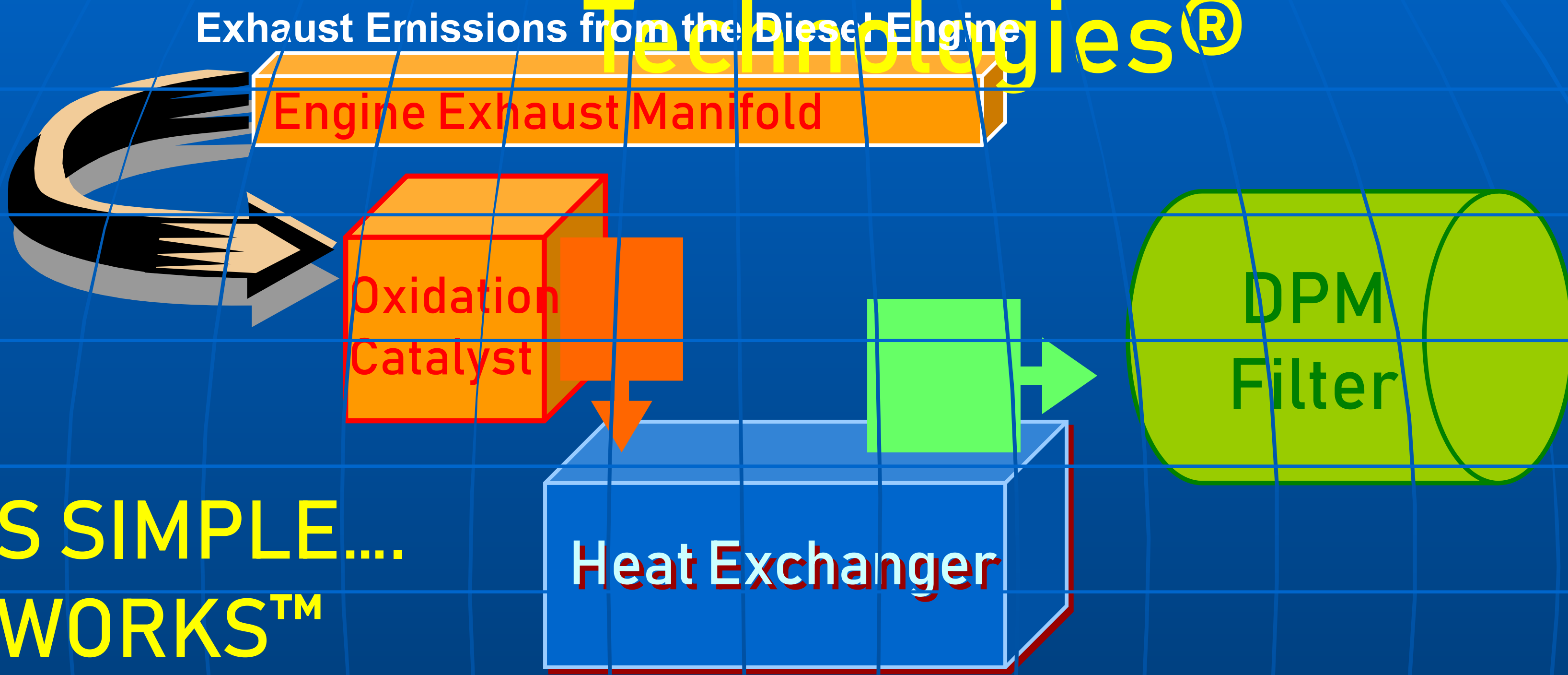
- The Dry System® Diesel Power Packages incorporate the most efficient methods to reduce Diesel Particulate Emissions from existing or new Diesel Engines used in Underground Mines.
- The Dry System® Diesel Power Packages are safe, user friendly and low maintenance and comply with stringent MSHA Diesel Regulations.
- The Dry System® will outlast Diesel Engines through multiple rebuilds and are exclusively available from Dry Systems Technologies®.

Dry Systems Technologies®

The Original – and still the Best™

- Prototypes of the Dry System® have been in operation since 1987 and production Dry Systems® have been in continuous Mine service since 1992
- More than 850 DST Dry System® Diesel Power Packages are currently in operation worldwide.
- Dry Systems® Diesel Power Packages are Approved and are currently operating in more than 75 Mining and Tunneling Projects in North America.
- Dry Systems® Diesel Power Packages have been in successful and incident free operation for a combined 5,000,000+ hrs
- Dry Systems® Diesel Power Packages are available for a wide range of new and existing Engine Models ranging from under 50 Hp to more than 350 Hp

Dry Systems Technologies®



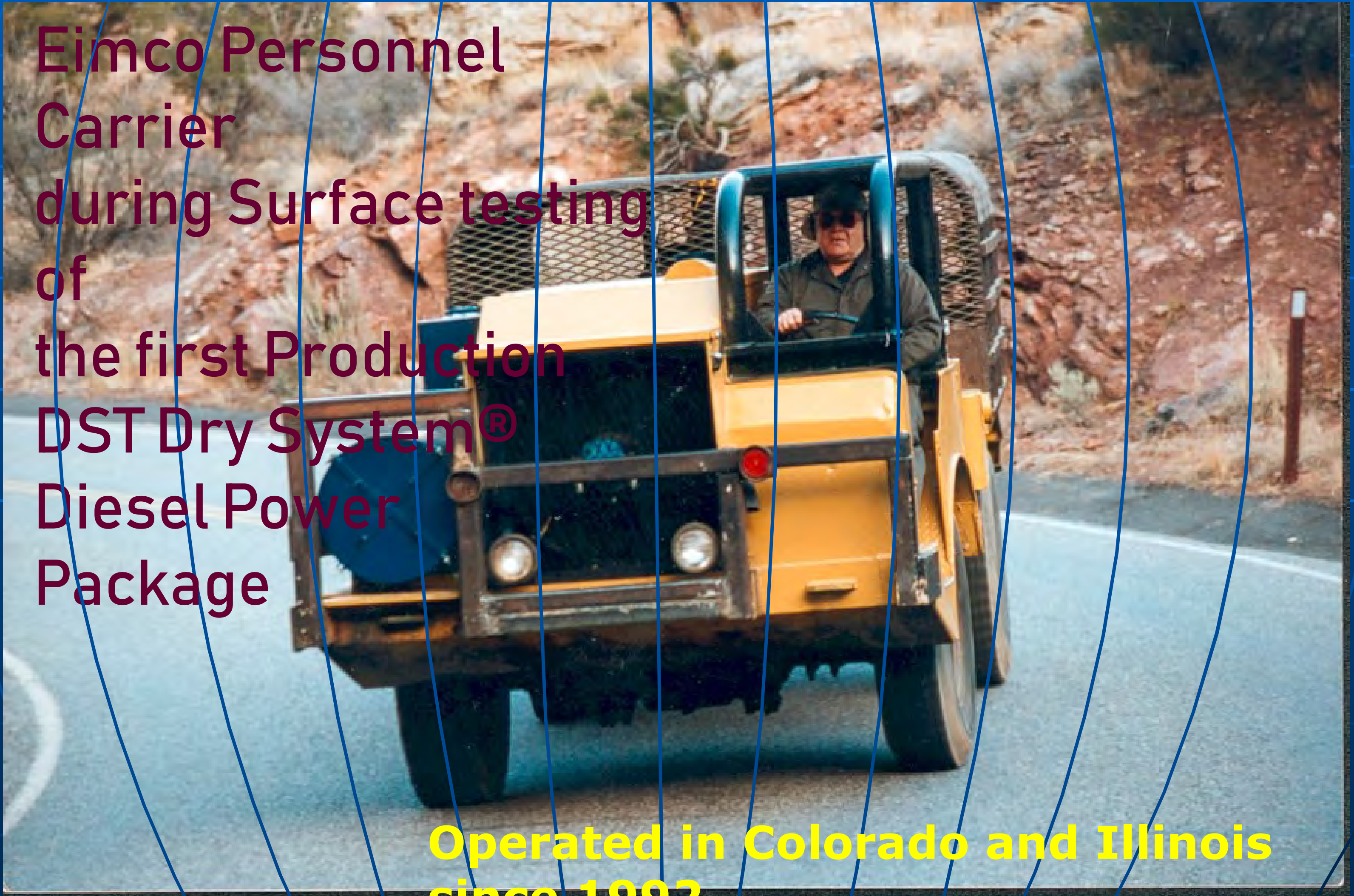
IT'S SIMPLE….
IT WORKS™

UNMATCHED PERFORMANCE

- 96% DPM REDUCTION
- > 90% CARBON MONOXIDE REDUCTION
- > 97% SULFUR REMOVAL
- NO OXIDES OF NITROGEN INCREASE

F

SYSTEM®



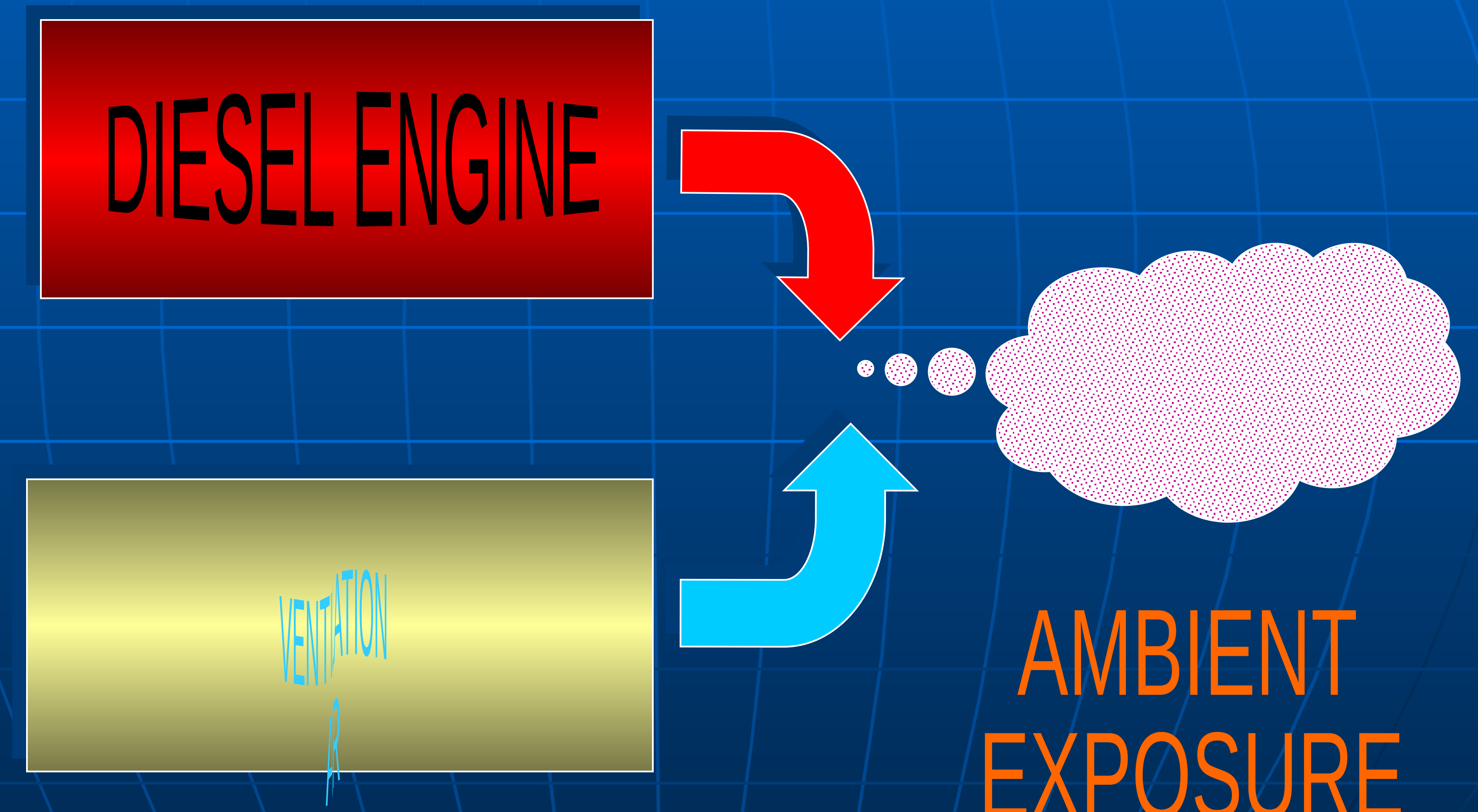
Eimco Personnel Carrier
during Surface testing of
the first Production
DST Dry System®
Diesel Power
Package

Operated in Colorado and Illinois since 1992

CURRENT SITUATION WITHOUT AFTERTREATMENT

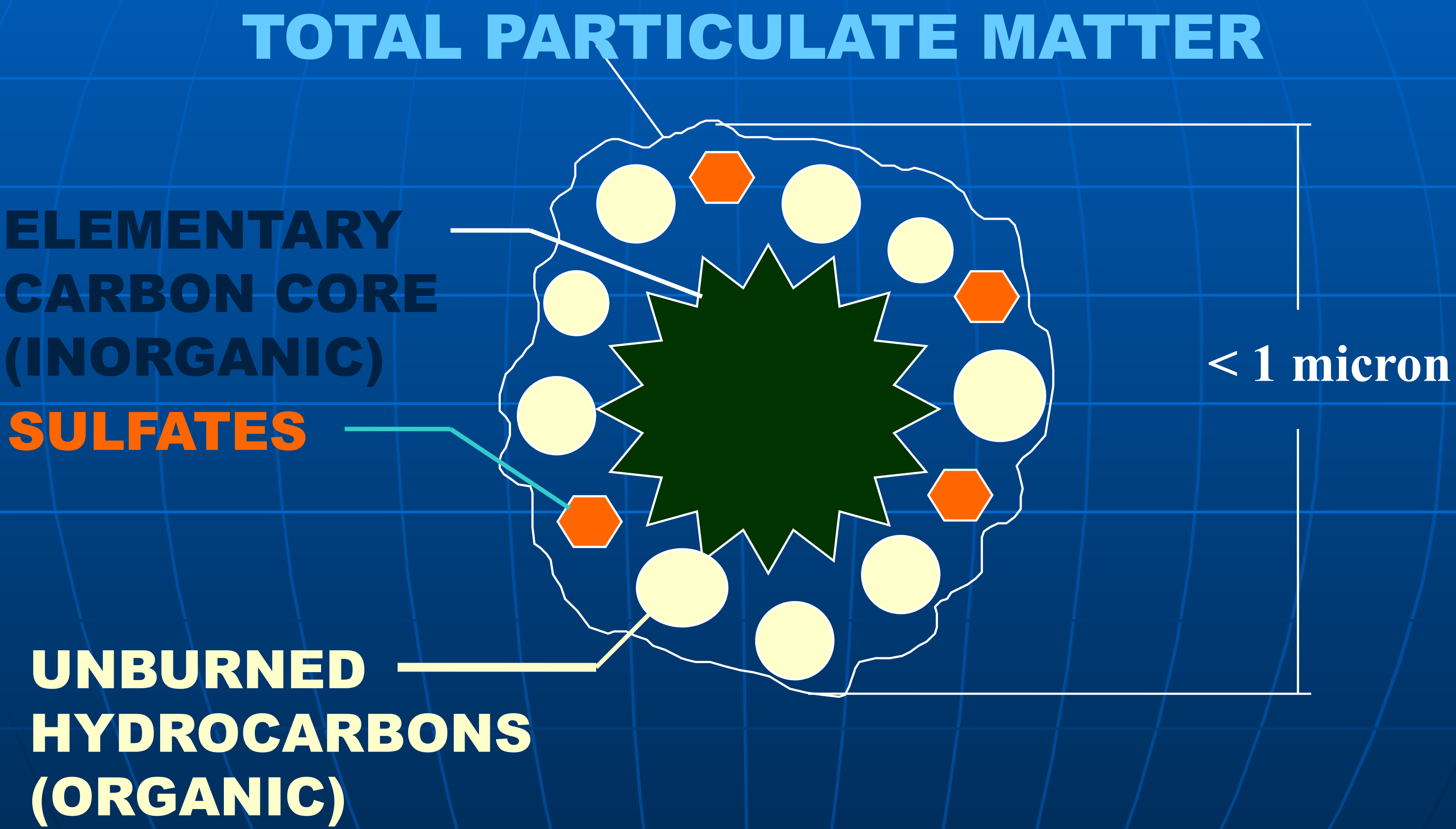
DIESEL EMISSIONS CONTROL

(Traditional Method by Dilution with Ventilation Air)



Smoke emitted from the unfiltered exhaust of a diesel scoop limits operator's view and contaminates the ventilation air

DPM COMPOSITION



E

0.15 mg/m3 (150 µg/m3) without After-treatment

Typical "Dirty" 30 g/hr (500 mg/min) Engine:

117,655 cfm (3,333 m3/min)

Typical "Clean" 5 g/hr (83 mg/min) Engine

19,591 cfm (555 m3/min)

AFTER-TREATMENT WITH DRY SYSTEMS TECHNOLOGIES® DIESEL POWER PACKAGES

D ®

Performance

- Dry Systems® reduces Diesel Particulate Matter (DPM) by 96%.
- Dry Systems® reduces Carbon Monoxide (CO) by 90%.
- Dry Systems® reduces Sulfur Dioxide (SO_2) and Sulfates (SO_4) by 97%. (reference for other markets)
- Dry Systems® reduces the Diesel Odor.
- Dry Systems® reduces Oil and Fuel based Hydrocarbons by 85%.

