to kill the strip-mining bill and pass more permissive clean air legislation causes some environmental lobbyists to view the project cynically. The leader of the lobbying effort for the strip-mining bill, Louise Dunlap of the Environmental Policy Center, believes the project is at best irrelevant and at worst a device likely to be exploited by the coal industry now as it mobilizes to weaken implementation of the new strip-mining legislation. Talk of making the proposed regulations more "flexible" conjures up in her mind an administrative nightmare.

Decker and Moss are acutely aware of such fears on the part of environmental lobbyists, however, and know that they are on their mettle to disprove them. Their project is so structured, they believe, that industry people could not dominate the fashioning of the final report and its recommendations even if they tried to—in particular, only seven people associated with the coal or utility industries are on the 24-member plenary group that will review and approve the report. Dunlap herself regards Decker, chairman of the industry caucus, as a sometimes naive but always exceptionally straight forward and fair-minded individual.

In any case, the coal policy project represents something new in the vast and confusing field of energy development and environmental management. And, whatever the uncertainties and possible pitfalls involved, on the whole it seems not a bad idea for industry and environmental leaders to sit down earnestly and amicably together and have a fling at applying the rule of reason.

—LUTHER J. CARTER

RESEARCH NEWS

Sulfuric Acid from Cars: A Problem That Never Materialized

Potential environmental problems often seem to roar into the public consciousness on a typhoon of publicity and then, once satisfactorily resolved, creep away like morning fog, leaving confusion in the minds of the majority of the public who think the problem still exists. This is certainly the case with the problem of sulfuric acid emissions from automobiles equipped with catalytic converters. Only 3 years ago, there was a great outcry because it appeared that toxic concentrations of sulfuric acid would build up on and near roadways if all automobiles were equipped with catalytic converters. Subsequent research has shown that this is almost certainly not the case, but this conclusion and the story of how it was reached do not appear to have been told. There may be some potential hazard under certain, very limited conditions, but that hazard seems to be quite small.

The story began in late 1972 when William R. Pierson and his colleagues at the Ford Motor Company found that the platinum and palladium catalysts that were designed to oxidize carbon monoxide and unburned hydrocarbons to carbon dioxide would also oxidize sulfur in the gasoline to sulfuric acid. Ford promptly notified the Environmental Protection Agency (EPA). Subsequent limited tests with prototype catalyst-equipped automobiles suggested that as much as 85 percent of the sulfur could be oxidized. EPA investigators incorporated these results into a mathematical model—the only one then available—for dispersion of pollutants from fixed sites such as smokestacks. This computer simulation predicted that, under the worst meteorological conditions, the air over a heavily traveled highway on which most or all of the cars were equipped with converters would contain high concentrations of sulfuric acid, perhaps as much as 120 $\mu g/m^3$. It is not clear precisely what concentration of sulfuric acid is toxic to humans, but most investigators considered this concentration to be potentially hazardous.

Clearly startled by these initial projections—which were contained, incidentally, in an unsigned technical report—EPA undertook a major project to determine precisely how much sulfuric acid would be emitted under actual conditions and what the health effects would be. A principal goal of this research was to place the agency in a position to promulgate regulations limiting sulfuric acid emissions, since the need for such regulations seemed clear at the time. Many of the results from this study were obtained in laboratory tests of automobiles and catalysts and confirmed in two major studies of roadway emissions. These were the General Motors (GM) Sulfate Dispersion Experiment and EPA's Los Angeles Catalyst Study (LACS). The first of these monitored emissions on a test track in Michigan, while the second monitored them on the San Diego Freeway in Los Angeles (see box). The results from these two studies, in particular, have largely dispelled the idea that sulfuric acid emissions would be a major problem.

The first important results were obtained from the GM experiment, since it was the shorter of the two. Those results suggested several major conclusions:

▶ The catalysts do not oxidize as much of the sulfur as had been predicted. Edward S. Macias and his associates at Washington University determined that the cars in the test converted approximately 12 percent of the sulfur in the fuel to sulfuric acid. GM investigators found that about twice this percentage was oxidized.

