DOCUMENT RESUME

ED 133 440 CE 007 800

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TITLE Materials Technology; 200 Years and the Future.
PUB DATE 76
NOTE 21p.; Paper presented at the American Industrial Arts Association conference (Des Moines, Iowa, April 18-23, 1976)

EDRS PRICE MF-$0.83 HC-$1.67 Plus Postage.
DESCRIPTORS Education; Educational Responsibility; Energy; Historical Reviews; *Industrial Technology; Matter; *Production Techniques; Speeches; *Technological Advancement

ABSTRACT

Focus in this paper is on the importance of materials technology, the matter and energy crises, and the interrelatedness of our increasing need for materials, and the implications for education. Following a short history of what materials have done for man and what man has done with materials, particularly in the development of various metals and composites, from the earliest records to the space age, the author notes that it was mainly through the rise of education in this country that science and technology grew to have a profound effect on the national economy and that the rapid development of materials technology in the past 30 years is one of the primary reasons for such seeming impossibilities as jet passenger planes. He observes that this materials technology development is continuing and challenges educators to look carefully at processes now shaping our world and those expected in the near future, not just to keep abreast of technology but to teach it to those who must follow. (MF)

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Materials Technology: 200 Years and the Future

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Materials Technology is a very important part of the lives of all of us today. The energy crisis and the materials shortage are front runners on today's headlines. I would like to spend a short time at the beginning of this presentation to explain why these two things are virtually inseparable in their importance to the world. Technology has been defined as the link which connects science and invention with the wants and needs of man. It covers both materials and energy, both of which are necessary for the wants and needs of man today.

There are three major similarities between the energy and materials crises: (1) Materials are made of that substance

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called matter which is equated to energy in a solid state. Changing wood into smoke and heat is, on a broad level, not unlike changing heavy hydrogen or deuterium into helium and energy. (2) There are great quantities of materials on earth and throughout the universe. The same is true for energy. The problem, however, is that the most useful forms of both energy and materials are limited in their accessibility and utilization. (3) Materials and energies are both being consumed at a rate approximating a geometric proportion. The easily accessible, high quality materials and energies and their sources are already nearly gone. The need for materials and energy increases at a rate far greater than the frightening growth of the earth's population.

We, as educators, must address ourselves to the specific problems we face today, and there are many. Here are just a few:

Energy: The rate of consumption increases astronomically while the major sources are being consumed at a frightening rate.

Population: The dire predictions of the consequences of the geometric growth of the world's people, while not yet true, are beginning to affect the lives of all of us.

Environment: The waste energy and materials are being concentra-

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ted in even greater quantities throughout the world. We do not yet know what the long time effects will be. We do have some very good evidence that it may well be at least as serious a problem as many are predicting.

Food: The world food problem is now approaching the crisis point. We in the United States are suffering little of the real result of the problem. Our cost of food has not yet risen to any alarming heights. To some extent, the United States has profitted by being in a position to well surplus food stuffs. But this food shortage is much more real to the rest of the world and could easily become the most serious problem we have in the shortest length of time.

Materials: The least talked of problem and to a larger extent one that will affect the average person in a more subtle way is that of materials. In a prosperous country such as ours and with the abundance of material things we have, it is hard to realize that the resources from which these material things come is limited and that we are fast coming to that limit. We import large quantities of materials into the United States to produce energy and to supply the raw materials for the world's largest industrial producers.

There are certainly other problems that could be added to

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this list. Some here could probably add the problem of declining public support and emphasis by the local, state and national government regarding education (especially since the drastic reduction in educational demands and enrollments predicted by so many have certainly not come true). Why then, on the subject of materials technology, bring in these other areas of concern? Because there is no way they can be separated. The interrelatedness of each of the areas mentioned prevents one from isolating any problem in one area and trying to solve it apart from relating it to the whole of the combined areas. As I have already stated, materials and energy share the same resources. Every area is affected by every other area. The increased demand for energy depends upon the consumption of materials. The prime source of energy is fossil fuels. Fossil fuels are also the prime source of materials for the polymeric and petrochemical industries. So with the decrease in this resource of fuel comes a decline in the materials it provides. Educational levies are increasing rapidly in the greater part of the world, especially in the developing nations. Expectations and demands for a better life which depend upon greater production of energy and materials, increase with education. Mehrens, in his paper on "New Dimensions in Space Age Education" says that

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technological effort has become interwoven with activities of government, industry, labor and education.