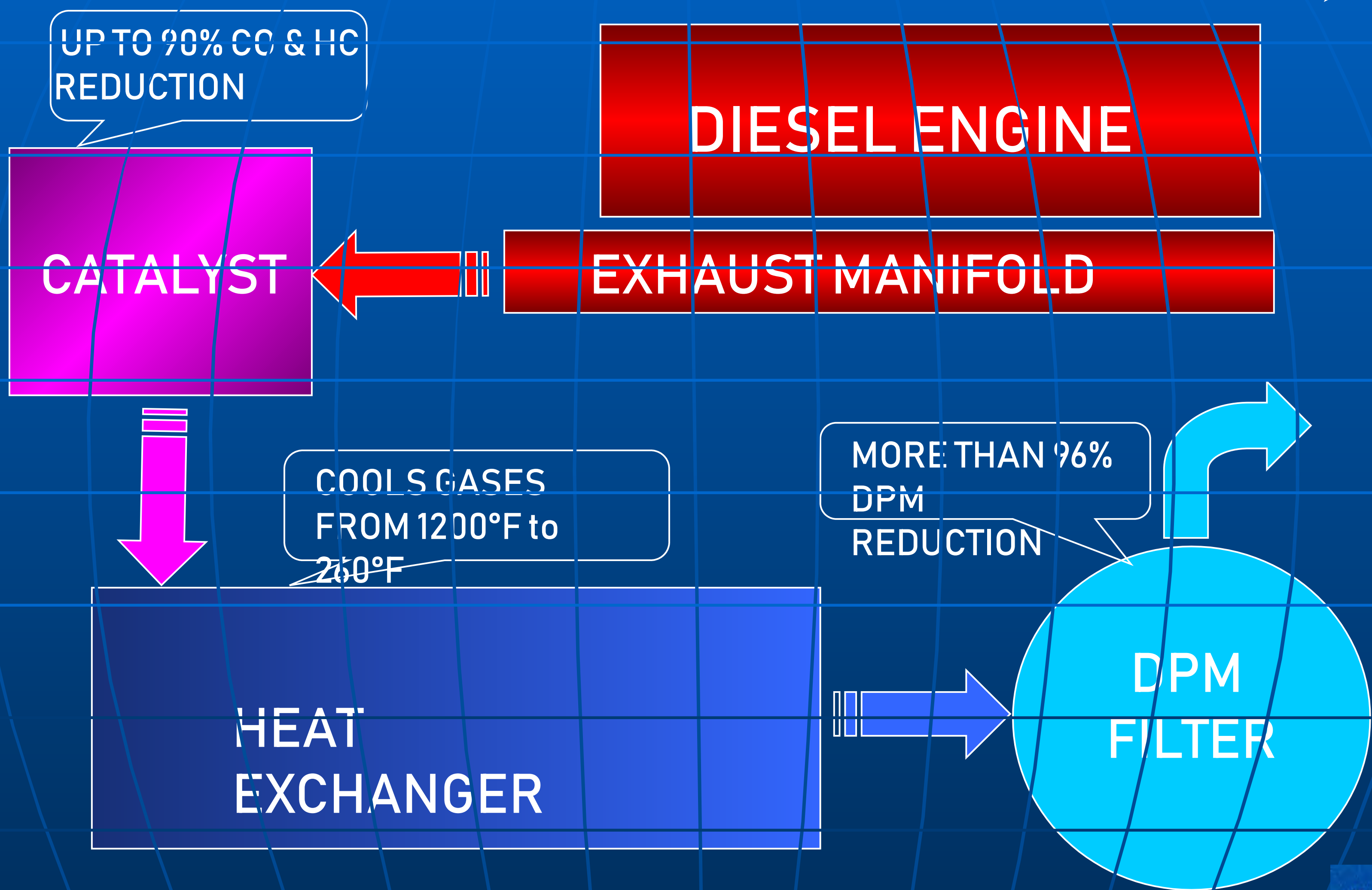
E

0.15 mg/m3
(150 µg/m3) with Dry Systems® After-treatment

Typical "Dirty" 30 g/hr (500 mg/min) Engine with Dry System® After-treatment:
4,695 cfm (133 m3/min)

Typical "Clean" 5 g/hr (83 mg/min) Engine with Dry System® After-treatment:
777 cfm 22 m3/min

THE DST DRY SYSTEM®



IT'S SIMPLE - IT WORKS

The Main Components of the "Dry System®"

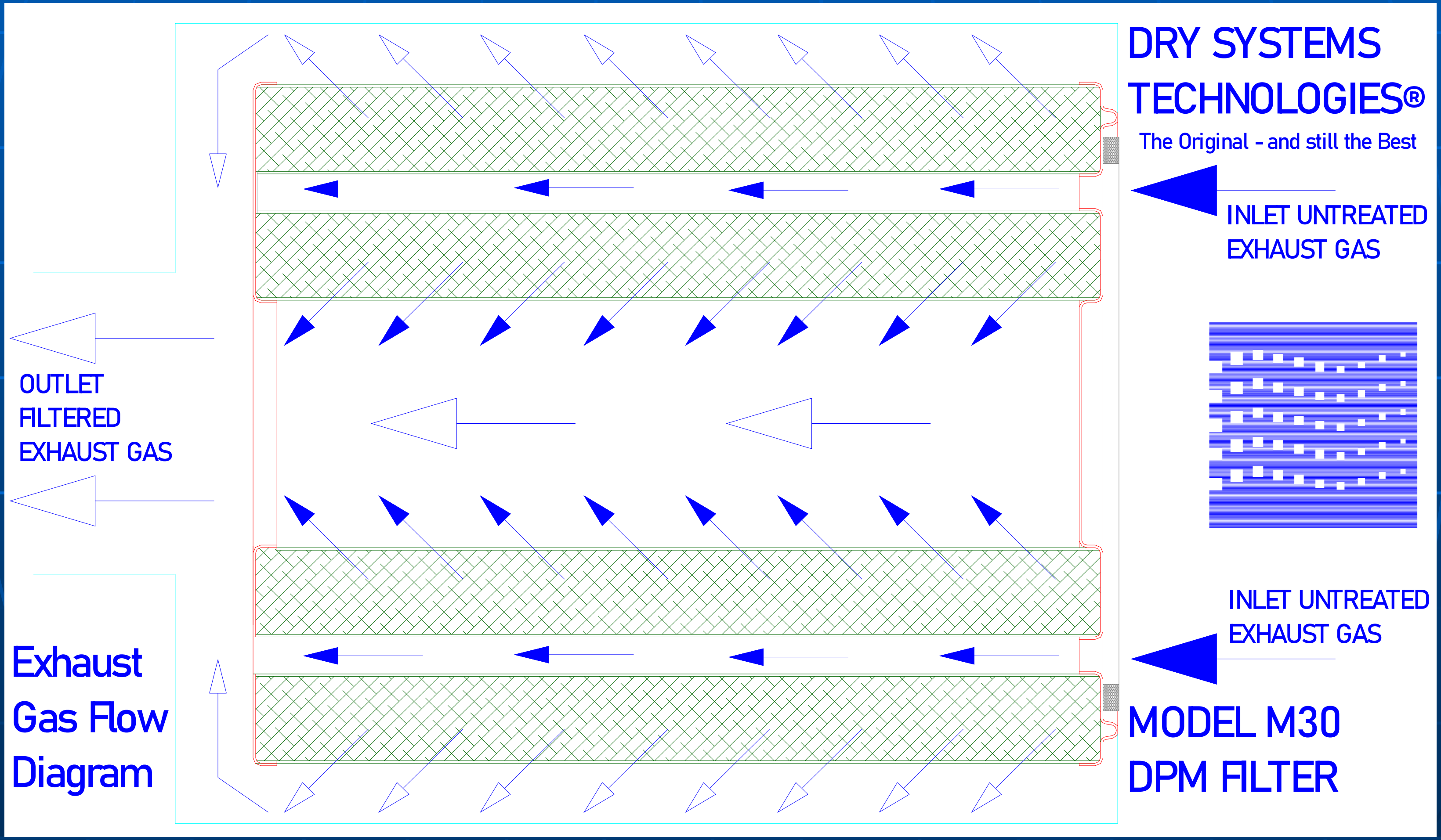
- Oxidation Catalyst
- Heat Exchanger
- Low temperature Diesel Particulate Filter
- Engine and Exhaust Cooling System
- Patented Onboard Cleaning System

The Dry System® Applications

- The "Dry System®" Diesel Power Package can be used anywhere where control of Gaseous and Particulate Emissions from Diesel Engines is required.
- The "Dry System®" Diesel Power Package can be used in Underground Hard-rock Mines and Tunnels.
- The Explosionproof Version of the "Dry System®" Diesel Power Package can be used in Coal Mines, gassy Mines and gassy Tunnels where explosionproof designs are required.
- The "Dry System®" Diesel Power Package is equally suited for Surface applications where control of Gaseous and Particulate Emissions from Diesel Engines is desired.

Flow through the patented Dry S

Particulate Filter.



Converted Permissible 973 and 320 Machines for Tunneling
New DST Model 35-S Scoop Available in Permissible and Non Permissible Versions

B

WITH THE DRY SYSTEM

- The Dry System® can be retrofitted to older "dirty" engines as well as newer "clean" engines.
- With an unequalled DPM reduction of 96%, the Dry System® saves cost with low ventilation requirements while providing the best possible ambient environment for miners.
- The Dry System® will last for the life of the engine and several rebuilds with very little routine maintenance.
- The Dry System® can be built to fit any machine with moderate machine modifications

Dry Systems Technologies®

Thank you for attending our Presentation

DIESEL TECHNOLOGY WORKSHOP

CURRENT BARRIERS TO DEPLOYMENT OF TECHNOLOGIES



Steve Cochrane – Maintenance Analyst

Blue Mountain Energy – Deserado Mine

Rangely, Colorado

BARRIERS OF PROPOSED REGULATIONS/TECHNOLOGY

- Current Underground Technologies for DPM
- Light Duty and Tier 4 Technology
- DPM in Underground Coal
- Cost of Tier 4 Technology

CURRENT TECHNOLOGY UNDERGROUND

- 3 Types of Equipment: Permissible, Heavy Duty, Light Duty
- Permissible – Scoop(s) - Dry Systems Technology

CURRENT TECHNOLOGY UNDERGROUND

- Heavy Duty – ASV Skid Steer, Getman Haul Trucks, Boom, and Grader
- DPM – Air Flow Catalyst System – Engine Control S

CURRENT TECHNOLOGY UNDERGROUND

- Current DPM Systems For Large Underground Equipment
  - DPM Systems Already Approved
  - Current Systems – Efficient
  - Easy to Maint … s and Maintenance Personnel

LIGHT DUTY

- Dodge Ram 2500, Welders

BARRIERS TO PROPOSED REGULATIONS/TECHNOLOGY

- Tier 4 Technology vs Light Duty Pickups

Passive regeneration occurs during normal driving whenever conditions are right to "burn" the particulates in the filter. This typically occurs during long periods of highway driving.

Active regeneration occurs once a predetermined filter capacity has been reached. At this point, the engine will release fuel into the exhaust stream, allowing temperatures to be reached such that particulate mater in the filer will be burned off.

BARRIERS TO PROPOSED REGULATIONS/TECHNOLOGY

- Tier 4 Technology vs Light Duty Pickups
  - Approved Underground Cummins Engines are De-Rated and Governed to 25 MPH
  - Engines Run at a Fraction of Their Rated Power
    - Our Study – 2005 Dodge Ram 2500, Cummins 5.9L
      - 0-10% Load - 34.9%
      - 11-20% Load - 14.1%
      - 21-30% Load - 8.9%
      - 31-40% Load - 3.8%
      - 41-50% Load – 3.6%
      - 51-60% Load – 3.5%
      - 61-70% Load – 2.1%
      - 71-80% Load – 1.5%
      - 81-90% Load – 1%
      - 91-100% Load – 2.3%

> 34.9 % Engine Run Time – 0-10% Engine Load

BARRIERS TO PROPOSED REGULATIONS/TECHNOLOGY

- Tier 4 Technology vs Light Duty Pickups
    - Always in Active Regeneration
    - Overcoming Current System for Regeneration Process
    - Technical Side of the Regeneration Process
    - Temperatures of the Regeneration Process

BARRIERS TO PROPOSED REGULATIONS/TECHNOLOGY

- Temperatures
  - Tier 4 Technology is based on heat to decrease DPM
    - U.S. Department of Agriculture – Forest Service (Diesel Exhaust Emission System Temperature Study
    - https://www.fs.fed.us/e … gement 085101816 –SDTDC De

Table 1. Average maximum temperatures along the exhaust system.

Maximum Measured Temperature	Average Temperature (°F) DPF Equipped	Average Temperature (°F) Non-DPF Equipped
Exhaust gas inside tailpipe	757	416
Exhaust gas outside tailpipe	695	396
Exhaust gas before exhaust cooler	1,089	~
Diesel particulate filter	494	~
After diesel particulate filter	707	~
Before diesel oxidizing catalyst	557	416
Diesel oxidizing catalyst	497	264

BARRIERS TO PROPOSED REGULATIONS/TECHNOLOGY

- Temperatures
  - Coal Dust Explosion Hazards – Clete R. Stephan P.E. – Mine Safety and Health Administration Pittsburgh, Pennsylvania -https://pdfs.semanticscholar.org/c050/3cda4f235e9ab14fd92d196baa12be4fd985.pdf

Minimum Ignition Temperature of Coal Dust Layers

Coal Rank or Type	Min. Ignition Temp (C)	Min. Ignition Temp (F)
Pittsburgh Seam Bituminous	170 C	338 F
Rhode Island (Cranston) Anthracite	520 C	968 F
Illinois No. 7 Bituminous	160 C	320 F
Pocahontas Seam Bituminous	220 C	428 F

BARRIERS TO PROPOSED REGULATIONS/TECHNOLOGY

- Temperatures
  - 30 CFR 7.101(b) Surface temperatures of any external surface of the diesel power package shall not exceed 302 F
  - 30 CFR 7.102(b)(1)&(2) Exhaust Gas Cooling Efficiency Test
    - Exhaust gas temperature at discharge from a <u>wet exhaust conditioner</u> before the exhaust gas is diluted with air shall not exceed 170 F
    - Exhaust gas temperature at discharge from a <u>dry exhaust conditioner</u> before the exhaust gas is diluted with air shall not exceed 302 F
  - 30 CFR 18.23 – Electric Motor-Driven Mine Equipment and Accessories - Limitation of external surface temperatures 302 F

BARRIERS TO PROPOSED REGULATIONS/TECHNOLOGY

- Temperatures

Table 1. Average maximum temperatures along the exhaust system.

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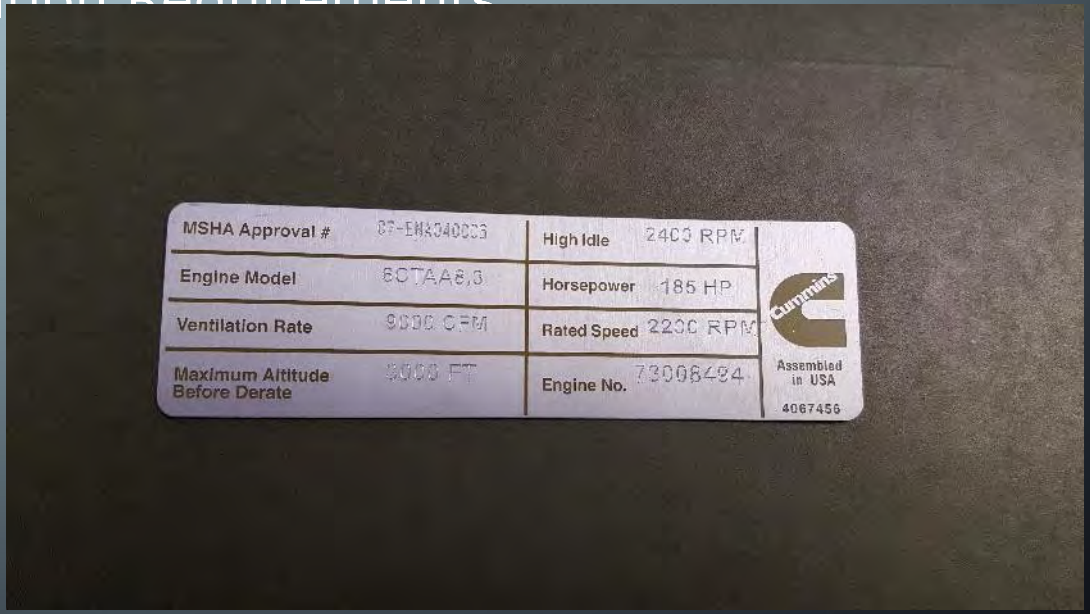
After diesel particulate filter	707	~
Before diesel oxidizing catalyst	557	416
Diesel oxidizing catalyst	497	264

BARRIERS TO PROPOSED REGULATIONS/TECHNOLOGY

- DPM in Underground Coal
  - Already Have Requirements – 2.5 Grams/Hour (Heavy Equipment), 5 Grams/Hour (Light Duty)
  - Limited data or studies of DPM in the underground coal environment
  - Underground Coal and Ventilation Requirements
    - 8000 CFM – Dodge Truck
    - 8500 CFM – Getman Hauler
    - 9000 CFM – Wagner Scoop
    - 4500 CFM – Skid Steer



BARRIERS TO PROPOSED REGULATIONS/TECHNOLOGY

- Cost of Proposed Technology
  - Permissible and Heavy Duty Equipment – Redesign Equipment
  - Light Duty - Pickups
    - No Supplier to Retrofit Current Fleet to Tier 4
    - Replace Current Fleet
      - Current Fleet 42 Pickups
        - $45,000 (New Truck), $10,000 (MSHA REGS/BODY WORK), $12,000 (Fire Suppression)
        - $67,000 x 42 = $2,814,000
  - Maintenance Cost
    - Labor Maintaining System
    - Parts – DPM Filters $3,500
    - Training

BARRIERS TO PROPOSED REGULATIONS/TECHNOLOGY

- Summary
  - Permissible and Heavy Duty Equipment – Current DPM System Works
  - Light Duty – Tier 4 Technology (High Maintenance)
    - Temperatures Undergrou
  - Lack of Data and Cost

THANK YOU…

DESERADO MINE
BLUE MOUNTAIN ENERGY

Concluding Remarks

- The MSHA RFI is Still Open for Comment
  - Will now Close at End of March 26, 2019
  - Workshop Proceedings Transcribed
  - Comments are Likely to Include Workshop Proceedings
  - Urge Comment Period be Extended Further to Allow
- Partnership Activities Should Continue
  - Later in 2019, Hold Another Workshop on Scientific Findings on Health Effects of Diesel Exhaust in Underground Mines
  - Must be Mindful that Debate is not Likely to Reduce Pressure from Multiple Quarters to Promulgate more Stringent Exposure Limits for Diesel Exhaust

Concluding Remarks (Cont'd)

- For Mining in Particular, the Legal Bar is Extraordinarily Stringent and Low
- Section 101(a)(6)(A)(1) of the Federal Mine Safety and Health Act of 1977 (30 U.S.C. §811(a)(6)(A)(1) is the Key

Concluding Remarks (Cont'd)

- The Secretary, in promulgating mandatory standards dealing with toxic materials or harmful physical agents under this subsection, shall set standards which most adequately assure on the basis of the best available evidence that no miner will suffer material impairment of health or functional capacity even if such miner has regular exposure to the hazards dealt with by such standard for the period of his working life. Development of mandatory standards under this subsection shall be based upon research, demonstrations, experiments, and such other information as may be appropriate. In addition to the attainment of the highest degree of health and safety protection for the miner, other considerations shall be the latest available scientific data in the field, the feasibility of the standards, and experience gained under this and other health and safety laws. Whenever practicable, the mandatory health or safety standard promulgated shall be expressed in terms of objective criteria and of the performance desired.