▶ The sulfuric acid is formed as very small aerosols or particles. Peter Groblicki of GM and Kenneth Whitby of the University of Minnesota found that the aerosols ranged in size from 0.01 to 0.1 μm. Aerosols in ambient air, in contrast, generally have diameters ranging from 0.1 to 1.0 μm. The smaller aerosols do not absorb as much water vapor from the atmosphere as the larger ones, and therefore the acid is not diluted as much. The investigators also found, significantly, that this small aerosol disperses as though it were a gas.

▶ The computer model used by EPA did not accurately represent real conditions. Steven Cadle, Paul Monson, and their associates at the GM Research Laboratories found that turbulence from the cars tends to lift pollutants up and away from the roadway, even when there is no wind. The model tends to overestimate pollutant buildup by a factor of 2 to 3 when the wind direction is parallel to the roadway, according to Charles S. Tuesday of GM, and may overestimate the buildup by as much as a factor of 20 when there is no wind at all.

▶ Sulfuric acid from automobiles is probably not a problem. Robert K. Stevens and his colleagues at EPA found sulfuric acid inside the passenger compartment of a test vehicle at concentrations ranging from 1.2 to 3.3 $\mu g/m^3$. They also found the average concentration of sulfates immediately downwind adjacent to the roadway to be about 3 to 7 $\mu g/m^3$. If the traffic density were about the same as that on the San Diego Freeway, the concentration would be about four times that amount, but apparently still well within the limits of safety.

The results from LACS are, if anything, even more encouraging. While this larger study generally confirms the more preliminary results obtained in the GM study, it generally indicates that there is even less sulfuric acid being produced. Total sulfates now being produced by catalyst-equipped automobiles on the San Diego Freeway, says Charles Rodes of EPA, are less than 1 $\mu g/m^3$. Since about 30 percent of the vehicle miles traveled on the freeway are by automobiles equipped with catalysts, the total contribution if all were so equipped would be no more than 4 $\mu g/m^3$. This amount is insignificant compared to the maximum ambient sulfate concentration of 70 $\mu g/m^3$, which occasionally arises from all sources in the Los Angeles Basin.

It cannot be said, however, that there is no potential for hazard. The small sulfuric acid aerosols produced by catalysts, called ultrafine aerosols, may penetrate much deeper into the lung than can the larger aerosols from fixed sources. They may travel all the way to the alveoli, tiny air sacs in the terminal compartments of the lung that exchange air components with the blood. Because the ultrafine particles may penetrate deeper into the lung, says Robert E. Lee, Jr., of EPA, it is possible that they may be more toxic than the larger aerosols. In the unlikely event they should prove substantially more hazardous, he says, then there might be some hazard to the drivers and passengers of cars traveling on congested roadways when there is little or no wind.

EPA is investigating the health effects of the ultrafine aerosols, but the project has been slowed by the difficulties of developing techniques to produce the aerosols in a reliable, consistent fashion. Only when these studies have been completed (probably in another 2 to 3 years) will it be possible to make a definitive estimate of hazard.

The natural question at this stage is why there is such a gross disparity between EPA's initial projections and their ultimate findings. A substantial part of the discrepancy arises, as mentioned previously, because the mathematical model for dispersion of pollutants breaks down under the worst meteorological conditions, when there is little or no wind and when the wind blows parallel

How the Tests Are Conducted

The General Motors (GM) Sulfate Dispersion Experiment was a more or less artificial attempt to determine the effect on air quality when large numbers of cars are equipped with catalytic converters. It was conducted on a 10-km straightaway at the GM Proving Grounds near Detroit, with 352 low-mileage 1975 and 1976 automobiles provided by the four major U.S. manufacturers. During October of 1975, the cars were run in packs for 2 hours each day at a speed of 80 km per hour. This mode of operation was equivalent to a traffic density of 5460 vehicles per hour.

