MATERIALS FOR THE PRODUCTION OF ATOMIC ENERGY

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Mr. Jesse C. Johnson, Director, Division of Raw Materials, Atomic Energy Commission, was born in Clallam, Washington, 2 February 1894. He was graduated from the University of Washington in 1917, having majored in mining engineering. After a brief period of service in the Army, Mr. Johnson entered the mining business and for a number of years was a consulting engineer with offices in Seattle, Washington. In 1942 he accepted a position with the Reconstruction Finance Corporation on the wartime metals program. He began his RFC work as an engineer and served as Chief Engineer from June 1944 to January 1946. He became Deputy Director of the Office of Metals Reserve in January 1946 and served in that capacity until January 1948. During this period he was in charge of domestic and foreign procurement of tin, lead, copper, and other metals; the metals subsidy program; and the metal production programs operated by Metals Reserve. Mr. Johnson joined the Atomic Energy Commission in January 1948, becoming Assistant Manager in Charge of the Domestic Production section of the Raw Materials Operations Office. He was promoted to the position of Deputy Manager, Raw Materials Operations Office on 18 September 1949 and to the position of Manager on 1 January 1950. He was appointed Director, Division of Raw Materials, effective 16 March 1951. This is Mr. Johnson's second lecture at the College.

MATERIALS FOR THE PRODUCTION OF ATOMIC ENERGY

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COLONEL DAVIS: Gentlemen, this morning we have the third in the series of lectures on natural resources.

The importance of the subject, "Materials for the Production of Atomic Energy," would be difficult to overemphasize. It is all too clear that victory in the next major war may well depend on the availability of raw materials for, and the ability to produce, atomic weapons. It is equally clear that atomic power and other benefits of the nuclear age will soon become an essential element of economic strength, not only in this country, but certainly, and probably sooner, in friendly western nations.

The speaker this morning is the Director of the Division of Raw Materials of the Atomic Energy Commission, Mr. Jesse C. Johnson. He is uniquely qualified to discuss the various aspects and problems of the provision of raw materials for atomic energy.

Mr. Johnson, it is again a pleasure to welcome you to the platform of the Industrial College of the Armed Forces and introduce you to the Class of 1958.

MR. JOHNSON: Thank you, Colonel Davis.

The subject, "Materials for the Production of Atomic Energy," might cover quite a large number of items, but there is but one basic material and that is uranium. Materials for structural purposes--steel, concrete, and particularly stainless steel--go into the large atomic energy installations; but these are obtained through the commercial markets, and we do not look upon them as special materials for the atomic energy program.

There are a number of other materials as well that are obtainable through the commercial markets, but have found special uses in atomic energy. I shall list these quickly at the beginning, of my talk.

However, without uranium there could be no atomic energy program, because uranium is the only material occurring in nature that is a fissionable material. The fissionable isotope, U-235, constitutes but

seven-tenths of 1 percent of natural uranium. So that in our search for natural uranium, at the start we are primarily interested in an isotope which constitutes only seven-tenths of 1 percent of the metal. However, in the course of the operation of a reactor, some of the U-238, the more plentiful isotope in natural uranium, is converted into plutonium, a fissionable material that is not present in nature.

Thorium also is capable of being transformed into a fissionable material, U-233. Consequently thorium, along with uranium, is one of the two materials that have been designated under the Atomic Energy Act as source materials; and any transactions in thorium as well as uranium are subject to license.

Of the miscellaneous materials having some special importance in the atomic energy program by reason of their nuclear properties as well as structural properties, zirconium is one. The chief use of zirconium metal is as a structural cladding and core alloying material, principally for naval reactors. Zirconium has low neutron capture cross-section, which means that it is relatively transparent to the flow of neutrons. It must be of high purity and free of hafnium.

Hafnium also has a use based on its ability to absorb neutrons, which is the opposite of zirconium. At first hafnium was considered to be, and was, a very undesirable impurity in zirconium. All of the hafnium we obtain is from zirconium ores. So that hafnium has the property of neutralizing, you might say, the desirable property of zirconium. But hafnium, an impurity removed from zirconium ores, now is a material of major importance for control rods for reactors. It is possible that the demand for hafnium may exceed the amount produced as a byproduct in the refining of zirconium. In that event hafnium could become the primary product in processing zirconium ores.

