NEW MATERIALS FOR NATIONAL SECURITY

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Dr. John D. Morgan, Jr., Consultant, Stuart, Florida, was born in Newark, New Jersey, on 14 February 1921. He received B.S., M.S., Ph.D. and E.M. degrees in Mining Engineering from the College of Mineral Industries, Pennsylvania State University, and also completed the ICAF extension course in 1953. Dr. Morgan served with the Corps of Engineers as a Major in World War II. Since that time he has been Assistant for Materials and Stockpile Policies, National Security Resources Board, Executive Office of the President (1948-50); Director, Materials Review Division, Defense Production Administration (1951-53); and Materials Expert, Office of Defense Mobilization, Executive Office of the President (1953-56). In 1956 he opened a consulting practice, specializing in business and defense problems in metals, minerals, and fuels. In 1957-58 he served as a member of the Special Stockpile Advisory Committee to the Director of the ODM, and in 1959-60 he was a member of the Special Committee on the Scope and Conduct of Materials Research of the National Academy of Sciences. He is a member of the Office of Civil and Defense Mobilization Executive Reserve and also a member of many technical and professional groups. He is the author of a book, "The Domestic Mining Industry of the U.S. in World War II," and numerous technical articles. This is his eighth lecture at the Industrial College.

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COLONEL BLACK: General Mundy, Gentlemen: Contemporary military technology is causing the blueprint of today to become the antiquity of tomorrow. Especially is this seen to be true in the current critical need for the development of new materials for some major items required in our national defense, atomic, and space programs of today and tomorrow.

In order to safeguard our national future we must effect an early and satisfactory breakthrough in the new materials development barrier. Today we assess the problems, both material and economic, that beset a complex venture of this kind.

I know of no more informed or professionally competent person in the materials field than our speaker for this morning, Dr. John D. Morgan. I am certain that after listening to his discussion that the problems in this area will be much better understood.

Dr. Morgan, it is a pleasure to welcome you back to the Industrial College of the Armed Forces, and especially do we appreciate your leaving that land of sunshine down in Florida to address us today. Dr. Morgan.

DR. MORGAN: Thank you, Jim, for that very courteous introduction. General Mundy and Scholars: It is a real pleasure for me to come up here, even though the weather is a little colder and wetter than I left in Florida. I lived on the Post here for four years during one time in my career and it is just like coming right home, and I said to General Mundy earlier that when I worked with some of the Government agencies in a civilian capacity, as well as a military one--agencies like the Office of Defense Mobilization--you certainly could tell which officers had had the opportunity to attend the Industrial College when dealing with them on matters of mobilization preparation. Oftentimes in the early days of the Korean war, for example, we would get very fine men, for example: senior Navy officers, right in off a tanker or something, who knew all about the Navy and sailing ships and such, but they had to spend a year or two learning their job in the Munitions Board or in the Research and Development Board, or in some other such agency in the Pentagon. At that time we couldn't afford, really, the year or so necessary to educate a man on the job. Whenever we would run into a man who had this Industrial College experience, it just saved a year or two of time and effort and made things go much smoother. So I am very happy to see that the ICAF has continued here and has expanded, and that you have this fine new facility to come to instead of the old temporary building that I remember. I think it's very good for the national security.

Today, I want to talk a bit about materials. You may wonder why we are concerned about materials. After all, you got this building built and there are a lot of materials in it. You didn't have any particular problem. You are all sitting on fine upholstery, and there is nice aluminum trim on the doors and everything. Why is there a grave national security materials problem? The military forces have long been interested in materials. In fact, most of the advances in material sciences, technology, or art, have come through military necessity. In the stone age the ancient caveman in his skin, when he made a stone axe, was probably engaged in fashioning a military weapon, because he wanted to hit the other fellow over the head with it. Then we had the bronze age, when the alloys of copper and tin were of interest, mainly because they made swords, spears, shields, and sharp prows for naval vessels. Then we had the iron age and now we are in the steel and light metal ages. We've been about 5,000 years taking advantage of stones, metals, and so forth, and we've got a good bit of experience behind us. Therefore, I want to show you some of the areas where we have experience behind us, what that experience means, and then, more importantly, some of the areas ahead, where we do not have experience, and why we face a "materials barrier" at the present time.

So I have to go back just a little bit to set some perspectives. If I oversimplify some complex concepts I hope the really technical men among you will forgive me. Take the old Brooklyn Bridge that they started making the wire for after the Civil War. They finished it in 1883. For nearly 80 years since the Brooklyn Bridge has stood there. It was designed in a period when they had essentially horse-drawn traffic, wooden vehicles, and pedestrian traffic, and yet that old bridge is there today carrying interurban rapid transit, heavy trucks, and so forth. How did they do it? First they put infinite care into making the wires that they used in the suspension system, and then the old civil engineers used what they politely called a "factor of safety." We could unpolitely call it a "factor of ignorance." In other words, they figured out theoretically how many steel wires they needed, and what size of girders, and so forth, depending on the situation, and then multiplied everything by 10 or by 20. So, obviously, the bridge that was built for the horse-car traffic in the 1880's still stands up today. Its relative factor of safety may have been reduced over the years as loads increase, but the original builders put in plenty of extra material to be on the safe side. Now, for something standing still on the ground you can afford to do that.

The military forces should use materials generously in many of the normal ground warfare applications, where reliability under adverse surroundings is paramount. From the Civil War to World War II many of the great advances in metallurgy came about as a result of the experimental work done by the Army and the Navy at their arsenals--such as the Navy Gun Factory, the Army Watertown, Watervliet, and other arsenals--and their proving grounds--Dahlgren Proving Ground, Aberdeen Proving Ground, etc.--where there was a constant testing of shell against armor plate as the services tried to find which was the best shell to go through the armor plate and which was the best armor plate to resist the shell. Since civilian industry didn't have a requirement for such strong metals much of the fine metallurgical work was done in the services, in "inhouse" service laboratories, and many uniformed men specialized in such technical work.

Well, then, that was the way it was done up to World War II. Previously we didn't have any insurmountable materials problems. True, in World Wars I and II we were cut off from many important raw materials and we had to use substitutes and develop uneconomic domestic sources, but that led eventually to the stockpiling concept through which by now, for common materials, we have made pretty good provision for being cut off from overseas sources of materials.

Now, however, we must look at what has been happening in the air. In World War I the speed of an airplane was perhaps 125 miles an hour. By 1925 the speed of a plane was doubled. At the end of World War II, and at the beginning of the Korean war, we were up to Mach 1, the speed of sound, around 700 miles per hour, depending on where you measure. Today in planes and in missiles we are talking of Mach 2 and Mach 3 and Mach 4 and more which is two, three, four, or more times the speed of sound.

In all our previous history, all our 5,000 years of metallurgical experience we generally were concerned with temperatures that never went much below minus 30 or minus 40 degrees Fahrenheit. This was probably as cold as it got in Russia or Alaska, or anywhere else where we were concerned. Oh, for a day or two it might have gone to minus 50 or minus 60, but minus 30 Fahrenheit was about the worst equipment had to stand. And for nearly all those 5,000 years, military items were generally concerned with operating about at normal outside temperatures--100 degrees Fahrenheit, at the outside 120--until we got to the internal combustion engine. Then our gasoline engines and diesel engines brought us to higher speeds and consequent higher temperatures. Then along came the jet engines and the rocket engines, and the missiles, so that we find that the temperature spectrum that we are now working with has been pushed up from normal temperatures to 6,000 degrees Fahrenheit, and we could still use much higher temperatures if we had the materials to stand up under such conditions. And now on the negative side, we find that instead of minus 30 or minus 40 degrees Fahrenheit, we are now working at only about 30 degrees above absolute zero. Absolute zero is about minus 460 degrees Fahrenheit. But we find that liquid hydrogen, which is used as a fuel in the new rockets and missiles, has a boiling point of about minus 420 degrees Fahrenheit, within 40 degrees of absolute zero. We find that fluorine that is used in the fuels boils at about minus 350 degrees Fahrenheit, and liquid oxygen boils at about minus 300 degrees Fahrenheit. So in just the last few years we have broadened the temperature spectrum range that we're concerned with from a low of almost absolute zero to the very hottest temperatures that we can achieve, already approaching 10,000 degrees Fahrenheit.

