Industry and the Pollution Problem

Both victim and cause of the pervasive pollution problem, industry at the same time has many skills and facilities needed to contribute to the solution of the problem at both the local and national level. Government's role could be to help define the problem and to coordinate and encourage the development of these talents

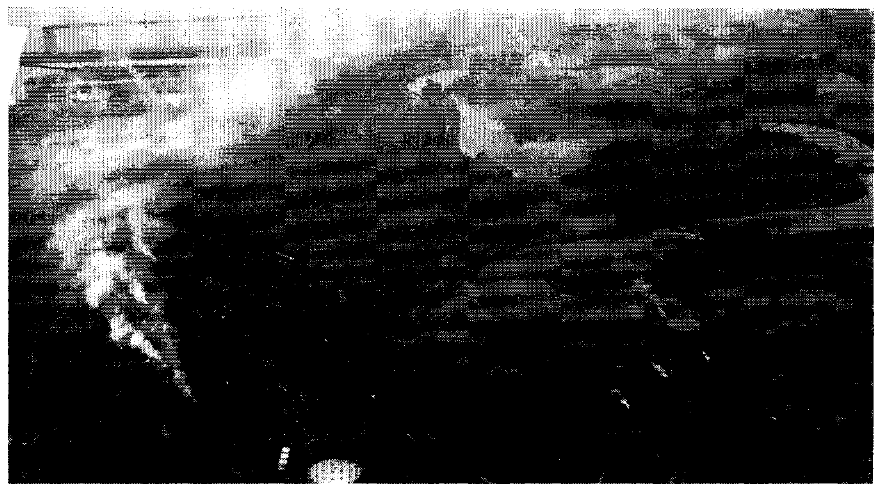
Industry is vitally interested in discussing the role of private industry in obtaining and developing new technology for pollution abatement because industry has a three-way involvement with the problems of environmental health and pollution.

First, industry is a major victim of the pollution problem. Pollution is an economic liability to industry. In a competitive world, American industry suffers added costs because it must constantly clean the air and water it uses. Investments in plants and facilities lose value as their environment degrades. It becomes harder to attract employees to many once-attractive areas of our country. And, most important of all, damage is done to employee health.

Second, industry is among the causes of the problem. Pollution can be defined as the presence of substances introduced to an environment by man which interfere with his safety, comfort, or health. Outmoded industrial processes, along with the gradual growth of manufacturing methods that seemed harmless on a small scale, have contributed to industry's role as part of the problem. Perhaps even more important, consumers have developed an insatiable demand for many products and services that are simultaneously essential to modern life—and a threat to it.

Third, industry is or can be a major contributor to the solution of the problems, not merely its own environmental problems but those of the entire nation. Thus...

- Industry has the *motivation*. As a major victim of the problem, industry should need no prodding in doing something about it.



Smog. *Industry is a major victim and cause of pollution*

- Industry has the *obligation*. As one of the contributors to the problem, industry should accept its responsibilities, as it is now doing in many localities.
- Industry has needed *skills and facilities*. As suppliers of research data, as designers and builders of instrumentation, as experts in sophisticated new methods of systems analysis, as developers of planned communities, as pioneers in control technology, and as manufacturers of new processes and equipment, American industrial organizations can play an important part, not only in preventing pollution but also in doing the actual job of cleaning our air and purifying our water.

According to a recent estimate, the cost of catching up in pollution abatement and keeping waste management up to date will total $100 million over the next 10 to 20 years. The chemical industry alone, for example, is spending an estimated 2 to 5% of its total capital investment for pollution control facilities.

The job of cleaning air and purifying water will be completed most rapidly if attacked on a competitive basis, seeking the most economic solutions and offering a profit incentive to those who learn how to do the job best.

At the same time, it would be folly to suggest that private enterprise alone can solve this massive national problem. There is an urgent need for cooperative action by government—at local, state, and national levels—to establish the permissible limits of pollutants and set the necessary goals and schedules for attaining a healthy—and esthetically satisfying—environment.

