I. INTRODUCTORY SESSIONS

Introductory statement by the Chairman

Welcome to the third Henniker Conference on National Materials Policy.

The context of this third conference is one of quickening pace, of movement toward the implementation of organizational ideas and suggestions for action discussed in the two preceding conferences.

The objectives of this third conference are to sustain national interest in the subject of materials policy, to generate ideas for possible legislative consideration, to demonstrate consensus on main themes of materials policy, and to focus national attention on the need for a strong, effective national network of materials information systems.

The first Henniker Conference, in the summer of 1970, was convened here at the request of Senator J. Caleb Boggs, the author of the bill that became law two months later—under the title National Materials Policy Act of 1970. At that first conference, we had a succession of prepared papers by leading authorities who collectively demonstrated the scope of the concerns that would need to be dealt with by the National Commission on Materials Policy. Incidentally, the idea of a Federation of Materials Societies was reinforced and strengthened at this meeting, after receiving encouragement at a 1967 meeting of the National Research Council.

The second Henniker Conference on National Materials Policy, in 1972, was organized with the encouragement and support of the National Commission. Commissioners and staff members were closely involved in the 1972 meeting. Its purpose was to examine in depth eight of the principal issues before the Commission. In addition, members of the Committee on the Survey of Materials Science and Engineering of the National Academy of Sciences discussed their forthcoming "COSMAT" report. The policy studies of the Department of the Interior under the National Minerals Policy Act of 1970 were described by Assistant Secretary Hollis Dole and by the Bureau of Mines Chief Scientist, Earl Hayes.

Since 1972, there have been many further developments in national materials policy. The National Commission made its final report June

30, 1973. The COSMAT report appeared in early 1974. The leadership in Congress, after meetings with leaders of the Administration, proposed legislation providing for Federal sponsorship of a comprehensive materials information system and a materials policy agency—in S. 3523 introduced by Senators Mansfield, Scott, Byrd, Griffin, Javits, and Brock. * Many other legislative proposals dealing with recommendations of the National Commission are also pending in Congress. Materials policy studies are commanding the attention of the Environmental Protection Agency, the Federal Energy Agency, and the National Science Foundation, as well as of the Departments of Interior, Agriculture, and Commerce.

This third Henniker Conference came about as the result of a proposal from the Board of Trustees of the Federation of Materials Societies to the Engineering Foundation, a year ago. It was suggested by the FMS that the precedent of two biennial conferences on national materials policy be continued by holding a third conference in 1974, under FMS management. It is my hope that this tradition will be continued in the future.

I had hoped to relinquish the chairmanship of this third conference to Mr. Nathan E. Promisel, whom all of you know as one of our most outstanding leaders in the field of materials policy. Unfortunately Prom had a series of medical mishaps that kept him from this service, but I hope that we will have the opportunity to meet under his leadership at a future policy conference.

The 1974 conference will focus on five problems: information systems, the international flow of materials, materials conservation through engineering design, materials recycling, and the role of the technical societies— stressing the international aspects. I would expect that in all of these subjects, attention would be given to the interaction of materials, energy, and environment. This theme of interaction was stressed at the second Henniker Conference and was the focus of the National Commission's report.

We will devote most of this opening day to a series of tutorial papers on the five topics of the conference. The next two days will be devoted to task force consideration of the topics. It will be the responsibility of the task force chairmen to prepare brief written reports to be distributed to all conferees by Thursday morning. Thursday will be devoted to plenary sessions at which the ten reports, two on each topic, will be reviewed.

Thursday night we will hear a more formal paper by Dr. Richard Roberts, Director of the National Bureau of Standards, Tonight we will hear from Dr. Julius Harwood of the Ford Scientific Laboratory on the auto industry's views on materials policy.

The closing day of the conference will be reserved for a number of shorter papers and a summary description of what the week has produced.

This proposed bill was subsequently enacted as a part of the Defense Production Act Amendments, P.L. 93-426, approved September 30, 1974.

Now it is my pleasant duty to introduce the keynote speaker of this conference, Mr. Emilio Q. Daddario. I should remark that I have been trying for four years to persuade him to find time in his busy schedule to attend one of our Henniker Conferences and I am delighted that he was finally able to do so. Unfortunately he will not be able to spend the whole week with us because he has a speaking engagement on Wednesday before the American Bar Association meeting in Hawaii.

While we were planning this conference here, Mr. Daddario took a keen interest in what we were attempting to do. In his present role as Director of the Office of Technology Assessment, Mr. Daddario has recognized the importance of assessing materials policies for the Legislative Branch. He has enlisted the support of the Federation of Materials Societies to survey the state of materials information systems. He has convened an advisory panel of materials experts to advise OTA. And he is formulating a program of assessments in the field of materials to meet the needs of Congressional committees in developing legislation.

It gives me great pleasure to introduce our keynote speaker, Emilio Q. Daddario, Director of the Office of Technology Assessment.

F. P. Huddle
Senior Specialist, Science & Technology
Congressional Research Service

KEYNOTE ADDRESS: EMILIO Q. DADDARIO

Ladies and gentlemen, I feel very much at home meeting with you here today at this third Henniker Conference on National Materials Policy.

Regretfully, I have been unable to participate in the two previous Henniker conferences. Yet, nonetheless, I appreciate the vanguard efforts of this conference in creating awareness of the critical nature of natural resources scarcities.

The “Spirit of Henniker“ is identical to the motivating force behind the long drive to create the Office of Technology Assessment as an early warning mechanism to alert Congress to the full spectrum of consequences—both good and bad—of our expanding technology.

Nor is it at all surprising to find that the great majority of OTA initial assessment topics are tied together by the common thread of concern about the availability y of natural resources and materials supplies. Not only are we developing an assessment in the specific area of materials resources, which I'll discuss in greater detail shortly, but we also are undertaking studies in the vitally related areas of oceans technologies, world food supplies, and the overall energy picture. The selection of these topics as OTA’S first and highest priorities directly reflects the priorities set by the Congress through its standing committees, in expressing its need for legislative assistance.

So I think it is quite fair to say that the message of the previous Henniker Conferences have been listened to in the Congress. And I can assure you that there can only be increased Congressional interest in the findings of this year's conference, and any future work accomplished in this important area,

To underscore this point, I'd like to review the record of Congressional response to the past results of the Henniker sessions.

At the first Henniker Conference on National Materials Policy, back in 1970, the topic was "Problems and Issues". The proceedings of the conference were published by the Senate Committee on Public Works. The keynote speaker was Senator J. Caleb Boggs, author of the bill that created the National Commission on Materials Policy.

That bill passed the Congress less than two months after the conference here, with no recorded dissent.

Just for the record, let me recall to you some of the names of the speakers at that first Henniker Conference: James Boyd, William J. Harris, Jr., Elburt F. Osborn (better known as "Ozzie"), S. L. Blum and N. E, Promisel. The reason for mentioning these particular speakers is that they are now serving on an ad hoc committee to advise the OTA on its program of materials assessments.

The second Henniker Conference on National Materials Policy, in 1972, was titled "Resolving Some Selected Issues". It was held while the National Commission was in its final year of deliberation. Speakers at that conference included the Chairman and Executive Director of the National Commission, the Director of the Bureau of Standards, and four past, present, or future Directors of the Bureau of Mines. Also present were most of the members of the Interagency Council for Materials. The point is that Henniker 11 afforded an opportunity for interchange between the Commission, created by the Congress, and materials experts drawn from the Executive Branch. Increasingly we have seen this pattern. Data collected and organized by executive agencies are analyzed by congressional agencies as the basis of policy determinations which the Executive Branch then is charged with implementing.

Recently in the Senate debate on S. 3523, a bill I shall say more about later on, the proceedings of this second Henniker Conference were cited in justification for the proposed legislation. The point is that when leading students of national materials policy assemble in a forum like this one, the Congress gives ear to their conclusions and findings. You are not wasting your time or the public's time when you sit down here to think about hard problems.