The cycle increases in dependence and intensity. The solution may come through knowledge if there is to be a solution. We in education must do all that we can to contribute to the solution. We cannot in good conscience be contributors to the problem. In the same paper as mentioned before, Mehrens also says that consequently, within the profession of industrial arts we must not stand still; there is considerable delay in the appearance of new technical knowledge in textbooks in the industrial arts, and an even greater lag before it appears in the teacher-training process..

A short history of what materials have done for man and what man has done with materials will lead us to the present and future and to what role materials have now and what they will have later.

Materials have been an integral part of man's environment from the beginning. Man has depended on materials for food, clothing, and shelter. The earliest records that man leaves are only those of materials. Early man used implements of stone, such as projectile points, scrapers, grinders, and other small hand tools. He used clay to make simple forms of pottery such

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as bowls, ovens, and so forth. The common metallic materials used today were discovered later by man as civilizations grew. His access to material resources increased. Copper and bronze were being used over 5000 years ago. Around 1200 B.C., the discovery of iron had a great effect on th life of near eastern peoples. Implements used in war, such as swords and daggers were then so much stronger than they had been previously. Egypt, which had risen to become a great empire only a few hundred years earlier was doomed to fall partly because of its lack of the resources of iron. She was still living in the bronze age while the rest of the world around it had progressed to the iron age. The gap between Egypt and her neighbors became bigger adn bigger until they finally overran her. The lack of an important material had severly damaged her world position.

Although materials were very important to early man, and even though his limited and unscientific knowledge of his world led him to the use of materials, most of the time, it was by accident. The slow emperical processes which increased the usefulness of materials to man over these several thousands of years was little related to education and specifically to science. The theories and explanations of materials were left to the philosopher while the potters and metal workers by trial and

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error developed materials. There was no understanding of the precesses involved.

Perhaps it is a coincedence that the first real efforts to utilize education, science and materials began about two hundred years ago. This is the bicentennial year and the theme of this conference is suppossed to reflect this time span. Harrison Brown, professor of Geochemistry and professor of Science and Government at the California Institute of Technology says that the actual level of science and technology in the United States was very low two hundred years ago and that when the land-grant colleges were created, there was almost an explosion in scientific research which has had a rpofound effect on our entire economy. This effect is destined to last for a long time.

If there was one aspect of life today that our Founding Fathers could not have dreamed of, it must be the fruits of science and technology. Lawrence A. Cremin, President of Teacher's College, Columbia University has said that the most revolutionary aspect of this society is what it's done in education. It has been mainly through this rise in education in our country that we have the fruits of technology and science to enjoy.

Harold E. Mehrens is again quoted as saying that in the

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1700's, England became supreme with only three million people on a small island, because it had some natural resources and knew how to use them. Before the invention of the steam engine, man had not known how to harness power even if it were available to him. After the invention of the steam engine, factories sprang up and the Industrial Revolution had begun. The Industrial Revolution depended in large measure upon the development of new materials and better methods of processing these materials. The metallurgist can point with pride to the great progress made in the ferro magnetic materials technology between 1750 and 1850.

The continual and accelerated need for more and better materials during the 19th century brought the increased use of science and education to discover new materials, solve problems and to accumulate and disseminate this knowleedge to the consumer.

It was during this time that a Swedish metallurgist named Rinman observed that carbon was the chief difference between Damascus steel and cast iron. This observation was studied by the great chemist Bergman whose resulting theory of the role of carbon was essentially correct. Three French scientists restated the theory and provided the basis for the development of high grade steel without the mystery which had clouded the development and use for so many years.

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The 19th century provided the development of many new materials and processes. In the field of ferrous metals, the outstanding achievement was that of producing molten low carbon "steel." Bessemer developed the well known Bessemer converter and Siemens the open-hearth furnace. It is notable that the open-hearth process was developed on the basis of science and was one of the few developments up to that time that was not emperical in nature.

Another example is stated by T.L. Birrell, President of the Plastics Insitute: The plastics industry as we know it today has developed during the past twenty-five years but prior to this there was a long prelude beginning with the birth of celluloid in 1862.