To date, the role of the national government in solving the problems of pollution has been to conduct and sponsor research aimed at defining causes and damage, establishing rules and regulations for emission control, and developing new devices and techniques to monitor and track the sources. Unfortunately, no one is now in a position to establish permissible pollution limitations, or long-range goals and schedules, because the problem is not sufficiently understood.

Congress cannot effectively outlaw cancer, because no one yet knows what causes it. In somewhat the same way, we have this problem with pollution. We know a good deal, but not enough, about what pollutants are in the air, water, and ground. We know a good deal, but not enough, about how they got there. We know very little, and nowhere near enough, about the actual effects of these so-called pollutants on either inanimate materials or living plants and bodies.

For example, I don't believe anyone really knows much about the tolerable limits for, say, ozone in the air before it becomes a health hazard—or the possible consequences of removing all ozone from the air. Perhaps facetiously, it has been suggested that before too many years—if positive action is not taken soon—some of our city dwellers will build up such a natural resistance to smog that they will avoid vacations in the country, where clean air might be too great a shock for their systems.

Certainly, with the possible exception of cancer and heart disease (which themselves may be related to pollution), there are perhaps no problems facing our nation where research is needed as urgently as in the case of environmental health and pollution. For example, relatively little research is still needed to get man on the moon, although no one questions the amount of superb engineering that must yet be done.

But we simply don't have the basic facts needed to launch an all-out assault on pollution. Research—lots of research—is urgently needed. In what areas of science? Who is going to do it? Who is going to pay for it? I will explore these questions briefly.

Basing my comments on research—particularly industrial research—with which I am familiar, I should like to list some of the areas where I think there are good potential opportunities for finding new knowledge that should be helpful.

Deciding what the problem is. I have already discussed the immediate importance of this part of the job. It is fortunate that throughout the world of science—in industrial research and elsewhere—life scientists and physical scientists are learning that they can work much more closely together than they have in the past. The continuing interaction of biology, medicine, and other life sciences with chemistry, physics, mathematics, and other physical sciences should help us to define better the true problems of environmental pollution before we spend too much time and energy on the wrong solutions.

For example, I think the time is ripe for some closed-loop experiments on a large scale. Some of my associates have suggested studies in which constant monitoring of pollutants and suspected pollutants is done over a large populated area. Information from such monitoring would be fed into a large computerized information system. Simultaneously, the computer would be given all possible information about the times and reasons for hospital admissions, reports from medical specialists about the number and severity of cases involving a specific list of diseases and disorders, statistics on absenteeism in school and industry, industrial productivity figures, death and accident rates. We all know the difficulties of establishing cause-and-effect relationships, but certainly if patterns and correlations could be established from such studies, we would have information vital for determining the direction of future research.

New monitoring and measuring techniques. Although great progress has been made in building machines that will sniff the air and taste the water, there is still much to be done. For example, we don't know enough about the extremely tiny particles that contaminate the air around us. I refer to particles in the general range of a few millionths of a centimeter in diameter—or less. The surprising fact is that although the particles in air larger than a tenth of a micron constitute some 90% of the total *weight* of all the particles, those smaller than a tenth of a micron constitute some 95% of the total *number* of all particles. More important, the total *surface* area of these small particles at least equals the surface area of the larger particles and in metropolitan areas is many times the surface area. It is on the surface of such particulate matter that waste gases are absorbed—and the fact is that we know little or

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This article is based on testimony Dr. Bueche gave last year before the Subcommittee on Science, Research, and Development of the U.S. House of Representatives nothing about how, what kind, or how much gas is absorbed by these tiny particles. Remember, too, that the smaller the particles the more likely they are to get into our lungs—and then discharge their contaminants into our bloodstreams.

