HEALTH SUPPORT FOR DIESEL ENGINE DEVELOPMENT PROJECT DESCRIPTION AND GOALS

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INTRODUCTION

The Office of Heavy Vehicle Technologies within the Office of Energy Efficiency and Renewable Energy (the "Office") has responsibility for fostering the improvement of motive power to meet the nation's heavy-duty transportation needs. It is clear that, for at least the next few decades, compression ignition (diesel) engines will continue to be the technology of choice for the majority of heavy-duty motive power in the U.S. New generation diesels have potential for substantial penetration into me-dium and light-duty applications as well. It is the purpose of this project to ensure that the remarkable, rapid engineering developments in diesel technology are not thwarted by a lack of understanding of critical health issues or a lack of health-related information for guiding engineering choices.

The advancement of diesel engine technology requires successfully meeting two engineering and public relations challenges: 1) Improving energy efficiency and cost-effectiveness of operation; and 2) reducing potential adverse impacts on health. There is a growing international concern for the health impacts of fine particulate air pollution, and the U.S. Environmental Protection Agency (EPA) is implementing a new National Ambient Air Quality Standard (NAAQS) for fine particulate matter ($PM_{2.5}$). Diesel soot, like particulate emissions from all internal combustion engines and most other combustion sources, falls within the $PM_{2.5}$ size range and contributes a variable portion of the fine PM in ambient air. There are also concerns for non-particulate emissions of diesel engines, such as nitrogen oxides and aldehydes. Thus, the potential health impacts of diesel engine emissions are under intense scrutiny, and there are pressures from groups with extreme views to eliminate the use of diesel engines alto-gether. To be successful in meeting both na-tional energy strategy goals and corporate fi-nancial goals, diesel engine manufacturers must take a proactive stance in understanding and addressing health issues, and fostering an appropriate view of diesel technology in the public mind.

This project was initiated to ensure that concerns for health were appropriately integrated into the Office's diesel engine development program. The purposes of this project are two-fold: 1) to ensure that the Office and developers of diesel engine, fuel, and emis-sions control technologies are aware of current health issues by serving as an information, interpretation, and communication resource; and 2) to provide the diesel technology community with an iterative feedback loop for assessment of the potential health impacts of alternate engineering choices. The overall goal of this project is to facilitate an appropriate future role for diesel engine technology by supporting the mitigation of health risks in parallel with the increases in utility and energy efficiency.

HEALTH INFORMATION SUPPORT

This project provides the Office with a readily available single point-of-contact resource for health information related to diesel technology. The Principal Investigator, Dr. Joe L. Mauderly, and other staff of the Lovelace Respiratory Research Institute, have been closely involved in both diesel health research and research on other airborne particle issues for many years, and are involved in numerous related activities of other DOE Offices, other agencies, government-industry working groups, industry associations, and individual engine manu-facturers. There is no other health research organization with broader involvement and perspective

regarding basic health research, interpretive, and regulatory issues concerning diesel emissions. Lovelace maintains an awareness of relevant meetings, presentations, publications, controversies, and regulatory actions and provides this information to the Program Office on a proactive basis.

This project coordinates health-related presentations and sessions at workshops and meetings sponsored by the Office, or other meetings in which the Office chooses to participate. This project also provides partici-pation, either electronically or in person, by appropriate health experts in discussions, briefings, or testimonies internal and external to DOE. This project also provides health-related information and briefing materials to meet the Office's communication needs.

It is the intent of this project to extend its information and communications support services to the Office's other contractors. The infor-mation transfer will be conducted through several avenues. First, this project plan and subsequent updates will be disseminated to appropriate individuals in the Office's contracting organizations to provide current background information and make them aware of the availability of the resources of this project. Second, the Principal Investigator or other appropriate experts will contact other contractors at the Office's request to address key issues related to the individual contractor's work. Third, this project will serve as an information, discussion, and briefing resource to contractors as requested, in much the same manner that it supports the Program Office.

TARGETED HEALTH RESEARCH

Identification of Critical Research Needs

This project will conduct research targeting specific information needs critical to the mission of the Office's diesel engine program. This effort differs from, and complements, those of other organizations in that it will be focused on, and limited to, laboratory and risk assessment activities directly addressing key contemporary issues facing the Office and its other contractors in the refinement of diesel technology.

A key function of this project is to identify health information needs critical to the Office's work by maintaining a current awareness of medical and regulatory issues impacting the future of diesel technology and influencing technological choices, reviewing current research sponsored by other organizations to identify information needs that are not being met, and developing and prioritizing focused research strategies to meet those needs. Awareness is maintained by attending scientific meetings and regulatory discussions involving diesel health issues and by keeping abreast of current literature. Project staff have been closely involved in these activities on a routine basis for many years. Project staff will work with the Office to identify appropriate fuel, engine, and emissions control technology meetings and discussions in which to participate, in order to identify critical linkages between health issues and technological choices.

