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NEW MATERIALS FOR NATIONAL STRENGTH

Mr. Charles W Morrill

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Reviewed by: Col Ingmire Date. 7 Feb 63

INDUSTRIAL COLLEGE OF THE ARMED FORCES

WASHINGTON, D. C.

1962 - 1963

New Materials for National Strength

20 November 1962

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INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington 25, D. C.

NEW MATERIALS FOR NATIONAL STRENGTH

2 November 1962

COLONEL WIKEN: This morning, gentlemen, we wind up the series of lectures on resources. We have as our anchor man, the Chief of the Minerals Branch, Bureau of Mines, Department of Interior, Mr. Charles W. Merrill. This is Mr. Merrill's second appearance at the Industrial College. His subject today is, "New Materials for National Strength."

Mr. Merrill, it is indeed a pleasure to welcome you back to the Industrial College and to present the Class of '63. Gentlemen, Mr. Merrill.

MR. MERRILL: Thank you, Colonel Wiken. Perhaps I should be back a little further, back in about 1930 I had a tour of duty in the Office of the Assistant Secretary of War, which was the predecessor of this college as I understand it. I wrote a report on organizing the civilian side of mineral resources for war and proposed that it be done on a commodity basis. That's the way it was done in the WPB, but I don't think that I had any influence on it.

As a mining engineer I find it easiest to attack my assigned subject, "New Materials for National Strength," from the engineering standpoint. Fortunately, the subject lends itself to this approach. A few words about engineering and its history should help to clarify the line of thought I shall try to develop. Engineering has been defined as the art and science by which the properties of matter, the resources of energy and nature, are making slow demand in structures and manufactured products. Many years ago engineering was divided into only two branches - civil and

military. Leonardo Da Vinci practiced both as evidenced by his planning a canal the Mediterranean across Southern France to the Bay of Biscay. And his design of military machines for the rulers of states in Northern Italy.

As time went on, the civil branch of engineering proliferated into many specializations. My branch - mining engineering - is one of these. The fact that the many-faceted engineering profession we now know originated in a two-sided civilian-military specialty, is important to recognize. It supports my thesis that the engineering of new materials can help insure national strength. This is true whether the engineer's efforts are directed to the civilian side, toward enlarging and stabilizing the economy, or on the military side in providing a strong and reliable defense. Moreover, we must always remember that this is a two-sided coin; a strong economy properly defended, and the obverse, a strong defense backed by a productive industrial economy. This vital interdependence is, as you gentlemen know, given positive recognition in the motto of this college - "Industry and Defense are Inseparable."

The maintenance of such a balance in a war of rapidly advancing science requires that new materials must be sought out, tested and adapted to the best and fullest possible use in both industrial and military applications. Anything less can only lead to national decline in the fiercely competitive world in which we find ourselves. How do we come by these new materials? As we learned early in the study of chemistry and physics, there are only a hundred or so elements. And, except for a few evanescent radioactive products of nuclear fission, we can't expect to increase this number. Thus, the basic building blocks from which we can make new materials are limited. Nevertheless, by combining these materials to form compounds, alloys

and mixtures, we can obtain a range of materials that is almost unlimited.

Moreover, a particular substance cannot be defined as to its properties or usefulness simply by chemical analysis. Special preparation like the heat treatment of metal or the aging of whisky may bring out unsuspected and highly desirable properties. And so, by combining basic substances and by treating them in various ways we can expect to have an enormous number of possible materials, each with a different combination of properties.

Although my subject is new materials, we cannot dismiss the old materials for consideration. They may have properties as yet undetected, or unmeasured, or they may have useful properties that can be accentuated by treatments that have never been knowingly applied. But whether our new materials are derived from substances hitherto unknown, or from newly-discovered properties of familiar substances, is always essential. Yet, we find ways to make them available in sufficient quantity and at a low enough price.

Man's discovery of the materials around him has been a slow process. The archeologists sketch a pre-history in which primitive man progressed from wooden clubs and natural stone missiles to a stone age with its stone-headed hammers, battle-axes spears, and arrows. Next came the pre-historic metals; copper, lead, tin, gold, silver and iron. Most, if not all of this progress,was by fortuitous discovery. It was much later that the scientific approach began to dominate progress in material utilization. Even today, some of our discoveries in utilization are accidental and not the result of scientific research. Nevertheless, one of the characteristics of the 20th Century has been the enormous application of research to define material needs,

to measure materials properties, and to bring the two together, in identifying new materials to meet our many and ever-expanding requirements. In fact, the accumulation of scientific knowledge in the materials field has caused what might be called an invention explosion.