On the basis of their recent work, some of my associates suspect that these mysterious tiny particles may have played an important role in tragic instances of mass air-poisoning such as those in London and Donora, Pa. After these particles have carried gases deep into the body, some of the contaminants may be released onto single cells. This may leave the cells helpless, or even cause their death. In any event, it has been observed that when many of these particles occur in the air, necessary life functions can be affected seriously. Surely, we must learn more about these particles.

Before leaving the subject of new monitoring and measuring techniques, I should emphasize the need for research and development aimed at making sophisticated laboratory devices economically feasible. It is relatively easy for a legislative body to pass a law prohibiting smokestacks that put "measurable amounts" of sulfur dioxide in the air. It is quite another thing to make such a law meaningful. With sophisticated research equipment, the most infinitesimal and perhaps inconsequential amounts become measurable. In the laboratory, the cost of such measurements may be of little consequence, but in practice, on top of the smokestack, it may be economically difficult to make barely adequate measurements on a continual basis. New instrumentation techniques, combining relative simplicity with extreme sensitivity, are now being developed, and a more intensive effort in this area should pay substantial dividends.

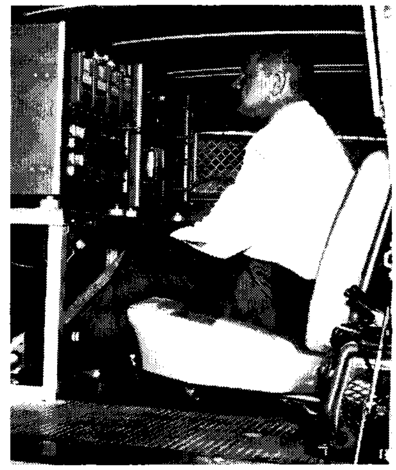
Systems analysis and management. I have already touched on this area in my suggestion for closed-loop experiments to seek correlations between pollutants and public health. The experience gained by the aerospace and electric utility industries in recent years has produced a new competence in handling multifaceted problems and optimizing systems. It has been our experience that under the general heading of systems analysis we have opportunities to attack the most complex problems through a three-stage process:

- An exhaustive collection and organization of data pertinent to the problem.
- A mathematical description of the interrelationships discovered, based on the data collected.
- A mathematical optimization, showing the best possible system.

A worthwhile community water-management system, for example, will have complexities which far exceed the capability of old-fashioned trial-and-error methods. It will be necessary to take into account not only the immediate technical accomplishment of a venture, but also the economics, future growth, reliability, maintenance, public acceptance, and many other community parameters. The aerospace industry uses a computerized approach to consider simultaneously millions of combinations of trajectories, weight, thrust, single- and multistage booster arrangements, vehicle configurations, and the like. The same kind of approach is now beginning to be applied to water-management problems. These certainly can and will be expanded to include a variety of other situations now affecting our environment.

Improved energy conversion and energy storage systems. The U.S. Public Health Service has pointed out that of the 133 million tons of aerial garbage dumped into the nation's atmosphere each year, an estimated 85 million tons—almost two thirds of the total—come from sources under the general heading of transportation. I have already mentioned our lack of definitive knowledge about which contaminants cause the most harm. Therefore, it may not be fair to say that two thirds of our air problems come from the internal combustion engine. However, in any case,

Mobile monitors. *Industry must assume the responsibility for the research that will lead to the development of improved sensing and monitoring techniques and hardware for what is a rapidly expanding market. Already, industry has taken some steps in this direction with such devices as the mobile unit (right) that uses a condensation nuclei counter for measuring trace atmospheric gases and particulates or the specially outfitted truck (bottom) equipped to trace and calculate the directions in which smoke and soot travel*



it is safe to say that this engine—the most-engineered product in human history—is a major problem as well as being a key factor in our economy and our entire way of living. (Incidentally, this is not just a problem in the car-crammed United States. For example, the World Health Organization reports that no fewer than 50% of the motorists in Paris are "on the threshold of intoxication"—not from wine, but from carbon monoxide.) One possible solution to the problem of the internal-combustion engine is, of course, to keep on improving it, with greater emphasis on more complete combustion and cleaner exhausts. You are familiar with efforts in this direction, although it is generally acknowledged that even with the best of luck it may be possible only to keep the present situation from getting worse. In the long run, I believe we must look toward other ways to convert chemical—or other kinds of energy—into mechanical energy.