Why are these high temperatures so important? There is a law of thermodynamics that says that the efficiency of any engine or process is proportional to the change in temperature that takes place in the engine. (Writing on blackboard) T_2--the hottest temperature minus T_1--the coldest temperature, divided by T_2--the hottest temperature--gives you the theoretical efficiency of the engine or the process. Because the exhaust gas temperature is limited by its surroundings--the only way that we can get more efficiency is to increase the T_2, the hot temperature, at which the device (airplane engine, rocket, motor, etc.) is running. How do we do that? Well, first we've gone from conventional fuels to exotic fuels, because we want something with more heat energy per pound. Just as a matter of comparison--a fairly high grade coal such as might be burned in furnaces or in the steel process may yield about 14,000 BTU per pound. Gasoline or kerosene of the type used in the internal combustion engine or the jet engine may be 18,000 or 19,000 BTU per pound. The zip borane fuels, which are supposed to give that extra thrust to the existing jet engine when they are injected, may go up to 25,000

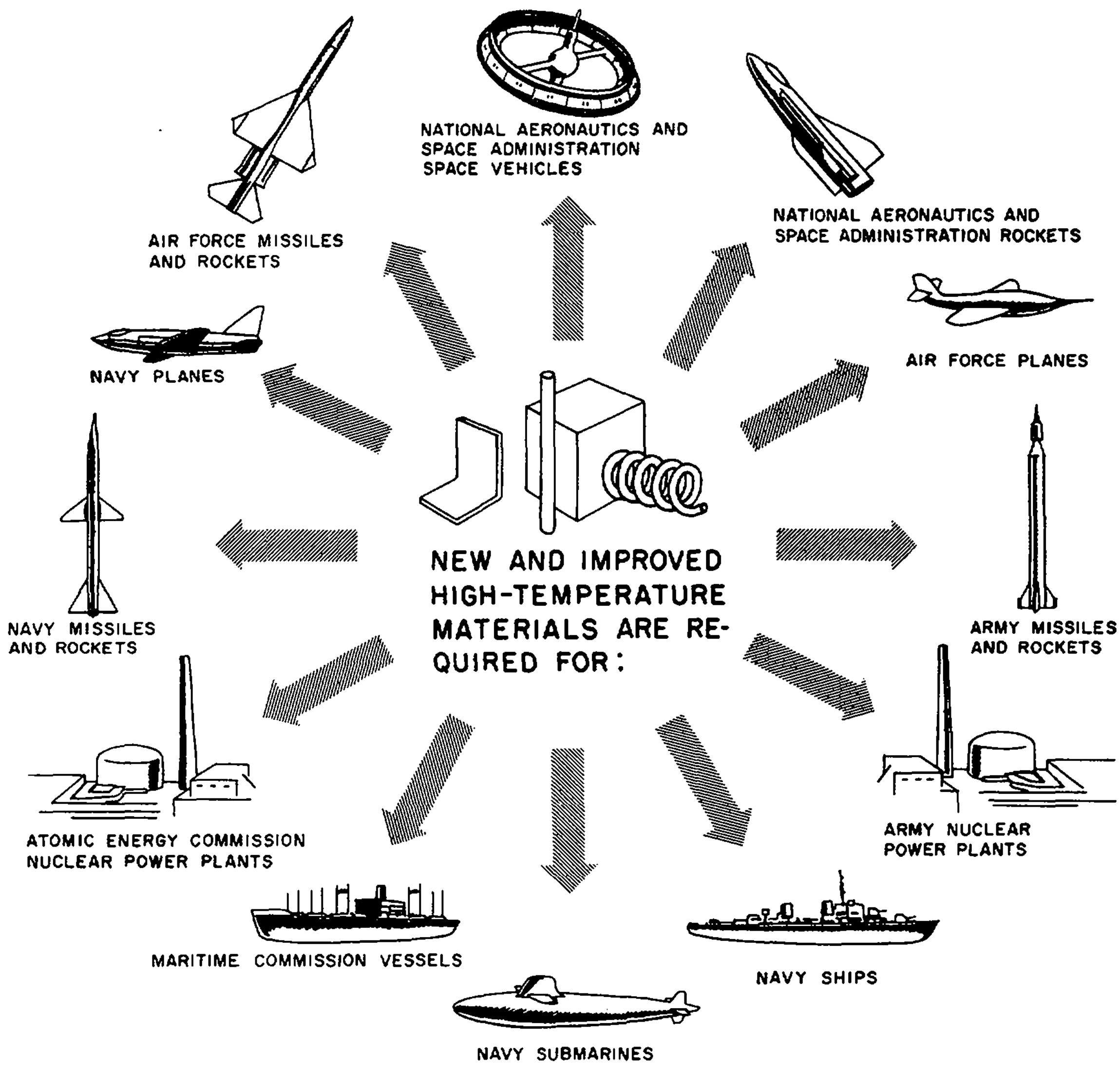
BTU. That's a one-third increase over the kerosene or the diesel oil. Liquid hydrogen goes to 51,000 BTU, which you can see is about three times the current kerosene heat value. And going far beyond burnable fuels will be the heats generated by nuclear energy, already used for submarine and vessel propulsion, and underdevelopment aircraft and missiles. So we've got hotter fuels. We have to have hotter places in which to utilize them.

Then when we get beyond normal elevations and on out into space we find not only extreme cold but also extremes of radiation that we don't yet fully understand, because here on the earth we are protected by the earth's atmosphere. We find absolute vacuum in outer space, far greater than any vacuum that we can make here on earth. We find meteorites moving with a velocity far greater than any missiles here on earth. We have the extreme problems of aerodynamic heating on reentering; and so we have entered a new era where our 5,000 years of slow, steady progress doesn't give us the answers, and every military service is involved (see Chart 1--page 6).

Now, the common materials are fairly well in hand for the day-to-day applications we need on the ground. I don't think we have to worry too much about them, but I just want to show you a few examples, some of which you may have seen, of what is being done with common materials, before we proceed to the uncommon.

I brought a few samples, just to show you. Here is a lightweight material. You can feel it after the lecture, during the intermission. It consists of a foamed polystyrene plastic in between aluminum sheets. It has aluminum on one surface, bonded to masonite for additional dent-resistance and it has aluminum on the other surface, too. It comes in several colors, is quite strong, is very light, and has a high insulation value. For trailers, barracks, vessel superstructures, etc. it would be very useful.

CHART 1 - NEW AND IMPROVED MATERIALS WILL FIND WIDE USAGE IN MANY END ITEMS UNDER DIFFERENT AGENCY JURISDICTIONS - FOR EXAMPLE : HIGH-TEMPERATURE MATERIALS



Here's another approach to getting a strong but light material. It's a honeycomb construction. You can probably see the little cells as you look at it from out there in the audience. Here we have a light sheet of aluminum bonded to a sheet of masonite, and then in the middle special paper honeycombs, treated against insects and treated against moisture. I have cut that panel open, so you can see that the only thing that is holding the front here is the paper. If you stand on it and put your full weight on it, the paper will take that strain. That's a very light and an insulating material for use anywhere on the ground. The honeycomb holds that metal very rigid, because it is supported over its entire surface. The honeycomb principle is used not only on the ground but also in our highest temperature airplanes where they are now working on honeycomb made of stainless steel. The honeycomb itself will be made of ribbons of stainless steel. The surface of the airplane will be a high grade stainless steel. The honeycomb underneath will be brazed to the stainless steel to make it tightly joined at every place. So the old aircraft construction of girders, plates, skin, and rivets isbeing done away with and instead there will be a smooth stainless skin surface, uniformly supported at every point by this stainless steel honeycomb. This will increase speed and reduce heating and corrosion.