Beryllium also has special nuclear properties. It is an extremely light metal. Beryllium is used in nuclear reactors as a moderator and a reflector; and it is of special interest for certain types of military reactors, such as reactors that might be used for airplanes.

Prior to the development of uses for atomic energy beryllium metal was not available commercially in the purity required. Beryllium alloys, however, had a number of important industrial and military applications. One of the earlier projects of the Atomic Energy Commission was the development of a refining process to produce beryllium metal of very high purity. As a result of this development work, beryllium

metal of reactor grade is now supplied by commercial firms; and the Commission no longer is operating a refinery.

Graphite of high purity has two principal uses in our program. One is as a moderator in graphite reactors of the Hanford type. The other is for crucibles for casting certain high-purity metals. Special high-purity graphite is required to prevent contamination from the crucibles. Synthetic graphite is used for both purposes, as natural graphite is not sufficiently pure.

The problem of obtaining a high-purity graphite during the early stages of the atomic energy program was an extremely important and difficult one. When a synthetic product was developed, the process of making it was one of the tightly held secrets. But apparently the production of reactor-grade graphite now is generally known to those countries engaged in atomic energy activities.

Liquid sodium may have application as a reactor coolant, and also as a carrier of nuclear fuels in a liquid metal fuel reactor. Commercially available sodium is usually sufficiently pure for the purpose.

Bismuth of high purity may also have potential use as a liquid metal for a pure reactor because of its property of being able to dissolve uranium. It could be used in some type of homogeneous reactor. The question is whether there would be ample bismuth suppliers for wide use of reactors using bismuth in commercial application.

Substantial quantities of high-quality aluminum are used as cladding for fuel elements. Aluminum also may be alloyed with fuels in certain types of reactors. Aluminum of sufficient purity for reactor use is available in the commercial market and there is no supply problem.

Titanium of high purity also is used in some extent in the reactor program, and the use may be extended.

That roughly represents the list of the more important types of strategic metals used in the atomic energy program other than uranium.

Uranium is the basic material, as I have mentioned, for the atomic energy program; and all expansions in the military weapons program had to take into consideration the supplies of uranium that would be available.

The production of industrial power from atomic energy also will be dependent upon the supply of nuclear fuels--uranium and possibly thorium.

I need not point out to this audience the importance of atomic weapons and atomic power units to our military position. The Government now has an investment of more than $6 billion in facilities for the production of fissionable materials and weapons. Although the plants for refining uranium and producing fissionable materials can to a large extent be used to support the power program, the present investment was based almost entirely upon the need for the weapons program. The figures given do not include the cost of uranium mines and ore processing plants. With few exceptions, these operations are privately financed and operated.

The development of atomic power for industrial use still is in the initial stage. Yet this Government and American private industry have already spent or committed about a half billion dollars for research, development, construction, and prototype plants. Additional hundreds of millions will be spent before competitive atomic powerplants are in operation in this country.

Because of higher power costs and the urgent need for energy sources, European countries are prepared to construct full-scale atomic powerplants on the basis of present reactor technology. Britain has started a 10-year program that will involve a total expenditure on the order of 3 billions of dollars, and is expected to have an installed capacity of nuclear power equivalent to about 6 million kw.'s by 1967. That will supply about 15 percent of Britain's power, and the nuclear fuel will do the work of about 18 million tons of coal annually.

The Euratom program, which is under consideration and under planning by the Euratom countries, calls for an atomic energy power development that would supply about 15 million kw.'s by about 1967. Although this program is only in the exploratory stage, there is no question about the need for the additional power. There seems to be no question but that electricity can be produced with present reactor technology at a cost that would be competitive with or cheaper than imported conventional fuels. Most of the European countries today have fully developed their hydroelectric resources, are operating their coal mines to the fullest extent, and are importing coal or oil from overseas. We are supplying coal to many of the European countries, including Great Britain. "Hauling coals to Newcastle" is no

longer an absurdity. Coal laid down in Europe costs from $16 to $20 a ton, that is, the American coal.