The fuel cell is a device that converts chemical energy directly into electrical energy, without moving parts and with inherently high efficiency, since it does not have the Carnot-cycle limitations which put a ceiling on the efficiency of ordinary heat engines. The fuel cell was invented in England, way back in 1839, but it did not have its first practical application until just short of two years ago in the Gemini V spaceflight. By practical application, I mean that this was the first time a fuel cell was used because it was the best way to do the job. No other power-generating system could have given the 14-day Gemini flight the on-board electric power it needed without exceeding the weight limitations.

Fuel cell. *The conversion of chemical energy directly into electrical energy in a fuel cell offers highly efficient operations in the absence of noxious fume emissions. This fuel cell operates at moderate temperatures and uses a broad range of hydrocarbon fuels which it combines with air to generate the electricity turning the motor at right. At G.E.'s R&D center, Dr. Leonard Niedrach (left) observes as Dr. Thomas Grubb pours diesel oil into the cell*

Equipment used for space flight is not inexpensive, and the success of fuel cells on the Gemini flights hardly means they are ready for automobiles or trucks. At present costs, fuel cell automobiles are economically out of the question.

However, we should not overlook the pace of recent progress in fuel cell research. For more than a hundred years there was only spasmodic interest in fuel cells, and virtually no scientific progress. But in the past decade all this has changed. Now there are literally thousands of scientists and engineers around the world working on fuel cell technology. The basic type of fuel cell on which the Gemini system is based was invented only about a dozen years ago. Since then, a very great deal has been learned, especially as government-funded programs have accelerated the pace of research and development. If the pace of discovery continues, we must consider that in the long run the fuel cell may be a major source of portable power.

Fuel cells have a number of inherent advantages. First, they have high theoretical efficiency, which could mean conservation of fuel resources. They are quiet. Most important, from the standpoint of pollution abatement, it is conceivable that fuel cells can be developed that will have no noxious exhaust at all. In the laboratory, fuel cells have been operated, at moderate temperatures, using ordinary hydrocarbon fuels such as natural gas and diesel oil. The scientifically astonishing thing about these cells is that in some types the reaction of the fuels with oxygen from the air goes "all the way": nothing is left except clean water, harmless carbon dioxide such as that which we all exhale when we breathe, and electricity. It remains to be seen, of course, whether complete fuel cell systems can be developed that will be "completely pure," but research has shown that such

Solids. *Research must lead to a total recovery and recycle of solid wastes as its ultimate goal*

a result is at least within the realm of technical possibility.

What are the problems with fuel cells? There are a variety of problems in addition to the obvious one: They now cost too much. One of the reasons for the high cost is that many otherwise-attractive cells require extensive use of precious metals—such as platinum—in the electrodes. Some of the most efficient fuel cells work only with hydrogen as a fuel, and although there is plenty of hydrogen in the world (very tightly tied to oxygen), hydrogen is an expensive fuel and likely will remain so for a long time. Then there is the matter of weight and size—present fuel cells tend to take up more space than we would like.

Let us consider the question: "When will we have fuel cell automobiles?" I for one don't know when, and I'm not really sure if. All I can say on this score is that on the basis of what we know now, fuel cells might someday be very attractive for vehicles because they might not give off any appreciable noxious exhaust, and they might be developed to fit into more compact portable packages, and they might be made inexpensively enough for general use in vehicles.

That's a mighty long list of "mights." But fuel cell research has great momentum. The need for alleviating pollution from vehicles is very great. The accomplishments of man, when he puts his mind to it, are being dramatically demonstrated in today's world.