There are several ways in which new materials may be recognized, and then made available for use. One was is through isolation. For example, the existence of aluminum as a metal was unknown until reduction of some of the aluminum salts 150 years ago revealed this light metal to man for the first time. Only a century ago one of Napoleon the III'd's proudest possessions was a table service made of this light metal. After aluminum had been isolated its properties had to be defined before new uses could be sought. Then, methods had to be deveoped for working the new metal, and most important, for reducing it at a cost that would make it available for use on a large scale. It took over 50 years to reach a stage of assured quantity and low price that attracted major users. As a matter of fact, the development of demand through new uses proved more troublesome to the Aluminum Company of America in its early years, than did the problem of supply.

On the supply side, however, it was necessary to search the whole world for the ore - bauxite - and to find low-cost power for reducing the bauxite by a few salt electrolyses. The upward trend of use of aluminum still is proceeding at a rate much faster than the average for all metals.

Another way in which a new material becomes available is through synthesis. By synthesis we have obtained, largely from mineral raw materials, such products as synthetic rubber which has taken more than 1/2 the market from natural vegetable

rubber in the last 25 years. The field of synthesis, including the production of new alloys, as well as chemical compounds, and mixtures, already has given us such varied items as nylon, monel metal, chrome magnesite basic refractory bricks, and many other materials. The discovery of an unsuspected physical or chemical property in an old material is still another way by which we can obtain what is, for all practical purposes, a new material. For example, the finding that pre-historic metals silver would form light-sensitive halides became the basis for the vast photographic industry including motion pictures and much of television.

In other instances, the mere accentuation of materials properties suited them for new applications, as the heat treatment processes for steels have greatly increased their usefulness. Digging a little deeper into the discovery of new materials we find instances where the perception of a new phenomenon makes us take another look at an old material. For example, the concept of current electricity is only some 400 years old. The phenomenon of static electricity as exhibited by lightning or by static charges built up on objects was experienced - though not scientifically explained - by pre-historic man. But current electricity as revealed through the researches of Galvonie, Ampere, Farraday, and many others, call for a review of old materials to evaluate such properties as electric conductivity.

I will refer later to the profound effect the property of high conductivity has had on the copper-mining industry. Thus, the electrical age brought copper recognition as a new material to be used in a field quite distinct from those of its early applications. Another way in which we can discover new materials or new uses for old ones, is by more precise measurement of properties. To a considerable extent the

development of the transistor depended on measuring the purities or impurities in terms of one part per million, or even one part per billion. This post-war II development consumes germanium and silicon of hyper purity. In this use they are new materials though both have long been known to science and idustry.

Finally, and in some cases, the most important step in the development of a new material, is its introduction into use. Even after a new material and its application have been brought together in the mind of the research worker or in his laboratory testing, there remains the problem of commercial introduction. Architects and engineers must be made aware of the possibilities of the new material and must be convinced of its superiority compared with that of old proven materials which are to be replaced. Where an entirely new product is to result, the problem of market development and other such factors must be faced. Moreover, the forward-looking designer may find almost insurmountable resistance among production engineers, and even among workmen. Production managers may say that any trouble occurring from a material change-over will be blamed on the new material, which can prove a most convenient excuse for failure due to other causes, like poor workmanship.

At any rate, it must be recognized that the acceptance of a new material usually lies only at the end of a long and tortuous road. It has been alleged that the military mind is no more flexible toward new ideas, though the developments of recent years seem to belie this. Along this same line there is also the problem of assuring top management of an adequate, dependable and low-cost supply of the new material through the discovery and development of new ore bodies, the financing and building of substantial processing plants, or other prerequisites to the establishment of a

flow from raw materials source to consuming plant. In this connection the broadened and more reliable supply base may grow out of engineering advances like the development of a new mining or metallurgical method, that from it, the profitable exploitation of abundant but formerly economically sub-marginal ores.

In other instances latent ores are brought into production by government actions like subsidies, special tax treatment, price guarantees, or other such preferential or subsidy treatment. In many instances growth is very slow at first because neither suppliers nor consumers are willing to be the first to make a big-scale commitment.

The remainder of my talk will be devoted to case histories of some selected new materials that illustrate the points that I have made so far. Zirconium and hafnium, metals made available to industry by isolation by metallurgists. Claproth discovered zirconium in 1789 and Basilius prepared the metal in 1824. Neither man apparently had any idea that another element was present in the metal he prepared, and it was not until 1922 that Coster and Von Evesy, making use of x-ray techniques, a nnounced the discovery of a new element which they called halfnium. Now, it was evident that the metal prepared by Basilius and subsequent investigators was by no means pure zirconium, but zirconium alloyed with about 2% hafnium. Still, for some purposes, this alloy was perfectly satisfactory. Minor quantities of it were used in powder form as getters, in vacuum tubes, as a constituent of ignition trains in photographic flash bulbs, and as a source of intense white light in pyrotechnics.