In France the cost of power at the present time is reasonably economic by European standards. But the head of the French Atomic Energy Commission said that for incremental power they cannot see a cost less than one to two cents per kilowatt-hour; and that if nuclear power could be available at a cent and a half per kilowatt-hour, it would be the answer to future power growth. The target now--and the Europeans believe they can reach this target--is about one cent a kilowatt hour using present reactor technology. Power at that cost would not be commercial in the United States, where our average costs are five to eight mills. In certain areas with low fuel cost or where hydroelectric power has been developed on a large scale, we have costs around three mills.

I would like to go back for a moment to the establishment of the raw materials program at the beginning of 1948--just about 10 years ago. We then had the problem of assuring adequate supplies of uranium for defense, with special emphasis on finding and developing new sources of production on the North American continent.

In 1948 we had only three sources of supply--the Shinkolobwe mine in the interior of the Belgian Congo, the Port Radium mine on Great Bear Lake on the Arctic Circle, and the vanadium-uranium deposits of the Colorado Plateau. More than 90 percent of our uranium was coming from Shinkolobwe mine. It had to be shipped 1,400 miles by rail and river to reach the coast, and 7,000 miles across the Atlantic to our east coast. Our whole atomic energy program, our weapons program, at that time depended largely on that one mine. The production in Canada was relatively small.

The problem then was to expand production wherever possible. Neither the Shinkolobwe mine nor the Great Bear mine was in position to expand substantially. They were small mines, limited in size, with an uncertain life.

The Great Bear Port Radium mine is 1,200 miles by lake and river north of railhead. Seven transfers are involved along this water route, including two truck hauls to bypass rapids. For nine months of the year the water route is closed by ice, and for nearly two months the mine is inaccessible even by air. This small mine offered no promise for expanded production.

At the beginning of 1948 there was very little uranium production on the Colorado Plateau. There had been no production in 1946 following the wartime treatment of accumulated vanadium mill tailings. The deposits that were known and had been developed over a period of 10 to 20 years were all small, and a production rate of a few hundred tons of uranium oxide a year was all that was reasonably certain.

Aside from these three sources, we knew of some small deposits in Portugal, some low-grade phosphate and shale deposits in the United States, and uraniferous gold tailings of South Africa.

The South African gold tailings offered the best chance of a large new source of uranium. Between 50 and 60 million tons of gold ore were being mined annually, and about one-third of this tonnage contained from a quarter of a pound of uranium oxide to one pound per ton, averaging about half a pound. The remainder, mostly the ores of the Main Reef series around Johannesburg, contained only about a tenth of a pound or less of oxide per ton. There was enough of the so-called higher-grade material for a major program. So the tailings that contained less than one quarter of a pound of oxide were not considered in our program.

The large reserves of phosphate rock in this country contain from one-fifth to one-tenth of a pound of uranium oxide per ton. But even with an annual phosphate rock production of about 10 million tons, we could hope for only a few hundred tons of byproduct uranium a year. The use of commercial-grade phosphate rock for the sole purpose of uranium production is almost out of the question economically.

We have billions of tons of uraniferous black shale in Tennessee and adjoining States, but 10 to 15 tons of this material would have to be mined and chemically processed to obtain one pound of uranium. The cost of uranium would be extremely high. It would be from $30 to $50 a pound. But even this source had to be considered.

So in 1948 the Commission found itself with the ore supply I have just outlined, $2 billion of facilities for the production of fissionable materials, and a $3 billion expansion program under consideration. Atomic weapons had become the most important element of our defense planning. The military requirements for fissionable material had to be met. Our one big hope, of course, was the discovery of large high-grade uranium deposits, new Shinkolobwes.

There was little question about the things we had to do, but how to get them done was another matter. The principal objective of the raw materials program were these: To assure maximum continuing production from the Skinkolobwe and Port Radium mines; to initiate extensive prospecting and exploration of favorable areas of the world, particularly in the United States and Canada; to obtain available production from Portugal; to develop an economic process for recovering uranium from South African gold tailings and get a production program under way as soon as possible; to develop a process for recovering byproduct uranium from our wet-process phosphate fertilizer and chemical operation; and to be prepared to utilize our low-grade shales in case of necessity.

Now, I shall attempt to give you some figures on how these programs developed and tell you something about the nature of those developments.