I can't promise or guarantee that we'll all be driving a fuel cell car. But I can assure you that in our own company we feel that fuel cells are extremely promising for both long-range research and more immediate development work. We're spending a lot of our own money on it, and I don't hesitate to recommend fuel cell research and development to others—including a continuation of support by the Federal Government.

Incidentally, we should not let the glamor and potential of fuel-cell research cause us to overlook the tremendous opportunities for improving electrical storage batteries. There are few greater challenges for researchers today than the discovery and development of better ways to store electrical energy. An improvement in the efficiency, weight, and cost of storage batteries could have substantial impact on electric vehicular transportation long before fuel cells.

Battery-operated vehicles would be extremely "clean" themselves, of course, but we must remember that we will have a net gain in the fight against pollution from battery-operated vehicles only to the extent that methods which provide energy to charge the batteries are not themselves contributing to pollution. I shall have some comments on this in a few moments, but first let me continue with some other areas of technology where I think there are important research opportunities.

Water treatment. There is no shortage of ideas in this area. Almost any scientist or engineer worth his salt probably can suggest a novel approach to the cleaning or desalination of water. Finding economic solutions is quite another matter. However, I am quite optimistic that intensified effort will produce significant results in the near future. Of utmost importance here, I believe, is that we view the various clean-water problems in proper perspective. Pre-use cleaning and after-use cleaning of water are two substantially different subjects, and there also is a considerable difference between the problems of industrial waste and community waste. Each of these is different technologically as well as economically. A wide variety of solutions will be required.

Air cleaning. Also, of course, there is a difference between air conditioning and air cleaning. We believe that new ideas in the electrostatic precipitation of particles, and for removing other contaminants from air, in combination with more conventional air conditioning, can add to the human comforts now achieved by cooling the inside of buildings. We need to clean the air in which we live—starting with those small volumes of air contained in our homes, factories, and offices. To satisfy this need, intensive research is being conducted on permeable membranes that can remove waste gases while—at the same time—returning oxygen to the inhabitants of the building. At best, however, such interior air-cleaning is only an intermediate step toward the ultimate objective of keeping the outside air clean. But, even as an intermediate step, it is important enough to demand further attention in the nation's laboratories.

Pollution from insect control methods. Without getting into that argument about changing the balance of nature. I should like to point out that chemistry is such a versatile and adaptable science that an intensified effort in insect-control research should permit us, in effect, to have our cake and eat it, too. A recent example of a successful chemical effort to eliminate the bad while keeping the good was the solving of the detergent problem: using new chemistry to create the new soft detergents without in any way diminishing their unique cleaning powers. I have every confidence that, with sufficient research effort, it will be possible to improve substantially our health environment through improved soft insecticides and alternative methods of insect control—and without frightening anyone except, possibly, the insects.

Sewage disposal. One of the most intriguing ideas stemming from recent research in microbiology is the prospect of using biological processes to convert domestic sewage into two valuable products: water pure enough for drinking, and a high-protein feed for animals. As we have noted, the simple objective of producing clean water is, of itself, a sufficient motivation for extensive industrial research effort. When the added incentive of producing a profitable by-product is considered, there is every reason to undertake the extensive fundamental research that must be accomplished before this prospect becomes practical reality.

Solid waste disposal research. Discarded automobiles, household garbage, and the like produce a problem that cannot be overlooked indefinitely without causing permanent damage to our environment. Society has the responsibility of ridding itself of these waste materials, whereas industry, in addition, carries the burden of minimizing their occurrence. Research must lead to the total recovery and recycle of these wastes as its ultimate goal. Large-scale facilities on community and urban levels need to be developed to process a wide variety of substances in an economic manner.