The discovery of hafnium in 1922 inspired a number of investigations in developing methods for separating hafnium and zirconium. Beginning in 1925 the results of

these investigations were published from time to time, and by 1939 several processes, uniformly laborious, were available. These were of some significance to scientists, but for reasons already stated, of scant commercial interest. Crystal bar zirconium, still containing about 2% hafnium, were sold in 1943, for $630 per pound. And in 1945, at $315 per pound. These prices seemed to indicated the possibility that improved technology and larger-scale production might broaden the use of zirconium for its admittedly desirable properties, by increasing the availability and lowering its price.

Accordingly, the Bureau of Mines in January 1945 began work toward this end. The development process was guided by William J. Kroll. Some years earlier Dr. Kroll had developed a process of producing titanium by chloride metallurgy, and foresaw the successful application of the process to zirconium. Because of the resistance of zirconium to many corrosive environments at temperatures up to 500 degrees centigrade, the United States Air Force and the Atomic Energy Commission each became interested in the metal during 1927. However, the Air Force ultimately required alloys resistant to corrosion at temperatures far higher than 500 degrees, hence no applications were developed.

The Atomic Energy Commission needed a material resistant to corrosion at moderate temperatures, but it required also that the material be transparent to fast neutrons. Early data showed zirconium to have a nuclear absorption cross-section of 2 1/2 barns. But this figure was not considered absolutely reliable. Further measurements made on the purest zirconium available showed the maximum value to be 4/10 barns. And incidentally, they pointed to the need for removing hafnium

from zirconium to realize the latter's real value as a reactor construction material.

In 1950 a method had been developed to affect the separation, economically, and the production of reactive grade - that is, hafnium III zirconium - was on its way to adoption by private industry. This happened four years later - in 1954 - a record production of 1,697 tons was achieved in 1961 when the price of the metal was reduced to $6.25 a pound. On the other side of this coin was the consequent availability of relatively pure hafnium. Unlike zirconium this was found to have a nuclear absorption cross-section of 105 barns. Once this was determined, the potential value of hafnium as an atomic control rod material was immediately recognized. It was compared with a silver cadmium alloy which had been the favored material up to this time, and was found to be superior.

Hafnium production has attained an importance equal to that of zirconium and was sponsored by the Navy Burea of Ships which adopted both hafnium and zirconium for use in reactors installed in the vessels of the nuclear fleet. Hafnium and zirconium remain outstanding examples of metals that had relatively little use and that were without outstanding while in the alloy formed by joint reduction of the mineral zircon as it occurs in nature. However, when made available by careful metallurgical isolation they are both valuable to industry.

Industrial diamonds; a commodity made available in unlimited quantity by synthesis from carbonaceous material. The United States depends to a considerable degree on industrial minerals produced by synthesis. Among these are artificial corundum, silicon carbide, cryolite, quartz crystal, and molite. A recent and important addition to this list is industrial diamonds.

In February 1955 the General Electric Research Laboratory at Schenectady, New York, announced that diamonds had been produced by subjecting carbonaceous material to ultra-high pressures and high temperatures. This was the first fully-confirmed report of the transformation of ordinary carbon into diamonds. In February 1957 a commercial production plant was in operation at the metallurgical products department at General Electric in Detroit, with an annual capacity of several million carats of diamonds - 40-mesh and smaller - suitable for many important industrial applications.

Since then, production processes have been improved and today several types of manufactured diamonds equal to or better than natural crushing bort are available for most applications requiring material 20-mesh and smaller. The process requires pressures of about a million pounds per square inch, and temperatures of about 3,000 degrees fahrenheit. Metal catalysts are used - usually nickel - but sometimes iron, chromium, manganese and others.

In 1961 General Electric announced the Research Laboratory at Schenectady had produced good-quality industrial stones 1/10 of a carat in size; and inferior stones as large as one carat also were made. The present timetable of the manufacturing plant at Detroit calls for commercial production of industrial stones suitable for cutting tools and drill bits, within the next few years.

Soon after the first announcement by General Electric in 1955, DeVere's Consolidated Mines Limited began research on diamond synthesis. This work was successful, and in 1961 a production plant was completed in the Republic of South Africa, containing 75, 500-ton automatic presses. That plant reportedly has a capacity

large enough to supply the world's needs of diamonds for resinoid, bonded grinding wheels.