Another area that is receiving considerable attention is the matter of optimum design. I will try to give you a demonstration here. You have to integrate both the design of the structure and the material to get the best result. For example (demonstrating) if you take a couple of individual corks, they just wiggle around; they don't have any particular strength. But if you take those corks and compress them with an end loading, which is supplied by my fingers--in other words pushing in here and pushing in here (indicating)--those corks become quite rigid, and they can stand a strain. This is the principle used in prestressed concrete. Concrete, as you know, is very strong in compression--when you push on it, put a weight on it. It's very weak in tension--when you stretch it or pull on it. Well, one older approach in concrete design has been to put steel reinforcing rods in the part of the concrete beam that was subjected to tension. For example, in the bottom of a beam, where stretching would take place, steel rods were inserted. Now they have gone a step further. A number of concrete blocks can be put end to end and high tensile strength wires strung right through the middle of them, and then tightened to put all of the concrete in extreme tension. This makes a very strong beam, because the whole thing is in tension. And made with the centers hollow, a lighter weight beam results.

We can do all sorts of things like that on the ground. Here's a material that many of you may be familiar with. You all know about conventional plywood. One of the newer developments is a type of chipboard, illustrated here, where they just use little bits of chips of wood and put them together with plastic binder, and this has more dimensional stability than any equivalent piece of plywood. It won't warp out of shape because the particles are all of uniform dimension and randomly arranged.

One development in conventional materials that I feel I should mention is the development in plastics often taking the place of metals. I'll give you an idea of how great that development is. In 1949, about 10 years ago, about 790,000 short tons of plastics were produced and used in the U.S.A., while in 1959 about 2,945,000 tons of plastics were used. In other words, that's almost a fourfold growth in the use of plastics. And, when you consider that plastics are much lighter than metals, on a volume basis, which is the way many of these materials are used, that's a very great increase.

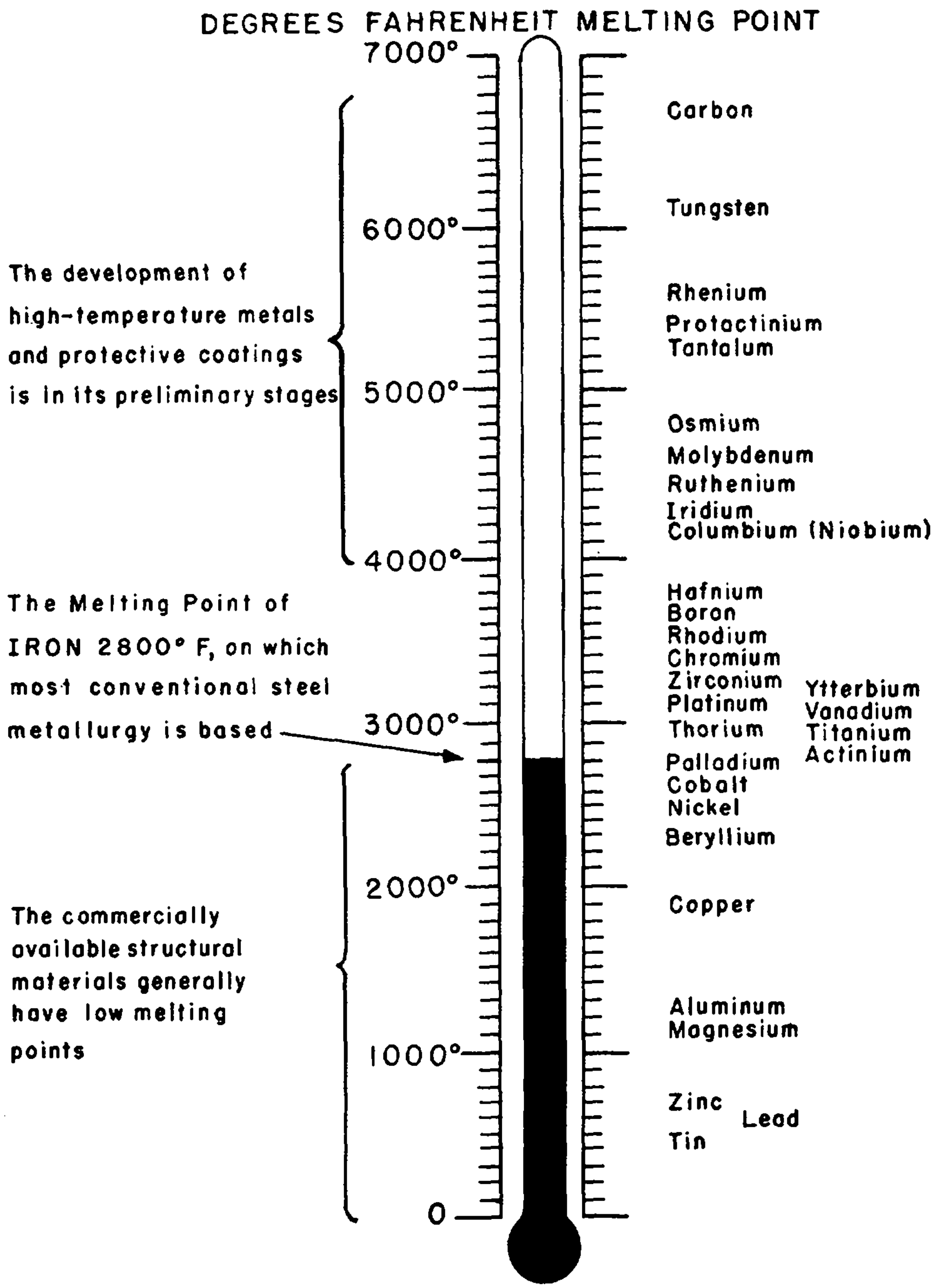
You can't just judge the demand for a metal or a material on a price-per-pound basis. For example, a new plastic, delrin, costing about 95 cents a pound was recently announced. You might just think offhand, "Well, who's going to use that when zinc alloys are 13 cents a pound, when brass alloys are 30 cents a pound, and when aluminum is 30 cents a pound?" But, when you figure that many things are made to get a certain dimensional stability, the important thing is the volume, not the weight. Then, when you consider that a zinc alloy has a specific gravity of about seven, and this new plastic probably has a specific gravity of only about one and one-half, it takes much, much more zinc alloy at 13 cents a pound to fill out the same volume as the plastic. In fact, when you consider the ease of forming, fabrication, coloring, etc. there are many price advantages in plastics. But all this is for conventional temperatures. Now, having taken care of the conventional situation, I'd like to take off into the high-temperature situation.

Chart 2 (page 10) shows temperatures in degrees Fahrenheit, running from zero up to 7,000. Ranged off over here (indicating) we have the melting points of elements. From the melting point of iron, 2,800°F and below, I have indicated only certain common structural metals and elements, such as lead; zinc; aluminum; and copper. The dark column that stops at nickel, cobalt, and iron, is the limit of our present common metallurgy. This is the metallurgy of iron, steel, and stainless steel, which is made of iron, nickel, cobalt, and chromium. In fact, none of the stainless steels will serve anywhere near the melting point of iron (about 2,800 degrees). Instead they'll probably give out at about 60 percent of the melting point. Sixty percent of the melting point is roughly 1,800 degrees Fahrenheit, which is just about the upper limit of our present metallurgy that we know how to work with on any scale.

Above iron Chart 2 shows every known element. These are the only things we have to work with. Here we find such elements as titanium, vanadium, platinum, zirconium, chromium, hafnium, columbium, molybdenum, tantalum, phenium, tungsten, and carbon. There are no other known elements above iron than those shown on Chart 2.