Combustion research. Unburned fuels are part of our aerial garbage, along with unwanted combustion products. I have mentioned the current efforts to improve internal combustion engines themselves. We should also note the opportunity in the area of altering and improving the fuels used, not only in automobiles but also in power plants and countless other industrial and domestic coal- and oil-burning sources of combustion pollutants. New knowledge about basic combustion processes is giving us new hope for simultaneously improving efficiency and reducing unwanted effluents.

In our own company, of course, we are highly interested in central-station electric power generating plants of all types: hydro, fossil fuel, and nuclear. Although we do not manufacture the part of the equipment in a coal-burning station which involves combustion products, as major contributors to the total station—through turbines and generators and other equipment—we are naturally concerned about alleviating the pollution-potential of the total system (which may be more of a problem in some areas than in others). Thus we have been actively engaged in combustion research for many years, and we are actively seeking ways to reduce unwanted effluents from the fossil-fuel plants which are the mainstay of today's electric power system in this country. These problems are extremely difficult and complex; much progress has been made over the years, and recently built stations are far superior to older power plants. Additional progress should be possible, but the economic consequence of applying technically feasible ideas for removing combustion by-products must not be underestimated.

It is only natural, when faced with the problems inherent in fossil fuels, to think about other energy sources. Hydroelectric power is wonderfully clean, although there are sometimes differences of opinion about the environmental aspects of building dams, regardless of the cleanliness of the electric generating process involved. Although hydro is not the whole answer by any means, because of limitations in suitable hydro sites, there still remain a significant number of opportunities to install more hydroelectric generation facilities in the U.S.—and in a manner supporting the objectives of conservationists.

But the matter of greatest interest to those worried about pollution is the news about nuclear power. First of all, economic nuclear power has come of age much quicker than earlier predictions. Nuclear stations are being installed at a rate far ahead of even the most optimistic predictions of a few years ago. It is difficult to overstate the scope and importance of the revolution in power generation we are experiencing right now.

The nuclear news is especially interesting for those concerned with pollution because the cleanliness of nuclear power plants also has exceeded expectations. There are, of course, no combustion products at all. And the amount of radioactive material emanating from these plants is so small that it is even less than the tiny amounts of radioactive waste emitted by conventional coal-burning power plants as the result of radionuclides occurring naturally in coal.

Certainly, there are many additional opportunities for research to help improve our environment. Those I have mentioned seem particularly important to me because I am aware of research progress in all of them. Success in many of them—if not all of them—seems inevitable.

But although I am aware of progress in these areas, I am not at all satisfied that enough research is being done in any of them. Which brings us to those two difficult questions: Who is going to do it? And who is going to pay for it?

These are difficult questions. Considering the amount of attention that has been directed to them, it is obvious that if they were easy we would have had answers long ago. I should like to make some comments on these questions, but I certainly do not want to suggest that I have all the answers.

It may be helpful to divide the kinds of research opportunities I have been discussing into a smaller number of classifications. We need research aimed at giving us better ways to find out what pollutants are in the air and water and when and how they got there. We need research aimed at learning the effects of these pollutants, especially on people. We need research aimed at keeping certain pollutants out of our environment in the first place. We need research aimed at removing pollutants from our environment.

Research in these classifications of monitoring, causes, effects, preventive regulation, preventive technology, and removal can be further consolidated, for purposes of this discussion, into two categories:

- Research that will produce information useful for establishing standards, determining necessary regulations, enacting appropriate laws, and suggesting methods.
- Research that will produce information useful in developing hardware and systems that can be manufactured and sold.

In the first category is much of the needed exploration about the causes, effects, and preventive regulation of pollution.

In the second category is most of the research that should be done in the areas of improved sensing and monitoring techniques, prevention systems and devices, and methods of removing pollutants that can't be kept out of the air and water in the first place.