Investigators from GM and the Environmental Protection Agency (EPA), as well as several EPA contractors and grantees, measured concentrations of sulfates, sulfur dioxide, ammonia, ammonium ion, and total suspended particulates (TSP) at each of six sites distributed on both sides of the roadway. GM engineers equipped eight of the vehicles to emit sulfur hexafluoride as a tracer and concentrations of this compound, as well as meteorological conditions, were also monitored by GM.

Pollutants on a Real Highway

The Los Angeles Catalyst Study (LACS), in contrast, was designed to monitor all automobile-related pollutants on a real highway. The site was selected because catalyst-equipped cars were first introduced in California, because meteorological conditions in Los Angeles are very stable, and because the traffic density is very high, reaching a maximum of near 20,000 vehicles per hour. The actual site was along the San Diego Freeway on the grounds of the Veterans Administration Hospital near the University of California. EPA established two monitoring stations on each side of the freeway, from which the investigators monitored meteorological conditions, the pollutants studied in the GM test, and oxides of nitrogen, carbon monoxide, and lead. Monitoring was initiated in June of 1974. This permitted determination of baseline concentrations of pollutants before manufacturers introduced catalyst-equipped cars in September and October of that year.

The wind direction at the LACS site most of the time is perpendicular to the freeway; during the daytime, the wind blows primarily inland from the ocean, while at night the direction is reversed. The production of pollutants by automobiles on the freeway in both tests was monitored by subtracting the concentration of pollutants at the upwind site from that measured downwind. EPA plans to continue monitoring at the site for at least one more year, and perhaps longer.

How Have the Catalysts Worked?

In addition to the data about sulfate emissions, the LACS results have provided some interesting information about air quality in the area and about the efficacy of catalysts. The background levels of TSP and lead, according to Charles Rodes of EPA, have changed very little since 1974, but the background concentration of sulfates has decreased by about 25 percent. The reason for this decrease is not clear, but it probably results in part from increased use of low-sulfur fuels at fixed sites.

Emissions of carbon monoxide by automobiles on the freeway have decreased by about 25 percent since 1974, Rodes adds, primarily because of the use of catalytic converters. Similarly, emissions of TSP and lead decreased about 25 percent from 1975 to 1976 because of the decreased use of leaded gasoline and because the catalyst oxidizes carbonaceous material that would otherwise be emitted as particulates. Emissions of oxides of nitrogen, however, increased by about 50 percent in the same period, demonstrating again the need for some kind of system to control that pollutant. Results from LACS and other studies also show that platinum and palladium are not ablated from the catalysts, as once was feared, and that emissions of the two metals are negligible. In general, then, it must be concluded that the use of catalytic converters and lead-free gasoline has so far achieved its purpose without contributing to new environmental problems in the process.—T.H.M.

to the roadway. The model predicts that the pollutants will concentrate immediately above and adjacent to the roadway, but the two experiments show that this is not the case. David Chock of GM has developed a new mathematical model that takes into account what was learned in the GM study and is now working on others that incorporate results from both studies.

Perhaps more important is the fact that the catalysts are not oxidizing as much of the sulfur as they were expected to. This discrepancy results, according to Ronald L. Bradow of EPA, from the way in which the original tests were run. In those first studies, concentrations of sulfuric acid were measured in the exhaust of cars running at constant speeds for long periods. This procedure gives erroneously high results when extrapolated to conditions on roadways.

When the motor is run at constant speeds, there are very small concentrations of carbon monoxide and hydrocarbons in the exhaust gases passing over the catalyst and as much as 85 percent of the sulfur can, in fact, be oxidized. But the resulting sulfuric acid, Bradow says, initially remains bound to the catalyst in the form of aluminum sulfates. As the rather substantial capacity of the catalyst is reached, high concentrations of acid begin to appear in the exhaust—a condition that was met in the constant speed tests.