Last fall, there was a joint meeting of the National Academy of Sciences and the National Academy of Engineering to review the findings of the Commission, the COSMAT Study, and the second Mining and Minerals Policy Report. Congressman Mike McCormack was one of the principal speakers, and attested to the interest of his Energy Subcommittee of the House Committee on Science and Astronautics on materials matters.

I should take note also that Professor Morris Cohen of MIT, who chaired the COSMAT Study that produced the excellent report, "Materials and Man's Needs", is with us here at Henniker III. * And let me add that this report along with the report of the National Commission on Materials Policy, is receiving close study at OTA by our ad hoc committee on national materials policy.

Over the last year something like a hundred different bills have been offered in Congress dealing with materials subjects. There have been a score of hearings and numerous reports and committee prints on materials subjects.

For example: Industrial Materials, Problems and Issues for the Congress. Resource Conservation, Resource Recovery, and Solid Waste Disposal. Special studies on solar energy materials, oil shale, lignin, waste materials recycling, substitutes for bauxite, corrosion, Rhodesian chromite, strip mining, and a host of other problems are right now receiving Congressional attention.

An interesting contract has been placed with the National Materials Advisory Board in the Academy of Sciences to investigate lagging technology and opportunities for technological advances in the basic materials industry. This study was placed with the Academy by the Congressional Research Service at the request of the House Committee on Science and Astronautics and is scheduled for completion this year. It represents a first use of the Academy on an in-depth technical study for Congress in materials management and a further recognition that technical advice on legislative issues can be systematically contracted for by Congress from the Academy.

I can see ahead of us a large prospect of further Congressional interest in securing technical underpinning for legislation. Take, for example, the recent article by Senator Tunney in the Washington Post, in which he declared:

> "We must accelerate research and development efforts to use existing materials more efficiently in products and systems, and to prepare substitute materials. In addition, the recycling of solid waste, the development of energy-efficient, nonpolluting automobile engines, the mitigation of metal corrosion, and changes in energy pricing structures—all issues presently before the Congress, and all with a potential for vast mineral and material savings—can go far to meeting our needs now and in the future. "

I am informed that at your meetings of technical committees, Academy panels, and the like, the question is repeatedly raised as to whether anybody is listening. Believe me, somebody is. A hundred legislative proposals is something to contend with. I do not mean to suggest that they will all be passed into law. The legislative process is something we all need to understand better. A bill is only the first step. The second step is to convince a Congressional committee that the bill warrants attention so that hearings are scheduled. The third step is to present evidence at the hearing that the measure is sound, needed, useful, and publicly supported. The hearing also serves the important

* *Unfortunately, Dr. Cohen was prevented, by an illness in the family, from attending this conference. His absence was deeply regretted.*

function of building a national consensus. Here the technical societies can help by educating the public on the issue, its meaning, and its public value. Ordinarily, when a bill is intelligently explained to the public and to the Congress, if it has merit it receives favorable reception in the Congress and becomes law. Increasingly, the bills in Congress are coming to have a technical content. That is an important reason why OTA was created. I propose to say something later on about the role of OTA in the field of materials. But first I want to tell you about a bill that could have a large impact on the materials community in the very near future. I refer to S. 3523, the "Mansfield Bill", which proposes to create a temporary "Commission on Supplies and Shortages'.

The bill was conceived in principle at the first meeting of majority Senators, last January 24. It was discussed in Senator Mansfield's speech, February 1. It was the subject of a letter from Senator Mansfield and Senator Hugh Scott, minority leader, to the President, February 19. It was converted into a bill, with Executive Branch concurrence and bipartisan support, May 22. It was reported from the Senate Commerce Committee June 5, and was passed by the Senate June 12. Since then the measure has been under consideration in the House Committee on Banking and Currency. In view of the strong bipartisan support the measure has received, I would expect it to pass this year and become law. (Ed. note: The measure became law.)

Briefly, the bill provides for two things, First, it sets up a temporary commission to design a permanent institution to keep tabs on materials, to sound the warning in case of threatened dislocations, and to propose remedies. It must report its recommendations on this matter within six months. Second, from the moment it is established, the temporary commission will also serve the function of the permanent institution until Congress has had time to act on its recommendations to create the permanent institution.

Basically, the first function is a task combining technical understanding with political science. What is needed is an agency to coordinate the collecting of materials data, to perform analyses of the data, to draw conclusions, and to design remedies to correct dislocations.

This concept was first proposed by the Paley Commission in 1952. It was revived by the National Commission in 1973, and the need was dramatized by the petroleum crisis—or energy crisis, if you like—-of this past winter.

The Congress, increasingly, is concerned with this vital matter of monitoring our nation's materials well-being. It is my hope, also, that the Office of Technology Assessment will be permitted at constructive role in support of Senator Mansfield's plan. I believe we have the charter, and the interest, and are gathering the resources to contribute to this essential endeavor.

Let me conclude my talk with a description of what OTA is doing in the field of materials.

The Office of Technology Assessment, to give OTA its formal title, was created by statute in October 1972. It has gotten underway carefully because it is a new and highly experimental venture, a new social invention. Its purpose is to provide sound technical advice to the Congress on legislative issues, to give early warning of technical opportunities and dangers, and particularly to look at all the consequences of technical decisions and innovations. Yet it has already issued an assessment on “drug bioequivalence” and has ongoing programs in solar energy, rapid transit systems, food, and the oceans. These are being performed at the request of Congressional committees and are sure to have an effect on legislation of concern to those committees.

Organizationally, OTA consists of a board of six Senators, six Congressmen, and the Director of OTA; a Technology Assessment Advisory Council, and a working staff.

Our first step in defining our universe was to ask the Congressional Research Service in the Library of Congress to tabulate for us the major technical issues confronting Congress. This was an impressive task that presented us with two large volumes of issues that might be candidates for assessment. A number of these issues involved materials.

Next, we invited the chairmen of Congressional committees to identify for us the issues they wanted us to study. In response to one such request, Representatives Olin Teague and Charles Mosher, Chairman and Ranking Minority Member of the House Committee on Science and Astronautics, replied, January 22, asking that OTA

> Focus particularly on what materials problems are likely to develop in the next five to ten years with regard to those metals, rare earths, and other materials on which the United States predictably will have to depend for a substantial part of its needed supply through imports. We should also like to know what magnitude of materials R&D should be launched in the relatively near future in order to alleviate problems of this kind.

Late in 1973, with some help from the Congressional Research Service, we outlined a program of materials assessments for Board approval. The plan was divided into short-range and long-range assessments. The short-range program, in its present form, has four items: (a) an assessment of the present adequacy of materials information systems; (b) an assessment of ways to conserve energy through materials management; (c) an assessment of ways to ease U.S. materials vulnerability through production of domestic materials; and (d) ways to use the stockpiling principle to encourage domestic minerals production, put recycling of materials on a sound economic footing, stabilize prices, and reduce our vulnerability to foreign actions.

Last January 3rd, I wrote to the Federation of Materials Societies inviting their help in assessing materials information systems. The Federation agreed to help, and later in this program you will hear a report from Dr. Jack Westbrook, chairman of the Federation’s Materials Information Committee, on what has been learned about materials data systems, their adequacy, completeness, and accessibility.

I recognize that this investigation is only at the close of its first phase. There will be much more hard work ahead. One of the five tasks before this Conference will be to give us guidance on how to proceed from here.

In our search for techniques to enlarge the competence of OTA, one scheme has been to organize advisory groups or panels to provide technical advice, analyze our programs to recommend changes, and provide a bridge to the broader technical and also nontechnical community. A week ago today in our conference room we held a first meeting of our OTA ad hoc committee on national materials policy. We asked this committee to suggest ways in which the OTA could best benefit from the Henniker 111 Conference, and that topic occupied a considerable part of the meeting. I hope you appreciate the purpose of this action, which is intended to ensure that your deliberations here receive maximum visibility to the Congress as it takes up materials issues.

Another request to the Committee was that it examine our OTA program of materials assessments, recommend additions and deletions, suggest priorities, and help us design assessment studies.