In September 1962 General Electric announced laboratory-scale production of diamonds utilizing ultra-high pressure and high temperature without a catalyst. The pressure achieved was about 3 million pounds per square inch. And the temperature was about 9,000 degrees fahrenheit; in both cases about three times the requirements when using nickel catalysts. At the other extreme, the Tokyo Shibara Electric Company Limited, recently announced that it has developed a process for synthesizing diamonds at 120,000 pounds per square inch and 1,400 degrees fahrenheit. This diamond is about 1/10 millimeter in diameter. According to the company the process could result in much lower production costs, and consequently, a lower price to consumers.

Tungsten; a metal that became a new material when a natural phenomenon was recognized and put to use, employing one of tungsten's superior properties. Thomas A. Edison, while experimenting with the electric light bulb in the 1870s noted that a flow of electricity occurred in a vacuum between an incandescant source and an electrically-charged pole. Edison reported this hitherto unobserved phenomenon now known as "The Edison Effect," but did not put it to practical use.

In about 1910 Lee DeForest, taking advantage of the Edison Effect, inserted a third element into the bulb which resulted in the modern triode tube, the indispensable basis for radio and television until the more recent advent of the transistor. Tungsten, because of its ability to operate at a high temperature and to withstand bombardment by high-energy particles without impairment of its emissive qualities,

has proved to be an excellent material for the radio tube cathodes.

Copper and sulphur; materials made available in abundance and at low cost by major advances in methods for their extraction from the earth. First let us take copper and trace its history from about 1900 to date, as a material made abundant through advances in mining technology. Copper has been produced at a cost and in quantities that made possible the 20th Century development of electric power generation and distribution, and that structured the communications industry as we know it today. This was accomplished largely as the result of two major breakthroughs in the art of mining. Mining must always be looked at by the engineer as a matter of economics. He must always consider the kinds and amounts of energy that must be expended to separate a mineral or mineral constituent from its natural environment in the crust of the earth.

Reductions in mining costs may be achieved by applying cheaper forms of energy or by reducing the amount of energy that must be supplied. Before the turn of the century most copper came from relatively small high-grade deposits, using methods that required much hand-labor. That is, large outlays of expensive human energy per unit of copper produced. Furthermore, the small size and relative scarcity of such deposits is such that in the aggregate it is doubtful that they could meet today's demands even if sufficient human energy were available. The large low-grade deposits from which almost all United States copper is now produced, became economic only through the development of two mining methods that were radical departures from earlier technology.

The first of these - blockading - reduced the expenditure of energy required, in-

cluding human energy, by utilizing the potential energy already available in the ground, to break and transport the ore to a loading point. In this method the ore is undercut sufficiently to cause it to cave and move by gravity toward the previously prepared loading points.

The second method - open-pit mining - makes possible even greater savings because where ore deposits are so situated as to make its use feasible; in open-pit mining the economy achieved by using increasingly larger and more efficient machines, which permit the application of cheap energy.

Obviously, either of these mining systems requires large capital expenditures for plant, equipment, and preliminary development work. They are feasible, therefore, only where the total copper content of the deposit is extremely high. However, the value per ton of the ore may be low. Of course, both systems have been improved tremendously since their introduction, until today it is possible to produce copper economically from ores containing as little as 14 pounds of metal per ton.

In the non-metallic field sulphur offers an example in which a new extraction method affected availability even more spectacularly than copper. The relative industrial productivity of a nation can be measured by the quantity of sulphur used, largely in the form of sulphuric acid. The world could not have reached its present industrial heights if it had depended on sicilian sulphur or that recovered from alkali wastes or sulphide or sulphate minerals. The flash process of mining deep sulphur domes with super-heated water introduced about the turn of the century provided the means for producing low-cost sulphur. Development of this process not only lowered production costs, but also made it possible to transport sulphur

more economically.

The material produced could be handled readily, stored, shipped, and converted to acid near the point of consumption. I made a study of the price of seven selected materials including copper and sulphur, in terms of constant dollars, and average industrial hourly wages. It is interesting to note that the average industrial worker could buy nine pounds of copper with an hour's pay in 1961, whereas, the same wage would purchase only 1 1/4 pounds in 1890, a 7-fold increase in 72 years despite the depletion of resources during the period.

The record for sulphur, which begins in 1904, shows an increase in the worker's purchasing power from 25 pounds in 1904 to 244 pounds in 1961, an increase of over 9-fold in 58 years.

Columbium; a metal made available in quantity by a government-guaranteed floor price. Discovered by Hatchett in 1801 and first prepared in the pure state by Von Volten in 1905. Columbium, nevertheless, was of little industrial interest until recently. The essential reasons for this lack of interest were the absence of a broad resource base. Engineers were understandably reluctant to include in their design of equipment, any component requiring a metal for which there is neither adequate nor dependable supply, nor its corrolary assured uniform quality. Industry for some years has been aware of the value of columbium as a steel additive, but the rapid development of modern aircraft resulted in the material's reappraisal.