Government, university, and industrial laboratories can all contribute in all of these areas. But it might seem logical to assign the bulk of responsibility in the first category to the Government, since much of it concerns very large-scale public health matters, since it is going to be more effective for the Government to coordinate and conduct many of the massive experiments involving large areas and large numbers of people, and since the initial predominant impact of this part of the work will be, by the definition I have used, on the establishment of necessary laws, regulations, and recommendations.

Obviously, university laboratories (with government support) can make important contributions in much of this work.

In spite of the Government's basic responsibility in this category of the work, the special skills of industrial research can be extremely helpful. Further, the early involvement of industry in all aspects of the pollution problem is essential to pave the way for prompt action once the goals have been set. And, of course, since private industry wants to contribute its knowledge and viewpoints about proposed regulations to combat pollution (especially in regard to the technological and economic feasibility of such proposals), the early and continued involvement of industrial research should be helpful to all concerned.

Industry itself should assume the major responsibility for the research which will lead to hardware and systems needed to monitor pollutants, plus that related to the technology of prevention and removal. The market for sensing and monitoring equipment should grow substantially in the near future, and I believe industry will be missing an opportunity if it does not substantially increase its research effort here at once. (I know one company that is increasing its effort.) In the area of technology for prevention and removal, industry probably will not be motivated to a truly large-scale effort until the monitoring, causes, and effects research makes it possible to identify the guilty pollutants and quantify the objectives in removing them.

Thus, Government will have to carry proportionately more of the research burden in the early stages of this fight than in the latter stages. Once the necessary rules, objectives, and timetables are established, industry will know better how to channel its efforts. But even as this is being done, and even as the problems are being defined, we should continually remind ourselves that the most desirable eventual solutions will come most rapidly if attacked on a competitive basis. The most economic solutions will be diligently sought by private enterprise, and a profit incentive for those who learn how to do the job best will produce the desired results far quicker than any other approach.

As to who will pay for this research, the same sort of pattern seems appropriate. Industry has opportunities it should explore with its own funds in helping develop the kind of monitoring techniques that obviously are needed now. Similarly, industry should be willing to invest more—right now—in the areas of prevention and removal technology where there is no doubt of the eventual need.

But the big surge in industrial research expenditures probably cannot be expected until the needed "ground rules" are better established. Thus we would look forward to a pattern of increased research expenditure by both government and industry, with the early predominant role of government tapering off and industry's contribution rising rapidly as the objectives become clearly defined.

I assure you that the company I represent has been and is deeply concerned with the technology of pollution abatement. We have tried to take the lead in doing things—frequently very expensive things—that are the responsibility of good corporate citizens in the communities across the nation where we work and live. Similarly, we have devoted a substantial research effort to many areas of technology relating directly to the pollution problem, and we are constantly increasing these efforts. We think it is just plain good business to do these things.

I assure you that we will study the findings of this committee with great care, and we will work vigorously on behalf of making the best contributions we can toward improving the quality of life by protecting and improving the environment in which we work and live.

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Dr. Bueche is known for his work on the physics and chemistry of polymers and the effects of high-energy radiation on plastic materials. At G.E. he contributed to the success of many scientific projects ranging from improved synthetic diamonds to selective membranes, and from new fuel cells to a basic chemical technique called oxidative coupling. The author of many technical papers and holder of a variety of patents, he is also a member of the Board of Directors of the American Chemical Society and has held numerous other ACS posts, including chairmanship of the Kendall Award Symposium (1957), vice-chairmanship of the Division of Polymer Chemistry (1962), and chairmanship of that division (1963). He is a fellow of the American Physical Society (1963) and a member and past chairman of the executive committee of the division of high polymer physics. Dr. Bueche also serves as chairman-elect of the board of trustees of the Gordon Research Conferences and has held other posts within that organization. In addition to his other activities in many scientific organizations, Dr. Bueche includes membership in such scientific and honorary societies as the National Society of Professional Engineers, AAAS, Alpha Chi Sigma, Gamma Alpha, Phi Kappa Phi, Phi Lambda Upsilon, Sigma Xi, and ACS.