The first three quarters of a century is largely a story of the individual effort and achievement. The struggle by dedicated individuals with real faith in their mission was the key to overcoming the many stuggles which provided the basis for much of the materials used in the plastics industry today. "A hard beginning maketh a good ending." A French minister of education said some 80 years ago that it is sometimes necessary to separate practice and theory because life is short but they should always be combined when possible because life is complex.

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The late 1800's and early 1900's produced a rather astounding development of materials, materials science, amd materials technology. Newer materials, higher quality and more exact control of the properties was paralleled if not surpassed by the application of these materials into a myriad of industrial processes. Perhaps no single greater application of these materials was to have the affect that the first manned flight by Orville and Wilbur Wright in 1902 did.

The materials and power for the first flight were available but the need was for a satisfactory design. The development of the airplane quickly brought about the need for better materials for air frames and power plants. The materials development kept pace with the available energy sources for aircraft up to the end of World War II. It was at this point that the materials development fell quickly behind. The jet engines made available a useable source of power far beyond the limitations of the materials available.

To cite an example, look at the first American built operational jet fighter, the Bell "Shooting Star" P-80. This was indeed a fine aircraft and with its $10,000 paint job could almost attain sonic speeds. The $100,000 engine, made of the best available materials for strength, heat and corrosion resis-

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tance were used. The engines were so designed that they could be removed and replaced in only thirty minutes. This was necessary because the engines lasted for only 10 hours of flight. It is interesting to note that few of the first engines actually lasted the full 10 hours of life expectancy. The engines needed new and better materials. The emperical experiments coupled with the rapidly developing scientific knowledge of the atomical structure of materials produced materials that within five years could operate hundreds of hours with little wear.

The "progressive march of science" which Thomas Jefferson talked of is very much evident today. In the seventy-five years since man's first flight, he has developed and utilized materials to make manned flights to the surface of the moon. In July of this year, the United States will soft land the first unmanned vehicle on the surface of Mars. Supersonic aircraft are common today and hypersonic aircraft are within a few years of being commonplace.

The period from 1900 to 1945 could be called many things, but one which stands out quite prominently is that is was a period of great chemical growth. Perhaps it could rightly be called the chemical age. But this growth in chemicals has not stopped. It

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has rather increased in tempo and led into growth in other areas.

Today physics is the scientific metallurgy. Physics replaced chemistry with the development of the X-Ray diffraction and the electron microscope. The emperical methods of studying materials has given way to scientific investigation. There is, however, a significant difference between the past and present methodology of the study and utilization of materials. The past was fractured into many diverse areas of materials and sciences.

Today, the materials scientists, materials engineers, and materials technologists are concerned with the total technology of materials.

Metals are alloyed not only with other metals, but with a wide variety of non-metals to produce materials with specific or special properties not possible without drawing upon the complete range of elements. Composite materials are finding new uses as the desired special qualities of one material are retained and incorporated into another material with some other specific quality or property.

While fiberglass is still the main composite material, other materials such as boron filaments, silicon carbide, and graphite are being tested.

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Refractory materials are being studied but not independently. The trend is to utilize the inherent properties and knowledge available of all materials to produce the exact material needed.

The integration of the concepts of physics, chemistry, metallurgy, and mechanics, which considers the properties of materials from atomistic, electronic, and structural relationships rather than from arbitrary groupings of chance is looked upon by many as one of the most important developments in the history of materials.

This development has spawned the present trend toward such courses as Materials Engineering, Materials Science, Materials Technology, and Materials and Processes which are prevalent in today's educational institutions both at the secondary and higher education levels.

Education is the necessary part of the success of building of national economies and of solving man's problems. Victor Wegotsky states in his introduction to "Materials in Space Technology" that one of the biggest developments has been the emergence of the materials system and the welding together of the linkage among the materials scientists, the designers and the fabricators. This recent development in education has pro-

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duced materials with amazing properties and processes to meet the needs of the technological world.we live in.

It is with this background that we now look towards the future and try to discern some of the possible developments.