The South African program, which was initiated by a production contract in 1950, now involves 17 uranium plants, drawing tailings from 27 mines. The uranium plants range in capacity from 40,000 to more than 200,000 tons of tailings a month, with a combined treatment rate of approximately 1.8 million tons of tailings per month or 22 million tons a year.

In addition, eight flotation plants, with a combined capacity of 1 million tons of tailings a month, recover pyrite from a portion of the uranium plant tailings. Seven sulphuric acid plants will burn approximately 40,000 tons of pyrite a month to produce 45,000 tons of sulphuric acid needed for dissolving the uranium out of the tailings.

The total cost for the uranium, flotation, and sulphuric acid plants is about $190 million. Two-thirds of the financing was done by the Export-Import Bank, and one-third by the British Ministry of Supply. Britain and the United States are in partnership in the production from South Africa, in the Congo, Portugal, and Australia.

The uranium process used for the South African ores is essentially this: The gold ore slimes are digested in sulphuric acid in large rubber-lined tanks. Following digestion, the pulp is filtered and the filtrate goes to an ion-exchange section. The uranium is absorbed on ion-exchange resins and then eluted from the resins with ammonium nitrate.

Lime is then added to the eluate to reject the iron and sulphate, and the solution is treated with ammonia to precipitate the uranium. The uranium precipitate is then repulped to about 35 percent solids; and the slurry, the final product of the mills, is shipped by tank truck to a central calcining works, where the slurry is weighed for payment, calcined, and packaged in drums for shipment. The central plant is owned by the Combined Development Agency, the partnership organization of the United Kingdom and the United States. The product shipped will average about 80 to 85 percent uranium oxide.

The Canadian program upon completion of construction now under way will be about as follows: The small original mine and mill at Great Bear Lake near the Arctic Circle. That mine will be about exhausted in 1959. A 150-ton mill near Yellow Knife on Great Slave Lake. Three mills in the Athabasca area, with a combined capacity to treat 4,500 tons of ore daily. Eleven mills in the Blind River district of Ontario, with a combined capacity of 34,000 tons of ore per day. Three mills in the Bancroft area of Ontario, with a combined capacity of about 2,500 tons per day.

With the exception of one property in the Athabasca area and the Port Radium Mine, both of which are owned and operated by the Canadian Government, the Canadian uranium operations, as in the United States, are privately owned and operated and were financed by private capital.

The total capacity of all Canadian uranium mills will be approximately 43,000 tons of ore per day. Production is estimated to reach 14,000 to 15,000 tons of uranium oxide annually by 1959. The total investment in uranium mines and mills will then be between $300 and $400 million.

In the United States program we now have 12 mills in operation, with a daily capacity to process approximately 9,500 tons of ore. Mine production and milling rates are about in balance at the present time. Ten new mills, which are under construction or covered by contract, will increase the total milling capacity by about 10,000 tons of ore per day, or up to about 20,000 tons. This rate of production should be reached about the end of 1958, when the domestic production of uranium oxide will be from 15,000 to 17,000 tons a year.

We are the leading uranium producer of the world at the present time. This year Canada will be in second place, and South Africa in third place.

This represents a major change in both the production rate and the production pattern since 1948. We had no domestic production in 1946, practically none in 1947, and little in 1948. Total production at that time was relatively small throughout the world; and had it not been for the development of the Commission's atomic energy program, there today would be little basis for the development of large reactors for power. The British power program could not have been under way, and the Euratom program probably would not be under consideration.