Chart 2 shows that there is not much point in taking comfort from how well we've done in aluminum metallurgy. There is not much point in thinking how well we've done in steel metallurgy. What we have to know is how are we going to get these higher temperatures, these higher T_{-2}'s. How are we going to withstand these reentry conditions? I'll tell you how we've been doing it up to now. We've been doing it by makeshift designs. Without burdening your mathematical theory too much. I just want to cite the basic theorum in probability that governs how a number of components work when they are joined together. I'll just give you a simple illustration and you'll see how it works. If you had three boxes here--such as the first stage, the second stage, and the third stage of a rocket--you would want to know the probability of these three stages functioning reliably together. You would first have to assess the probability of each one working individually. I am going to pick just a simple numerical example and show how it works. Let's say that the probability of the first stage functioning correctly is 9/10: that is, there are 9 chances out of 10 that it will work. Let's say the probability of the second stage is also 9/10. The probability of both stages working together is 81/100. That's the product of the two individual probabilities. In other words, when you hitch the two stages together, the probability of them working reliably becomes 81 percent. Then when you hitch on the third stage, if you want to take an assumed 9/10 for it, you multiply your 81 percent by 9/10 and you get about 73 percent as the likelihood of the three stages functioning correctly in unison.

Chart 2 -Only a Small Number of Elements Have High Melting Points
(This chart shows all known elements above iron and major metals melting at lower temperatures)



Of course, in a real case, it isn't that simple. The probabilities of each part in a rocket or a missile working are much higher than 9/10. They may be of the order of .999 or .9999 or even .99999. But there are literally hundreds of thousands of parts in each one of these missiles and rockets, and, when many many .99999s must function together the ultimate probability gets much smaller, and that's why every other rocket or missile falls into the ocean today.

Because we don't have the high-temperature materials to make the design simple, we must resort to complex design tricks that increase the probability of failure. Since we don't have a material that will resist the 6,000 degrees Fahrenheit of the exhaust jet temperature at the nozzle, we say, "Let's circulate the fuel around the nozzle to cool the nozzle." Well, the first thing that does is cut down the T_{-2} in that other equation. So you are taking a little of the efficiency out of the heat. The next thing it does is put in the additional mechanical complexities of the pump and the tubing that circulate the fuel around the nozzle. Then, because we don't have a nose cone that will stand up under all the conditions of reentry, we say, "Let's try ablation. We'll mix in some ceramics and some other material, and the outside will evaporate." Well, if it does all that uniformly as it comes in, it doesn't change the aerodynamic characteristics too much, but suppose one little piece over on one side evaporates quicker than one over on another and then the missile begins to wobble. Then it doesn't come in quite on the target.

Up to now all of these materials problems have been worked on almost entirely incident to developing end items. The Army, the Navy, and the Air Force, and within the Army people like the Signal Corps and the Ordnance, and in the Air Force several different offices, and in the Navy the Bureau of Aeronautics and the Bureau of Ordnance (which two were recently merged into a new Bureau of Naval Weapons) and the Bureau of Ships, and others make contracts for end items. They don't usually specify what materials to put in an end item because they don't know. So they specify performance characteristics. The services go to the aircraft and rocket and the engine manufacturers--and the Space Agency and Atomic Energy Commission also are doing the same--and say, "We want an end-item of such and such a weight for such and such a performance." Then these private contractors go out through hundreds of subcontractors and try to get all these little valves and pieces of tubing and material, and so forth, and put them together. Then they test them and find why they don't work, and then they try to improve the parts that fail. As a consequence of that, quite a bit of work is done on materials. But it is haphazard. It's scattered all over the place. It may be that one or two companies have already worked on and solved problems in connection with one end item that some other company would like to know about in connection with an entirely different end item.

In recent years there has begun to emerge a consciousness that, while we've still got to keep on working on the end items, we are up against a materials barrier, and we find this barrier in every program of every service. We find it in the Army, Navy, and Air Force, we find it in the Space Agency, and we find it in the Atomic Energy Commission--because, obviously, even in AEC their attempts to make efficient power reactors for military purposes and for civilian purposes are governed by that same T_{2} minus T_{1} equation. These latter agencies need higher temperature materials and they also need specialized materials with certain nuclear characteristics to stand up in the highly radioactive fields of their reactors.

So we now have emerging the idea that materials problems must be attacked on a broad front directly as materials problems. That makes it a very difficult thing, because in our civilian pursuits, in our college and our scientific training, there are no disciplines at the present time clearly labeled "materials." There are civil engineers who design bridges and they know a good bit about that. There are aeronautical engineers who design airframes. There are mechanical engineers who design engines. There are metallurgists who work with metals. There are electrical engineers who work with transistors, diodes, condensers, and tubes. Then there are ceramists, who have studied ceramics and who work with the oxides and the nitrides of the metals. Then there are physicists and chemists, and physical chemists. Each pursues a very narrow area with great ability but none of them can bring the whole body of available knowledge to bear on the materials barriers holding up the defense efforts.

What is being done about it? Very little is being done at the present time, I regret to say. I think it is fair to say that the problem is recognized, and recognition of any problem should be the prelude to solution. I believe from what Colonel Black said that you've all had copies of the 1960 report of the National Academy of Sciencies' Committee on the Scope and Conduct of Materials Research entitled, "More Effective Organization and Administration of Materials Research and Development for National Security." This report makes a number of very specific recommendations. Some of which are already being worked on. If they'd leave all the committees out of Washington and give the responsibility to some specific agency along with the money to solve the problem, we'd be all right. But in any event we had a committee here making a report, and the problem is recognized at a high level.

Now I'll briefly describe what small steps are going on. But I want to say that I personally think they are totally inadequate to the threat that we face. The Defense Department is putting up some money, about $20 million a year, or something like that, to assist universities in establishing materials science centers on a graduate level, where their faculties of physics, chemistry, metallurgy, ceramics, and so forth, can bring these different disciplines and their graduate students and professors together to work on the problem. The Department of Defense, through the Director for Defense Research and Engineering, has gone to each of the three services on several occasions and found out what basic materials work they are supporting and what additional work they would like to support but do not have the funds for, and then the Director of Defense Research and Engineering has made available additional funds to the tune of about $20 million a year to carry out projects.

There have been great surveys made. Here's one (holding up), entitled "Report of the Committee on Refractory Metals" made by the Materials Advisory Board of the National Academy of Sciences. It is devoted wholly to these materials on the top of the high temperature chart (Chart 2): tungsten, rhenium, tantalum, molybdenum, platinum, columbium, chromium, and vanadium. It says what the sources are and what the problems are ahead for each one. It's about an inch thick, almost too much for any top official in the Pentagon to read, so they took that and they made a summary of it. There's the summary, about 34 pages. Then to get it up to the top level they made a summary of the summary. They have been working more than two years on getting the report and the summary and the summary of the summary. I hope now they are getting on with the task of doing something.

There are a couple other problems that I'd like to talk to you about along this very line, some that I've had personal experience with. Back in 1948 and 1949, when we were getting ready, some of us, for the war that we thought was coming--though official policy seemed largely to ignore the possibility of war at that time, we were supposed to be closer to peace than we had ever been at any time--we got talking with the Air Force people about their high-temperature needs, and at that time it was high temperatures for jet engines. We knew then we had to go above 1,800 degrees. The Air Force wanted to go up to columbium, with a melting point of about 4,400 degrees Fahrenheit. But they weren't going ahead. You know why? Because U.S. geologists--and I don't mean this critically, but it's the sort of thing you have to watch--said there were only a million or so pounds of columbium in the whole world that they knew about, and that this wasn't enough to make the jet engines in quantities that the Air Force wanted, and that therefore we ought to forget about columbium, for they could make only a few engines. When the Korean war came along here's the kind of program we put in. Since there was little known about potential sources of columbium, we couldn't go out and make sensible procurement contracts with suppliers. They didn't know where the sources were or the costs of production. The going price was about $1.40 a pound, so we announced a columbium-tantalum program to the world--not just to the United States but to the world--and we said, "In the next five years, whoever delivers a pound of columbium ore of certain specifications to the Government will get the $1.40 a pound plus $1.40 bonus." It was a 100 percent increase. And, in less than five years, we got 15 million pounds of columbium ore of specification grade delivered to the Government.