As early as 1946 columbium began to be designed into jet engines as a material capable of withstanding corrosion at high temperatures. When it also became apparent that columbium had nuclear absorption cross-section of only 1 1/10 barns,

making it of interest as a construction material for nuclear reactors, the foundation for increased demand for the metal, and consequently of its ores, was well-laid. The war in Korea brought about a rapid increase in requirements of columbium for use in jet engines. Demand, in fact, was so far in excess of known quantities of known supplies in even marginal and sub-marginal ores, that United States' geologists raised doubts as to whether the world's resource base could meet the proposed programs. Steadily-increasing ore prices evidenced considerable pressure on known raw materials sources.

Accordingly, on May 29th, 1952, the Defense Materials Procurement Agency announced a program of purchase and stockpile ores of columbium and tantalum at a government-guaranteed price of $1.70 per pound of contained columbium oxide, plus basis 50%, plus or minus 2¢ per pound for each percentage point above or below 50%. In addition a 100% bonus was given each producer. This program continued in force until June 2, 1955, when General Services Administration announced the quota had been filled. Very little of the columbium ore purchased had been offered by domestic producers. However, late in 1956 the Congress authorized the purchase of an additional quantity of domestic concentrates at prices identical to those of the previous world-wide program.

In addition, the government contracted with a producer in Idaho, for about a million pounds of mixed columbium and tantalum oxide. Delivery was completed in 1959. As a result - direct or indirect - of these support programs, the resource base was greatly expanded. Tin mines in Nigeria, the Republic of the Congo, and Malaya, developed ore bodies, installed beneficiation facilities, recognizing

columbite as a valuable co-product, and became reliable sources of the mineral. In addition, the intensified exploration for columbium deposits led to the discovery of numerous large bodies containing the columbium mineral parachlore. This mineral is now competing with columbite as a raw material for ferrocolumbium production, and represents a large part of the Free World resources. It is now conservatively estimated at 7 1/2 million tons of contained columbium.

Titanium; a metal made available to industry by a new metallurgical extraction process and by major metallurgical advances in refining and working. In the 1930s the late R. S. Dean, then Chief Metallurgist of the Bureau of Mines, had a rare inspiration. He compared the occurrence of elements in the earth's lithosphere and hydrosphere with their quantitative industrial use. And observed that some elements of great abundance in nature were almost unused by man. One of these was titanium. It was the 9th most abundant element in the earth's crust, and of the structural metals, only iron, aluminum and magnesium were more plentiful.

Titanium has been discovered in 1790 and had been produced in relatively pure form by 1910. Yet, it had never been available to industry in quantity. Dr. Dean ordered an investigation of titanium's properties, of processes of its extraction from ore, and of the metallurgical problems connected with its use. After conducting a critical survey and small-scale tests of virtually all known methods for making titanium, the Bureau of Mines decided that a process invented by W. J. Kroll could be developed most quickly on a large scale. The Bureau's research effort was concentrated on this method which involves reducing titanium and tetrachloride with magnesium under an inert atmosphere, into a titanium sponge.

It soon became evident that the development of large-scale reactors operating at 900 to a 1,000 degrees centigrade would be difficult. Titanium metal is very reactive at these temperatures and the reduction had to be either in an atmosphere of inert gas or at a high vacuum. It was learned that virtually no incurries could be tolerated in the new material because they would invariably contaminate the metal product. Methods for purifying the titanium tetrachloride had to be developed; in order to evaluate the product and to understand the causes and sources of contamination in all stages of the production process, procedures had to be developed for analyzing titanium metal and intermediate products incident to its production.

In ten years of research, the size of the batch produced was gradually increased from a few grams to 200 pounds. During this period the Bureau stimulated interest in the metal by demonstrating the industrial feasibility of the technique, and distributing free samples for end-use tests. Production of titanium sponge metal, however, was not an end in itself. The sponge had to be consolidated before useful forms could be made from it. In the first technique used by the Bureau, titanium powder was ground and compressed in an inert atmosphere or vacuum, and after vacuum annealing, it could be rolled into sheets or forged. Later the application of consumable electrode arc-melting technique to titanium resulted in a purer product and made operations on a larger scale possible.

In the early 1950s the government encouraged the expansion of a titanium metal industry by offering various forms of financial incentives. However, technical obstacles to actual application of the metal could not be by-passed. Industry had to learn how to work with titanium. Basic data on its physical and chemical proper-

ties had to be determined, and day-to-day experience with the metal in commercial mills and aircraft plants had to be translated into techniques of forging, bending, rolling, extruding and joining, this new material to specifications. Today the titanium industry is one of our vital industries. Some 95% of the metal produced goes into high-performance military and civilian aircraft, missiles and spacecraft.