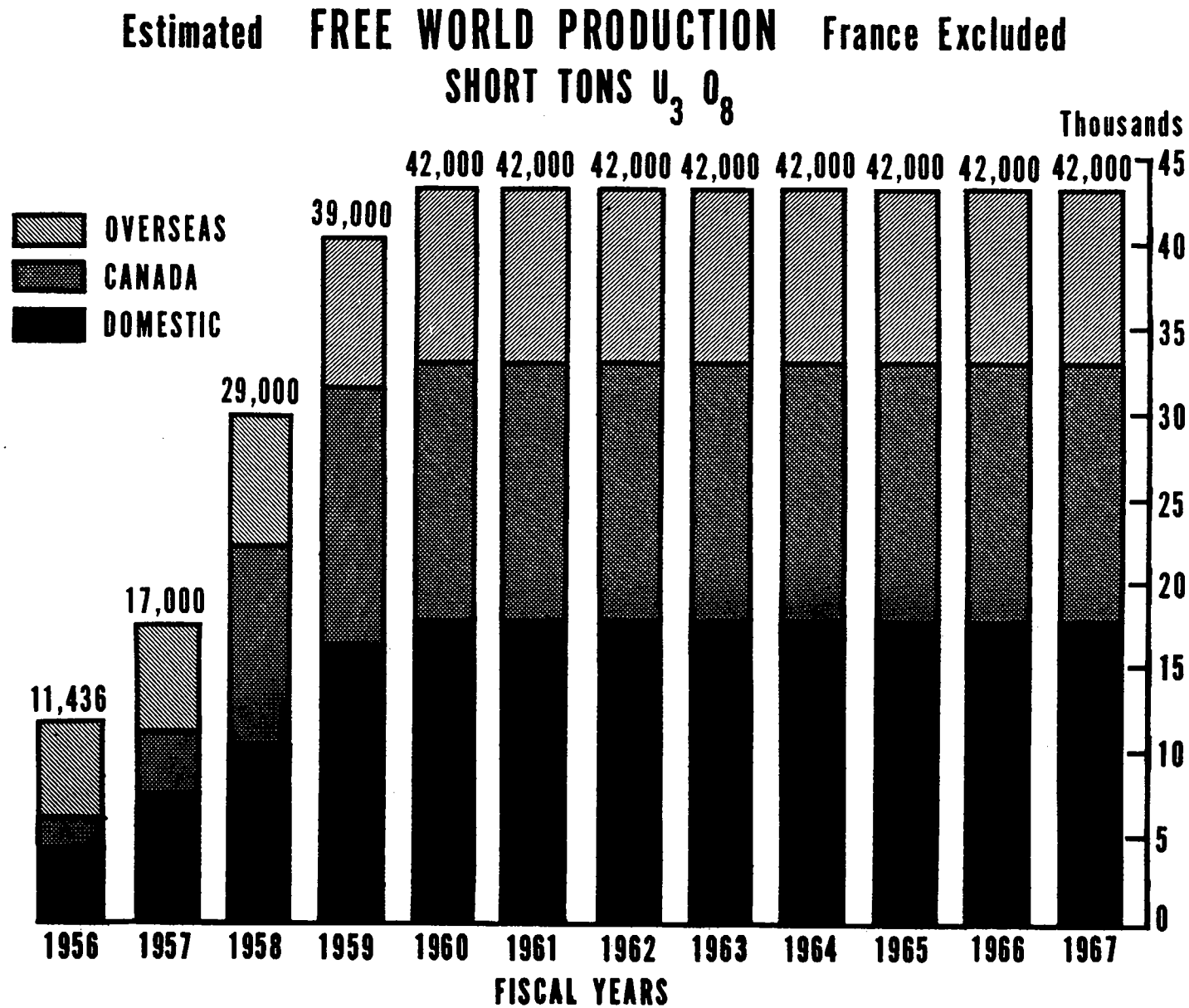
The expansion of uranium production and the development of uranium resources have made possible the industrial atomic power program.

As for the military program, it would have been possible, of course, to obtain most any quantity of uranium that the military desired at a price. We could have obtained uranium from shale at a cost from $40 to $50 a pound. Today the average cost of uranium oxide to the Commission is around $10 a pound; and it is being reduced by new technology and larger mills to about $8. We look for a market price of about $8 a pound by 1962. The Commission has established a buying program from 1962 to 1966 with a guaranteed price of $8 per pound.

In Canada and in the United States the initial period was one of interesting private capital, particularly the prospectors, to get out in the hills and find uranium. To do that, both countries established guaranteed prices for uranium ores and other incentives in order to get out the thousands of prospectors who are really responsible for the new discoveries made in the United States and Canada. It was as a result of this program, which took three or four years before it finally bore fruit, that today North America is the world's most important source of uranium, and will be producing over 80 percent of the uranium outside of the Iron Curtain by the end of 1958, and the United States is the leading producer of the world.

This chart, page 10, indicates the change in the free world since 1956. The production prior to 1956 is classified. So on an unclassified basis we are able to show only the world production from 1956 on through and project it through 1967.