Curtailment of Contribution of Light-Duty and Medium-Duty Diesel-Powered Vehicles to Exposure of Underground Miners to DPM: Burden, Challenges, and Opportunities

by
Aleksandar D. Bugarski
National Institute for Occupational Safety and Health (NIOSH)
Pittsburgh Mining Research Division (PMRD)

The Mine Safety and Health Administration (MSHA)/
National Institute for Occupational Safety and Health (NIOSH)
Diesel Health Effects Partnership Meeting
Washington D.C.
January 23, 2019

Ever since introduction of the DPM regulations [30 CFR Part 72, 30 CFR Part 57], the focus was on reducing contributions from heavy-duty (HD) vehicles.

- The priority was given to HD vehicles for the following reasons:
  - high output engine operated over HD cycles;
  - high utilization factors;
  - role in the development and production process…

- The medium-duty (MD) and light-duty (LD) vehicles were traditionally considered as a secondary contributors:
  - less powerful engines operated over MD and LD cycles;
  - operated in better ventilated areas…

- Over time, relative contribution from MD and LD vehicles became more substantial:
  - efforts to control contribution of HD vehicles were productive;
  - travel distances in the mines grew over the time;
  - utilization of MD and LD vehicles is high as ever…

Several working definitions of HD and LD vehicles are currently used in underground mining industries.

- In the case of underground coal mining fleets, the MSHA clearly differentiate between HD and LD equipment [30 CRF 75.1908]:
  - HD diesel-powered equipment is:
    - equipment that cuts or moves rock or coal;
    - equipment that performs drilling or bolting functions;
    - equipment that moves longwall components;
    - self-propelled diesel fuel transportation units and self-propelled lube units; or
    - machines used to transport portable diesel fuel transportation units or portable lube units.
  - LD diesel-powered equipment is any other equipment that does not meet the aforementioned criteria.

- In the case of underground metal/nonmetal mining, the delineation between HD and LD vehicles is fuzzy:
  - engine output;
  - vehicle categories; and less frequently
  - duty-cycle…

For underground coal mining, the diesel particulate matter (DPM) emission standards [30 CFR Part 72] for the HD diesel-powered equipment are more stringent than those that apply to LD equipment.

- The MSHA regulations [30 CFR Part 7, Subpart E] require use of MSHA-approved diesel engines in underground coal mines in the U.S.A.

- The contribution of diesel-powered vehicles to personal exposures of underground coal miners to DPM is indirectly limited by limiting particulate matter emissions to:
  - 2.5 grams per hour of DPM for permissible diesel-powered equipment [30 CFR 72.500];
  - 2.5 grams per hour of DPM for non-permissible diesel-powered HD equipment [30 CFR 72.501];
  - 5.0 grams per hour of DPM for non-permissible diesel-powered LD equipment [30 CFR 72.502].

- Since the regulations do not require monitoring personal exposure of underground coal miners to DPM, the data is not available to verify the hypothetical impact of those prescribed control strategies.

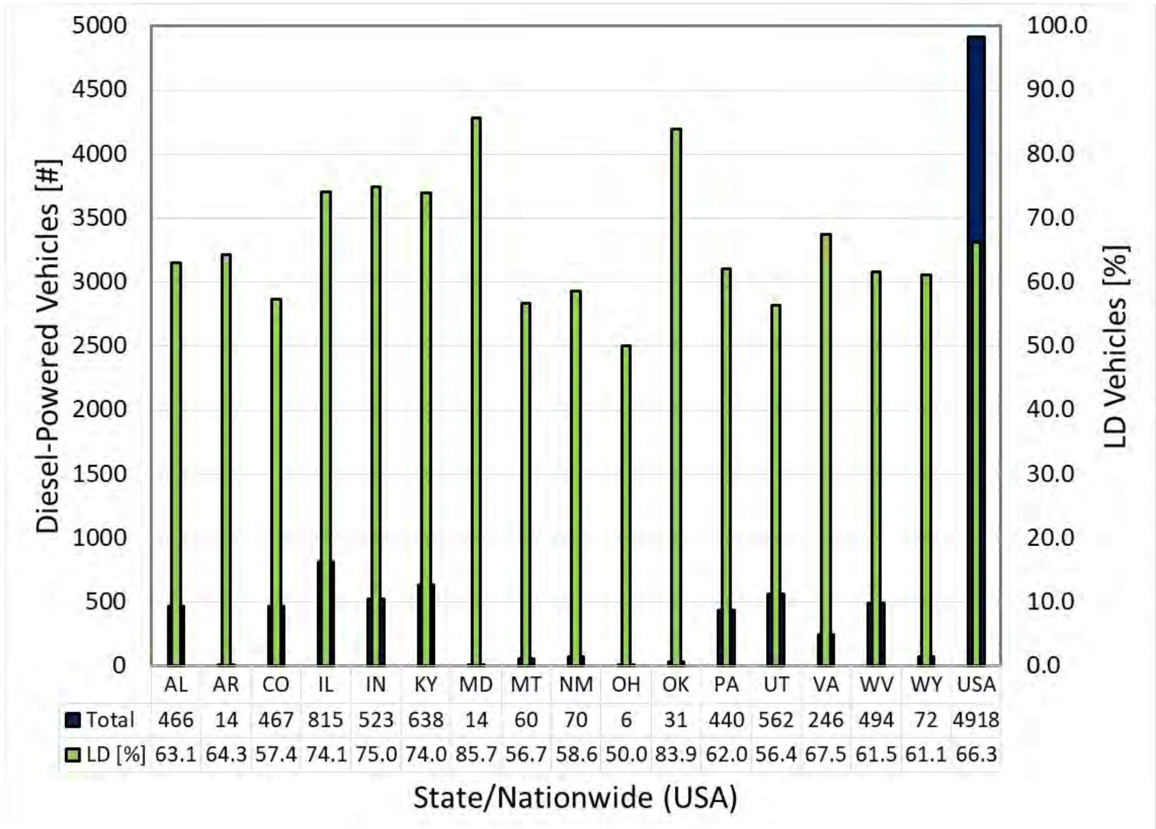
The DPM standards for underground metal/nonmetal mining diesel-powered equipment are more stringent for engines [30 CFR 57.5067] with power outputs between 37 kW (50 hp) and 560 kW (700 hp) than for sub-37 kW (50 hp) output engines.

- The MSHA regulations [30 CFR 57.5067] require use of diesel engines that are:
  - approved by MSHA under 30 CFR Part 7 subpart E or 30 CFR Part 36; or
  - approved by EPA - listed in Table 57.5067-1.
- Those emission standards are dated and trailing behind current Environmental Protection Administration (EPA) emission standards [EPA 2016].

	EPA category	PM limit
40 CFR 86.094-8(a)(1)(i)(A)(2)	light duty vehicle	0.1 g/mile
40 CFR 86.094-9(a)(1)(i)(A)(2)	light duty truck	0.1 g/mile
40 CFR 86.094-11(a)(1)(iv)(B)	heavy duty highway engine	0.1 g/bhp-hr
40 CFR 89.112(a)	nonroad (tier, power range)	varies by power range:
	tier 1 kW<8 (hp<11)	1.0 g/kW-hr (0.75 g/bhp-hr)
	tier 1 8<kW<19 (11<hp<25)	0.80 g/kW-hr (0.60 g/bhp-hr)
	tier 1 19<kW<37 (25<hp<50)	0.80 g/kW-hr (0.60 g/bhp-hr)
	tier 2 37<kW<75 (50<hp<100)	0.40 g/kW-hr (0.30 g/bhp-hr)
	tier 2 75<kW<130 (100<hp<175)	0.30 g/kW-hr (0.22 g/bhp-hr)
	tier 1 130<kW<225 (175<hp<300)	0.54 g/kW-hr (0.40 g/bhp-hr)
	tier 1 225<kW<450 (300<hp<600)	0.54 g/kW-hr (0.40 g/bhp-hr)
	tier 1 450<kW<560 (600<hp<750)	0.54 g/kW-hr (0.40 g/bhp-hr)
	tier 1 kW>560 (hp>750)	0.54 g/kW-hr (0.40 g/bhp-hr)

The analysis of the inventory of diesel-powered vehicles [30 CFR 72.520, MSHA 2018a] in underground coal mines indicate that the LD vehicles dominate those fleets.

- Total of 4918 diesel-powered vehicles are operated in 157 mines:
  - Permissible HD: 318 (6.5%);
  - Non-permissible HD: 1270 (25.8%);
  - **Non-permissible LD: 3261 (66.3%);**
  - Fire fighting and ambulance equipment: 17 (0.3%);
  - Unknown: 52 (1.1 %).

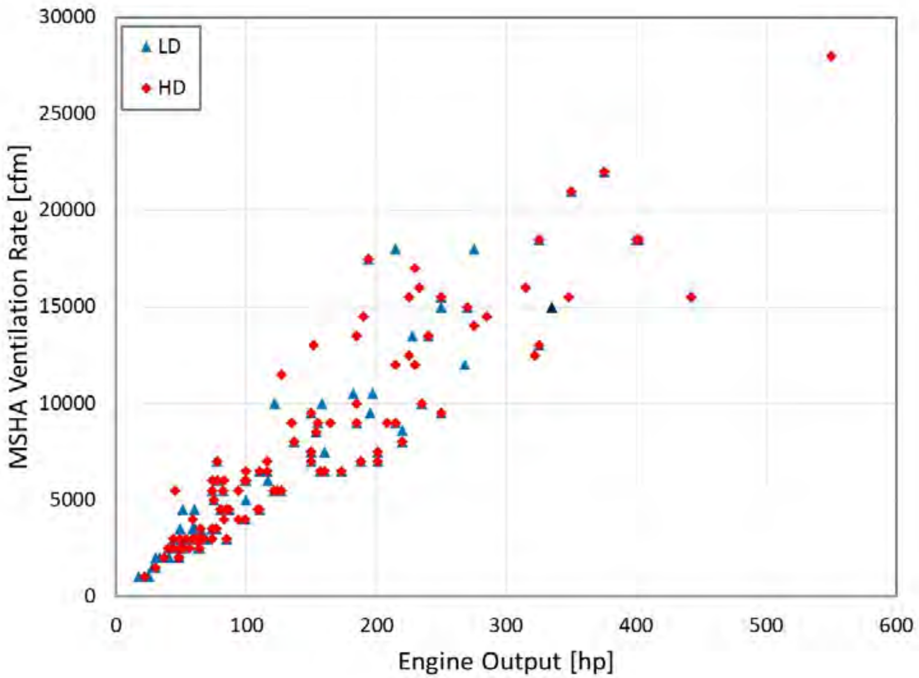


Underground coal mines are using wide variety of engines in LD diesel-powered equipment [MSHA 2018a].

- 103 different models of MSHA-approved engines (07-ENAXXXXXX and 7E-BXXX) power 3261 LD vehicles .

- A broad spectrum of power outputs:
  - kW < 19 (hp < 25) (4.9 %),
  - 19 ≤ kW < 56 (25 ≤ hp < 75) (34.0 %),
  - 56 ≤ kW < 130 (75 ≤ hp < 175) (34.0 %),
  - 130 ≤ kW < 225 (175 ≤ hp < 302) (20.4 %), and
  - 225 ≤ kW < 450 (302 ≤ hp < 603) (6.8 %).

- Apparently, the LD vehicles in underground coal mines in the U.S. are not necessarily powered by low output engines, but might be operated over LD duty-cycle.



The LD vehicles represent large fractions of underground metal and nonmetal diesel fleets.

- The inventories of diesel-powered vehicles used in underground metal and nonmetal operations are not publically available.

- The limited survey that we performed at several mines across the spectrum of the commodities (metal, nonmetal, stone) revealed that the differentiation between HD and LD vehicles is fuzzy and subject of personal interpretation:
  - HD: Haulage trucks, LHD vehicles, drills, fuel/lube truck…
  - MD: (treated sometimes as HD or sometimes as LD): shotcrete truck, ENFO loader, scissor truck, grader, scaler, welding truck…
  - LD: personnel carriers, side-by-sides, utility vehicles, tractors, 400 hp pickup trucks…

- The LD and MD vehicles appear to make 60 or more percent of the examined fleets.

Several pathways are available to underground mining industry to address contribution of diesel-powered vehicles to exposure of underground miners to DPM:

- Acquisition of new or re-powering existing vehicles with advanced engine and exhaust aftertreatment technologies;
- Retrofitting existing (EPA Tier 2 and Tier 3) engines with viable DPF systems;
- Substituting petroleum based fuels with cleaner burning fuels;
- Improving quality of existing and acquisition of new environmental enclosures and filtration/pressurization systems for MD and LD vehicles;
- Substitution of selected vehicles with electric-powered vehicles…

Acquisition of New or Re-powering Existing LD and MD Vehicles with Advanced Engines

It appears that there is plenty of potential to reduce engine emissions from aging coal diesel-powered fleets [MSHA 2018a].

#	MSHA Approval Number	Make and Model, kW (hp) @ rpm	DPM [g/kW-hr / g/hp-hr]	EPA Standards [g/kW-hr / g/hp-hr]	DPM [g/h]	Number [#]
1	07-ENA040004	Deutz BF4L2011, 58 (78) @ 2800	0.11 / 0.08	0.40 / 0.30	3.7	388
2	07-ENA040002	Deutz BF4M2012, 75 (100) @ 2500	0.11 / 0.08	0.40 / 0.30	4.51	314
3	07-ENA040015-1	ISB-215, 160 (215) @ 2900	0.20 / 0.15	0.20 / 0.15	15.56	263
4	07-ENA050001	Mitsubishi S4S-DT, 57 (77) @ 2500	0.24 / 0.18	0.40 / 0.30	6.91	244
5	07-ENA030001	Mitsubishi s4s, 47 (63) @ 2500	0.35 / 0.26	0.40 / 0.30	7.65	171
6	07-ENA040012	Deutz F4L2011, 48 (64) @ 2800	0.27 / 0.20	0.40 / 0.30	6.52	155
7	07-ENA040011	Deutz F3L 2011 (D 2011L03i), 36 (48) @ 2800	0.27 / 0.20	0.60 / 0.45	4.89	130
8	07-ENA070006	Cummins QSB4.5, 82 (110) @ 2500	0.24 / 0.18	0.30 / 0.22	11.1	125
9	07-ENA100009	Cummins ISB 6.7, 164 (220) @ 2900	0.12 / 0.09	0.20 / 0.15	9.22	115
10	07-ENA040004-1	Deutz BF4L2011, 58 (78) @ 2800	0.11 / 0.08	0.40 / 0.30	3.7	75
19	07-ENA140005	Kubota D902-E4, 16 (22) @ 3200	0.54 / 0.40	0.40 / 0.30	4.25	40
24	07-ENA140006	Kubota D1105-E4, 19 (25) @ 3000	0.15 / 0.11	0.40 / 0.30	1.42	33

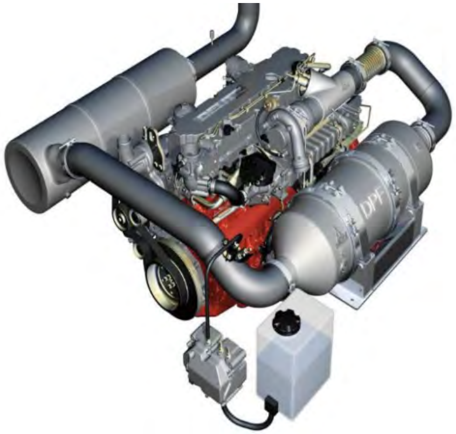
EPA Tier 2/Tier 3

EPA Tier 4 final

- The most ubiquitous engines in the LD vehicles are those that meet U.S. EPA Tier 2 and Tier 3 DPM standard and few meet U.S. EPA Tier 4 final standard.
- Approximately 49.3% (1,608 out of 3,261) pieces of non-permissible LD diesel-powered equipment emit less than 5.0 g/hr of DPM.
- Approximately 23.6 % (771 out of 3,261) pieces of non-permissible LD diesel-powered equipment emit less than 2.5 g/hr of DPM.
- The majority of engines in the LD vehicles that meet 5.0 g/hr standard without filtration systems have outputs under 37 kW (50 hp).

Attrition of older vehicles and engines should play important role in the process of reducing contributions of HD and LD diesel-powered vehicles to DPM burden.

- In the case of metal and nonmetal mines in the U.S., the typical life expectancy of diesel engines varies with type of equipment:
  - haulage truck life expectancy is approximately 15,000 hours;
  - LHD vehicle life expectancy is approximately 12,000 hours;
  - shotcrete vehicle or ANFO loader life expectancy is anywhere between 8,000-15,000 hours;
  - LD vehicles last between several months and several years.
- Therefore, depending on utilization factor, the spontaneous attrition might take some time:
  - the haulage trucks and LHD vehicles are repowered every 3-5 years.
  - the LD and MD vehicles might be repowered every 5-10 years.
- When replacing engines, operators might opt for alternative contemporary low-emitting engines rather than the rebuilt engines of the same kind.
- In the case of smaller LD vehicles, the relatively fast vehicle attrition might help implementation of advanced engine and exhaust aftertreatment technologies.



However, it appears that the attrition of the LD vehicles in the underground coal [MSHA 2018] and other mines is happening rather slow and that the industry still did not fully benefit from the recent technological advancements in engine and exhaust aftertreatment technologies.

- Over past two decades the U.S. EPA [EPA 2016] emissions standards gradually became more stringent.
  - PM standards for engines with outputs between 75 and 130 kW (100 and 175 hp), evolved as follows:
    - 1997 (EPA Tier 1): no standard
    - 2003 (EPA Tier 2): 0.30 g/kW-hr (0.22 g/hp-hr);
    - 2007 (EPA Tier 3, never adopted): 0.30 g/kW-hr (0.22 g/hp-hr);
    - 2011 - 2014 (EPA Tier 4i and Tier 4f): 0.02 g/kW-hr (0.01 g/hp-hr).
- Lately, EU introduced the more stringent particulate mass and particulate number emission standard [EU 2016]: the Euro Stage V engines with power output between 19 and 560 kW should not emit more than 0.015 g/kWh of PM and 1×10^{12} #/kWh of PN.