The Army's portable recoilless rifle - the Davy Crockett - is made from titanium. In terms of technical achievement, the utilization of titanium in such critical applications, after only a decade of commercial development, is remarkable.

This concludes my examples of the new materials for national strength. We have seen new materials become available in a number of ways. Some new materials are first recognized when isolation from impure mixtures reveal unexpected valuable properties. Other new materials result from synthesis. Old materials are rejuvenated through the discovery of hidden properties or through finding ways to accentuate recognized valuable properties. When new phenomena are uncovered in the natural world, old materials are considered in the light of this new knowledge and new utilities may be disclosed. More precise measurement of properties can reveal new applications of old materials thus making them new to the industry.

And finally, there are economic factors as influenced by related advancing technology, or the exercise of government power, that can speed new uses for materials through the assurance to potential users, of a reliable abundance at low cost. There are many examples that must be passed over for lack of time. Moreover, there are undoubtedly many new materials awaiting recognition or application, and there are doubtless innumerable needs among us as yet unrecognized. Much

of the initial work in defining new needs, and in discovering and developing new materials to meet these new needs, will lie with research workers. However, the prompt and full application of promising new materials to industrial and military needs lies to an important extent in the hands of forward-looking military officers and civil servants like yourselves.

It has been a pleasure to appear before you and I hope I have made some contribution to your understanding of this continuing problem. I thank you.

QUESTION: Mr. Merrill, you mentioned columbium. When I was in Norway not long ago they were doing some very interesting work - but they prefer to call it niobium - they were doing some very interesting work on the metallurgical reason for the niobium alloy characteristics. They also have some deposits of niobium, in Norway. This is probably not completely atypical of the metallurgical field or the mining field. Are there other cases - are we keeping in close touch with what's going on overseas?

MR. MERRILL: Well, we try to. We have about a half-dozen mineral attaches at strategic points around the world. Of course, that only gives you about one per continent - which isn't very many. I'm not familiar with this particular work. There are two major utilization fields. One is a stabilizer in steel, and the other is in these very high-temperature alloys which they use in jet engines. And then, there are the two great sources. One is a high-grade material in columbite or tatalite, and the other is in the pyroflors which are just beginning to come in.

QUESTION: Sir, would you care to comment on molecular engineering and the

degree of success we're achieving in structuring new materials at the molecular level?

MR. MERRILL: Well, that question has come up a number of times. I'm not an expert in advanced physics, but when I've raised the question I've been told that - transmutation is really what you're talking about - is a long way ahead of us. Recently a new program was put into effect to strip the helium out of natural gas going to market and charge it back into a field which is almost all helium. This was financed under a program that will cost about a third of a billion dollars. And I asked the question when it was being considered, "Should we invest a third of a billion dollars in a program that will not pay off until about 1990 with the possibility that the hydrogen bomb creates helium?"

And the answer was this; that if we made as much helium as we're going to save by the hydrogen method, even if we could do it and control it, we'd get the world so hot we couldn't live on it. So, I suspect that there would be some very severe limitations in being able to either provide or absorb the energy for molecular transmutation.

QUESTION: Is aluminum coming to replace copper to any extent as an electrical conductor?

MR. MERRILL: Yes, it's replacing it substantially, particularly in long distance, in transmutation. It has some difficulties. Pound for pound it hasn't as good conductivity, but having a larger cross-section for the same - I mean, cross-section for cross-section it hasn't the same conductivity, but pound for pound it does better because of its larger cross-section. To have the same number of pounds per

foot of wire it isn't quite as strong. Its built with a steel core in some of the long-distance transmission lines. Because of its larger diameter there's the problem of providing for the wind pressure and the load of accumulating ice during storms. These are engineering problems, depending on the area in which the lines are strung. But all in all aluminum is advancing. We might put it this way; that before World War II - if I can remember my figures - copper sold for 12¢ a pound and aluminum for about 30¢. Today copper sells for about 30¢ and aluminum for about 24¢. So, aluminum has come down 20% and copper has gone up 250%, which is a very powerful factor.

All of these things in the commercial world have to be economic. That isn't quite so important in the military world.

QUESTION: Are the Russians making equal or more progress in the development of this material?

MR. MERRILL: Well, we don't know too much about the Russians. Our information comes to us by indirect methods somewhat of an espionage nature in many cases. Tremendous amounts of their literature are being studied. Considering the fact of how far the Russians were behind when this tremendous push forward when World War II began, they may have a greater percentage increase. But I feel convinced myself that on a quantitative basis we are certainly holding our own. Many of these things, as soon as they are invented, why, it's almost impossible to keep the secret, so, there is a tendency for the underdeveloped to equalize with the developed, particularly when both of them have somewhat the same objective.