So you don't want to hang back because of someone's theory or assertion that there isn't enough of any of these elements. The reason there isn't enough of most things is that nobody looks for them unless there is a need for them. Rather than sit around and say, "Which should come first, the chicken or the egg?" what we need is an expansion of the supplies of the raw materials prior to or simultaneous with the development of the metallurgy of the material and the arts of how to use it.

This concept has been very hard to put across. We put it across in the early days of the Korean war because everybody was scared stiff that the war would expand and get to be a bigger one. As soon as things got a little more peaceful, and as soon as the Budget Bureau got a little firmer grip on the chain of command, materials expansion was tapered off.

I'll give you another story. The highest temperature metal has a somewhat higher melting point but it is an amorphous material, not a metal, so it should be obvious that tungsten would be a very important metal. But the Government was reluctant to take tungsten into the stockpile when the Chinese offered it prior to the Korean war at $10 a unit. A few months after the Korean war started the price went to $80 a unit. Then the Government started to buy. Where we had previously produced only 3 million pounds a year in this country--and used about 6 or 7 million for normal tungsten alloys, not for high-temperature materials--the Government had to put in a program in which we said, "We'll pay $63 a unit for any domestic production." Compare that to the $10 at which it could have been bought. By 1955 tungsten mining production in this country went up to 16 million pounds a year, while we were using about 8 million pounds. So the domestic production alone grew to about double the domestic use of the material at that time, given an incentive. This is another illustration of why the supply base must be expanded in the case of high-temperature and special-property materials. Now we've got the tungsten on hand and can justify doing the experimental metallurgical work required to find proper alloys.

It's not enough to just get one of these metals and have it as a bar of metal and say, "Well, now, the problem is solved." That is only the beginning. You have to alloy metal and shape it, and join it. While we can readily roll conventional aluminum and copper and steel alloys, how are we going to roll a high-temperature metal whose melting point is higher than the melting point of all the conventional rolling material? The roll would melt before the new metal would. How are we going to weld new high-termperature metals when they oxidize under almost any condition? We need a lot of experimental work on joining these high-temperature metals once we have them. Should they be riveted, bolted, or crimped together? Should we arc-weld them? Should we weld with special coatings? Or in a shielded atmosphere? Could we submerge the arc in a flux? Could we spot-weld them? Could we braze them? How do we best put them together? Perhaps plasma jets, electron beams, or ultrasonic methods would help. There is some thinking to the effect that we should use powder metallurgy--that is take the metal or alloy in a very pure form and make it into a finely divided powder, compress the powder, sinter it, then forge it, and thus have it in the required shape. There is so much that needs to be done where we don't have the experience today. Almost any plant of any reasonable size today can handle aluminum, steel, or copper alloys. Practically no one can handle these exotic materials, even if we had them.

Just one illustration of what the services are doing to alleviate this problem is shown by what they call the "In-Fab" setup sponsored by the Navy with the Universal Cyclops Steel Company. They have made a steel chamber 42 feet wide, 97 feet long, and 23 feet high. This chamber is airtight. They are going to work in that chamber with argon, which is an inert gas that doesn't react like oxygen or hydrogen or nitrogen in the normal atmosphere. They are going to work in this room with 99.995 percent pure argon, and have temperatures of 4,000 degrees Fahrenheit so as to handle the new hi-temp. metals. The workers will have to work in shielded suits, with outside controls, and all that sort of thing. But that's just one facility. So you can see how remote we are from any major effort in attacking this problem.

Before concluding I would like to say a little about the stockpile. As I have said before, on conventional materials, like copper, lead, zinc, tin, manganese, chrome, and so forth, our present strategic stockpiles, if we can keep the Budget Bureau from selling them to get the money to balance the budget, will be adequate to meet many of the threats, not only of all-out war but also of economic warfare and limited warfare. And I underline that economic warfare and limited warfare, because, what do you think the Communists are doing in Cuba with that nickel production that we encouraged there with the Freeport Sulphur Company and at the U.S. Government-owned Nicaro operation? That was some of the nickel we were going to count on. Now they are going to trade that off to the Chinese or Czechs or some other Communists for something they need from abroad. What do you think the unrest in Africa is about? Do you think it is just to stir the natives up, or is it also intended to eventually deny the U.S. and Europe the raw materials of the African Continent? So we want to go pretty slow in selling off our stockpile today just to get a little money, when we see these political and economic warfare threats ahead. If we leave the stockpile alone it is in pretty good shape on the conventional materials.

Look at the "Stockpile Report to the Congress" made by OCDM. Here is the latest one (holding it up) dated October 1960. You can have access to it. Look at the list of 76 materials being stockpiled. Several of the high-temperature materials that I have mentioned are not even on the stockpile list. Rhenium isn't on the stockpile list, and it has a melting point near tungsten. They are not stockpiling any rhenium. Why not? They say, "Well, we don't have any specifications or certified requirements for it." Naturally they don't. But they ought to be getting it in any form at this time. They ought to get it as a waste or an alloy or a rock or anything else that has rhenium in it, and stockpile it. You don't find tellurium on that list, which has very interesting thermoelectric properties relating to converting electricity into heat, or, conversely, heat into electricity. So there's a lot yet to be done when it comes to stockpiling for future security needs.

I'd like to close by just saying that I wish we knew more about what the Russians are doing. We don't. I'll just show you a textbook here. You are free to examine it in the intermission or afterward. It was prepared about 10 or 12 years ago by a noted Russian geochemist by the name of Fersman. The interesting thing about this textbook is that it was prepared first for their scientists and then this edition was run off for students by the Ministry of Children's Literature. They do show that the book is for the more advanced students in the grade schools. I want to tell you that there is information in this of a type that I didn't get until I had finished several graduate courses in my own fields of mining, geology, geophysics, and so forth, and which the average engineer would never get. I'm going to hold this up and show you just one illustration (see figure 1, page 18) of what the Russians have in their book for their children. Remember it was 1948 when this book was issued. This was the period of peace that we had never been so close to before. They show the tank, and all the alloying metals needed for it such as columbium, tungsten, molybdenum, manganese, nickel, and chrome. The tank is shooting off shells, and they show the ingredients in the shells. Above is a military airplane, made from titanium, mercury, copper, molybdenum, chromium, and nickel. And they show the searchlight beam, with all the rare earths listed that go into making the searchlight components. So their little kids had an early appreciation of the strategic importance of these materials. You don't see Russia today relying on imported materials from very many countries. You see them with an adequate stockpile. You see them developing their own resources. And you see them infusing this consciousness of the military importance of materials at the earliest stage. The kids that read this book in 1948-1949, and 1950 are the scientists today who are working on those rockets and missiles over there. I think they are probably doing pretty good work.

I think we've done good work, too, but we must recognize that we are in a race. It's not good enough to just keep on doing as we have been doing. It's not good enough, in my opinion, to have the strength to obliterate the enemy. Some defense planners say, "Well, we can sit back. We can blow the enemy up three times over and he can blow us up only twice, so he's not going to do it." But if he develops one good, efficient, rocket that has the means of delivering a powerful weapon far more precisely, far more accurately, and far more reliably than we can do it, and if he demonstrates his proficiency to do that, he may hold the deciding edge. It isn't the total size of your arsenal; it's who shoots first. Maybe he doesn't even have to shoot it at us, though I think he will. Maybe all he needs to do is put on some convincing demonstrations. Then all the wavering nations may question whether to side with us, to try to be neutral, or to throw in with the side with the largest cannon in the modern sense.