The 1956 production was 11,000 and a fraction. It gets up to 17,000 and then gets up to 29,000. The United States production is on the bottom in the heavy part. The Canadian is above. Our production gets up to about 18,000 tons a year. The Canadian will be about 14,000. If you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went back to 1946, the dark line on the bottom would be zero. The Canadian was small. A major part of our uranium came from overseas until about 1953.

The United Kingdom is a partner with the United States in overseas purchases. The uranium has been allocated by the two countries on the basis of their respective requirements. The United Kingdom also is now purchasing some Canadian uranium. The total amount that will be available to the United States will be something in excess of 30,000 tons a year.

Now, I might make just a few comments on the future of uranium.

On the reserve position, the United States now has estimated reserves of about 70 million tons of ore, containing about 175,000 tons of uranium oxide. Canada's official estimate is 225 million tons of ore, containing about 237,000 tons of oxide. South Africa has an estimate of 370,000 tons of uranium oxide, in over 1 billion tons of ore. Total world resources, as we know them, resources of the type that could supply uranium at around present commercial prices, would be about 1 million tons. Much of this, however, must be produced over a long time.

Requirements for uranium are extremely difficult to predict. One of the estimates recently made by an AEC analyst indicates that by 1960 civilian and United States military may be from 23,000 to 37,000 tons a year of uranium oxide.

For 1965 the estimate for civilian power demand, domestic and foreign, is about 11,600 to 16,600 tons a year. By 1970 civilian power, domestic and foreign, is estimated to require in the range of 33,000 tons to 48,000 tons of uranium annually. By 1975 the range may be 67,000 to 100,000 tons and by 1977, 90,000 to 137,000 tons per year.

These are civilian requirements. If the military demand is superimposed on that, the total requirements may be from 100,000 to 150,000.

The free world production rate for 1959 is projected at 42,000 tons annually. This year the domestic production will be around 9,000 to 10,000; but by the end of 1958 it will be between 15,000 and 18,000 tons.

Our immediate position is one where existing production, plus the production that will come in from plants now under construction or planned, will be about equal to the requirement. Instead of the policy that we pursued in the past, of getting all we could as fast as we could, the Commission's policy will have the objective of attempting to hold uranium purchases at a level consistent with reqirements, and at the same time encourage the development of new domestic resources, so that there will be resources to support the industrial power program of the future.

Thank you.

COLONEL DAVIS: Mr. Johnson, I believe that everything so far has been unclassified.

MR. JOHNSON: That is correct.

COLONEL DAVIS: If anything comes out during the question period that is otherwise, Mr. Johnson will say so.

Gentlemen, Mr. Jonnson is ready for questions.

QUESTION: Could you tell us generally what is known of the uranium resources of the Soviet bloc and the adequacy of those resources to meet the Soviet requirements?

MR. JOHNSON: I do not know. Apparently the Soviets are finding enough uranium for a rather large program. We were familiar with the Joachimsthal deposit of Czechoslovakia, which had a long history before the war. It dates back to 1600, as a silver mine. We felt that as long as the Soviets were pouring thousands of slave laborers into those operations--and all I know is the reports in the papers--it was reasonable to assume that they had no large, rich deposits in the hinterland. Recently I have seen no such reports. This might indicate the development of more economic sources.

QUESTION: Could you tell us what progress has been made in recovering the uranium that has been put through the piles?

MR. JOHNSON: There is no major loss. I am not familiar with the details of the waste recovery operations, if that is what your question relates to.

First, in all of the operations along the line, scrap material is recovered. Of the material that goes into Hanford for the manufacture of plutonium, the rods are all taken out and redissolved and the plutonium separated and the uranium recovered. The gaseous diffusion plant at Oak Ridge separates the isotope U-235; and the isotope U-238, depleted in the U-235, is stored in containers. So that most of the material that has gone into the program is still in stocks. It has not been discarded as waste or lost.

QUESTION: You have partly answered my question, but what happens to the U-238 that has been depleted? And the second part of my question is, Is there any further use for the U-238 that is stored in these tanks? Is anything being developed in the way of use for that U-238?

MR. JOHNSON: Since the development of the atomic energy program, uranium has not been available for commercial use except in some very small quantities for essential chemical uses.