A. B. Wilder as quoted in the preface to "A Hundred Years of Metallurgy says:

> We study the past
> Because it is a guide to the present
> and a promise for the future.
> The struggle for a better world is strengthened
> by the hopes, ambitions, and deeds
> of those who were before us.
> As we look backwards
> our attention is directed forward.

One thing for sure. Materials technology will not remain static. If there is one thing we can learn from the past, it is that predictions are more often in error not because they are made in too short a time reference, but because they prescribe time and knowledge developments at a pace far too slow.

Let me give the following example: In 1946 at the conclusion of World War II, a national conference was called by those involved in the aircraft and flight industry. Government, civilian, military, and industry were all represented. Their published conclusions contained these predictions in paraphrase: Jet aircraft will be used as fighter aircraft and possibly for some types of bombers; military transports are a distant possibility

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but not a likely development; the use of civilian jet passenger planes are not considered a possibility for the forseeable future. Thirty years have passed and now we have the C-5A, 747, and the Concord. One of the primary reasons for these seemingly impossibilities was the rapid development of materials technology.

What will the materials of tomorrow be? Steel, in the past has already been improved in such ways as the addition of chromium so that our kitchen knives are now rustproof and stainless. As one of the standards of materials technology, it has already been developed with a tensile strength of 500,000 P.S.I. Steel of tomorrow will certainly reach one million P.S.I. (Recent developments have been published which indicate this prediction may have already been achieved in laboratory conditions.) Steel of tomorrow will almost certainly be manufactured in space. Foamed steel, steel with uniformly dispersed alloying elements, steel with uniform grain structure, and steel with little or no atomic dislocations are but a few of the many possibilities.

Aluminum, first formed into a metallic state within the past two hundred years, and the workhorse of the past and present space age will continue to be developed. New alloys at

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one time considered outside the realm of possibility will be developed to extend the use of earth's most plentiful metallic substance.

Copper and copper alloys will be used along with many of the well known materials of the past such as brass, bronze, and nickel alloys. The new clad materials will be greatly expanded to provide many structural applications with electrical, corrosive, and physical properties.

New materials not common to industry will become increasingly used in industry. Beryllium and titanium, developed within the past thirty years will find much more common usage.

Refractory materials, especially those metallic materials such as molybdenum and tungsten and the recently isolated elements of columbium and tandalum will continue to be developed to meet the need for higher and higher thermal and corrosive environments.

Glass, a very common material will become far more useful as such alloys or compounds as ultralow-expansion titanium silicates and cerametals are developed. Structural glass and silicates will almost have to be developed to replace organic materials now being used.

Manufacturing in space, already begun on the sky lab

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missions, will be increased greatly by the early 1980's. The space shuttle will make possible the ferrying into space and bring back much larger quantities of materials and equipment needed for the many scientific investigations needed to develop technology.

The implications and expectations of "zero" gravity hard vacuum processing of materials are trully mind-boggling.

Levitation melting, the process of suspending a material in a magnetic field and melting and resolidifying the material is possible in only minute quantities here on earth. In space, large quantities could be processed in this manner. The added attraction of "zero" gravity provides almost perfect spheres upon resolidification not possible here on earth. A drop of water contracts from an irregular shape into a perfect sphere with a surface velocity of 150 mph. In the case of iron, the velocity is near that of sound. The use of molecular forces for processing materials in such a manner could produce accuracy within angstrom units. (one hundredth millionth of a centimeter).

Soviet scientists reported in 1973 the production of metallic hydrogen. Such a material if stabilized could revolutionize the transmission of electrical energy since it is theorized that it would be super conducting. Fabrication of super light struc-

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tures would be possible also.

The use of environmental and energy fields to produce materials not even dreamed of is very likely within the next twenty-five years. Magnetohydrodynamics has already produced temperatures of 100,000,000° F. Pressures 10,000,000 times greater than our atmosphere are expected.

The ability to form materials at the atomic and sub atomic levels is well within the realm of possibility. Such materials could well revolutionize the present industrial and technical world at least as much or more than iron did the ancient world of the bronze age.

And what of tomorrow's education? Will we still be using the same materials and methods we use today?

Perhaps we, as educators, should look carefully at the developments now shaping our world and the expected developments of the near future as well.

The challenge we face is not just to keep abreast of technology, but the infinitely harder task of teaching this technology to those who must follow.

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