A third question was as to how OTA could best serve the proposed Mansfield Commission when it became a fact. On this point, the Committee advised us that our plan to assess materials information systems, already in progress, would be invaluable, and should be pursued with vigor.

Finally, we asked the Committee to recommend the form that a permanent OTA materials panel should take. That question is expected to be on the agenda of the second meeting of the Committee, September 20.

To conclude this recital, I want to express my appreciation to all those in attendance at this conference. In turning your attention to national—and, indeed, international—aspects of materials policy, you are contributing to the development of an economically sound and stable society. Avoidance of dislocations in supply-demand is important for all of us. An orderly global flow of materials is basic to world peace. The frugal use of materials is a practical necessity in our shrinking world. So is the recycling of our wastes into reuse. And worldwide technical cooperation to share expertise to these ends is an eminently sensible way to their achievement.

WELCOMING REMARKS ON BEHALF OF THE FEDERATION OF MATERIALS SOCIETIES

John B. Wachtman, Jr.
President-Elect,
Federation of Materials Societies

I would like to add an expression of welcome on behalf of the Federation of Materials Societies (FMS) which is responsible for organizing and managing this conference under the general sponsorship of the Engineering Foundation.

Our Federation president, Dr. Eugene Merchant, is in Australia on a business trip and our executive director, Mr. Nathan Promisel, is indisposed. Both had wished to attend and both regret not being able to be here. On their behalf and on behalf of the Board of Trustees of FMS I would like to express our pleasure at having all of you here. This is a working conference and we count on your active participation to make it a success.

It is very appropriate that FMS should be the organizer of this third Henniker Conference on National Materials Policy because the organization of FMS itself took place partly at the first of these Henniker Materials Conferences four years ago, FMS was formally incorporated in June two years ago with the general goal of providing a national focus for materials activities of such broad character that cooperation between individual technical societies is required for most effective execution. The members of FMS are materials-oriented societies, not persons. Current membership includes ten member societies and half a dozen observer societies; through these member and observer societies FMS seeks to represent the broad materials interests of some half million materials scientists and engineers and to serve the public interest in materials.

Time does not permit me to review the full scope of FMS activities but I would like to give you two examples. First, an FMS committee under Doug Ballard prepared a report to Jim Boyd of the National Commission on Materials Policy dealing with materials conservation through effective utilization. Second, an FMS committee under Jack Westbrook is currently responding to a request from Mr. Daddario, Director of the Office of Technology Assessment, for assistance in evaluating the scope and quality of the sources of materials information. We will have an interim report from Dr. Westbrook later in the conference.

We have a challenging week ahead of us. I hope you will find it interesting and worthwhile.

MATERIALS RESEARCH: A STRATEGY TO IMPROVE THE PERFORMANCE OF MATERIALS

Richard W. Roberts
Director, National Bureau of Standards

Back when I was in high school, I can remember my English teacher making us memorize a poem. By now I've forgotten the title; I've even forgotten the author. But the first couple of lines of that poem still stick in my mind. And they are:

> "Back of the beating hammer, by which the steel is wrought
> Back of the workshop's clamor, the seeker will find the thought . . ."

Now that poem never won a Pulitzer Prize, it never made the author rich, but it did make an impression on me. Today we still have the clang and the clamor, we still have the beating hammer. But more than ever we need the thought. True, the seeker can find it if he looks long enough, looks hard enough. But the balance must shift. The poem refers to a time in which raw power, raw materials, raw labor, were able to transform this great land of ours. Today we live in a different age. The thought, the research, the innovation, the synthesis, all of these must go together in a much stronger way if we are to advance our way of life. And that's why we're here—to talk not so much about the clang and the clamor but to talk about the thought. To talk about new ways of advancing or even maintaining our life style without doing great damage to our environment, our economy, our succeeding generations.

Given that materials are fundamental for the well-being of the American people, given that we expect to continue economic growth, and to meet the requirements of an increasing population, we have no choice but to take a hard look at our materials usage. To maintain economic growth, in view of limited resources, we must develop intelligent plans that impact every phase of the materials cycle. We need to assure a reliable supply of raw materials. We need to develop innovative techniques for recapturing and reusing materials after their original function has been served.

These problems, of course, are not trivial. If they were, we wouldn't be here today. And they aren't new. The search for guidance officially began in 1930, when President Hoover established the first commission on materials policy. In the 44 years since that time, materials technology has undergone an explosion in areas like aerospace, electronics, nuclear technology and the plastics industry. These advances, if anything, have increased the urgency of the quest for firm materials policy.

In my opinion, there are two distinct but nonetheless overlapping aspects of our materials problems. One aspect is that of policy, the framework of principles and rules that is used in deciding a course of action. The other part of the materials complex—I prefer that word to problem or crisis—concerns the how of implementing that course of action. But, of course, the two are by no means separate; there is an interrelationship between policy and procedures that is as hard to unravel as the question of the chickens and the egg.

For the sake of convenience, let me divide my remarks roughly into two broad areas. First, I'll talk about the materials cycle—especially the area of use—and then I'll concentrate on policies affecting the cycle, and how they can be firmed up.

It's obvious that we will continue to use materials. If, however, we can build our materials so that they last longer, and perform better, then it is obvious that the cycle from raw material to scrap can be extended. By improving the performance of materials, by making them work better and last longer, we can indeed make a strong contribution to materials conservation, and a lasting contribution to assuring the resources of future generations.

To be fair, I must point out that some economists claim we have nothing to worry about, that if the price is right, we can always recover scarce materials from low grade ores, or we can develop new, substitute materials. But lacking this absolute faith, I feel that materials conservation especially through the mechanism of improved performance, is the immediate, and probably the long-term answer to many of our shortage problems.

In terms of fuels, which I'll touch on but briefly, there are tremendous savings to be made in our use patterns. Both the daily papers and the technical journals have been filled with articles on how to use our present fuels more effectively. The organization that I represent, a group of 3,600 people in some 30 major buildings in Gaithersburg, Md., Boulder and Fort Collins, Colorado, and Kekaha, Hawaii, has cut total energy consumption by about 20%, doing so without major discomfort to the staff or disruption of our technical programs. In a very real sense that is, indeed, improving the utilization or performance of a critical raw material.

But in a more complex sense, if we can improve the performance of other materials, we can also go a long ways towards achieving our goal of energy self-sufficiency. The implications for improved performance in this area are clear. If we can develop the right materials, we can assure higher efficiency, greater reliability, longer life and reduced cost for the projected processes for coal gasification and liquefaction and new energy conversion systems such as high temperature gas turbines, fuel cells, MHD, combined cycle power plants and nuclear reactors. But developing new or adapting existing materials is just one small part of the large framework needed to support the goal of energy independence. This goal, like everything great or small, has its price, and in this case, according to the National Academy of Engineering report, the private capital investments alone are expected to run $500 or $600 billion. The magnitude of the challenge and the problem of capital availability are strong incentives to do the job right the first time. For instance, when a single pressure vessel costs tens of millions of dollars, a few failures can spell economic ruin.

There are other imperatives calling for improved performance arising from many forces in our society. For instance, in recent years, we have seen increasing militance on the part of the American public in demanding upgraded performance and improved safety. We have institutionalized these demands somewhat through creation of a Federal independent regulatory commission, The Consumer Product Safety Commission and private sector groups such as the Consumer Federation of America. In addition, there is strong pressure to bring into being a Consumer Protection Agency. Precedent-setting court decisions involving product liability provide a strong incentive for manufacturers to improve the performance of their products. In the private sector, insurance agencies have been putting increasing pressure on their corporate clients to attend to the details of performance.

It should be clear by now that if we somehow increase the performance of materials, we will probably pay an initial economic penalty. Notice I said initial economic penalty. However, if judiciously undertaken, actions to improve performance will prove beneficial over the long term.