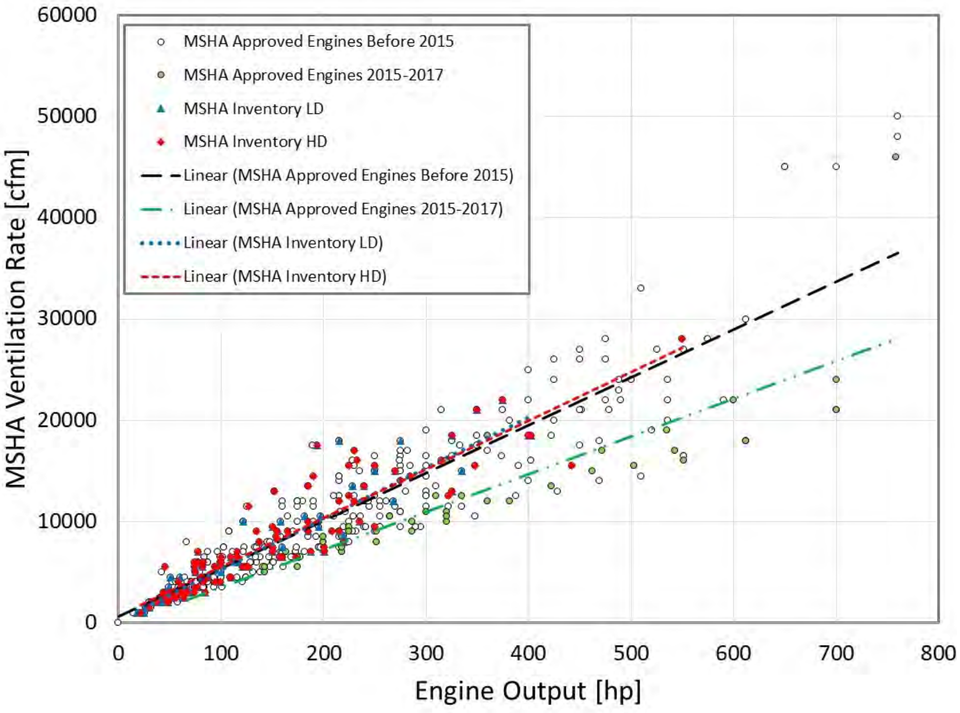
Tier 3

> 90% reduction in PM
> 90% reduction in NO_X

Tier 4f

MSHA engine certification data [MSHA 2018b] indicate that replacing older engines with adequate engines certified after January 2015 could result in lower ventilation rate requirements.

- MSHA approves diesel engines for use in underground mines under 30 CFR Part 7, Subpart E.
- Emissions are determined using ISO 8178-C1 test protocol (Non-Road Steady Cycle, NRSC)
- Ventilation rate is determined for each engine as an amount of air necessary to dilute the gaseous emissions from the engine to 1972 ACGIH TLVs for:
  - Carbon Dioxide (CO_2) - 5000 ppm
  - Carbon Monoxide (CO) - 50 ppm
  - Nitric Oxide (NO) - 25 ppm
  - Nitrogen Dioxide (NO_2) - 5 ppm



CANMET engine certification data also indicate that replacing EPA Tier 1,2, and 3 engines with selected EPA Tier 4i and 4f engines would result in lower ventilation rate requirements.

- **CANMET approves diesel engines for use in underground mines [CANMET 2018] under CAN/CSA-M424.2-M90 [2011] or under** CAN/CSA-M424.1-88 [2011].

- **The emissions data determined for 18-mode test are used to calculate exhaust quality index (EQI):**
  - $(EQI) = \frac{CO}{50} + \frac{NO}{25} + \frac{DPM}{2} + 1.5\left(\frac{SO_2}{3} + \frac{DPM}{2}\right) + 1.2\left(\frac{NO_2}{3} + \frac{DPM}{2}\right)$
- Ventilation rate is calculated at each of 18 test modes to reduce EQI to a value of 3.
- Ventilation rate is calculated at each of 18 test modes to reduce EQI to a value of 3.
- Alternative ventilation rates are recommended by NRCan/CanmetMINING where, some of the gases govern ventilation rates rather than the EQI criterion.
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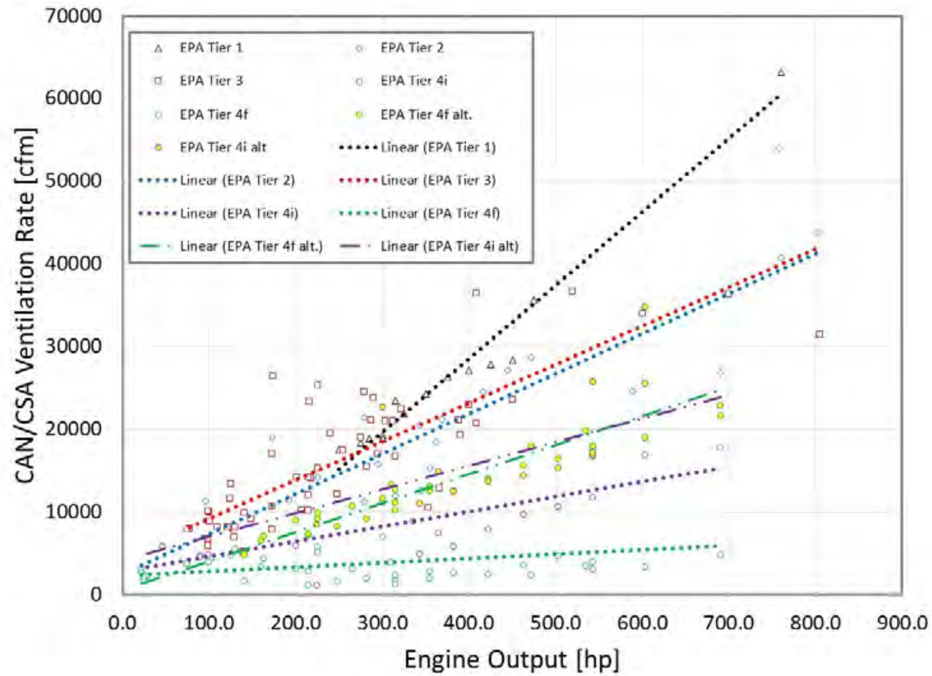


Re-powering low output engines might not necessarily produce desired effects.

- Out of the engines that meet EPA Tier 4 final standards [EPA 2016], the low output engines that are not fitted with DPF systems might contribute more to DPM concentrations than high output engines fitted with DPF systems.
- The emission standards are specific to the engine output:
  - < 19 kW (< 25 hp) is 0.40 g/kW-hr (0.30 g/hp-hr);
  - 19 ≤ kW < 56 (25 ≤ hp < 75) is 0.03 g/kW-hr (0.02 g/hp-hr);
  - 56 ≤ hp < 560 (75 ≤ hp < 750) is 0.02 g/kW-hr (0.01 g/hp-hr);
  - ≥ 560 kW (≥ 750 hp) is 0.04 g/kW-hr (0.075 g/hp-hr).
- The LD vehicles powered with engines with outputs below 19 kW (25 hp) might be prime candidates for replacement with similar battery-powered vehicles.

Viable Retrofit-Type DPF Systems for Existing (EPA Tier 2 and Tier 3) LD and MD Engines

Application of various advanced in-cylinder emissions strategies might produce +90% reductions in the mass of particulates emitted, but +90% reductions in the solid particulate number emissions can only be achieved through use of diesel particulate filter (DPF) systems and filtration systems with disposable filter elements (DFEs).

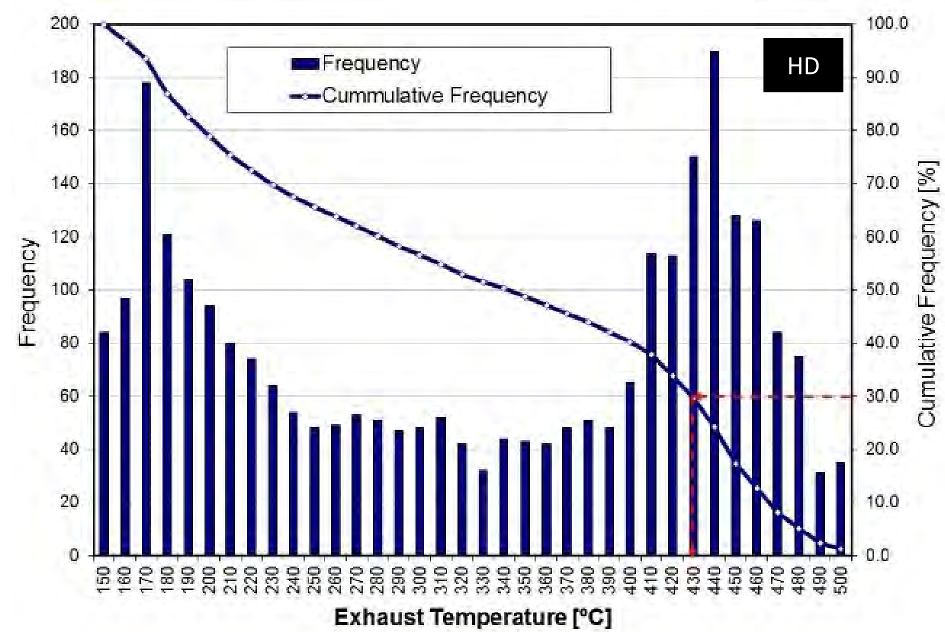
- Promulgation of DPM regulations resulted in gradual increase in number of the engines retrofitted with exhaust aftertreatment systems such as DPF systems and filtration systems with DFEs.

- According to the coal mining inventory [MSHA 2018a]:
  - over 97% of permissible HD vehicles are equipped with filtration systems with DFEs;
  - over 90% of non-permissible HD vehicles are equipped with DPFs and filtration systems with DFEs; and

- Apparently, the filtration systems play very pivotal role in curtailing DPM emissions from LD underground coal mining equipment:
  - Nationwide, the engines in 672 out of 3,261 LD vehicles in underground coal mines, approximately 21% of non-permissible fleet, are retrofitted with DPFs or DFE systems.
  - All diesel-powered LD vehicles in Pennsylvania and West Virginia underground coal mines are retrofitted DPF or DFE systems.

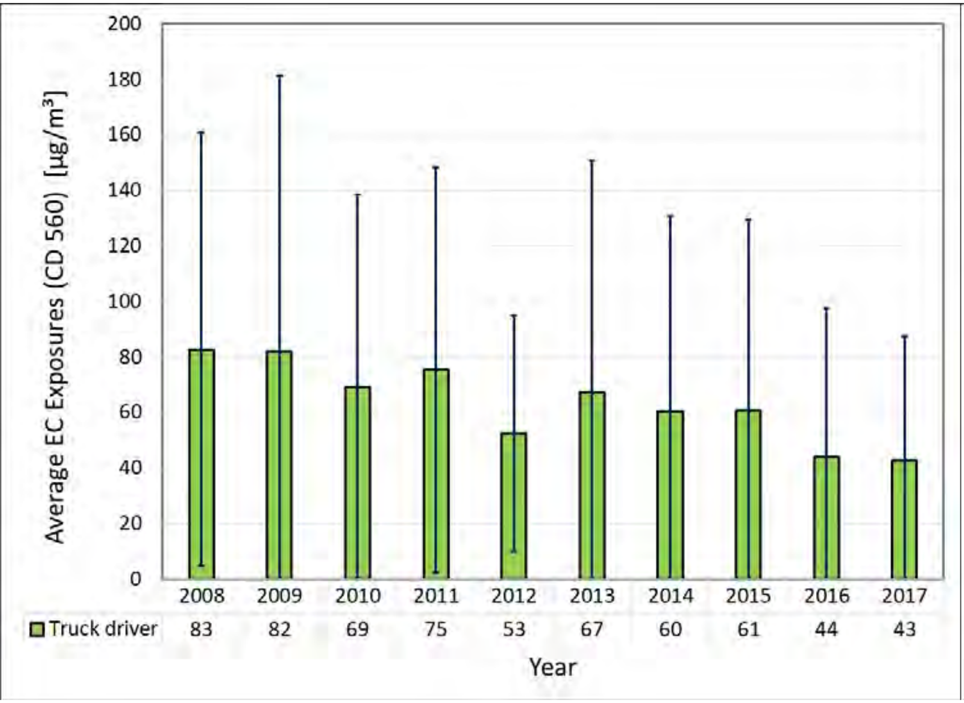
The major focus of the efforts to retrofit diesel-powered vehicles with DPFs in underground metal/nonmetal mining fleets were on haulage trucks and LHD vehicles [Demeres 2017, Deayton 2018, Lessard et al. 2018].

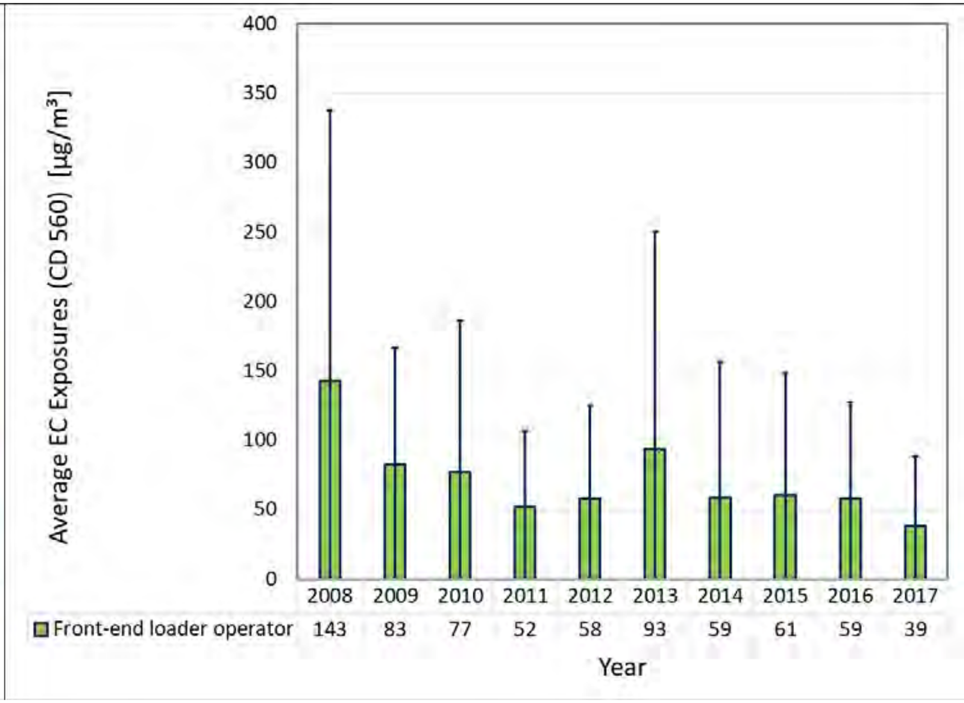
- Operators primarily retrofit haulage trucks and LHD vehicles with DPF systems:
  - perceived as the major contributors to the exposures of underground miners to diesel aerosols and gases;
  - operated over duty cycles that are characterized by higher DPM emissions;
  - operated over duty cycles that favor passive regeneration of DPF systems;
  - several manufacturers offer viable products…



The efforts to reduce particulate emissions from haulage trucks and LHD vehicles operated in underground metal and nonmetal mines coincided with gradual reductions in exposures of the operators of those vehicles to elemental carbon (EC).

- The average EC exposures of truck drivers and LHD operators gradually decreased [MSHA 2018c, Bugarski and Potts 2018]:
  - truck drivers: 83 μg/m³ to 43 μg/m³ and
  - LHD operators: 143 μg/m³ to 39 μg/m³.

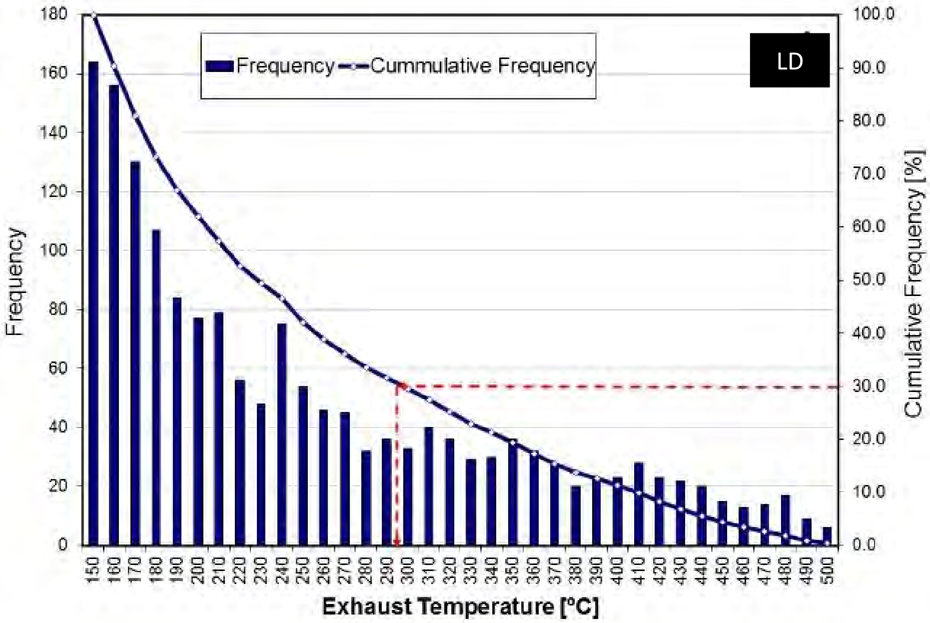




Retrofitting LD or MD diesel-powered vehicles from underground metal/nonmetal mining fleets with DPFs proved to be much more challenging.

