Attachment B: Comments on Uncertainty in the Estimates of Respirable Elemental Carbon Emissions and Exposures

Professor Demers' presentation at the May 4, 2015 HEI Conference conveyed the impression that the respirable elemental carbon ("REC") estimates used in the various DEMS epidemiological analyses were quite certain. This position is clearly at odds with the views of other authorities. For example, this subject is addressed in a report – "A global and historical perspective on the exposure characteristics of traditional and new technology diesel exhaust" (May 2012) (the "Perspective report"), prepared by five trade associations, including the Truck and Engine Manufacturers Association ("EMA"). That report was prepared with input from many of HEI's sponsors and was submitted to the International Agency for Research on Cancer prior to the meeting in Lyon, France in 2012 at which the cancer hazards of diesel engine exhaust were reviewed.

The Perspective report includes information highly relevant to the work of the HEI Panel. For example, on page nine a summary is provided of the development of emission controls for diesel engines as follows:

> While there were emission controls in place for diesel engines prior to 1988 (and Euro l), the emphasis was primarily on oxides of nitrogen (NOx), carbon monoxide (CO), and hydrocarbon (HC) emissions. Particulate emission control was accomplished only indirectly through standards for visible smoke. Thus, particulate emissions from on-highway diesel engines were unregulated until 1988 in the US and 1992 in Europe. Industrial and off-road (including marine and locomotive) engine emission standards generally lag on-highway engine standards by several years – the first non-road particulate standards appeared in 1996 in the US and in 1999 in Europe. Because of the significant impact that different diesel technologies have on the character of diesel emissions, the emission technologies incorporated in the diesel engines under consideration in any epidemiological or toxicological study must be identified carefully and specifically. In that regard, and given the fact that engines manufactured before the above dates were unregulated for particulate emissions, it should be noted that all diesel engines covered by the exposure periods at issue in the various epidemiological studies conducted to date, including the recently published NCI/NIOSH 'Diesel Exhaust in Miners Study' (DEMS) (Attfield et al. (2012); Silverman et al. (2012)), fall into the 'unregulated particulate' category.

The Perspective report goes on to offer a commentary on the REC estimates used in the DEMS analyses starting on page 59 in a section entitled "9.2 Specific Problems in Using CO as a

Surrogate for Diesel Exposures. There is no cross-engine correlation between CO and PM."

That section provides in relevant part as follows:

> More recently, a set of five exposure papers published in 2010 and 2012 chose to rely on CO as a surrogate for respirable elemental carbon (REC) in developing an exposure estimate methodology for a lung cancer epidemiology study of non-metal miners (Stewart et al. (2010); Coble et al. (2010); Vermeulen et al. (2010a, 2010b); and Stewart et al. (2012))."
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> In the absence of direct measurement of REC, the authors attempted to establish a useable CO-REC relationship. The papers made the following assumptions: (i) CO and PM emissions from different diesel engines correlate sufficiently well; (ii) historical CO emissions correlate sufficiently well with and can be estimated based upon aggregate engine horsepower; and (iii) the overall correlation of CO and PM emissions from different diesel engines is sufficiently proportional and linear to allow for 1:1 scaling over the years of the study. Significantly, none of these assumptions is correct, as can be demonstrated by the available technical data and analyses." (Underling added for emphasis).
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> More specifically, emissions experts and the relevant peer-reviewed literature have conclusively established that there is no correlation between CO emissions and PM (or REC) emissions among different diesel engines and that the CO/PM relationship is unique for each engine type and perhaps for each engine (Clark et al. (1999)). The wide range of average CO/PM ratios is simply too great to allow the inference of PM directly from CO (Clark et al. (1999)), and data taken using a variety of test schedules, vehicles, engines, and geographic locations have shown that there is generally no reliable or unique relationship between CO and PM integrated over a test cycle (Clark et al. (1999), (2001)). Thus, there are no overall (fleet) relationships between CO and PM (Xu et al. (2005)). In particular, the CO/PM correlation coefficient for the relevant data sets – older diesel engines – was no higher than 0.12, and for some data sets the correlation was even negative (Figure 23, McKain et al. (2012)). Moreover, the slope of the regression lines for differing CO/PM data sets varies significantly, further underscoring that there is no sufficient correlation and linearity between CO and PM emissions from different diesel engines.

The foregoing discussion focuses on issues related to on-road diesels. Nonetheless, it is highly relevant to the specialized use of Mine Safety and Health Administration ("MSHA")-compliant diesel equipment in Trona Mine I as well as the other seven mines in DEMS. In general, reduction in exhaust emissions, including diesel particulate matter ("DPM"), from the diesel engines used in mining followed by a decade or more the emissions reductions achieved for on-road diesel engines. It is well recognized that exhaust emissions from diesel engines are influenced by many factors. One of the most important factors influencing engine emissions during the last part of the 20th century was the replacement of "indirect injection" with "direct

injection" engines. In the 1960 to 1980 time period, the use of "indirect injection" engines predominated. This is very important since these engines were well known to have higher DPM emissions than the "direct injection" engines. It is our understanding that the cleaner "direct injection" engines were first introduced in on-road applications, followed by their introduction later in off-road applications, including mining operations.

A major point never made in the HEI Panel presentations is that methods for detailed measurements of DPM emissions were not developed until the late 1980s. The development of REC measurement technology occurred even later. Hence, the lack of information on the specific DPM or REC emissions for diesel equipment used in the DEMS mines pre-1985, when the most relevant DPM/REC exposures occurred, relates to the lack of measurement methods. It follows then that the DPM/REC emissions of engines and the resulting workplace exposures to DPM/REC must be estimated.

Inevitably, any estimation of emissions from diesel-powered mining equipment used pre-1985 will depend in part on extrapolations made using measured DPM/REC emissions from on-road diesel engines. An abundant emissions data set is available for these engines, especially after EPA began to regulate on-road engines and DPM measurement technology became available. As an aside, regulations for non-road diesels were not issued by EPA until 1994 and by MSHA even later at the end of 2001.

We understand that some individuals have argued that the DPM emissions from diesel engines used in mining are so different from the on-road diesel emissions that data from on-road engines data should not be used in any extrapolations made for estimating mining equipment emissions. This position seems extreme since the data from the on-road diesels is what is available. However, it should be recognized that use of the data from on-road diesel engines will likely under-estimate what the emissions were from the mine diesels due to the lag in introduction of improved technology for non-road applications of diesel technology. An interesting question is that if the DPM emissions from diesel engines used in mines is sufficiently different from on-road diesels, is it appropriate to use the DEMS data for any quantitative estimation of lung cancer risk from ambient DPM which arises predominantly from on-road engines? A complete report from the HEI Panel should address this important question.

As emphasized in Attachment A, it is important for the Panel to address the uncertainty in the various approaches to estimating the REC emissions in the mines and the REC exposures of

the workers enrolled in DEMS. As noted in Attachment A, the uncertainties in the REC exposure estimates need to be considered jointly with uncertainties in the various epidemiological analyses to provide a clear picture of the use of analyses of the DEMS data for risk assessment.