But if a product lasts longer, and requires less maintenance, then its life cycle cost is likely to be lower in the long run. This concept, however, is one that is not readily understood or is now accepted by the public, and educational efforts will be required. Equally important is the education of our designers, whose traditional approach has often been one of working towards low initial cost.

The designer, as well as the product line manager, must also concentrate on techniques of production. Not only need the best material be chosen for a particular application, but better fabrication techniques as well must be considered in the quest for better products.

And while improved performance would aid the materials conservation and utilization goal, it could also have the beneficial effect of allowing better products to capture a larger part of the world market.

Consider the current status of United States goods. Factors like the high cost of labor in the United States impede our ability to compete for certain markets. Couple that with the fact that much of the world is now catching up in many areas of technical sophistication, and we have to accept that we no longer enjoy our former competitive advantage or reputation. The last fact was brought home to me a few weeks ago by a comedian on T.V. He said, "Take Japanese technocracy and you get radios. Take German technocracy and you get cars. Take American technocracy and you get Japanese radios and German cars". The comment wasn't complimentary to any of the parties mentioned. And as is most humor, it was a perversion of a small element of truth. But it came off as funny, not because it said anything about technocracy, but maybe because it reflects trends in the marketplace that exasperate Americans. The place where the United States could and actually should be competing more effectively is in the area of high technology, high performance. Look at the success of our aircraft. Defense needs have been largely responsible for improving performance in this area, and those improvements have carried over, sometimes by mandate, into commercial practice. As a result, our aircraft are not only highly reliable, they are also more durable than others on the market and so require less maintenance. We are, therefore, virtually without a competitor. And the same is true of computers and other high technology items.

By now 1 hope it's clear that improved materials performance is imperative if we, and other nations, are to maintain or achieve a high standard of living. The question at hand is how do we achieve better performance? Take a look backwards for a moment, to a point 20 or 30 years ago. How did materials science advance from that time to the present? How did we produce new metal alloys, refrigerants, polymers, lubricants? By research and its application. That formula worked and worked well in the past, and will continue to work well today.

True, things are more complex today, but progress will continue to depend on materials research. To achieve improved performance, there are at least five technical options we can use either singly or in consort. These options are:

1. Development of new materials.
2. Development of new processing techniques.
3. Improvement in manufacturing and fabrication techniques.

4. Improvement in nondestructive evaluation techniques.
5. Improvement in design theories and concepts.

Now, to get from here to there, from current knowledge to improved materials, will take a full range of talents, from the brilliant fundamentalist to the pragmatic production specialist. There must be a climate that encourages innovation. Ample rewards must be given to those who ‘‘dare’ try a new approach to solving a problem. and alternative pathways must be available to those whose work has come to a nonproductive point.

Except in those cases of overriding national interest, such as defense, nuclear power, or space exploration, the bulk of materials performance improvement falls in the private arena. After all, the pressures of the marketplace, the force of law, the demands of the public, and the actions of their competitors all impel a firm to product acceptance, which we hope will mean product improvement.

And, of course, we all recognize the great and continuing materials contributions made by universities. Sound theoretical and applied work is generated across a broad spectrum, and better mechanisms are needed for coupling this new information to areas where it is needed. The value of both the Federation of Materials Societies, and the local chapters of the technical and professional societies must be fully recognized, for these organizations provide the grass roots forums where the academician and researcher interact with the engineer and technologist on an interorganizational basis to discuss their individual needs and ideas. Expanded company support for the continuing education programs sponsored by the technical and professional societies, and conducted by people who are leaders in their particular fields, would allow industry to capture broad experience and new ideas at minimum cost.

Previously I said that responsibility for improving performance rests largely with industry. But it is not a one-way street. There are opportunities for government, industry, universities, and technical societies to cooperate in a four-way effort. Such cooperation is, in fact, absolutely essential to success in certain areas. Let’s look at coal gasification and liquefaction technology for a moment.

At the present time, the Federal Government and the private sector are trying to create an economically viable synthetic fuels industry. Central to the creation of this industry is the development of materials which will be capable of withstanding the hostile environment of these processes. When developed, these improved materials will be used to build pressure vessels, and they must be acceptable to the American Society of Mechanical Engineers’ Boiler and Pressure Vessel Code. If they were not accepted, it would be difficult, if not impossible, to build plants using the new materials because the Boiler and Pressure Vessel Code have become part of the local building codes. In addition, insurance companies would not provide coverage for a facility which did not meet the minimum standards of the profession. Therefore, cooperation is needed at almost every step in the process.

Various Government laboratories are capable of making general contributions to improving performance, and the National Bureau of Standards is one. One of our strategies is to promote the exploitation of nondestructive evaluation techniques (NDE) and to concentrate on improving design theories and concepts. I choose NDE because it is essential to assuring improved performance and because it is measurement intensive. Design theories and concepts are chosen because their successful implementation depends heavily on our being able to characterize and understand the properties of materials.

If we look at the gas turbine, we find an excellent example of how NDE and design can go hand in hand to improve materials performance. In order to improve the efficiency of gas turbines, we must go to higher temperatures. But higher temperatures create a materials problem, as most metals will melt at the desired operating conditions.

Ceramic turbine blades can, indeed, withstand the higher temperatures, but until recently their fracture characteristics have eliminated them from serious consideration. Recent major material innovations, in the private sector, have led to the development of a class of fracture-resistant ceramics. Research pioneered at the National Bureau of Standards on crack propagation in glass and ceramics has shown that it is possible to predict the length of time to failure of brittle materials operating under stresses. The ability to determine when and under what circumstances the material will fail coupled with a full knowledge of the characteristics or properties of materials will make it possible to design around the difficult problems that remain.

We need stronger measurement support in many areas for improving the performance of materials. Until very recently, NDE has been mainly a qualitative tool, very useful for the detection of major flaws in materials. However, with the advent of a drive toward fracture safe design, NDE is moving to a higher level of precision.

Despite the advances that have been made, NDE is not yet a precision technique. Consider ultrasonic testing, one of the most popular NDE approaches. No standard is available against which to make meaningful calibrations; phase and frequency data that could greatly increase the information output are ignored; and automation to increase efficiency and reduce operator variability needs to be more widely used. Similar problems are common to other NDE techniques, and a great deal of fundamental work lies ahead if NDE is to become a truly useful, quantitative tool.

Looking toward the future, we can discover other areas of materials technology that government, industry, and academia will have to support more fully in order to meet the needs of improving performance. We will have to increase the study of materials in extreme environments, improve and develop new nondestructive evaluation techniques, further exploit predictive testing and concentrate on safeguarding materials through work in corrosion prevention of metals and in the abatement of the aging and deterioration of plastics, and so on.

I have directed the first part of my speech to the need for improving material performance, a need stimulated by a demand for increased efficiency, for product safety and an opportunity for materials conservation, and have reviewed the strategy for attaining it. Basically, we see that we face difficult technical problems, and, for the most part, achieving improved materials performance will take a cooperative action at the technical level involving industry, government, academia and the professional societies. But, above the technical concerns, we need a well-defined policy framework to guide the country in managing its material resources. It is to the broad subject of materials policy that I would now like to direct my remarks.

We might now ask the question, "Does the United States have a materials policy?" I believe that one of the clearest statements of materials policy is set out in the Mining and Mineral Policy Act of 1970. This Act implies that, for the most part, supply and demand will be left to the economic forces in the marketplace. Other policy elements were in existence before the passage of this Act. They are a collection of diffuse, uncorrelated, and often contradictory strategies which govern specific areas related to materials supply. They consist of executive orders, administrative rules, and statutory and common law. If one has the time and inclination and knows where to look, one can find them set out in multiple places in the United States Code, The most notable description of the policy elements are laid out in the following acts of Congress:

The Organic Act for the Geological Survey 1879, The Organic Act for the National Bureau of Standards 1901, The Organic Act for the Bureau of Mines 1910, Strategic and Critical Materials Stock Piling Act 1946, Defense Production Act 1950, Atomic Energy Act 1954, Internal Revenue Act 1954, Domestic Minerals Act 1953, Agriculture Trade Development Act 1954, Helium Act 1966, Mining and Mineral Policy Act 1970, Resource Recovery Act of 1970.