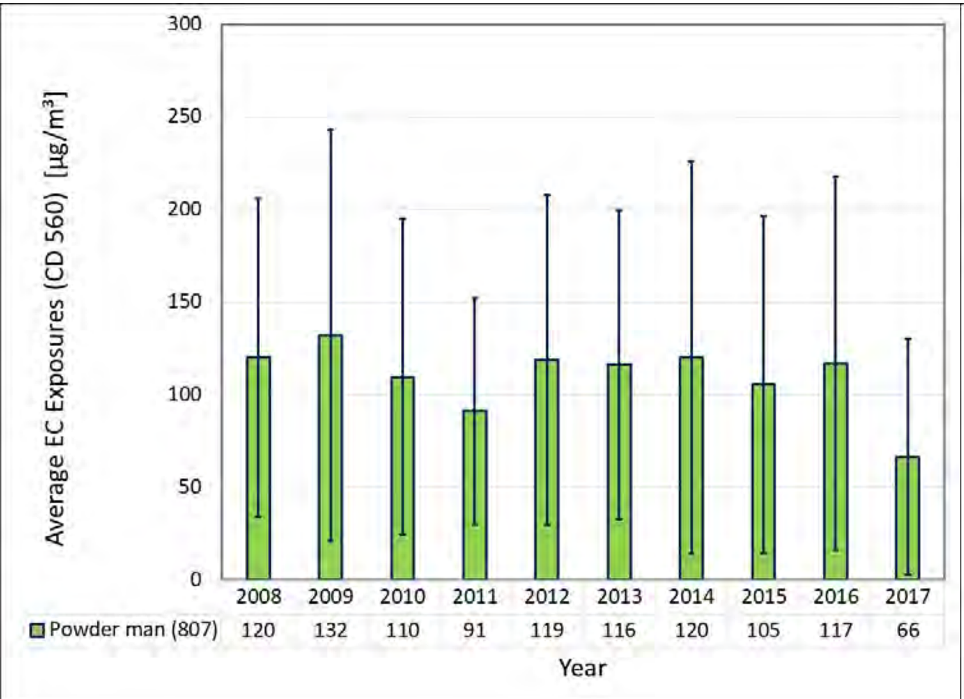
- Operators infrequently report retrofitting DPF systems to LD vehicles [Stachulak 2017]
  - perceived as minor contributors to the exposures of underground miners to diesel aerosols and gases;
  - operated over duty cycles that are characterized by low DPM emissions;
  - operated over duty cycles that do not favor passive regeneration of DPF systems;
  - few manufacturers offer viable products…

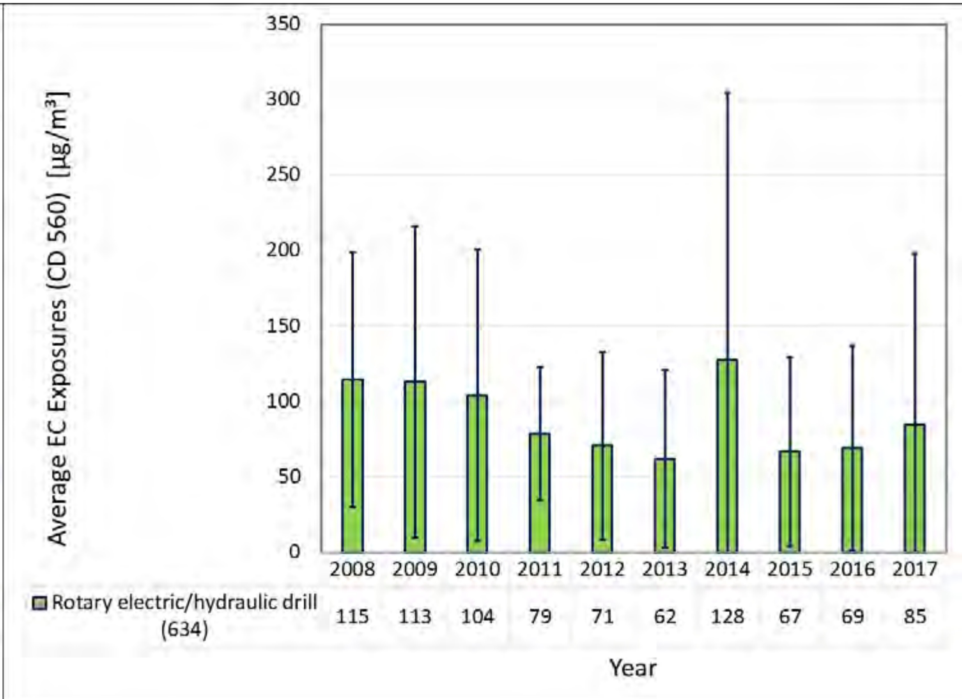
- More work is needed to develop retrofit-type DPF systems viable for LD applications.



The average EC exposures for powder men/shotfirers/shooters/blasters and rotary electric/hydraulic drill operators did not exhibit noticeable decline over the period between 2008 and 2017 [MSHA 2018c].

- Emissions reduction efforts should be diversified to address emissions from equipment other than haulage trucks and LHD vehicles and to reduce exposures of all occupations in underground mines.



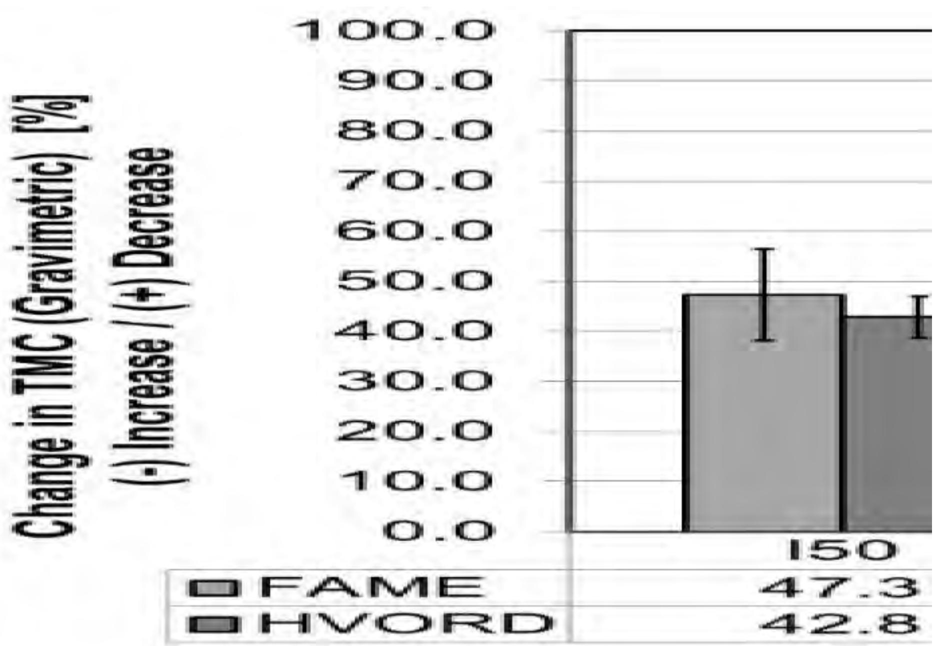


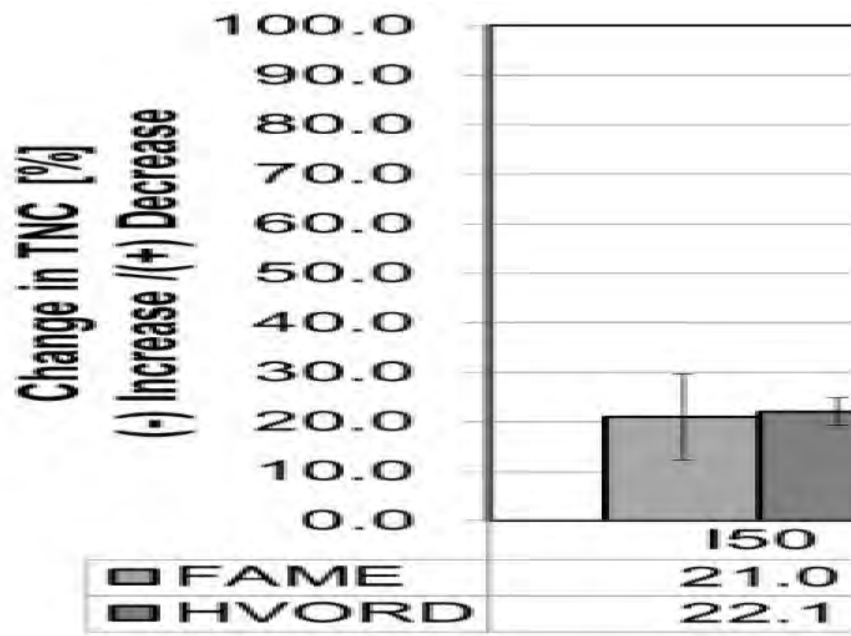
Substitution of Petroleum Based Fuels with Cleaner Burning Fuels

Substitution of petroleum-based diesel fuels with fatty acid methyl ester (FAME) biodiesel and hydrotreated vegetable oil renewable diesel (HVORD) are used as a viable strategies to reduce particulate matter emissions.

- When compared with ULSD, both FAME biodiesel and HVORD reduced emissions of total mass concentration (TMC) and total number concentrations (TNC) of aerosols [Bugarski et al. 2017].

- Substituting fuels might address emissions from HD, MD, and LD fleets.





Improving Quality of Existing and Acquisition of New Environmental Enclosures and Filtration/Pressurization Systems for MD and LD Vehicles

In some operations, environmental enclosures with adequate filtration/pressurization systems are used to reduce exposures of HD equipment operators to DPM [Noll et al. 2014].

- Only few LD and MD vehicles are equipped with environmental enclosures with adequate filtration/pressurization systems that provide desired reductions in DPM exposures.

- When available on LD and MD vehicles, the environmental enclosures and filtration/pressurization systems typically do not meet the same quality standards as those on HD equipment.

Substitution of Selected Vehicles with Electric-Powered Vehicles

Substitution of diesel-powered vehicles with electric-powered vehicles could be ultimate solution for practical elimination of exposures to diesel aerosols and some other pollutants.

- Electric-powered vehicles of various types have been workhorses of the underground coal mining industry.

- On the contrary, use of electric-powered vehicles of various types in the metal and nonmetal underground mining industry is rather limited.

- Underground mining industry could potentially benefit from replacement of diesel-powered vehicles with electric-powered vehicles:
  - Battery-powered;
  - tethered (cable) operated;
  - trolley operated; and
  - hydrogen fuel cell powered.

Rapid development of battery technology greatly improved the viability of battery-powered underground vehicles.

- Substitution of diesel-powered vehicles with battery-powered vehicles potentially could result in [GMG 2018]:
  - improved working environment (no DPM, less noise…),
  - better energy efficiency,
  - lower ventilation requirements;
  - lower heat generation;
  - lower maintenance requirements;
  - better equipment performance.

- However, electrification of mines might require major changes in mine design, mining methodology, and management [Schinkel, 2015; Mullally, 2017; Huff, 2018; GMG, 2018].

- Legal framework needs to be developed to facilitate implementation of these technologies in underground mines.

- If implemented, electrical underground vehicles might improve sustainability of mining industry.

We at NIOSH PMRD would like to assist the industry in addressing some of the aforementioned issues.

- We are currently working on:
  - Developing and evaluating technologies and strategies to prevent overexposures to DPM of critically affected occupations in underground metal and nonmetal mining operations;
  - Implementing and evaluating novel and emerging advanced engine technologies for HD, MD, and LD underground mining applications:
    - DPF retrofits for Tier 2 and Tier 3 engines; vs. Tier 4 final engines vs. Euro Stage V engines; vs. battery power;
  - Developing and evaluating canopy air curtains for mobile underground mining equipment such as ANFO loaders;
  - Developing and evaluating filtration and pressurization systems for environmental enclosures for mobile underground mining equipment;
  - Developing and evaluating advanced disposable filter elements for use in filtration systems for permissible diesel-powered equipment;
  - Improving DPM monitoring methodologies;
  - Improving ventilation strategies…

- We are actively searching to partner with industry to address some of the aforementioned and other related issues.

All aforementioned activities might fit well within the International Council on Mining and Metals (ICMM) Initiative for Cleaner Safer Vehicles (ICSV).

- ICMM brings 27 of the world's leading mining companies and over 30 associations together to address the various challenges associated with sustainable development of mining industry:
  - African Rainbow Minerals, Anglo American, Anglo Gold Ashanti, Antofagasta Minerals, Barrick, BHP, Codelco, Freeport-McMoRan, Glencore, Gold Fields, Goldcorp, Hydro, JX Nippon, Lonmin, Minera San Cristóbal, Minsur, Mitsubishi Materials, MMG, Newcrest Mining, Newmont, Orano, Polyus, Rio Tinto, South32, Sumitomo Metal Mining Co., Teck, and Vale.

- ICMM members joined forces with 13 major suppliers of mining equipment to develop innovation roadmap for making mining vehicles cleaner and safer:
  - Caterpillar, Cummins, Epiroc, GE, Hexagon Mining, Hitachi Construction Machinery, Komatsu, Liebherr, MacLean Engineering, PBE Group, Sandvik Mining, and Rock Technology.

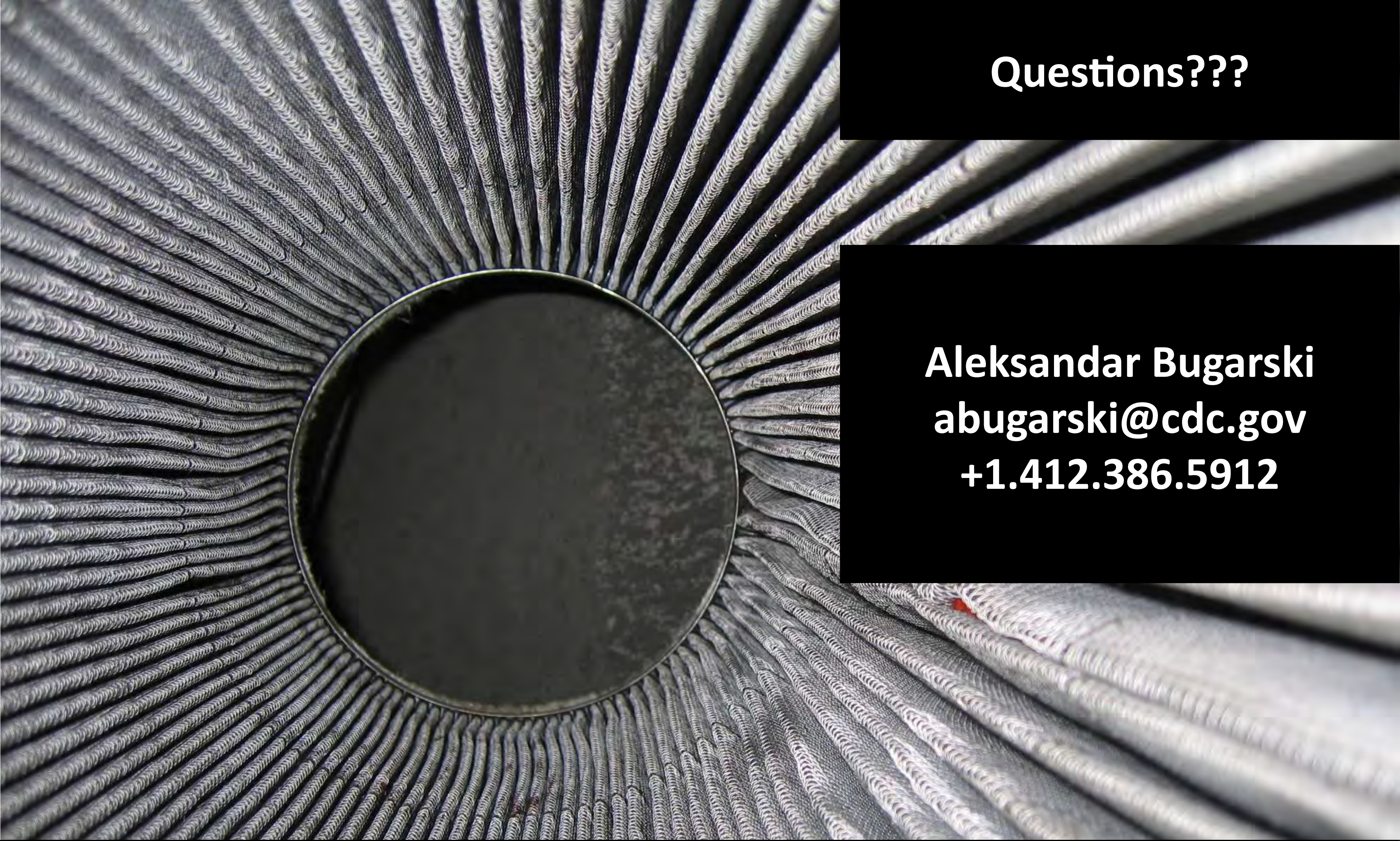
ICMM
International Council on Mining & Metals

- On October 30th 2018, during the International Mining and Resources Conference (IMARC) in Melbourne, Australia, the CEOs of ICMM member companies and leading equipment suppliers announced ICSV to the public.

- The plan is to minimize the operational impact of diesel exhaust by 2025.

- The project is open to everyone.

CDC Workplace Safety and Health NIOSH



Questions???

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Modern diesel engines:

Emissions characterization and health effects

Rashid Shaikh, Ph.D.