Normal driving conditions entail frequent periods of acceleration and deceleration, even on the open highway. During these periods, the concentrations of hydrogen, carbon monoxide, and hydrocarbons passing over the catalyst increase, and reducing conditions are created. The catalyst-bound sulfate is reduced to sulfur dioxide under these conditions and released from the catalyst. Tests at many different facilities on large numbers of new cars subjected to driving

Speaking of Science

Mathematics and Magic: Illumination and Illusion

Superficially, mathematics and magic seem antithetical. Good magicians successfully hide their methods to maintain illusions. Good mathematicians illuminate their methods. Magicians perform for the public and hope for both public acclaim and admiration by other magicians. Mathematicians generally concentrate on impressing only a small group of people in their own area of specialization. Typical of many mathematicians' views is that of Fritz John of the Courant Institute of New York University. John proclaimed that he sought neither fame nor fortune but only "the grudging admiration of a few close friends."

In certain cases, however, an understanding of both mathematics and magic can lead to unique ways to analyze results of experimental research. Statisticians often acknowledge the fact that unexpected subjective elements may affect results of experiments and their own attempts to analyze data, but few are experts at ferreting out where and how these elements occur. One statistician—32-year-old Persi Diaconis of Stanford University—is unusually skilled at this sort of analysis. Diaconis is well versed in the art of illusion since he spent 12 years as a professional magician before becoming a mathematician.

Diaconis is so talented as a magician that other experts rank him among the top three magicians in the world for close-up tricks (such as card tricks). As a sideline, he spent the past 10 years analyzing parapsychology experiments and debunking so-called psychics. His experiences as a magician played a major role in his decision to become a mathematician, and now those experiences aid him in devising ways to account for often inadvertent subjectivity in analyses of experimental results. Diaconis' thoughts on why he became a magician and how his life as a mathematician is affected by his knowledge of magic illustrate why he is uniquely qualified for his current research.

Diaconis' interest in magic goes back to his childhood—he says he did his first magic tricks at the age of 5. Something of a child prodigy, he progressed quickly through school and entered City College of New York when he was 14. However, he soon dropped out of college and ran away from home to become a professional magician. After working for a while with magicians James Randi (The Amazing Randi) and Day Vernon, Diaconis struck out on his own at the age of 17 and built a considerable reputation. He studied magic seriously during this period, visiting other magicians and collecting books. Diaconis estimates that he now has 2000 to 3000 books on magic.

By the time Diaconis was 24, the lonely life of a magician began to wear on him, and he went back to college with the stated aim of gaining a classical education. While at college this time, he was lured into mathematics. His interest in mathematics grew from his days as a magician, when he made up magic tricks based on mathematical principles, tried to analyze gambling strategies, and was consulted on the design of experiments on extrasensory perception. Those experiments, he points out, often require sophisticated statistics for their analysis.

When Diaconis finished college he entered the Ph.D. program in statistics at Harvard University. Because he wanted to succeed in graduate school on his own merits, Diaconis carefully kept quiet about his previous life in show business. When he obtained his degree and accepted a job at Stanford, however, he found out that the game was up. *Time* wrote a story about him, which Diaconis found posted on Stanford's bulletin boards. After that, says Diaconis, "I thought it was time to come out of the closet."

Although he still practices magic for about an hour each day and still gives an occasional show, Diaconis stresses that he would rather be known for his research interests and accomplishments than for his magic. He was recently embarrassed as a result of an incident that occurred when he did a show for the Air Force. The local newspapers wrote about him, and their stories were picked up by Associated Press under the head "Prof. Does Magic."

A quiet, unpretentious man who seems to move in slow motion, Diaconis bears little resemblance to the stereotypical glib entertainer who is skilled at sleight of hand. He admits that when he made his living as a magician, he learned to take control of a conversation by telling anecdotes. But, he says, "It's a relief to get away from all that now—to be a more-or-less anonymous member of a group rather than always trying to be the center of attention."