As you can see, the predominant impact areas of these policy elements are the development of resources and production capabilities. In other words, they cluster around the supply end of the materials spectrum. At the other end of the spectrum. the disposal end. we see a newly developing area of policy. With either end of the materials spectrum pretty well covered or at least accounted for, we now face the no man's land of materials utilization and performance where policy has not yet made significant inroads.

How is policy formulated and who are the policy makers? Policy is created through a variety of techniques. The three predominant methods are Congressional action in creating new laws, administrative rule making and Executive Order. The first two methods work on the principle of establishing a thesis and creating a public forum to elicit comments. The forum consists of public testimony before a Congressional committee or, in the case of administrative rule making, a hearing before an examiner. Once a policy has been established through the legislative procedures, administrative rule making or Executive Order, its validity can be tested in court where it is upheld or overturned, based on the interpretation of the court. An Executive Order is established without public hearing, but it is subject to the same test by the courts as the legislative and administrative approaches. In some cases, policy can be established by the courts through the interpretation of common law, the body of precedents that was created by previous court decisions.

In response to the question, "Who creates the policy?", I would say that theoretically the individual is capable of creating policy. The individual can establish a need by pointing out to his elected representatives that a certain course of action would be beneficial. However, since the individual is usually not sufficiently prepared to take on the problems of promoting a policy idea, such groups as trade associations, technical and professional societies, private industry, labor unions, and consumer groups can and should make their views known.

The obvious conclusion is that this country has a fair capability to formulate recommendations for a materials policy. What we lack is an authority in the government whose prime interest is in guiding the materials policy on a day-to-day basis.

If you look at how recommendations for materials policy have been handled over the past five to ten years, you will notice that advisory groups, such as the one here this week, are called together for a short time to review the current status of materials policy and to write a report. They then disband. In fact, in the last ten years, seven different groups have passed through the ritual of preparing reports and disbanding. Despite the great effort by these groups, until there is a well-defined organizational structure to take the recommendations of advisory groups such as this one and fight for them through the legislative process, I can guarantee that no unified materials policy will ever be established or implemented.

Some tentative progress indicates that we are maturing in our approach to managing materials. For example, the Interagency Council on Materials was intended as a forum for discussing materials problems at a high level in Government, but it has virtually become inoperative. However, a counterpart to ICM, the Committee on Materials, is being created as a subcommittee of the Federal Council for Science and Technology—the advisory group most directly linked to the Executive Branch of Government. The Congress has created the Office of Technology Assessment to "provide early indications of the probably beneficial and adverse impacts of the applications of technology and to develop other information which may assist the Congress". OTA's willingness to utilize the Federation of Materials Societies shows that the office is basing its work on a solid foundation of competent and wide-ranging technical expertise.

What we see taking shape is the organizational framework necessary to guide the development and implementation of a unified materials policy. We have to see that framework through to completion if we are to receive the support we need to carry policy and strategy through at the technical level.

So, in my presentation tonight, I have outlined the need and the strategy for improving the performance of materials. To make the construction complete, I have tried to sort out where we stand and where we need to go with materials policy. And now, briefly, I would like to bring the parts together again by reviewing the basics.

To realize the essential materials improvements, we have to adopt a strategy based on research and risk taking. We have to take our five technical options: materials development; processing; fabrication; design; and nondestructive evaluation, and exploit them.

These innovations will take money to develop, and more money will be necessary to see them through to the marketplace. Consumers, large-scale consumers like industry and Government and the individual consumer, must be willing to pay the price. The acceptance of this new philosophy, especially by the individual consumer, will come about only after a thorough education program to get the consumer to consider life cycle costing as a major factor of customer acceptance.

We have seen that this country has on numerous occasions asked eminent groups to review our materials problems and make recommendations. Over all, good advice has been generated, but we've been guilty of a major failing: We have not acted on that advice. The time to start correcting our error is now. If we continue to fail, we will have to accept that the situation will only go from bad to worse.

This is the third Henniker Conference. The previous participants have worked long and hard at identifying problem areas in the materials field. We have done so at this meeting as well. But the time has come for more than discussion, argument, agreement, and resolutions. The time has come for us, as individuals, as technical managers, as members of influential societies, as concerned citizens, to call for, to participate in, and to implement a national materials policy.

MATERIALS RESOURCES—R&D RESPONSE

Extracts of a paper by Julius J. Harwood,
Director, Physical Sciences
Scientific Research Staff, Ford Motor Company

The paper summarized the rising interest in national materials policy following the appearance of the report of the National Commission. It cited the COSMAT report, the earlier Henniker Conferences, and the emergence of the Federation of Materials Societies. However, the main driving force was pervasive shortages of materials, intensified by the shortage of petroleum. In response, said the author, many industries were undertaking their own analyses of the materials crisis. One such analysis had been performed at Ford Motor Company. The rest of the paper dealt with some of the findings of this analysis.

Issues examined included:

(a) 1. Economic and availability trends for major automotive production materials for the 1976-1980 period, and the general conditions which might be expected to affect the availability and supply of materials for the remainder of the 20th century.

2. Identification of critical problem areas in materials in future requirements.

3. Elements of a supply strategy to minimize future materials

TABLE 1. ROUGH WEIGHT OF MATERIALS IN 1974 FORD COMPOSITE VEHICLE.

Material	Pounds per Vehicle	% of total
steel	3,368	71.8
Ferrous Castings	761	16.2
Aluminum	65	
Copper	36	0.76
Nickel	2	0.04
Zinc	58	
Lead		1.2;
Glass	115::	
Plastics	120	2.4
Rubber	132	2.8
Total	4,689 lbs.	

availability risks and contingency plans to adapt to changing supply situations.

4. Influence of materials costs on future utilization patterns.

5. R&D needs for the development of new or substitute materials and the potential of enhancing materials availability through recycling and solid waste disposal of scrap materials.

6. Industrial facilities and capacity needs with respect to future requirements and demand/supply balance.

The study identified the pattern of use of materials in auto manufacture. Findings were summarized in Tables 1 and 2. As an afterthought, the speaker noted that the impact of catalytic converters in 1975 would be significant:

(b) Introduction of catalytic converters in 1975 will turn the automotive industry into a predominant consumer of platinum/palladium precious metals. 1975 catalytic converter volumes will require as much 409 type stainless steel as the steel industry produced in 1973 overall. Limitations in melting and fabricating facilities capacity in the industry and shortages in

TABLE 2. AUTOMOTIVE INDUSTRY MATERIALS CONSUMPTION (1972).

Material	Automotive as 92 of U.S. consumption
Plastics (1974)	5
Copper	8
Aluminum	9
Nickel	11
Steel and cast iron	20
Zinc	33
Rubber	66
Lead (battery and T. E. L.)	68
Platinum (est. 1975)	70

Source: a) Motor Vehicle Manufacturers Association of U.S.
b) Third Annual Report of the Secretary of the Interior (1974).
c) Supply Staff and Plastics Development Center.
d) Bureau of Mines Information Circular 8565 (1973).

ferrochrome supply may make 409 stainless a troublesome supply situation for the near future,

Next, the analysis addressed the question of materials resource availability as it related to the auto industry. It identified materials in which the United States is dependent on foreign sources (Table 3), discussed domestic sources of materials (Table 4), and assessed the rising needs of other countries (Table 5). It concluded:

(c) While the overall resource availability picture for the next decade is reasonably encouraging, competition among nations for the World's raw materials and energy will be more intense than during any time in the past. We anticipate therefore, that material shortages will continue to be prevalent and materials supply problems will be an ongoing way of life. All of this assuredly will mean higher materials costs.