Critical health issues amenable to research will be identified and prioritized on a continuing basis. Issues to be addressed under this project and their priorities will be proposed by this Institute and research will be initiated in consultation with the Office. An awareness will be maintained of the issues being addressed by other organizations, to avoid duplication of effort. Opportunities for the Program Office to partner with other organizations to accomplish needed research will be identified and brought to the Office's attention.

Research Currently Underway

1. Development of Standardized Soot Toxicity Assays

There is a need for standardized cell or tissue culture assays for rapid, inexpensive screening for differences in the toxicity of soot due to changes in size and composition. Several potential assays are available, but none have been evaluated, optimized, and standardized as a first-line screen for the effect of subtle

differences in soot characteristics on cellular toxicity. The first laboratory effort initiated in this project was aimed at meeting this need. The responses of candidate assays to test particles are being compared. The principal challenge is to establish an assay system and measurable response indicators having sufficient sensitivity to reflect subtle differences in soot, which is a material of low acute toxicity.

A suitable assay would have two purposes: 1) for use in other toxicological research planned under this project; and 2) to screen the toxicity of soot generated by the Program's other participants. When the assays are adequately developed, this project will provide direct support to other contractors by making the screening capability available on request. It is envisioned that samples sent by other contractors will be analyzed at this Institute, and that the assays may also be applied in "real time" at other sites.

2. Determination of the Health Impacts of Reduced Soot Size

Current soot emissions standards are based on mass, and remarkable progress has been made in reducing mass emissions. However, some approaches to reducing mass concurrently reduce soot particle size and can result in a net increase in the number of particles emitted. There is growing scientific, regulatory, and public interest in the health significance of ultra fine particles, but there is a paucity of actual data. There are a few toxicological data sup-porting the plausibility of concerns that reduc-ing soot size may increase its toxicity by reducing its clearance from the lung, increasing its penetration into lung tissues, increasing its distribution to sites outside the lung, and increasing the bioavailability of soot-associated toxic compounds. At present, there is broad speculation that reducing soot size would increase its toxicity and perhaps even offset health gains made by reducing mass, but there have been no comparative studies and no data exist on which to judge whether toxicity would be reduced, unchanged, or increased. Although the present mass-based emissions standards are not driving expenditures to reduce particle numbers, it is rapidly becoming critical for the diesel technology community to determine whether or not soot size is likely to become a critical health and regulatory issue.

This project is initiating experiments to generate information, as rapidly as possible, on the potential health importance of reduced soot size. The studies will use both the cell and tissue culture test systems described above, and studies of animals inhaling particles of different size. The experiments will use soot, carbon particles to which specific organic and inorganic compounds can be adsorbed, and noncarbonaceous radiolabeled particles, to answer key questions.

The most important issue, and the first to be examined, is the extent to which the penetration and distribution of ultra fine particles after deposition in the respiratory tract differ from those of larger respirable particles. Solid particles larger than 0.1 μm are generally scavenged by alveolar macrophages after deposition on the lung surface. Small amounts can penetrate through the surface cell layer, but largely stay within the lung interstitium and lymph nodes. There is anecdotal evidence suggesting that smaller particles may escape collection and clearance via the macrophage system, penetrate readily into and through surface cells, and distribute throughout the body via the blood. This will be determined first using radioactive silver particles that can be located and counted in other tissues. If size-related differences in dosimetry are found, it will be determined if soot-like carbon particles behave similarly.

Both cell systems and animals will be used to determine if toxicity and bioavailability are important issues. The relative cytotoxicity and inflammatory potential of fine and ultrafine soot will be compared by measuring cell damage, the production of chemical mediators of in-flammation, and pathological responses of intact lungs. Animals and cells will be exposed to carbon particles coated with specific compounds by vapor adsorption and soot generated from burners or engines burning fuel with radio labeled constituents to compare the

bioavailability of soot-associated organics and metals. Release from the soot will be determined by measuring the desorbed compounds in cells and fluids after removal of particles, and by measuring the production of metabolites.

3. Comparative Life-Cycle Risk Assessments

There is inadequate information on the comparative "life cycle" health risks of diesel and competing technologies. A comprehensive view of health risks includes not only tailpipe emissions, but also fuel production and transport, evaporative emissions, collision-related explosions, and fires, etc. Diesel engine technology has advantages over gasoline engine technology in all of these facets of risk, but the comparative risks have not been adequately estimated and communicated. If ultra fine particle number proves to have health signifi-cance, the generally unrecognized fact that contemporary gasoline engines contribute heavily to the ambient ultra fine particle load through tailpipe and evaporative emissions would be another point of comparison. Opportunities for comparative life-cycle risk assessments will be explored and if feasible, such assessments will be coordinated or performed under this project.

SUMMARY

This project will provide the Office, participants in its diesel technology development programs, and the diesel fuel, engine, and emissions control technology community with dedicated support focused on identifying and resolving, in a proactive and objective manner, critical path health issues. This support has already proven useful to the Office, and should prove increasingly useful to its other program participants.