Director of Science

Diesel Technology Workshop

MSHA/NIOSH Diesel Partnership

January 23, 2019

Outline of Presentation

GOAL: Summarize HEI's work that supports controls for diesel engine emissions

- What is the Health Effects Institute
- HEI's program: Advanced Collaborative Emissions Study (ACES)
  - Phase I and II: Emissions characterization of 2007 and 2010 MY HHD engines
  - Phase III: Health effects testing of a 2007 engine
- Conclusions from review of the diesel miners study
- Overall Conclusions

HEI

What is the Health Effects Institute

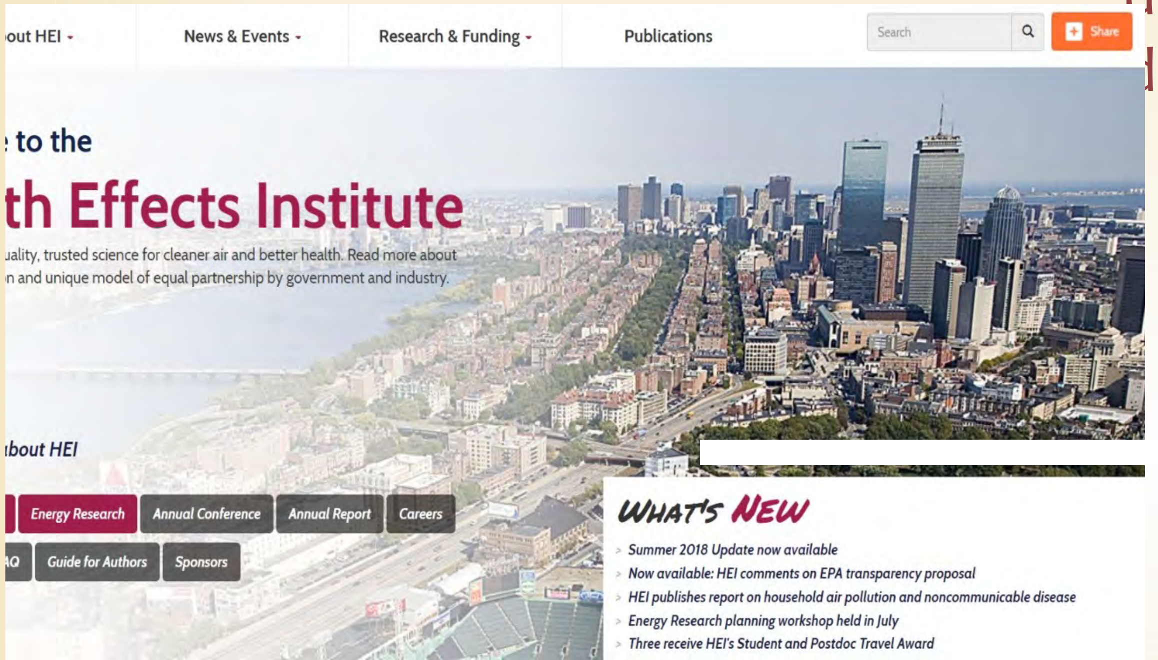
- Independent, non-profit institute, providing high quality, impartial scientific information on the health effects of air pollution, since 1980
- Balanced Core Support:
  - US EPA and Industry (Worldwide Motor Vehicle)
- Additional Partners
  - DOE, CARB, Oil Industry (API, CONCAWE), Foundations
- Governance
  - Independent Board of Directors
  - Expert Scientific Committees – Develop, oversee and intensively peer review all research
- Hundreds of scientific reviews, reanalysis conducted around the world
- Scientific Research Organization:

  HEI does not advocate policy

HEI

HEI’s Activities

- ***Targeted Research and Reanalysis***
  - Over 350 Studies on a wide variety of air pollutants: PM, ozone, diesel, air toxics, Exposure, Epidemiology Accountability
  - Reanalysis of critical studies
- ***Authoritative Literature Reviews***
- ***Global Health***
  - Middle and Low Income Countries
- ***NEW Energy Research Program***
  - Potential Exposures and from unconventional oil and gas development



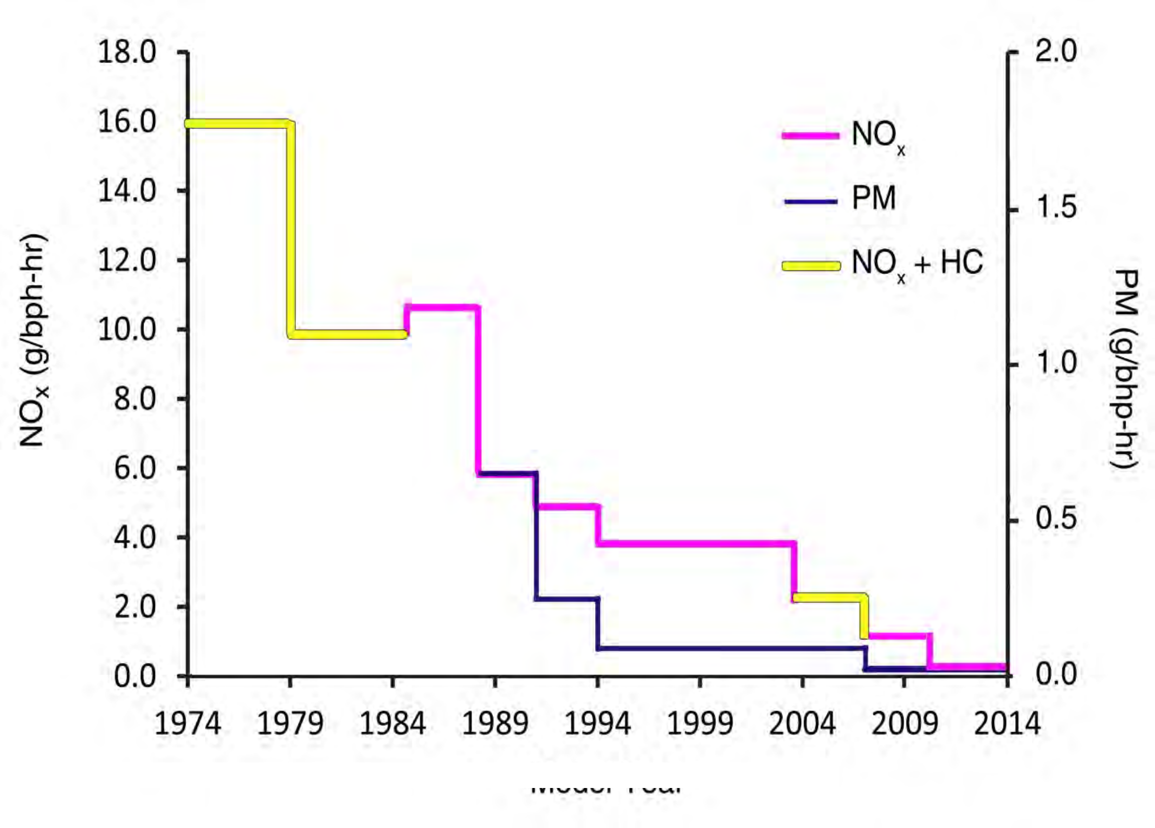
All Publications available at HealthEffects.org

Diesel Emissions

Toxicity of Diesel Emissions

- 1970s and 1980s:
  - In vitro studies with PM and its extracts ⇒ Mutagenicity
  - Rat inhalation studies with PM ⇒ Carcinogenicity (lung)
  - Epidemiology Studies ⇒ Suggestive of Carcinogenicity (lung)
- International Agency for Research on Cancer (IARC)
  - 1988 Panel: DE is "probably carcinogenic to humans (category 2A)
  - 2012 Panel: DE is a "known humar carcinogen" (category 1)
- Other national and regional actions

Regulation of Diesel emissions



Recent HEI Diesel Related Activities

- Advanced Collaborative Emissions Study (ACES)
  - Most rigorous and comprehensive investigation for new tech. diesel engines (DPF and SCR) meeting 2007 and 2010 EPA regs
    - Emissions characterization of four (4) 2007 engines and three (3) 2007 heavy duty highway diesel engines
    - Health effects testing in animals for emissions from a 2007 engine
- Diesel Emissions and Lung Cancer -- Epidemiology
  - Expert HEI panel conducted a detailed analysis and evaluation of the latest [OLD] diesel epidemiological studies
    - Examine utility for quantitative risk assessment
    - Assistance and dada access from NIOSH and NCI for DEMS

The Advanced Collaborative Emissions Study (ACES)

Rationale

The new developments motivated HEI's automotive and government sponsors, and others, to ask HEI to undertake ACES research:

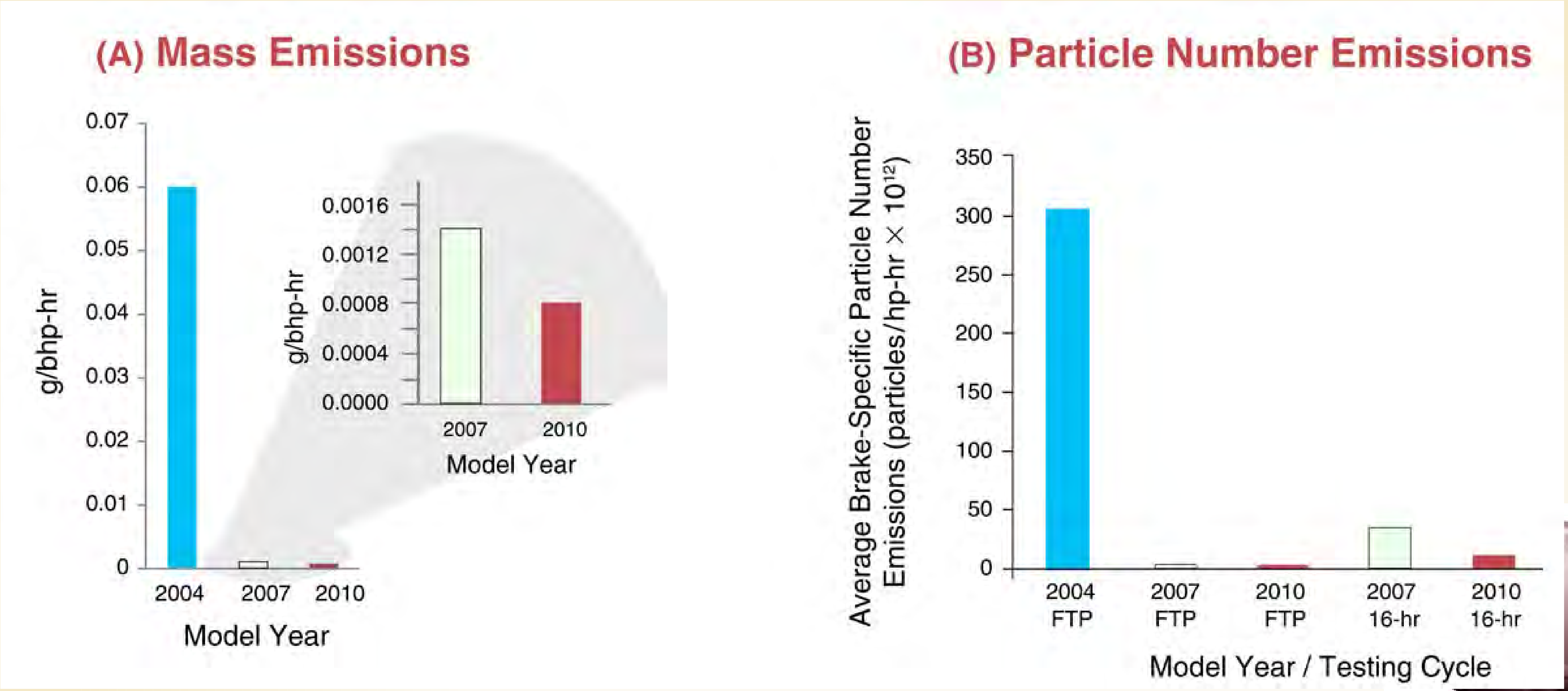
- Confirm that advanced-technology diesel engines, after-treatment systems, reformulated fuels and reformulated oils developed to meet the 2007/2010 emission standards will result in substantially reduced emissions
- Substantial public health benefits are expected from these reductions
- Most pollutants will decrease, but new species may be formed
- Although health effects are expected to be reduced, new technologies should be evaluated before widespread introduction

Design

- Emissions characterization (Phases I and II): FTP and 16-hr cycles
  - Four 2007-compliant HD engines that meet the 2007 $PM_{2.5}$ standard
  - Three 2010-compliant HD engines that meet the 2010 std for $PM_{2.5}$ and NOx
- Health Testing (Phase III):
  - Health effects in rodents, chronically exposed to a 2007 engine emission, to study cancer and non-cancer endpoints

HEI

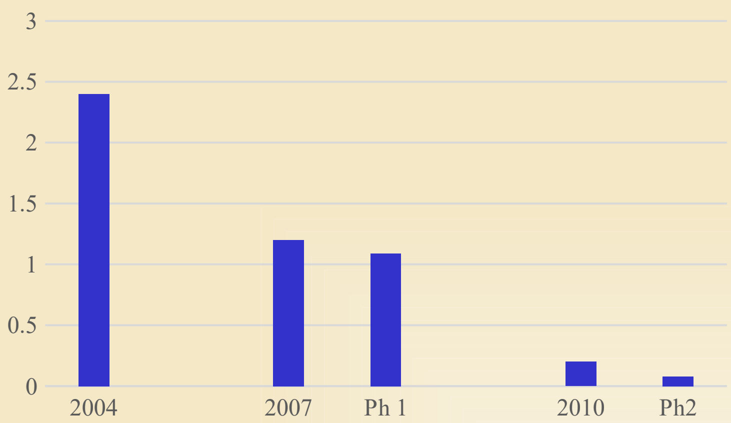
ACES Ph. 1 & 2: Reduction in PM & PN Emissions



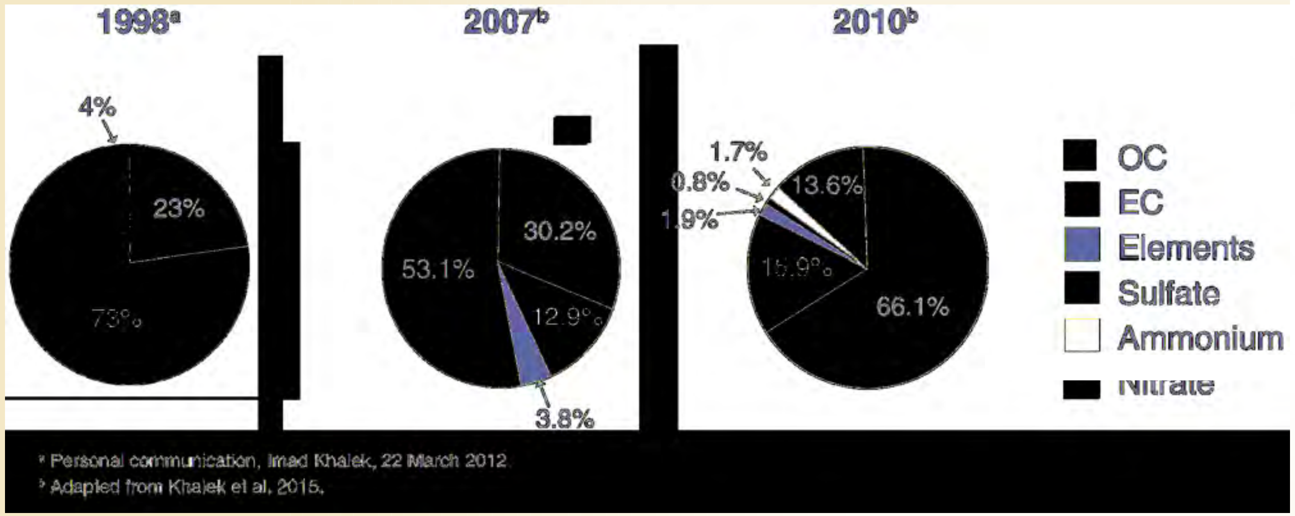
Dara from Khalek et al. 2009 and 2013

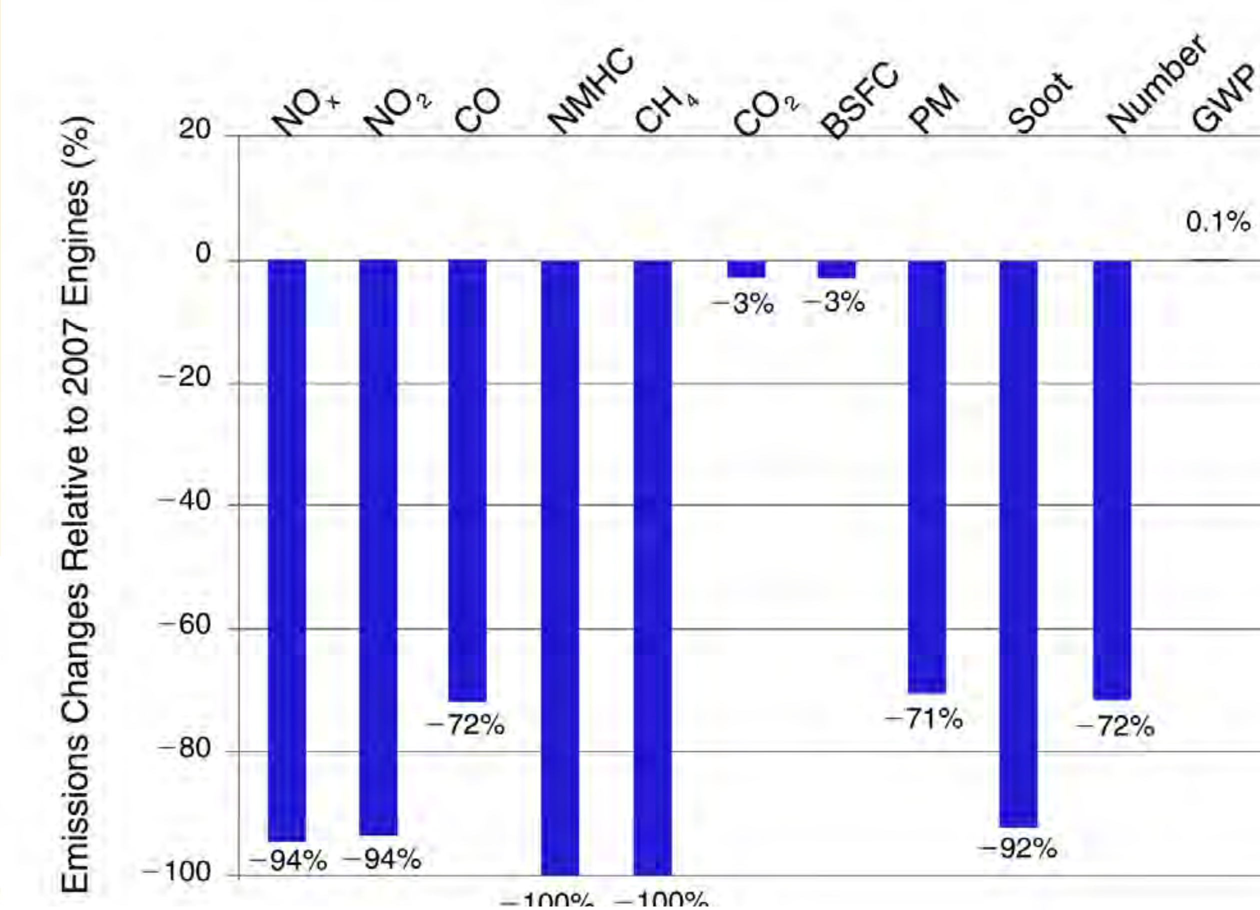
ACES Phase 1 and 2 results, cont

Reduction in NOx Emissions (g/bhp-hr)



PM Composition





Conclusions of ACES Phases I and II

- After-treatment systems highly effective in lowering emissions:
  - PM and PN lowered by ≥ 95%
  - NOx lowered by ≥ 90%
  - All regulated emissions meet or exceed standards
  - Levels of other toxic compounds, VOCs and SVOCs lowered by 80 to 99%; PAHs and nitro-PAHs down by > 99%
  - No new compounds detected
- Limitations:
  - Laboratory and not real world testing
  - SCR issues under certain conditions