Materials costs are an important consideration for the auto industry. Inflationary trends in materials "have pushed the materials fraction of our total costs to an all time high". The trend is expected to continue (Table 7). For this and other reasons the scenario of auto materials supply, as perceived by the auto industry, is as follows:

(d) During the remainder of this decade materials will be an irritating and periodically critical supply problem area. Materials shortages will be prevalent. Not only in some individual commodity areas will there be insufficient capacity to satisfy demand, but there will be unprecedented world wide intense competition for materials. Some projections for the steel industry indicate a 2-10 million ton shortfall between demand/supply by 1980. The United States share of available world resources will decrease. We anticipate as likely possibilities materials embargo pressures

TABLE 3. SOURCES OF U.S. MINERAL REQUIREMENTS (1972).

Mineral	U.S. requirements imported, %	Major foreign sources
Metals		
Chromium	100	USSR, South Africa, Rhodesia
Aluminum (bauxite and metal)	%	Jamaica, Surinam, Canada, Australia
Manganese	95	Brazil, Gabon, South Africa, Zaire
Tin	77	Malaysia, Thailand, Bolivia
Nickel	74	Canada, Norway
Zinc	52	Canada, Mexico, Peru
Tungsten	44	Canada, Bolivia, Peru, South Korea
Vanadium	32	South Africa, Chile, USSR
Iron	28	Canada, Venezuela, Japan European Economic Community (EEC)
Lead	26	Canada, Australia, Peru, Mexico
Copper	18	Canada, Peru, Chile, Zambia, Zaire
Polymers		
Rubber (natural)	100	Malaysia
Petrochemicals (plastics and synthetic rubber)	29	Central and South America, Canada, Middle East

Source: Final report of the National Commission on Materials Policy (1973).

TABLE 4. U.S. RESERVES AND RESOURCES OF *AUTOMOTIVE MINERALS**

	Reserves (at 1971 prices) as % of probable cumulative demand, 1971-2000	Resources as % of minimum anticipated cumulative demand, 197 I-2000
Sufficient supply through 1980		
Iron	67	200-1,000
Copper	87	70-200
Lead	50	70-2(K)
Zinc	48	200-1,000
Vanadium	24	200-1,000
Insufficient supply through 1980		
Aluminum	3	200-1,000
Nickel	5	70-200
Tung Len	17	30-70
Manganese	0	70-200
Chromium		Insignificant
Tin	0	Insignificant
others		
Petroleum	14	70-200
Coal	Adequate	1 000,+
Natural Gas	25	30-70
Platinum	6	30-70

*Reserves are mineral deposits which can be exploited profitable under present economic conditions. Resources are reasonable known deposits, but requiring greater investment and additional technological developments.
Source: Final Report of the National Commission on Materials Policy (1973).

*TABLE 5. WORLD RESERVES AND RESOURCES OF AUTOMOTIVE MINERALS**

	Reserves Years of supply (Base: 1971 consumption)	Resources Estimated additional years of supply (Base: 1971 consumption)
Minimal world supply problem		
Iron	110	Large
Aluminum	185	Large
Nickel		Large
Vanadium	370	Large
Increasing world supply/cost problem		
Chromium		Large
Manganese	60	Large
Copper	45	
Tungsten	42	NA
Lead	23	100+
Zinc	23	100
Tin	17	30
Others		
Platinum	119	
Petroleum	35	200+ (shale oil and coal)

*Reserves are Mineral deposits which can be exploited profitably under present economic conditions. Resources are reasonably known deposits, but requiring greater investment and additional technological developments.
Source: Second and Third Annual Reports of the Secretary of the Interior (1973, 1974).

TABLE 6. U.S. AND WORLD MATERIALS REQUIREMENTS,

Commodity	Year	World requirements	Us. *70* of world
Aluminum (1000 metric tons)	1950	1,584	52
	1970	9,855	35
	2000	46,743	33
Copper (1000 metric tons)	1950	3,009	43
	1970	7,191	26
	2000	19,693	22
Iron ore [million tons)	1950	116	46
	1970	413	19
	2000		13
Zinc 1000 metric tons)	1950	2076	44
	1970	4,913	22
	2000	13,448	21
Liquid fuel (million metric tons, coal equiv.)	1950		58
	1970	2,328	35
	2000	8,498	25

and threats, with perhaps no long term sustained impact, but certainly capable of causing local difficulties.

Accordingly, a four-part strategy is proposed:

(e) 1. Alert, as early as possible, the outside market to any major upward shift in specific materials usage. We clearly recognize that two to three year lead time or more may be required for materials producers to effect significant capacity expansion.

2. The extended lead time emphasizes the need for establishing early-on, continuous liaison and communication among product planning/engineering, manufacturing and supply activities concerning product assumptions and materials requirements to ensure availability of required materials to support our future vehicle programs.

3. Maintain periodic updates of availability, supply and economic projections to establish a monitoring and early warning system.

4. Explore feasibility of alternate materials to provide flexibility to compete in shifting materials supply markets.

The auto industry’s response to these challenges requires a strong R&D effort, directed toward (f) “materials substitution, recycling, solid waste disposal and materials processing to provide new sources of materials, reduce scrap generation and increase productive utilization

TABLE 7. MATERIALS PRICE INCREASES, SEPTEMBER 1973-SEPTEMBER 1974.

Material	Increase since October 1973, %
Steel	36
Aluminum (primary)	56
Aluminum (secondary)	76
Copper	43
Zinc	[illegible]
Magnesium	[illegible]

of available materials to offset tight supply and increasing costs of materials'

But materials shortages are only one aspect of concern for materials in the auto industry. Materials are a "key common feature" underlying efforts to deal with such other issues as:

(g) Materials Shortages
Energy Crisis
Exhaust Emission Control
Manufacturing Environmental Control
Safety, Damageability and Crashworthiness
Fuel Economy and Weight Reduction
Noise
Recycling and Solid Waste Disposal
Guaranteed Minimum Product Durability

Policies of R&D in materials for use in auto manufacture are extensively influenced by the diminishing availability of petroleum. On the subject of materials substitution, Dr. Harwood had this to say:

(h) The energy crunch has made weight reduction, in particular, a new way of life for the automotive industry. Lighter weight/higher strength materials, lighter designs and structures and new vehicle size and weight concepts are being intensively pursued. Starting with about 1971, increasing vehicle weight as a consequence of product improvements and the added requirements of safety, damageability and emission control systems became a problem of concern with reference to deteriorating fuel economy.

High strength-low alloy steels, aluminum alloys and plastics are the prime candidate materials being considered for weight-reduction opportunities. All three sometimes are in direct competition as substitutes for conventional low carbon steels so widely used in vehicle bodies and structures. Magnesium is also receiving more limited consideration and in the long term future the potential of high modulus/high strength composites may become practical.

A simplified analysis showing the thickness and weight reduction and cost savings possible through the use of HSLA steels is illustrated in Figure 1. This potential has led to detailed design studies which indicate that substitution of HSLA steels for some 300 lbs. of hot rolled low carbon steels can achieve some 50 to 75 pounds of weight saving.