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Figure 1

ЗАНИМАТЕЛЬНАЯ ГЕОХИМИЯ А. В. ФЕРСМАН

Г. И. ДЕТСКОЙ ЛИТЕРАТУРЫ 1948

Химические элементы в военной технике.

So new and improved materials hold the key to the future success of the whole defense effort in my opinion.

Gentlemen, it has been a pleasure to be here this morning, I'll answer questions later.

COLONEL BLACK: Dr. Morgan, during the intermission we had several questions as to what lies behind this cloth. So will you assuage the interest and take a few minutes to explain it, please?

DR. MORGAN: Thank you, Jim. This was a chart (see Chart 3 and Table 1, pages 20 and 21.) I had hoped to cover in perhaps more length in comparison with chart 2 when talking about the need for stockpiling. You will recall that chart 2 listed all the elements in rising order of melting points. Chart 3 shows in a recent industrial year the source of our supplies for many of these strategic materials. I'll just read off some and show you where some of those materials are, to give you an idea of the situation. We are world sources for vanadium, magnesium, and molybdenum. In the case of copper, mercury, zinc, lead, bismuth, fluorine, cadmium, cobalt, and bauxite we import major quantities. And when we come to columbium, antimony, nickel, beryllium, chrome, manganese, asbestos, platinum, mica, tantalum, tin, and diamonds, we import nearly our total supply.

Note especially the high-temperature materials. Here's tantalum almost wholly imported. That's a high-temperature material. Tungsten I didn't put on, because we can be either domestically self-sufficient or wholly dependent on imports from foreign sources, depending on price. That's why you don't see that on there. Rhenium--we don't now use any and we don't import any, so there's no point in putting that on the chart. Molybdenum--we are self-sufficient in. Columbium is almost wholly imported. Hafnium is derived from zirconium, which comes largely from imports. This shows that in a normal commercial year for many of the important materials we are dependent to a great degree on imports. Hence there is the need for stockpiling.

Chart 3

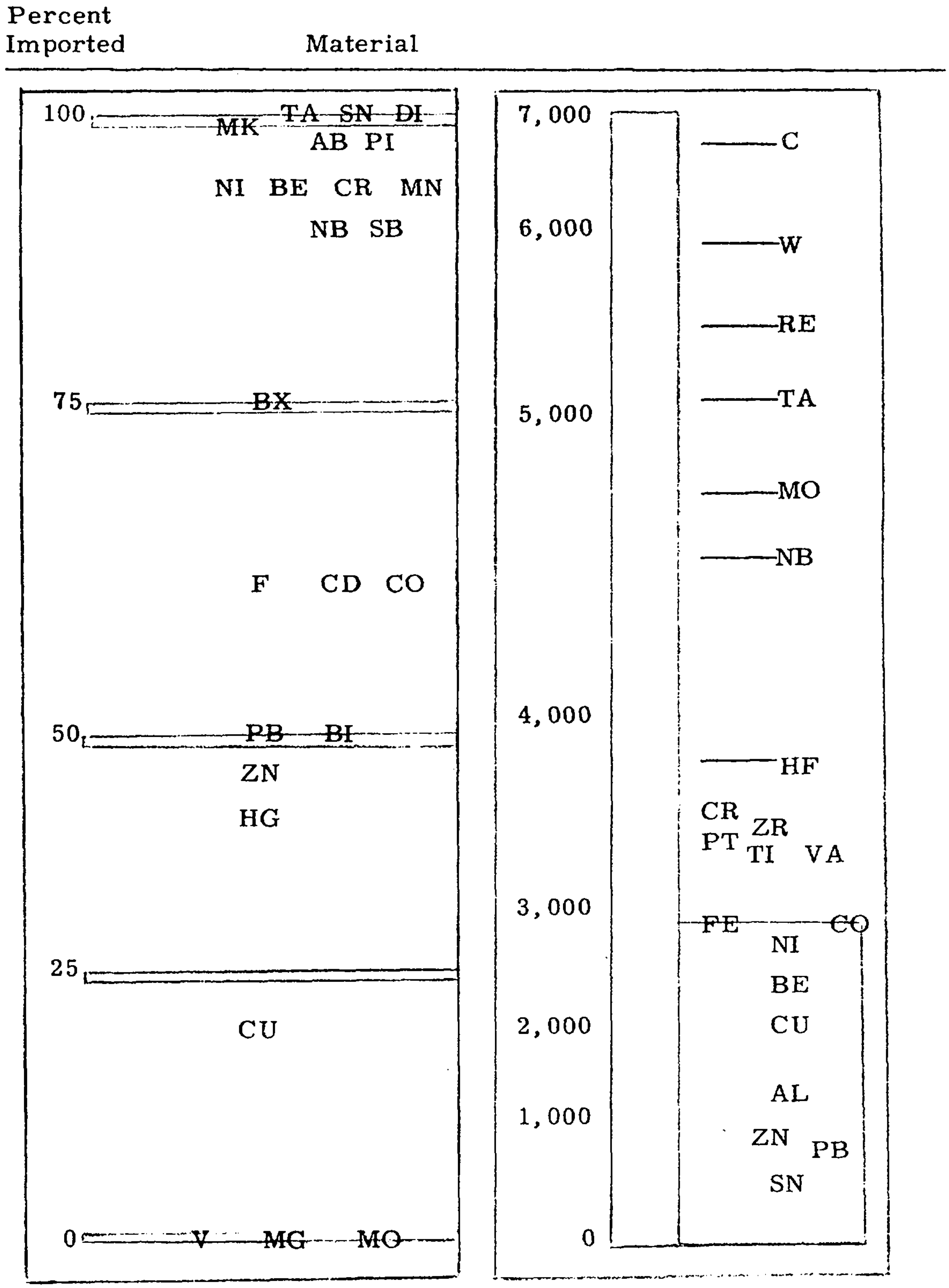
Percent
Imported
Material
100
MK
TA SN DI
AB PI
NI BE CR MN
NB SB
75
BX
F CD CO
50
PB BI
ZN
HG
25
CU
0
V MG MO
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
C
W
RE
TA
MO
NB
HF
CR
ZR
PT
TI
VA
FE
CO
NI
BE
CU
AL
ZN
PB
SN

Table 1 - Strategic Materials Imports in a recent Year (Metals and Minerals Only)

Aluminum	Manufactured, 75 percent from imported ores
Antimony	Import 85 percent of primary supply
Asbestos, amosite	Import 100 percent
Asbestos, chrysotile	Import 90 percent plus of strategic grades
Asbestos, crocidolite	Import 100 percent
Bauxite, abrasive	
Bauxite, metal grade	Import about 75 percent
Bauxite, refractory grade	
Beryl	Import 90 percent
Bismuth	Import 50 percent
Cadmium	Import 70 percent
Celestite	Import 95 percent
Chromite, chemical grade	Import 100 percent
Chromite, metallurgical grade	Import 90 percent
Chromite, refractory grade	Import 100 percent
Cobalt	Import 70 percent
Columbite	Import 85 percent
Copper	Import 20 percent
Corundum	Import 100 percent
Cryolite, natural	Do.
Diamonds, industrial — bort and stones.	Import 100 percent, synthetic process can produce some of requirements
Fluorspar, acid grade	Import 50 percent
Fluorspar, metallurgical grade	Import 65 percent
Graphite, Ceylon — crystalline and amorphous.	Import 100 percent
Graphite, Madagascar — crystalline and amorphous.	
Graphite, other than Ceylon and Madagascar—crystalline.	Nearly self-sufficient
Lead	Import 50 percent of primary lead
Magnesium	Manufacture from sea water
Manganese, battery grade, natural ore.	Import 90 percent
Manganese, battery grade, synthetic dioxide.	Manufacture from imported and domestic ores
Manganese, chemical grade, type A ore	Import 100 percent
Manganese, chemical grade, type B ore	
Manganese ore, metallurgical grade	Import 90 percent
Mercury	Import 40 percent
Mica, muscovite block, stained A/B and better	
Mica, muscovite block, stained B and lower	Import 98 percent
Mica, muscovite film, first and second qualities	
Mica, muscovite splittings	
Mica, phlogopite block	Import 100 percent
Mica, phlogopite splittings	
Molybdenum	United States produces 90 percent of world supply
Nickel	Import 90 percent
Platinum group metals:	
Iridium	Import 25 percent
Palladium	Import 98 percent
Platinum	Import 95 percent
Quartz crystals	Import 100 percent, can be produced synthetically
Rare earths	Essentially self-sufficient for cerium groups, problem could arise if demand for heavy, yttrium groups increases
Rutile	Essentially self-sufficient
Selenium	Essentially self-sufficient, part refined here from imported copper ores
Talc, steatite, block	Synthetic can meet needs
Talc, steatite ground	Essentially self-sufficient
Tantalite	Import nearly 100 percent
Tin	Import 100 percent
Tungsten	Can produce present needs at over market price
Vanadium	Present excess because coproduct with uranium
Zinc	Import 45 percent