HEI

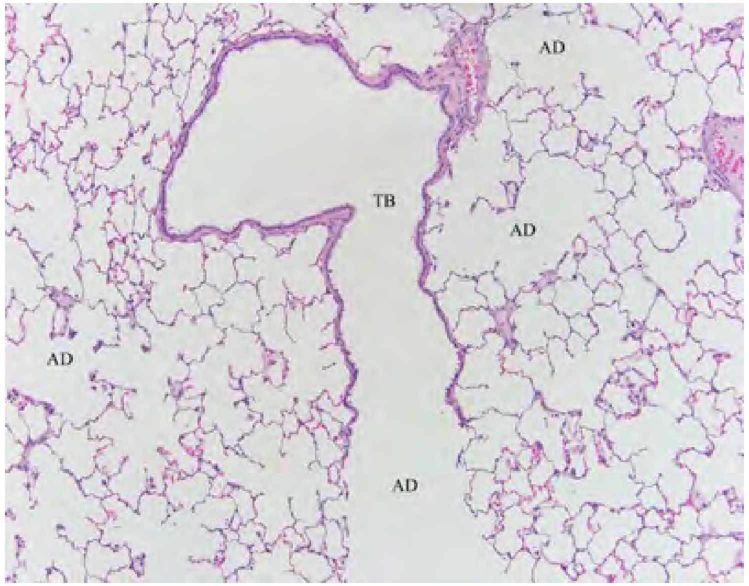
ACES Phase III: Goals and Design

- Hypothesis: Emissions [from a new technology diesel engine] will not cause an increase in tumor formation or substantial toxic effects … although some biological effects may occur.
- Design: Give as high a dose as possible
  - Lifetime (~ 30 months) inhalation exposure in a rat strain (Wistar Han), susceptible to lung cancer
  - Exposure: A 2007 engine, 30 months, 16 hrs/day, 5 days/week
  - Atmosphere: PM too low, so rely on NO_2 levels; high, medium and low, plus clean air control (4 levels)
- Extensive monitoring and sampling of exposure atmospheres
- Serial sacrifices at 1, 3, 12 and 24 months: terminal sacrifice at 28-30 months

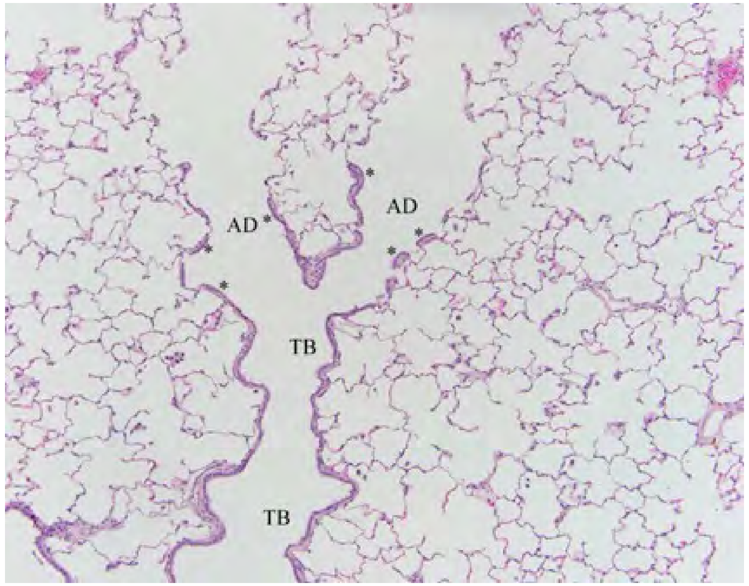
Phase III Major Findings

- **No increase in tumors in the lung or at any other site**
  - Some effects on the lung were observed, but most likely related to NO2 exposure (based on observations in pure-NO2 exposure studies)
  - Of > 100 endpoints studied, few showed changes, related to mild pulmonary inflammation and oxidative stress
- **MAJOR difference from studies with old-technology diesel emissions** (with very high levels of PM)
  - Lung tumors and other toxic effects are seen in many similar experiments
- Additionally, <u>ancillary studies </u>showed no genotoxic effects, or cardiac or vascular changes
- **Confirmation of the study hypothesis:** Exposure to new tech diesel did not cause in increase in tumors

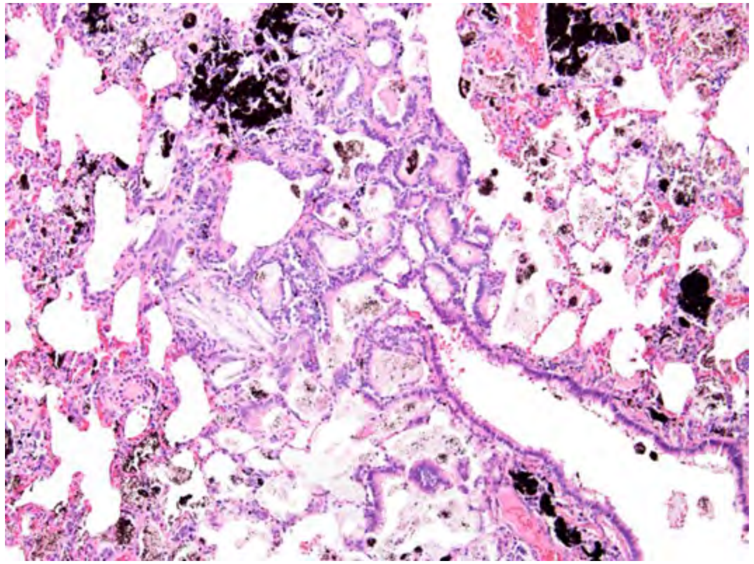
ACES Control: Clean Air



ACES: High Exposure



Old diesel exhaust exposure



Courtesy: U. Heinrich

Diesel Epidemiology Studies

- Many past studies – serious limitations made interpretation difficult
- Some recent studies overcame many of the limitations:
- Most important among these: NCI-NIOSH led study among >12,000 miners who worked in non-metal mines (Silverman and colleagues)
  - Data available from NIOSH and NCI
- Additional analysis and commentaries by:
  - HEI DEMS panel
  - Crump, Moolgavkar and colleagues
  - Other critiques

Epidemiology -- Conclusions

- Exposures – from old technology diesel engines as well as retrospective
- DEMS study – worked carefully over an extended period of time to develop historical exposure profiles and collected and analyzed data on lung cancer and addrressed confounding
- Association between exposure and lung cancer reported and replicated, and found to be robust
- Uncertainties remain; many explored by Silverman et al as well HEI and other investigators

Where does this leave us

- Old technology diesel emissions:
  - Toxicity, including animal carcinogenicity, of old technology diesel emissions well established; components investigated
  - Human epidemiology studies point to association between exposure and lung cancer
- Many national and international bodies have acted based on such information
- New Technology diesel engines – technology highly effective in controlling PM and other toxic compounds
- Emissions do not produce cancer in an animal test
- Ideal way to reduce air concentrations and exposures

Acknowledgements

- Sponsors: Motor vehicle industry, EMA, DOE, EPA, API and CARB; others
- Partners: Coordinating Research Council; Southwest Research Institute; Lovelace Respiratory Research Institute; and others
- Principal Investigators: Imad Khalek (SWRI); Joe Mauderly and Jake McDonald (LRRI); others
- Over 12 oversight and review committees

All publications and reports at www.healtheffects.org

Thank you

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www.healtheffects.org

Investigating Health Effects at Very Low levels

- 2012 paper on effects at lower levels in a Canadian Census Cohort (CanCHEC)
- Are they real?
  - Questions about
    - exposure estimates
    - Confounders?
- HEI is funding three teams: US, Canada and Europe
- Goal: rigorous testing of low-level associations

PM associations below 8 μg/m³

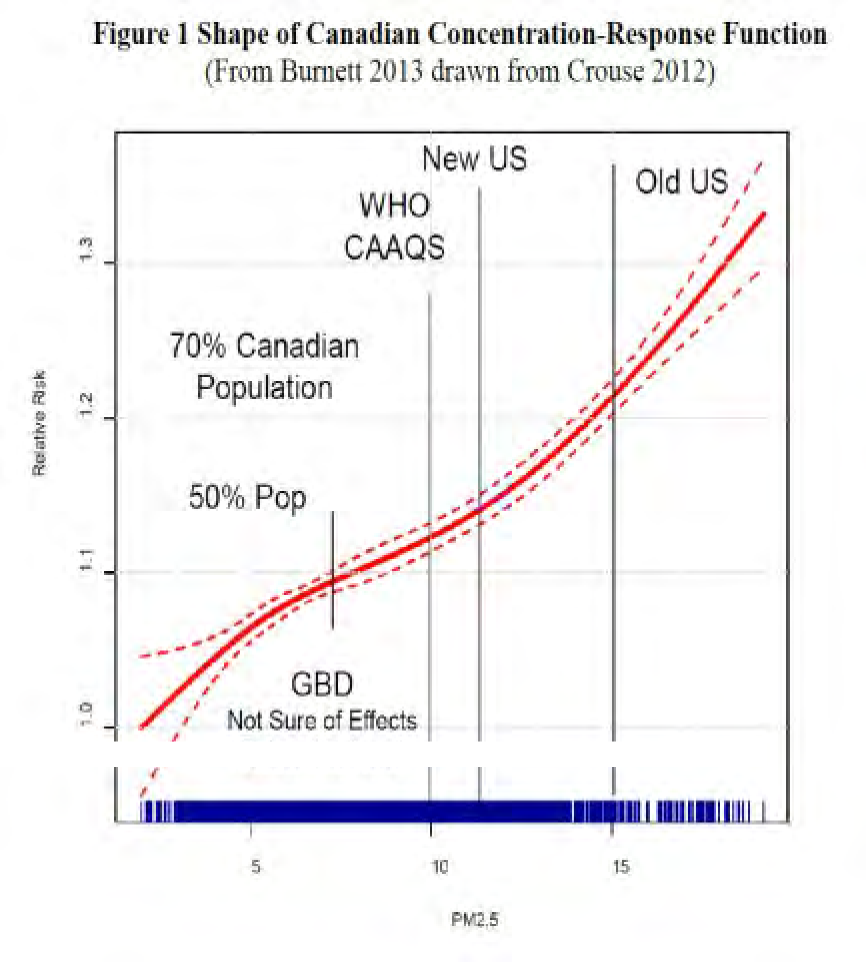


Figure 1 Shape of Canadian Concentration-Response Function
(From Burnett 2013 drawn from Crouse 2012)

Conclusions from the US Study

- Francesca Dominici (Harvard) looked at 66 million Medicare enrollees, exposure estimated using satellite and other methods
- Evidence for Concentration– Response relationships
  - PM: Almost to zero (no threshold?)
  - Ozone: To at least 30 ppb
    - Though wider confidence intervals
- Additional analyses underway
  - Causal and other statistical models
  - More detailed analysis of Medicare Survey population (smaller population but with confounders such as smoking)
  - Medicaid data
- Medicare data are public
- Study findings under HEI Review

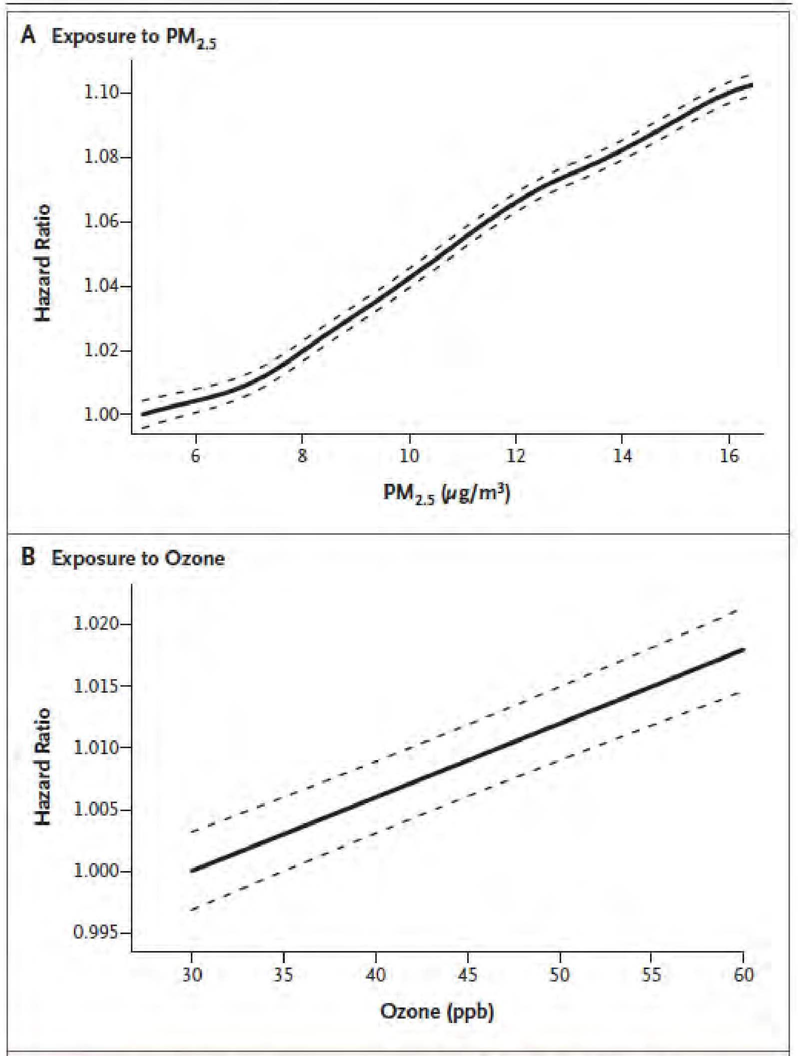


Figure 3. Concentration–Response Function of the Joint Effects of Exposure to $PM_{2.5}$ and Ozone on All-Cause Mortality.

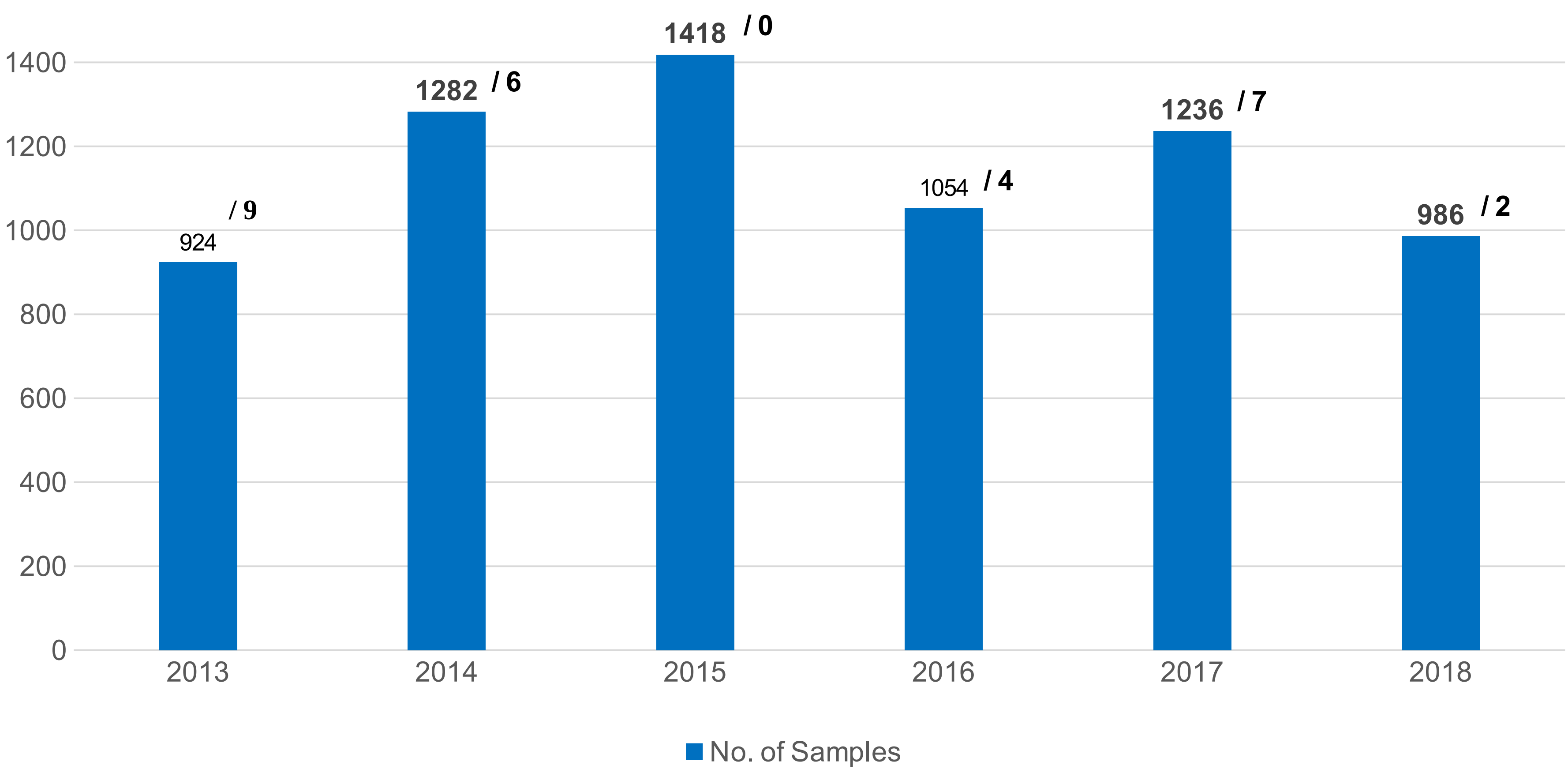
A log-linear model with a thin-plate spline was fit for both $PM_{2.5}$ and ozone, and the shape of the concentration-response surface was estimated (Fig. S8 in the Supplementary Appendix). The concentration–response curve in Panel A was plotted for an ozone concentration equal to 45 ppb. The concentration–response curve in Panel B was plotted for a $PM_{2.5}$ concentration equal to 10 μg per cubic meter. These estimated curves were plotted at the 5th and 95th percentiles of the concentrations of $PM_{2.5}$ and ozone, respectively. The complete concentration–response three-dimensional surface is plotted in Fig. S8 in the Supplementary Appendix.