Aluminum with a three-fold weight advantage over steel, obviously offers significant potential for weight reduction. Up to 75 pounds of aluminum are being used in current U.S. car models. The die-cast aluminum intake manifold for the 2.3 liter Pinto engine represents a 20-pound weight savings over cast iron at no cost penalty. In our Ford heavy truck W series, aluminum cabs weigh only 75% as much as steel cabs with a 460-pound weight saving,

As with HSLA steels, intensive development and application

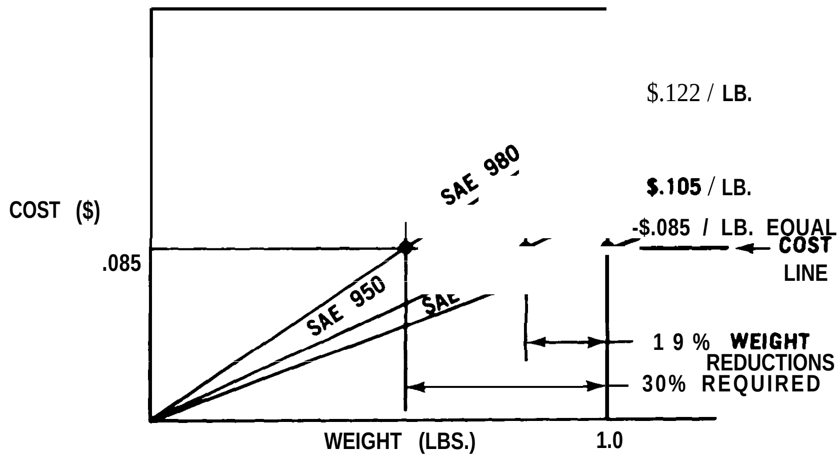

Figure 1.

evaluation programs are underway for the substitution of aluminum. These cover four main areas of application:

a. Wrought structural shapes—hoods, deck lids, tailgates, doors to replace sheet steel
b. Cast engine and powertrain components—engines, cylinder heads, transmission housings to replace cast iron
c. Radiators and heat exchangers to replace copper and brass
d. Wiring harnesses to replace copper,

HSLA steels are utilized extensively as bumper reinforcement bars in 1974 Ford vehicles. Brackets, frames, cross members, body structure components and the like are under prototype engineering evaluation for the weight saving potential of HSLA steels.

The combined utilization of HSLA steels and aluminum can achieve weight savings of hundreds of pounds in future car designs. There still are open technical issues to be completely resolved and there may be significant cost penalties involved with the use of aluminum sheet stampings, But the overall systems advantages from major integrated weight reduction might reduce the cost disadvantages to acceptable levels. Design studies and prototype programs to delineate and validate cost effective applications are being intensively pursued.

Among the new parameters in the future substitution of aluminum are the cost uncertainty and supply assurance. The aluminum industry is already performing at practically full capacity and increased automotive utilization of even 100 pounds per car will require major industrial expansion from the initial raw materials to foundry capacity and other fabricating facilities. In the new tight market place of materials any major shift in specific automotive materials usage or substitutions will require meshing with capacity plans of material producers.

This may be particularly true for plastics, which are so sensitive to the petrochemical feedstock supply situation. Petrochemical feedstocks currently consume about 5% of the supply of petroleum. By far the most dramatic growth of all of the automotive materials has been in plastics. The average 1973 car contained approximately 130 pounds of plastics (Table 8); conservative projections prior to the energy crisis indicated a 100%o increase in vehicle plastic usage by 1980. The stakes have become very high with new fabrication methods and new polymeric formulations opening up the vehicle market to exterior body use and structural applications. Sheet molding compound (SMC) practice is a notable example of this.

TABLE 8. PLASTICS USAGE PER CAR, INDUSTRY AVERAGE.

Model year	Pounds per car
1940	3
1945	5
1950	9
1955	15
1%0	20
1%5	32
1%8	50
1%9	65
1970	90
1971	110
1972	120
1973	130

But perhaps the real kick-off was the demonstrated experience that redesign in plastics would provide improved productivity and cost benefits, despite the often higher unit materials costs. Reduction in number of parts, assembly operations and labor all combined to produce a net cost savings. This is particularly true for front end assemblies. The 1974 Mustang II represents our first high volume car programmed with a one-piece plastic front end. Body panels, energy absorbing bumpers, deck lids, hoods, etc. are other application possibilities receiving much attention.

Continued development of plastic fabrication techniques, amenable to large volume production and higher forming rates, approaching metal stamping operations, will further accelerate exterior application developments.

It would appear that the competitive usage positions of steel, aluminum, plastics and other related materials, will depend markedly upon the relative price and capacity trends during the next few years. For some applications, relatively modest shift in prices can change the cost effectiveness and shift competitive aspects of substitution possibilities.

Before leaving the field of R&D opportunities in materials substitutions, let me mention briefly the exciting challenges offered in the development of an all ceramic gas turbine. At Ford Motor Company, a major program has been underway for several years to develop a high temperature (2500° F inlet gas temperature) small gas turbine. The key feature of this program is the focus on the design and application of ceramic materials and components of the hot end of the turbine. The compressor, combustion chamber, regenerator, stator, nose cone and turbine rotor are major ceramic components under development. Silicon nitride and silicon carbide are the most promising candidates for high temperature and high stress conditions associated with turbine stators and rotors.

One of the more intriguing features of these ceramic developments has been the use of polymeric materials and polymeric fabrication techniques to produce shapes which are later converted to ceramic forms by appropriate conversion techniques.

Obviously the successful development of this all-ceramic power plant and its introduction into commercial production would be a major step in altering the materials resource requirements of automotive power plants.

Attention is also being given to manufacturing processes as a means of reducing requirements for materials. "One R&D response . . . is to develop opportunities for reduction in amount of original starting materials, processing steps, machining operations, scrap and offal content, and overall manufacturing costs". Examples cited of R&D in this area involved powder metallurgy forgings, various pressure-

LASER WELDING

- WELDING SPEEDS COMPARABLE TO CONVENTIONAL TECHNIQUES
- SMALL HEAT AFFECTED ZONE
- LARGE PENETRATION / WIDTH RATIO
- NO CONTACT WITH WORK REQUIRED
  GAP SIZE OF .010 IN. CAN BE TOLERATED ON BURN-THROUGH WELDS
- EASY MANIPULATION OF LASER BEAM

Figure 2.

forming methods, and laser technology. (The advantages of laser welding are enumerated in Figure 2; other potential uses are laser cutting, machining, and heat-treatment.)

Efficiency of materials use cannot be permitted to stop with the shipment of automobiles from the factory, The automobile, Harwood observes, “represents the country’s greatest single source of recyclable materials’. Rate of recovery is high: between 80 and 90 percent of junked cars are now being recycled. As a major consumer of materials and as a major generator of “obsolescent’ ’scrap, the automobile industry occupies a dominant position in the total materials cycle. Accordingly, says Harwood:

(i) We may anticipate that our industry will be subjected to a variety of pressures with respect to both recovery and utilization of materials from the recycling of its products and to product design to enhance recyclability.

He goes on to discuss at some length the role of the industry in relation to secondary recovery of materials:

(j) A considerable amount of recycled materials is already used by the automotive industry, as shown in Figure 3. Unlike metals, little attention has been paid in the past to the recovery of scrap plastics and polymeric materials.

However, Figure 4 indicates the average weight of plastic materials which will be generated as waste from junked cars. Since more than half of the eight million cars scrapped each year in the U.S. are processed by about 100 auto shredders, these can be concentration sites for plastic scrap. A shredder is a giant hammer mill machine which shreds entire automobiles into fist size fragments. The process produces three fractions: (a) A magnetic or ferrous fraction which is transported to steel mills and foundries for reuse, (b) A non-magnetic fraction which

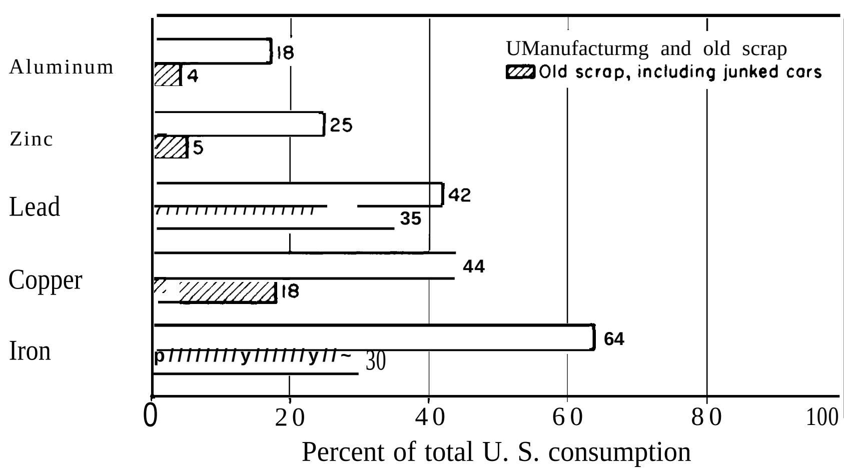

Figure 3. Nationwide recycled materials (1971).