When asked how his experiences as a magician bear on cycles similar to those that might be encountered on a freeway show that the average new car equipped with a catalytic converter and an air pump oxidizes about 10 to 15 percent of the sulfur in the fuel. Similar cars without air pumps oxidize 7 to 10 percent of the sulfur.

The catalyst's ability to oxidize sulfur, furthermore, appears to deteriorate much more rapidly than its ability to oxidize other pollutants. Tests in California on consumer-owned cars equipped with catalytic converters and air pumps indicate that the oxidation rate for sulfur is reduced to about 5 to 6 percent after 10,000 to 15,000 miles of operation, with little deterioration in the ability of the catalyst to oxidize pollutants. This is probably one of the factors that produce the apparent differences between the LACS and GM studies, since the latter tested primarily new cars.

Most air pollution investigators now seem to agree with EPA that sulfuric acid emissions are not a problem. Pierson, for example, has made some independent calculations that lend credence to the LACS results. Several studies have shown, for example, that the total output of sulfur compounds in the average car is about 30 mg/km and the average output of lead from those cars using leaded fuel is about 24 mg/km. The ratio of sulfur to lead is thus about 1.2. Measurements at the LACS site yield about the same ratio when corrections are made to account for the fact that only 70 percent of the cars use leaded gasoline. In a similar fashion, when the total amount of sulfuric acid produced by cars at the LACS site is divided by the total amount of sulfur compounds produced by the cars—again, corrected to reflect the number of cars equipped with catalysts—the ratio implies an average conversion rate of sulfur to sulfuric acid of 13 percent, in relatively close agreement with actual measurements on production

his life as a mathematician, Diaconis gives numerous examples. In one case, he noticed that experimenters often let psychics know, directly or inadvertently, whether they are guessing cards correctly. This is not so surprising, he points out, since people constantly pass nonverbal signals to each other through such things as changes in their tones of voice or body movements. In fact, this nonverbal communication forms the basis of a well-known magic act. One performer, for example, asks to have his check in payment for a show hidden in the auditorium in full view of his audience. He then comes on stage and finds the check by reading the nonverbal cues of the audience as he wanders closer to or farther from the check. "It's like the children's game of Hot and Cold," Diaconis says.

Diaconis' observations of the communications between psychics and experimenters led him to ask how much usable information is being transmitted in this way and what the best guessing strategy is. This is an especially important problem since it arises in many contexts other than parapsychology. For example, it has come up in clinical trials in ophthalmology. These trials involve tests of the participants' visual acuity. Some observers have noted that researchers often unconsciously give the participants hints about whether they are guessing correctly when they try to read the letters on the eye charts.

The problem of accounting for such feedback also arises in fields such as forecasting. For example, economists need some way of judging models for forecasting the economy. They must take into account the fact that they know what has happened in the past. Weather forecasters and those who try to forecast air pollution have similar problems. Diaconis points out that analyzing these guessing experiments with feedback is a difficult problem in combinatorics and statistics. Recently he and Ronald Graham, a mathematician at Bell Laboratories, Murray Hill, New Jersey, who specializes in combinatorics, came up with a scoring statistic which they believe provides an improved way to decide whether guesses under conditions with feedback are better than could be obtained by chance.

Diaconis' skill at detecting the differences between what people see and what they think they see aids him in studying a major problem in statistics. The problem arises in data analysis, which Diaconis describes as the drawing of pictures in order to make sense of data. Investigators often want to find some particular relation or trend in a set of data, and if there is any indication that what they seek might be there, they fixate on it. Subjective judgments, then, often creep into statistical analyses.