QUESTION: I notice you failed to mention helium in your lecture. Recently I read an article in a magazine which indicated that scientists at the California Institute of Technology in a recent experiment had led helium through a nose cone at temperatures which normally around the nose cone reached 18,000 degrees, and, in leading helium through this small pinpoint hole, it formed a molecular blanket around the nose cone which kept the temperature to 2,500 degrees. Also in regard to helium, I have heard about the recent experiments made in pyrogenics with low temperatures in which I believe helium goes to 7.2 degrees above absolute zero. It moleculizes in one form and takes other forms in lower degrees. Will you please speak to that in reference to your high temperatures in metallurgy?

DR. MORGAN: Yes. Helium is a very important inert gas that was used initially by the military, as you all know, in dirigibles and blimps because of its fireproofness and lifting qualities. It's now used in imert welding applications. I cited argon as such a material. Helium can also be used. We are fortunately self-sufficient and in fact one of the few world sources. It is recovered incident to natural gas processing in the southwest of this country. Because of its strategic importance it was perhaps the first material to be put under full Government control. In other words, in World War I, when they had the question of the zeppelins, they made helium into a Government monopoly. It still is under the control of the Bureau of Mines, which regulates the civilian gas producers. Fortunately we are self-sufficient in helium and are using it in a number of defense applications.

QUESTION: Doctor, my question concerns fabrication, inspection, and testing of the static environment of some of the new materials you have mentioned--for instance the honeycomb construction. A static test of that would seem to be considerably more difficult than a straight rivet construction, and in the higher temperature the static testing of the substructure in a ground environment. Are the inspection and testing methods keeping pace with even the lagging material evolution that you pointed out in your discussion?

COLONEL BLACK: Could you all hear that?

DR. MORGAN: I can repeat the question. It is: Are we keeping pace in inspection and testing? I don't think we are at all, for the simple reason that we don't even have adequate production facilities to produce these materials and fabricate them in the first place. So obviously there aren't enough testing facilities to simulate those conditions under which the end items are going to operate. This gentleman asked about the honeycomb. It's a very good question. How do you test it without destroying it? You can take a certain number of them, and statistically determine that maybe 5 percent or something like that is a representative sample, and tear the 5 percent apart and see how they tear apart, and destroy the 5, and then assume the other 95 of them are all right. That's one way of doing it. But on many of these things we need a test of each item. On these honeycombs, for example, we are working on all sorts of methods of testing. Sonic and ultrasonic vibrations are being employed. They may spread the stainless steel wing section out, cover it with sand, subject it to sonic vibration, and the sand pattern on top will show different variations where it vibrates differently, where the honeycomb hasn't been attached and where it has. They are working on ultrasonic and electronic devices that would pass over a section and make a recording of the ultrasonic response, the vibration that you'd get back from it. Then the chart would show where the defective area was, if there was one, and so forth. But it takes a lot of correlation and sampling, to make sure that you really know that the end result is what you want. It's a very great area that is only being scratched as we get new materials.

QUESTION: About a year and one-half ago a laboratory process was announced for casting molybdenum. I was wondering what progress is being made for developing a commercial process for it.

DR. MORGAN: They are working on that, but that brings up a very interesting observation that I am glad you gave me the opportunity to make. As I said before, it isn't just having the material. It's how do you design it and fabricate it and use it? Let's say we had a pure piece of molybdenum. Let's say that a jet-engine blade, which is now made of nickel, and cobalt alloy and which stands up at 1,800, were to be made of pure molybdenum. It wouldn't stand up at 4,800 degrees Fahrenheit--the melting point, but we might think it would stand up at 3,300 degrees which would be 60 or 70 percent of the melting point. But that's with regard to melting point only. Now it happens that molybdenum is subject to catastrophic oxidation at elevated temperatures. If we get any oxygen in there it immediately picks up the oxygen and goes to pieces. So it isn't enough just to be able to make the part out of molybdenum. We are going to have to plate it, or coat it with something of equal or higher melting point, and preferably fairly flexible and soft so that it has a self-healing structure. Maybe the molybdenum will have to be plated with a platinum metal or with rhenium or something like that. In fact, what they find makes a very strong alloy is an alloy of one-third rhenium and two-thirds molybdenum. Well, the U.S. could readily produce

100 million pounds a year of molybdenum, but we've only got a few ounces of rhenium per year. So how many pounds of the end item can you make of a one to two part alloy if you've got millions of pounds of one and a few ounces of the other? You see the need for developing rhenium supplies.

The point that I want to emphasize is that all of our materials that we know of today are complex things. They are not just simple materials. Take reinforced concrete--it has steel rods in it. It has gravel carefully sized. It has the cement. We must use clean water for best results. We must design the configuration of the end item. We must put a sealing coat on the outside, and so forth. A whole lot of materials and technology go into making a usable thing out of even a simple material like concrete.

QUESTION: Sir, you indicated that much research has gone on in various diverse activities in this field in Government--Army, Navy, and Air Force--in universities, and in industry. My question is: What efforts have we made to catalog this information on a national scale, particularly proprietary information, from industry?

DR. MORGAN: That, sir, is a good one. Here I'll just point out a recent report from Merrill, Lynch, Pierce, Fenner & Smith on "Research and Development and the Investor." Of course each one of these companies likes to point out what they are doing, and make it sound impressive so that people buy the stock, and everything goes up. If you look through this report, every other page has materials on it. There's tantalum, zirconium, pyro-ceram, delrin, and a host of others. You'd think that everybody is doing nothing but working on materials. Well, there is a lot of work going on in different places. But the cataloging of it is extremely difficult because of our patent laws. In the first place, many of the companies want to get patent rights if they develop something. So they are not going to announce their half-successes part way along the line.

Perhaps even more important than patent rights, however, are in-house procedures in a company that aren't even patentable, but where they have the knowledge of how to do certain things--the so-called "know-how" that industry talks about. This enables a company to bid on successive contracts cheaper than their competitors. So there are many things in this field that they wouldn't even try to patent, because, if they took out the patent, they would disclose what they were doing. It's more important that they don't disclose it and so keep the know-how within the company so as to be able to put in the lower bid the next time.