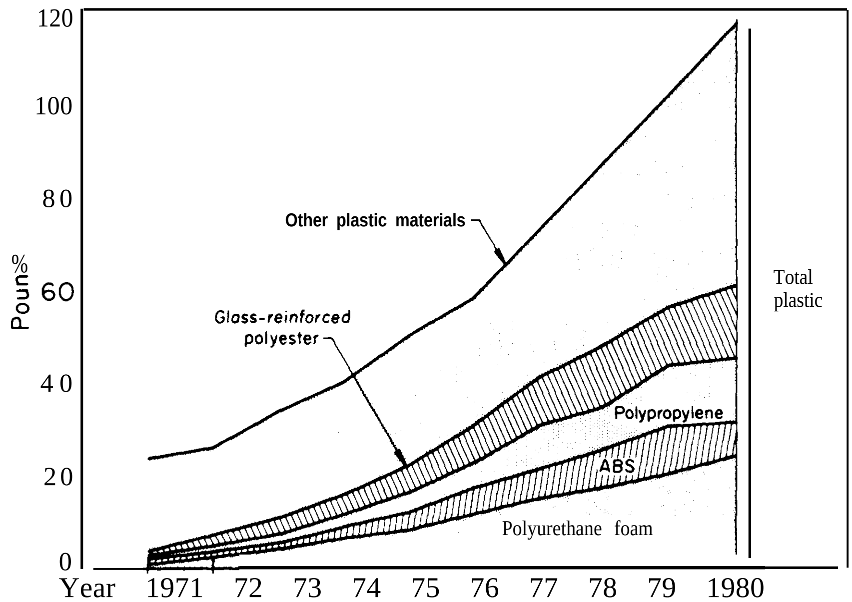

Figure 4. Average weight of plastic waste per junk car.

is shipped from many shredders to a few nonferrous metal . recovery plants, and (c) An air fraction consisting of low density materials, used in the past for landfill. (Figure 5.)

After about 1975, million-pound quantities of ABS, polypropylene and polyurethane foam will be generated from an auto shredder processing 100,000 units per year, Since polyurethane

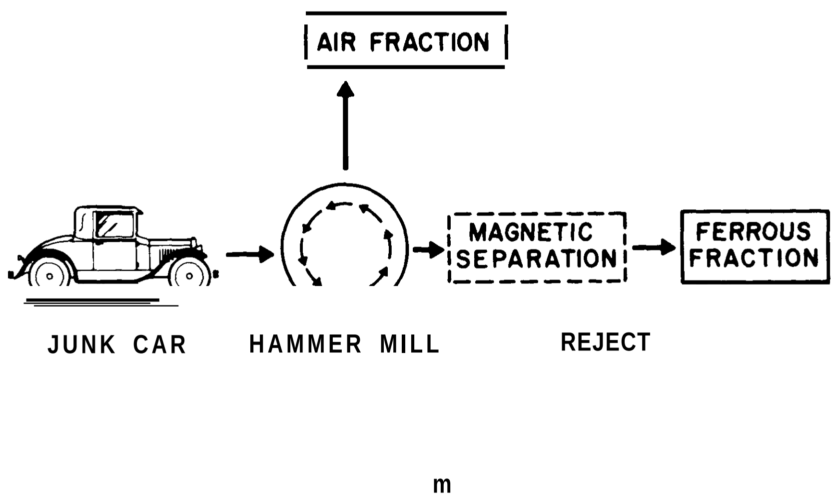

Figure 5.

foam is not a desirable landfill material, it can present a serious disposal problem by the late 1970's.

These considerations led to a cooperative Ford-Bureau of Mines program to explore methods for the recovery or disposal of these large quantities of plastic materials. Early results indicated that the recovery of plastics from shredded junk cars is technically feasible.

In our own laboratory, we have developed a relatively simple hydrolysis method which converts waste polyurethane foam into a liquid residue with a striking reduction in volume. The liquid itself, it is believed, can be used as a refoaming agent or for other chemical by-products. Engineering scale-up of this process is now underway. The process, of course, is adaptable to the reclamation of polyurethane waste generated during the manufacture of virgin foam products in our own plants.

The non-ferrous fraction from the shredders can be treated by dense media techniques for additional separation of materials. Table 9 presents the results of the density separation of plastics from the nonferrous fraction of a shredded 1972 Montego. Injection remolding of a fraction rich in unfilled ABS indicates that the remolded material has physical properties comparable with virgin reground ABS, (Figure 6). Work is underway to improve the impact properties of the remolded scrap through the use of blending agents. Recycling methods are also being explored for polypropylene, acrylics and PVC. One of the interesting questions to be answered is the possible degradation effects of long term aging, in service, on the properties of the reclaimed scrap.

The utilization of polymeric wastes as an energy (heat) source or for direct conversion into crude oil, is believed by many to be more attractive and feasible for the reclamation and reutilization of plastic scrap.

The automotive industry is one of the largest machine scrap generators in the world. Processes to convert such scrap to powder by crushing of the swarf have been recently developed and are potential new supply sources for iron powders. The iron powder

TABLE 9. ANALYSIS OF PRODUCTS FROM THE DENSITY SEPARATION OF THE NONMAGNETIC FRACTION (1972 MONTEGO TWO-DOOR G.T. HARDTOP SEDAN).

Product	1.075> d > 1.0 (lb)	1.16> d > 1.075 (lb)	1.20> d > 1.16 (- 1 inch)	1.20> d > 1.16 (+ 1 inch)
PMMA		0.04	2.57	
ABS (filled)		2.84		
ABS (unfilled)	15.3			
Polyvinyl butyral		0.87		
PVC-coated fabric		0.06	0.16	3.33
Rubber	0.4	3.63	0.66	1.66

INJECTION MOLDED ABS	RECLAIMED SHREDDER SCRAP	VIRGIN GRADE	VIRGIN REGROUND	VIRGIN REGROUND & BLENDED
TENSILE STRENGTH – (PSI)	6300	5500 MIN.	5500	5500
FLEXURAL YIELD STRENGTH – (Psi)	8500	9000	9000	
IZOD IMPACT STRENGTH (FT.-LB. / IN. OF NOTCH)	1.5	2.0-2.5	2,0	3.0

Figure 6.

obtained is useful for both conventional sintering practice and for the P/M forged preforms previously discussed, Cost estimates indicate economic feasibility for a facility to handle scrap produced by a typical, large automotive plant to produce powder of high commercial value from a low cost, contaminated, bulky scrap product. The General Motors Macro Mesh Process has been announced as being scheduled for production, to reclaim such machine scrap.

These are but a few examples of R&D approaches to recycling of scrap and wastes. We are convinced that this will be an increasingly important area to alleviate future materials shortages, offset rising prices and to optimize our utilization of resources.

By way of summary, Dr. Harwood observes that "Materials no longer can be treated as an independent variable in the materials/product transfer process. " Noting the interdependent relationship among materials, energy, and environment, he calls for "integration of materials, design, and processing into a materials systems approach". He continues:

(k) Realistic trade-off analyses and optimization of solutions to materials problems require the early integration and simultaneous satisfaction of all three factors in a materials systems way of life.

I would suggest that this not only has implications to industrial organizational and institutional arrangements for utilization and management of materials, but equally so for the education of materials graduates and perhaps more importantly for the entire engineering curricula as well. "

In summary, "the recent problems of materials availability, supply and costs have put a new focus on the role of materials in industrial operations and in national affairs. Perhaps, in a peacetime situation, it proved to be a needed catalyst for the proper recognition of the pervasive force of materials technology throughout our world. For the automotive industry in particular, future trends in materials supply and cost will certainly be an additional pressure and intensify other pressures. R&D programs in substitution, conservation, reclamation and management of materials can provide responsive opportunities to offset some of these pressures and problems. Materials processing and manufacturing research, recycling and a materials systems approach are key elements in the R&D response of the automotive industry in meeting materials resources challenges.