In classical statistics, according to Diaconis, these subjective judgments are ignored. However, many statisticians are now not only acknowledging such subjectivity but are trying to account for it. Diaconis is drawing on his ability to detect observers' biases in order to study his problem. He is analyzing how an observer's beliefs can be quantified and built into an analysis of data. His goal, he says, is to strike the right balance between a free and innovative interpretation of data and an objective, mathematical analysis.

Diaconis stresses that not all of his inspiration comes from his days as a magician. He works on standard problems in theoretical statistics as well as problems related to magic and extrasensory perception, and spends a quarter of his time on problems suggested by physicists at the Stanford Linear Accelerator, which involve the analysis of data described in many dimensions. Like other statisticians, he is motivated by particular problems that researchers in other fields bring him as well as by the inner beauty and consistency of the mathematics.

Diaconis has few regrets about his decision to become a mathematician. "I'll probably never be as famous a mathematician as I was a magician," he confesses. "And I'll never make as much money. A good magician can easily earn $1000 a day working at conventions." However, he finds the intellectual challenge of doing mathematics greater than that of inventing magic tricks. He enjoys the free interchange of ideas with his colleagues, and he appreciates the dignity of his academic life. In fact, he says, "If magic were performed in a dignified atmosphere for appreciative audiences, I probably would never have left the field. Too often you end up playing for drunks in casinos."

Diaconis, however, cannot escape his unusual history and cannot ignore the fact that it makes him stand out among mathematicians. As Frederick Mosteller, of Harvard University, points out, magicians have unique views about perception—ideas about what people observe and what they think they need to observe. "Magicians, more than most people, can easily accept or raise the possiblity that the conditions of an investigation are very different from what they are reported to be," he says. This perspective can be extremely valuable to a statistician who helps researchers analyze their experiments, as Diaconis' career points out.—GINA BARI KOLATA automobiles. These and other similar calculations, Pierson says, indicate that the LACS results are at least in the right ballpark.

There are, nonetheless, several potential problems with measurements in both the LACS and GM studies. Perhaps the most serious of these is that it has generally not been possible to measure concentrations of airborne sulfuric acid directly. It was attempted in the GM study, Stevens says, but the technique was not reliable. Consequently, most of the studies at GM and in Los Angeles involved measurements of sulfates, sulfur dioxide, lead, and carbon monoxide. Concentrations of sulfuric acid were then estimated from these other values. Because of the difficulties of measuring sulfuric acid, most measurements are expressed as concentrations of sulfates.

The measurement problem is further complicated by the fact that airborne sulfuric acid is rapidly neutralized by ammonia in the air. This phenomenon probably alleviates the pollution problem somewhat, since the sulfates thus formed seem to be less toxic than sulfuric acid in some systems. Special precautions must be taken, however, to protect samples from ammonia if they are to be stored between collection and measurement of acid concentrations. Several EPA contractors are developing and refining instruments for continuous monitoring of airborne sulfuric acid concentrations, and Stevens and his colleagues hope to be able to measure actual concentrations on the roadway at the LACS site next year.

Another problem has been the formation of artifacts on the glass fiber filters that are used to collect airborne sulfates for measurement. Artifact sulfate is formed from sulfur dioxide emitted by cars, so the artifact forms more rapidly on the downwind filter. The EPA investigators thus obtained erroneously high results initially when they collected sulfates for 4-hour periods. The concentration of artifact sulfate seems to reach a plateau, though, and therefore the concentration on the upwind filter eventually catches up with that on the downwind filter; thus the investigators are able to obtain what they believe to be relatively accurate results over 24-hour periods. But, critics argue, the wind direction changes during the 24-hour period. Since the freeway contribution to the concentration of sulfates in the air is obtained by subtracting the concentration at the upwind station from that at the downwind station, the change in wind direction should make the 24-hour difference between the sites abnormally low. (It should be noted that artifact formation is not observed with instruments in which Teflon membranes are used for collection; hence the investigators are confident that the overall measurements of sulfates, which are based on three different techniques, are not erroneous.)