N Engl J Mec 2017;376:2513-22.
DOI: 10.105 NEJMoa1702747

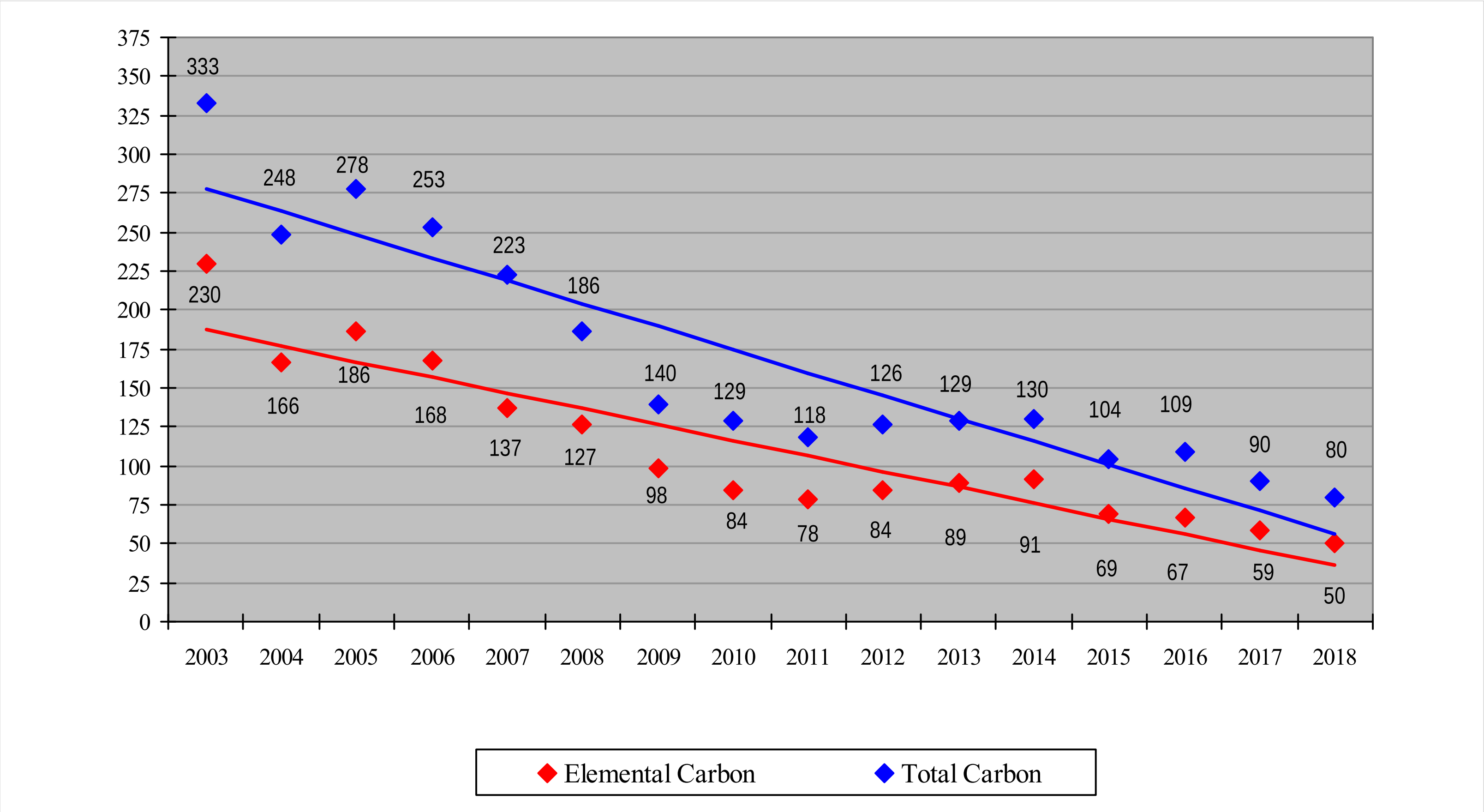
MSHA
Current Barriers to Deployment of Technologies Panel

January 23, 2019

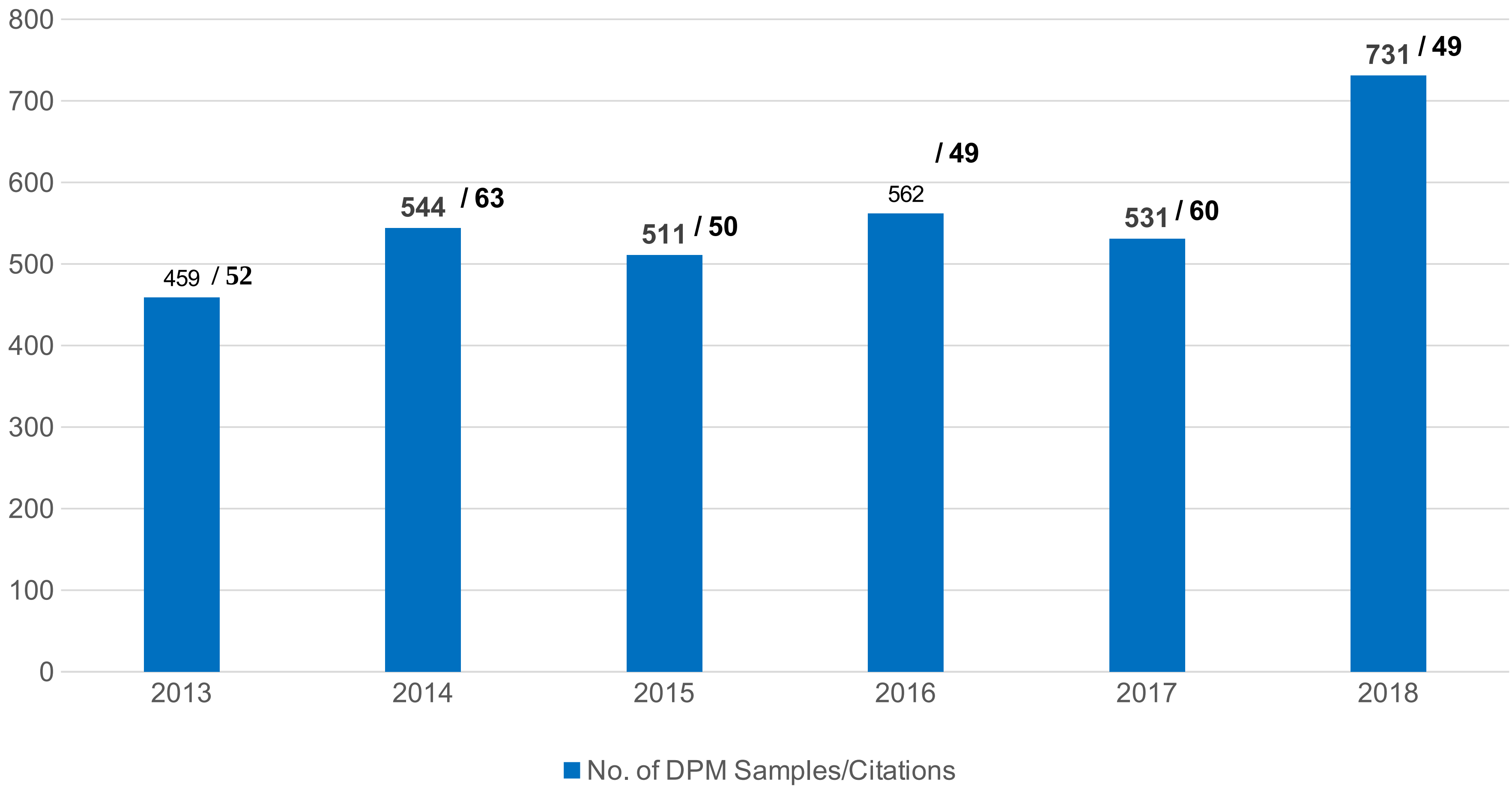
Underground Coal Mines Diesel – Exposure to CO/NO_2 Number of DPM Samples/Citations



Underground Metal/Nonmetal Mines Average DPM Concentration by Calendar Year



Underground Metal/Nonmetal Mines
Number of DPM Samples/Citations



Compliance Challenges

- Ventilation
- Maintenance

MSHA/NIOSH Diesel Partnership

Diesel Technology Workshop January 23, 2019

Terry Zerr – Mississippi Lime VP of Operations

MISSISSIPPI™ LIME

Discovering what's possible with calcium

Who is Mississippi Lime?

- Mississippi Lime Company (MLC) is one of the most diversified producers of lime and calcium-based products in North America serving customers coast-to-coast and internationally in a variety of markets.
- As a privately held company, Mississippi Lime has been producing products from one of the richest limestone reserves in the world for over 100 years.
- Along with our Core Values, our culture is focused on safety.

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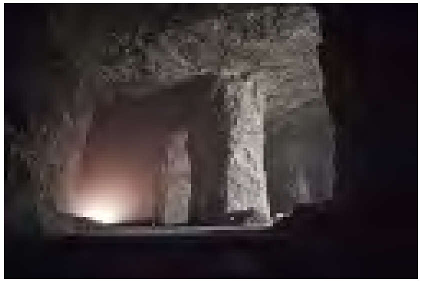
Discovering what's possible with calcium

MLC Markets

- Calcium has played an integral part of everyday life for centuries.
- Today, lime products serve as essential industrial chemicals in a broad range of industries including steel, flue gas treatment, water treatment, paper, chemical manufacturing, construction, food, glass, fiberglass paints, coatings, plastics, & agriculture.
- An average person uses approximately 5 oz. of lime daily.

MLC Mining Operations

- MLC owns and operates a limestone mine in Ste. Genevieve, MO.
- The current footprint is nearly 1,900 acres.
- The floor to ceiling height where we operate is ~90 feet.
- Safety is a top priority!
- Our miners have been recognized with the Sentinels of Safety Award five times since 1980.



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MLC Mining Operations (continued)

- We operate diesel equipment from 30+ different manufacturers with various degrees of tiered engines.
- Our mine ventilation plan is utilized to direct over 1,000,000 cubic-feet-per-minute of fresh air from over 60 ventilation shafts.
- Air quality is monitored with both hand-held gas monitors and periodic industrial hygiene sampling for Diesel Particulate Matter, dust, and other gases.

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DEMS Study

- MLC voluntarily participated in a Diesel Exhaust in Miners Study (DEMS) conducted by NIOSH between 1995 and 2001.
- Overall, the study included information on 12,000+ people in eight non-metal mining facilities.
- MLC provided information on approximately 2,000 current and prior employees who worked in our mine between 1947 and 1997.
- General results were released to the public in March 2012 via Internet posting.

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What has Changed?

- Diesel equipment was first introduced at MLC in 1947. Much has changed in the industry since then.
  - New regulations
  - New technologies
  - Diesel engines run more efficiently
- In 2008, a new crushing and screening plant was built in our mine.
  - Includes miles of electrically powered conveyors that reduced the size of our diesel powered haul truck fleet.
- Bio-diesel blends have been used for over 10 years which reduce elemental carbon emissions.
- A vast majority of our miners now work in climate controlled cabs.
- Our mine has increased use of water to suppress dust on roads
- More of our equipment has dust suppression systems.

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Barriers to Deployment of Technology

- The rate of equipment replacement with life cycles of up to 10 years and the higher cost of tier IV engines.
- The number of different technologies between tiers of engines and equipment manufacturers and the challenge to maintain them.
- The high cost of specialized DPM filters and the time required for changing.
- The use of multiple fuels sources for different tiered engines – biodiesel on earlier tiers versus straight diesel on tier IV.
- The design of equipment versus application – how to regenerate a pick-up that never goes over 25 MPH and dealing with idle time of trucks.

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Progress Continues

- Tier IV engine technology has evolved and reliability has improved.
- Approximately 10% of our mining equipment is now tier IV.
- Trialing network controls on ventilation system to optimize the flow of fresh air.
- Increased use and capability of machines to minimize miner exposure.

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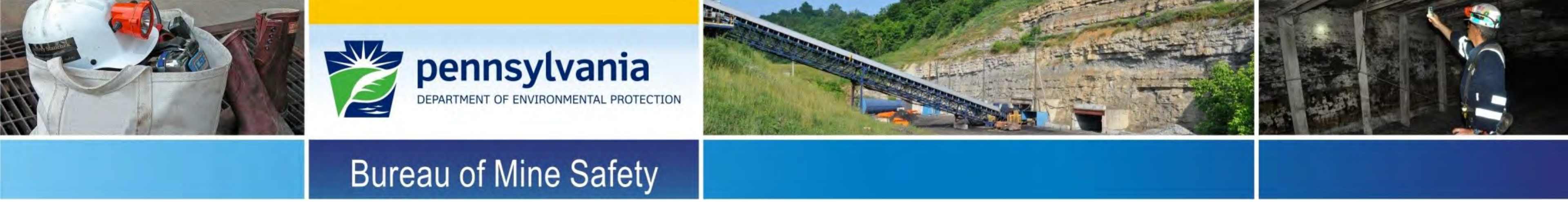


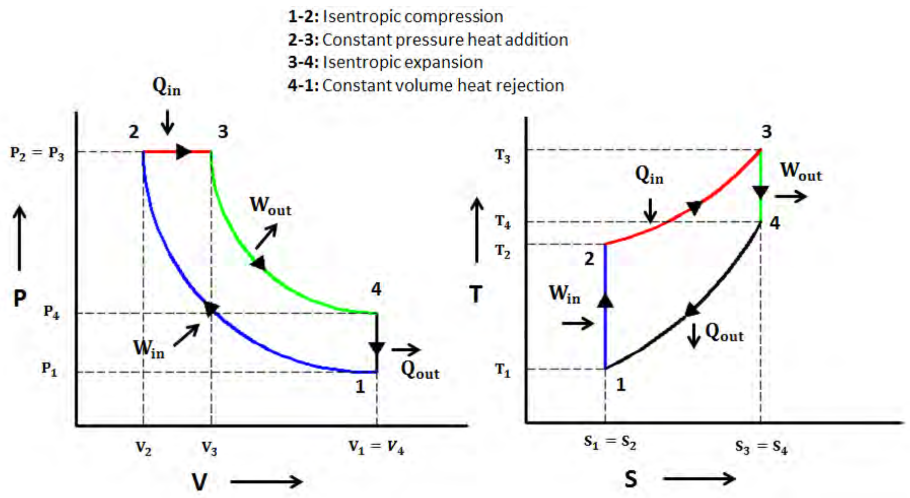
MSHA/NIOSH Diesel Partnership

Diesel Technology Workshop

Current Barriers to Deployment of Technologies Panel

Arthur Brower, PE

Pennsylvania Bureau of Mine Safety



P-V and T-S Diagram of Diesel Cycle

PA Diesel Program Overview

Pennsylvania Bureau of Mine Safety
Diesel Program Overview

The main components of PA Diesel Safety Program:

- The Law, Act 55, latest edition 2008, Chapter 4
- The equipment approval process
- The Technical Advisory Committee (TAC)
- Dedicated Diesel Equipment Inspector
- Diesel Training Instructor Certification

The Law

The Law was developed in conjunction with industry. This is one reason that we have very few issues with compliance other than the routine maintenance issues. The Law allows for the TAC to: *Evaluate alternative technology or methods for meeting the requirements for diesel-powered equipment as set forth in this chapter.*

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The Law

Chapter 4. **DIESEL-POWERED EQUIPMENT**

- Section 401. Underground use
- Section 402. Diesel-powered equipment package
- Section 403. Exhaust emissions control
- Section 404. Ventilation
- Section 405. Fuel storage facilities
- Section 406. Transfer of diesel fuel
- Section 407. Containers
- Section 408. Fire suppression for equipment and transportation
- Section 409. Fire suppression for storage areas
- Section 410. Use of certain starting aids prohibited
- Section 411. Fueling
- Section 412. Fire and safety training
- Section 413. Maintenance
- Section 414. Records
- Section 415. Duties of equipment operator
- Section 416. Schedule of maintenance
- Section 417. Emissions monitoring and control
- Section 418. Diagnostic testing
- Section 419. Exhaust gas monitoring and control
- **Section 420. Training and general requirements**
- Section 421. Equipment-specific training
- Section 422. Diesel mechanic training
- Section 423. Operation of diesel-powered equipment
- **Section 424. Technical advisory committee**

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The Approval Process

All equipment must be issued approval before use.

There are 2 approval types:

- BOTE-D For the diesel equipment
- BOTE-DEESFor the engine/emissions system package

The basic process:

- Submit technical package
- Technical review: On-site inspection and testing (safety systems, emissions, etc.)

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The Technical Advisory Committee (TAC)

The TAC is involved in all aspects of the process.

- Legislative
- Technical Guidelines and Standards
- Equipment Approval(s)
- Implementation of new technology
- Training and Certification requirements

The TAC is appointed by the Governor and consists of 2 members, one representing the interests of the miner, the other industry. Current members:

- Ron Bowersox (UMWA)
- Paul Borcheck (CONSOL, recently retired)

The Law allows for the TAC to: Evaluate alternative technology or methods for meeting the requirements for diesel-powered equipment. This allows for easy implementation of new technology.

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Inspection and Enforcement

The Bureau has an established position for a dedicated diesel equipment Inspector. This individual must have 10 years experience, electrical certification and have extensive diesel and inspection experience.

He rotates between mines and is responsible for equipment inspection and ensuring that the operators are not only complying with the Law, *but understand how to comply*, i.e., provide education and training. There are approximately 650 pieces of equipment in the Pennsylvania inventory.

He is equipped with an ECOM, IR temperature reading instrument and other equipment as he deems necessary to fulfil his duties. He is also involved with new approvals and the TAC.

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Training

There are 3 major areas of training:

- Operator-Equipment specific
- Mechanic
- Diesel Instructor (Train the Trainer)

All training programs must be approved by the Bureau.

Procedure for

APPROVAL OF DIESEL INSTRUCTORS

Submit a resume to the Bureau of Mine Safety to include:

- • Formal education
- • Work experience
- • Certifications held
- • Subject matter expertise
- • Training experience

The Bureau will approve instructors to teach specific course by one or more of three methods:

Method A

Instructor training by an approved organization.

- • Applicant can attend a three-day instructor training course approved by the Bureau (MSHA, OSHA, DEP, and others).
- • Successfully complete the instructor course.
- • Submit information to the Bureau on their mining experience, training experience, and subject matter knowledge.

Method B

- • Submit an application to the Bureau requesting approval to teach based on qualifications and teaching experience and include a list of the specific courses they intend to teach.
- • Submit information to the Bureau of their mining experience, training experience, and subject matter knowledge.

Method C

The Bureau may designate persons as provisional instructors to teach specific courses. Each such instructor is subject to follow-up approval based on the Bureau's monitoring classroom performance.

- • Submit in writing reasons why other approval methods would impose an extreme hardship.

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An Example of Flexibility to Adapt

The Bureau had traditionally required the use of polyamide coating for the control of surface temperatures on most emission control system components rather than ‘wraps’ or’ blankets’. The operators made a request to the Bureau and the TAC to investigate the use of blankets in lieu of polyamide.

The TAC in conjunction with the Bureau researched the matter and developed guidelines for their use. The process took about a month, the regular meeting intervals for the TAC. The guidelines developed:

- Must be custom fit to the piece, either by sample or CADD
- Must have a part number in order to make replacement easier if damaged
- Must be recorded in the equipment’s log book
- Obviously meets the requirement of keeping surface temperature < 302 deg F

This, in my opinion illustrates the flexibility that the PA Law allows for changes/advancement in technology.

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Bureau of Mine Safety

Questions/Discussion

Thank You

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