Prior to the atomic energy program, I think the main use for uranium was by the ceramic industry. There apparently is a market now in the ceramic industry, for coloring enamels for washing machines, refrigerators, and those things--a nice yellow or orange color. But I don't think that market will be very large. However, it is quite likely that the Commission may offer U-238, depleted in U-235, for sale; and possibly new markets will develop.

U-238 has a potential use in reactors as a blanket. It could be converted into plutonium. At present I doubt if there is any sizable market available for the depleted U-238, although potentially it may be a very valuable material.

QUESTION: Is there an immediate requirement by the Government for the tonnages of uranium that are being extracted, or is this a development phase with the material being stockpiled?

MR. JOHNSON: The production of uranium since the beginning has always been required immediately for the program. That program during all the earlier years was entirely military. As you know, recently the President has made available substantial quantities of enriched uranium for power development. But even during the past year our problem has been to get enough uranium to operate the production program at full capacity.

But, looking ahead to the end of 1958, the requirements, as we now see them, and the supply should be about in balance.

Depending upon what happens to requirements, we could have some over-production; or we may have to expand the production. During the 10 years that I have been with the program, the requirements have changed only one way, and that's been up. We may have reached the point here where there might be a change in direction.

QUESTION: How effective is aerial exploration, and at what depth under the surface can you detect uranium deposits? What percentage of the United States do you estimate has been explored by air?

MR. JOHNSON: As to the first part of your question, a covering of a few feet of earth, possibly less, is an effective shield. So you would probably be unable to detect buried uranium deposits with a Geiger counter even on the surface. The airborne work detects only exposed deposits.

The type of flying that has been most effective in the United States has been low flying. High flying has the disadvantage of recording large masses of higher-than-normal radioactive rock in the same manner as small concentrated deposits. So it's impossible to tell with the plane flying at a thousand feet or more in elevation whether the anomaly is a result of a significant ore body or from a large low-grade shale deposit containing higher-than-normal radioactivity.

Private industry has found a number of important deposits in the United States as the result of airborne work, including the largest that has been found, the Anaconda deposit. The flying has been concentrated in those areas where there are outcrops, such as the desert areas of the Colorado Plateau, New Mexico, Wyoming, and other areas where there has been some basis for believing that exposed uranium deposits might occur.

In going into a foreign country we would recommend aerial surveying to follow, not precede, geological reconnaisance that would select the favorable areas in which to look. Aerial traverse lines should be reasonably close together. So it is not adapted to general reconnaisance.

QUESTION: You mentioned the fact that in the United States the cost per kilowatt-hour of power runs from about seven mills down to

as low as three mills where there is hydroelectric power available. Nevertheless, there is the production of atomic energy electricity power under way in the United States. Would you tell us what is the expected cost in mills of power from those developments, and whether or not these are completely private developments or whether the United States is in some way subsidizing the activities?

MR. JOHNSON: You are getting into a field where I can't speak with any authority. The atomic powerplants, except for military purposes, now being built in the United States are not for the production of power primarily, but for information. In other words, they are pilot plants and not expected to be economic. The Government is building a reactor at Shippingport, which will be dedicated some time this fall. The private company is paying for the turbines and electro-generating equipment, but the reactor is Government-financed.

QUESTION: Would you give us a feeling for the possibility of lessening requirements for U-238 due to our ability to fuse lighter elements?

MR. JOHNSON: I am not qualified to pass judgment on the fusion process. I have been very interested in trying to get the answer. But the people working on it shrug their shoulders and say, "The uranium business has nothing to worry about."

The first problem is to find out whether fusion is scientifically feasible. If it is--and that's apparently a big problem--then the question is whether it will be economically feasible.

I also understand that if it's practicable at all, it will be for very large plants. Now, what a very large plant would be, I don't know. Maybe a million kw. It might have special application and still leave plenty of room for the atomic energy fission plant.

Certainly the European program and the British program--the British are working on fusion as well--and the Commission's program on power are not based upon any idea that the fusion process is going to be competitive in any near-term period. By "near term" I assume is meant 20 to 30 years or more in the future.

COLONEL DAVIS: Mr. Johnson, you have given us a very informative lecture and very useful answers to our questions. On behalf of the class, I thank you, sir, very much indeed.

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