In support of this view, critics point to the higher values obtained by Albert H. Bockian of the California Air Resources Board (ARB) at a site on the San Diego Freeway about 1.5 km from the LACS site. Bockian measured sulfate concentrations for 2-hour periods between midmorning and early afternoon. Traffic speeds are higher during these periods than during rush hour (when EPA conducted its 4-hour measurements), and each vehicle emits more sulfuric acid, but the total traffic density is slightly lower. Bockian found that the freeway contribution to the concentration of sulfates in the air ranged from 1.3 to 3.7 $\mu g/m^3$ (monthly averages), with the values for individual periods being as high as 7.5 $\mu g/m^3$.

In Agreement with GM

Bockian's results are similar to those obtained in the GM study, and even these higher values suggest that sulfuric acid is probably not an environmental problem. There is also a problem with Bockian's results, since he found comparable concentrations of sulfates during 1975 and 1976. The 1976 values should have been higher, since there were more catalyst-equipped cars on the road that year. This discrepancy will probably not be resolved until his results from the summer of 1977 become available later this year.

Another potential problem with measurements in the LACS study involves the effect of wind speed on the concentration of pollutants. The concentration of airborne lead at the downwind site, for example, increases with increasing wind speed up to about 7 km/hour, then decreases with further increases in wind speed. The concentration of carbon monoxide follows the same profile, but the concentration of sulfates, surprisingly, does not. This suggests, critics argue, that there may be some undiscerned factor affecting the measurement of sulfates.

Despite these potential pitfalls in all three studies, their results all suggest that the emission of sulfuric acid from catalyst-equipped cars should not be a problem. There are still a few loose ends to be tied up—particularly the concentration of sulfuric acid inside cars in congested areas and inside cars that are following other cars that emit higher-than-normal concentrations of sulfuric acid. But by and large, Lee says, EPA is directing its resources to other potential problems.

One of those problems may be emissions of sulfuric acid and other pollutants from diesel-powered vehicles. Diesel fuel generally contains about seven times as much sulfur as gasoline does, and diesel engines, Pierson says, oxidize about 2.5 percent of that sulfur to sulfates, possibly sulfuric acid. The average diesel, then, emits about as much sulfuric acid or sulfates as a new car equipped with a catalytic converter and an air pump. Diesels also emit much greater quantities of particulate matter.

These are not yet severe problems because there are few diesel automobiles on the road. Some foreign manufacturers, though, have discussed plans to market greater numbers of them in this country, and GM recently announced plans to market as many as 50,000 diesel-powered Oldsmobiles next year. If such a trend continues, it might yet be necessary to regulate emissions of sulfates and of particulates.

Another potential problem results from the use of methylcyclopentadienyl manganese (MMT) to boost octane in gasoline that does not contain lead. Tests at GM and Ford indicate that MMT plugs catalytic converter control systems and causes increased emissions of hydrocarbons. Similar tests by its manufacturer, Ethyl Corporation, have indicated that the additive does not interfere with the converters. EPA is now trying to resolve the differences between the studies and to decide which of the conflicting results is correct.

Still other problems involve the so-called three-way catalysts that will be introduced on some 1978 models to oxidize hydrocarbons and carbon monoxide and reduce oxides of nitrogen. The well-publicized possibility that these new systems may produce hydrogen cyanide seems to have been pretty well disposed of by now, but some investigators worry that the catalyst will produce excessive quantities of ammonia and that ruthenium will be ablated from the catalyst and emitted in a toxic form. These potential problems may turn out to be no more serious than that of sulfuric acid emissions, but EPA and others are presently tooling up to investigate them more thoroughly. The three-way catalysts will offer one advantage, though: the presence of a reducing segment of the catalyst substantially reduces emissions of sulfuric acid, laying that concern to rest at least for as long as the three-way catalysts are in use.

—THOMAS H. MAUGH II