QUESTION: I think we would all be interested, sir, in the relationship between

your division, the Bureau of Mines, and the metals industry of the country.

MR. MERRILL: Well, the Bureau of Mines starts out with the fundamental objective of - as its mission - playing its part in seeing that the country has a continuing reliable and adequate supply of minerals for the increasing population and the rising standard of living, and for the national security, produced under conditions as healthy and safe as is possible. Now, moving from that, the Bureau of Mines depends almost entirely on putting before the Congress a program of things that it thinks should be done, and receiving from Congress, funds for carrying those out.

The Bureau of Mines also will undertake work on a cooperative basis with industry or with other government agencies, or even with foreign groups if they seem to serve the national interest by accelerating work we're already doing or initiating work we have in our program that we have not already financed.

I would say that as far as industry is concerned in the research area we do not do the kind of marginal research that some people speak of as product development or trouble-shooting on products, etc. This means that we do not do too much in evaluating things that are already on the market, nor do we try to scale up new discoveries into commercial utilization; what often falls into development, pilot plan work, or demonstration work. I don't know whether that gives an answer or not.

QUESTION: Mr. Merrill, what do you see as the main problem in developing the new metal alloys that we need in the military space program? Is more federal money necessary?

MR. MERRILL: Well, it's awful hard to answer such a thing objectively, par-

ticularly if you're thinking about giving the money to the Bureau of Mines. All great things, I believe, in research, can easily be traced to some major breakthrough where an unsuspected area of knowledge in some way comes to the attention of the person working on the borders of knowledge already available. And so, I think it is very important that groups like the Bureau of Mines try to keep themselves rather largely at bench-scale work with a fair degree of their energy going into what is called "pioneering research" which should be adequately financed.

There are limitations, however, on this sort of thing. There are some things which you can't buy with money in this world, and one of them is research workers. There are only so many of them, so you have to grow. The Bureau of Mines is growing. The particular division of which I am the Chief had a budget of $6 million in 1955; today it has $15 million. That is, federal money outside of our contract and cooperative money. And I think that that is a rate of growth that we've been able to absorb and use properly. There are other groups that should be and are being financed.

Very important in Washington, and in this area, of course, is the Bureau of Standards. And then, in industry the universities have a very important role both to develop new research workers and to carry on a certain amount of research with their faculties and advanced students, and their many laboratories of one kind or another that are operating.

QUESTION: Mr. Merrill, is there much promise that uranium may be used for other purposes than nuclear energy, or in the energy field, for instance, in alloys and other materials?

MR. MERRILL: Well, at the present time we have undertaken the use of depleted uranium. The Atomic Energy Commission finds itself with a very large stock of uranium which has lost almost all of its fissionable parts. You know only one part in 135 or something like that is fissionable, and this sort of material is accumulated into hundreds of thousands of tons. We have worked on a number of schemes for its absorption, but I don't think we've had very much success in finding anything that is big so far. Uranium is very heavy. It is reported to be a very good material for alloying steel. We're working on that. It has been reported that it has possibilities in the thermoelectrical field. We are working on that.

It has been reported that it might have some use in the reduction of the noxious fumes from automobiles by catalyzing combustion, and work is being done in that. This has gone as far as somebody pointing out that we might use it for sinkers on fishermen's nets because it's heavier than lead and probably is very strong. That probably will use up some tonnage.

But the Atomic Energy Commission seems to find it difficult to dissociate the high price of undepleted uranium from the worth of depleted uranium. And I believe that a more realistic view on that might help. If the stuff isn't any good for atomic energy I have a feeling that you might sell it for just what you can get, even though it were very low.

QUESTION: Could you tell us of any other work the Bureau is doing that is parallel to past work in the use of titanium, columbium, or some of these other metals; in other words, what other abundant metals are available that the Bureau is working on now for future application?

MR. MERRILL: Well, of course, we're doing some little work on silicon. That's not a metal, but it's one of the very most plentiful things and has almost no use except ferrosilicon, perhaps, but that is merely to clean up steel and go off into slag, but it doesn't go to market. We have done some work on making very pure chromium. Almost no chromium is used despite the fact that you see it everywhere. That layer on the front of automobiles is so thin that it doesn't run to much poundage.

We did discover one thing which is very interesting. Ordinary chrome metal has an impurity which causes the alloy when irradiated to give off two rays; one that is deadly to human cells, and the other which is deadly to cancer cells. It's found that when the material does look pure, that the chromium itself gives off a ray that is only harmful to cancer cells. And so, some of our very pure uranium is being experimented with by a Dr. Meyers at Ohio State, I believe it is, who takes tiny wires of this and sews them into the flesh of cancerous folk, and he's having some success with this.