Then there is the difficulty of communication. We have found our libraries of scientific knowledge in just English expanding at a far greater rate than the individual scientist or engineer, or even a team of them, can keep up with. I am glad to say that the Defense Department is taking a step forward in this direction. At Battelle Memorial Institute, which is generally considered one of the high-class centers of metallurgical research, the Defense Department has set up and funded with Defense Department money what they call a Defense Metals Evaluation Center. A lot of information from all over the world plus technical information from trips in the field by the Battelle scientists, is put together, and from time to time they put out reports on the state of the art for the latest materials. The Defense Department has done the same thing at Picatinny Arsenal for plastics. They have a Defense Plastics Evaluation Center at Picatinny. And the Defense Department is now working on ceramics which offer some promise in the high-temperature field. Ceramics are resistant to high temperatures. They are extremely brittle, though. They don't have the ductility and the flexibility of metals. So Defense is working now on setting up a Defense Ceramics Information Center.

The transmission of this information from man to man and the translation of what scientists report into what design engineers can use is one of the very great difficulties in this area, and again it is one of the areas where so much more needs to be done than what is going on now.

QUESTION: Doctor Morgan, I was glad to hear you refer to items that we do not and should stockpile. Do you have any suggestions as to how we can apply mobilization requirements at the top of the military so that we can manage to set up stockpile objectives and get to work? I am speaking specifically at the moment of tellurium.

DR. MORGAN: The great game in Washington in peacetime--and I fear almost everybody thinks this is peacetime--is to pass the buck to some other agency or to solve your problem with the other agency's authority. So I'll tell you how this goes. The OCDM, which is in charge of the stockpile program, writes a letter to the Space Agency, the Atomic Energy Commission, and the Defense Department, and says, "Please let us have your firm mobilization requirements for any materials we don't have on the list." Naturally, all these things are experimental and haven't been worked on. There aren't any firm mobilization requirements for anything, if anybody wanted to know the truth, because we don't know what kind of war we are going to have to fight tomorrow morning. If it's the all-out nuclear war, we are going to fight it with the weapons we have today. If it's a limited war, we are going to fight it with some more divisions than what we have now, I hope, and they are going to need more weapons and supplies.

Just prior to the Korean war we were sitting around with a $12 billion military budget, and the next year it was $60 billion when the Korean war started. What were the firm mobilization requirements on 24 June 1950? They were entirely different on 26 June 1950. They never were firm, but they were military requirements. And in any period of extended economic warfare our materials needs would undoubtedly be greater than in all-out war.

OCDM is in the clear, now. They say, "We wrote this letter to the three agencies." Well, the Defense Department, now has the ball. So they write to the Army, Navy, and Air Force, and, to doubly cover themselves, they write to the National Academy of Sciences, and say, "If you hear of anything, you let us know." So now Defense is in the clear, and the buck is passed to Army, Navy, Air Force, and the National Academy of Sciences. Then the services go out and ask their private contractors: "What materials do you see on the horizon?" They get a lot of letters back and forth.

What we need is someone with the scientific vision to look at the total table of elements and decide scientifically which ones are the likely ones to be used in the future, and then, shortcutting entirely this mumbo jumbo of firm military requirements, we ought to go out and get an adequate supply of these materials in the raw state while the getting is good. I'd like to suggest how that might be done without money, in case there is anyone here from the Bureau of the Budget.

We have on hand--and both political parties have expressed concern about--$9 billion worth of agricultural surpluses--$9 billion. They are stored, and they are deteriorating. We take about a 10 percent loss each year on them. So there's nearly a billion dollars lost each year on the $9 billion agricultural surplus. If we don't have firm enough military requirements to justify spending the taxpayers' money for new materials, we ought to barter for them. At least for the new ones that we don't have any of--it isn't a question of how much rhenium we should have, we don't have any of it--we ought to go out and barter some of the wheat, corn, cotton, and oats that are spoiling with anybody in the world (and I would even include the Russians in that, if they are silly enough to give us rhenium) for some of the rhenium and the things that we need.

But, when you examine the latest barter list which just came out on 4 November 1960, what do you find on it? This is the list of materials which they now take in exchange of surplus agricultural commodities--no money necessary: Antimony--away down on the bottom of the temperature chart; amosite asbestos--well, that's good; you can always use asbestos; bauxite, the ore of aluminum--we can always use some more bauxite; hand-cobbed beryl--that's a good one, because, though beryl is fairly low on the temperature chart, it has a very low weight and a high modulus of elasticity, and it has some interesting nuclear properties--so beryl is all right; bismuth; celestite, the ore of strontium; chrome--you see chrome on the chart; diamonds; fluorspar; a couple of insignificant grades of manganese; mica; and tin. We've got enough tin for more than five years already, piled up in the country, but they're going out to get more tin by barter. Why not some of these high-temperature metals? I just cannot comprehend why not.

QUESTION: With respect to some of the high-temperature metals that we are not stockpiling, and even though it might be a bit difficult to know which ones to stockpile if there had been a determination made scientifically as to which ones we should stockpile, what in your opinion would be the dollar volume of these that we should try to stockpile? Second: What are the problems of these metals in storing them or warehousing them, if any? Third: What has been the reaction of the Secretary of Agriculture and the Secretary of State to your proposal with respect to bartering surpluses for these metals?

DR. MORGAN: A very good question. First, the volume: Well, we have already stockpiled about $7.6 billion worth of the common strategic materials. That works out to be about $40 worth per man, woman, and child in the country. It's not too great an investment when you consider that industry is the life-blood of our national security in any type of war. We've stockpiled $9 billion worth of agricultural surpluses. That's about $50 worth per man, woman, and child. I can't resist as an aside: We've also stockpiled about $200 million worth of civil defense supplies, which is about $1 worth per man, woman, and child. Go to the drugstore and see what $1 will buy. That's what they have stockpiled for civil defense.

But, I'd say that of all these high-temperature materials, lumped together, it would be good to get another billion dollars worth--over some considerable period of time, because you have to get the people out searching for them, and get ways of concentrating them, and all that, which don't exist at the present time. If we stockpiled more metals and minerals storage charges would be minimal and there would be no losses by deterioration. Indeed, in the long run the value of metals and minerals can only appreciate.

As to the barter, it's true that the State Department and the Agriculture Department have both resisted barter. I can tell you why I think they have, though this may be an oversimplification. I used to think when I was a little boy that the State Department represented the U.S. interests abroad. I found after I worked in Washington for a number of years that they have another function--that they represent the foreign interests here. Why we have all the other embassies here in addition it's hard to understand, because State does such a very good job of it. And, with Canada and with Argentina, and New Zealand, and all these other countries with surpluses of wheat and whatnot, that they want to sell either for dollars or for sterling currency every time we barter something we foul up normal business for the Canadians and the New Zealanders and the others, and they come in and complain. So State comes in and says, "Our trusted allies are complaining," and then the program is pulled back. That's one reason.

Now I'll tell you about the Agriculture Department. If they let the agricultural surpluses deteriorate, or if they throw them away--and a billion dollars or so is lost through deterioration or storage charges every year--why they just go to Congress and get an appropriation to reimburse the Commodity Credit Corporation's borrowing authority. They go to Congress and say, "Well, you farmers up here voted this purchase legislation. The stuff has spoiled now, so we need another billion to make the CCC whole." The result in that case is, the commodity is thrown away, and the taxpayer pays the additional billion dollars to make the CCC whole. Now, if they'd follow the barter route, the agricultural commodity would go abroad and would feed somebody. Maybe he couldn't pay for it in dollars anyway. Secondly, a strategic material would come back here and go in our stockpile. The CCC would still have to be made whole financially. So the Congress would appropriate exactly the same amount of money, to make the CCC borrowing authority whole, but in the second case the taxpayer would have a stockpile of additional strategic nondeteriorating materials of some value. But it's easier for the CCC not to bother with all that. The easy bureaucratic route is just to get the appropriation, unless somebody tells them to do it the other way. So the combination of the two pressures results in this very small barter activity.

COLONEL BLACK: John, our time is practically up. I think that you have really taken us beyond the new frontiers of physical knowledge. I am sure that because of your able efforts this morning we better understand and appreciate the many, many problems causing this new materials barrier.

Thank you very much for being with us.

(15 June 1961--5,000)O/de:dc