I wouldn't want this to be used to raise false hopes in any way because I'm not a doctor and I don't know how successful he is. But I do sign the orders for making the stuff and giving it to this doctor. He's been at it for quite awhile. We had an order from France for some, and now we have an order from India, which makes me think the thing has possibilities. But that, of course, doesn't run into tonnage, and since we were talking about these abundant minerals being available in abundance, it isn't very important to find them useful for these very specialized small quantity purposes.

We certainly would be very much interested if we did find a lead where the resource base was tremendous and the utilization was small.

QUESTION: Mr. Merrill, as a professional employee in the Interior Department, would you care to comment on the proposals which have been made by various groups concerning the establishment of a new government department to be headed by a Cabinet Secretary, to cover the area of science and technology?

MR. MERRILL: Well, this will only be a personal idea. I've been in government quite awhile now and the longer I'm here the more I think that reorganizations have their principal usefulness in that those that manipulate them are able to unload the dead wood and award brilliant young people who come up slowly through the ranks. But unfortunately, the manipulators who do these things are apt to be more interested in their friends and the disposal of their enemies than they are in their ability.

I think that the work can be organized many ways. I don't feel that the Bureau of Mines would be greatly benefited by being transferred into a large science organization. I do know this - I've been through two or three organizations myself - it's an almost unbearable load for two or three years to reorient thinking and to defend yourselves against adventurers until you can get rolling in the new direction. And I haven't found the profits worthwhile, personally. Maybe if I were the guy who manipulated them I would think so.

QUESTION: I was going to ask if you see any possibility in the future toward economically attaining a general mining of the sea as a possibility of replacing the resources.

MR. MERRILL: Well, of course, in the first place, the sea has been productive of common salt since prehistoric times, and that business continues. The sea has yielded, in our time, substantial quantities of magnesium, and it continues to do so. We have two large plants down in Texas; they're industry plants. Bromine is recovered from the sea and is an important ingredient of tetraethyl lead which is used in gasoline. Many of the figures you see about the worth of the sea are based on cubic miles of sea water, and most people are unable to conceive of how big a cubic mile is. And I feel sure that there has never been a mine that has yielded a cubic mile of rock, let alone a cubic mile of ore or coal. So that, these large figures like a million dollars worth of gold per cubic mile of sea water still is just infinitesimally small.

There has been one other area of yield from the sea that has had a recent major popularity, and that has been accumulations on the bottom of the sea. Now, some of the material that's causing quite a lot of interest now was reported by Charles Darwin in the "Cruise of the Beagle," I believe it was, back in 1840 or so, before he wrote the "Origin of Species and Descent of Man." He noted that there were manganese accretions and these contained some copper and nickel.

We have no evidence that convinces me that these crusts on the bottom of the sea or these nodules are deep enough at any point to permit economic gathering. Operating under water has been done by mines with floating gold dredges for many years, and when you get down to a hundred feet below the level with a gold dredge you have to have dollar gravel instead of 10¢ gravel. So, I suspect that breaking up stuff on the bottom of the sea would have to be pretty rich material. But that's

one of the things proposed.

Now, there has also been a phosphate formation reported off the Coast of California. I'm not sure whether it was lower California, or California; it's not too far from San Diego. I believe there is actually a concession on it now, and people are trying to see if it can't be mined. That would seem more reasonable because that would be fairly deep, because we do know that the material in Florida which has probably accumulated the same way can be examined on dry land.

I would like to make this one point; that a good part of the surface of the earth is covered with material that accumulated on the bottoms of seas, and there are any number of cliffs around the country that can be examined at leisure without any diving equipment or anything else, to see whether there are any accumulations of nodules. There are almost no mineral deposits in the world - that is, commercial - which represent sea-bottom accumulations that have not been enriched. The minerals of Minnesota are an enriched iron-bearing materials that have accumulated at depth, probably. The coal beds that weren't in the sea; they were in fresh-water swamps apparently. Oil has migrated into the deposits that are worth working. It was laid down and was apparently too scattered to be commercially worked.

The Chamberlain Manganese Nodules; now, this would be a real nodular proposition which I think was a sea-bottom accumulation. Good manganese ore runs 48% and it's mined pure that way. These nodules make up about 1% of the shale up there, and the nodules only run about 16%. So, you see, you get down to something less than 1% to compete with material that's 48%. So, that makes me very discouraged that we haven't found on land where we can know all about it and where

we have the careers of geologists who have spent a hundred years looking at it; that give much evidence that the sea ever had a great thick accumulation of rich material on its bottom.

COLONEL WIKEN: Mr. Merrill, a number of these gentlemen have a twelve o'clock appointment, so I'm going to cut this off. On behalf of the class I want to thank you for a very interesting morning.