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MATERIALS FOR THE PRODUCTION OF ATOMIC ENERGY

Mr. R. L. Faulkner

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INDUSTRIAL COLLEGE OF THE ARMED FORCES

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MATERIALS FOR THE PRODUCTION OF ATOMIC ENERGY

30 November 1955

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MATERIALS FOR THE PRODUCTION OF ATOMIC ENERGY

30 November 1955

COLONEL NYQUIST: The classification of the lecture this morning is unclassified.

It is doubtful if any of us in this room ever heard of atomic energy or the atomic bomb prior to the closing days of World War II. However, in the past ten years there has been so much discussion and so many articles written on both atomic energy and the atomic bomb that now even our children in the grade schools are well aware of its importance. So today we are going to devote our time to that portion of the course in Natural Resources which deals with the "Materials for the Production of Atomic Energy."

Mr. R. L. Faulkner, assistant director for Foreign Procurement, Atomic Energy Commission, whose biography has indicated to all of you his excellent qualifications to discuss this subject, will now talk to us on "Materials for the Production of Atomic Energy." It is my pleasure now to introduce to you Mr. R. L. Faulkner.

MR. FAULKNER: General Hollis, General Calhoun, Colonel Nyquist, Members of the Faculty, and Students:

As part of your study of natural resources, I have been asked to discuss the materials essential for the production of atomic

power and fissionable products, including radioactive materials.

Since previous lecturers have covered materials for the production of steel and its alloys, as well as nonferrous and light metals resources, I will confine my talk largely to radioactive materials. There are several less common metals, however, that have particular application to reactors which I should touch on briefly before going on to talk about uranium and thorium.

Selection of reactor components has involved many compromises and a continuous effort to develop new alloys and to test new materials. The development and testing of better materials to meet the needs of the high temperature reactors planned for power production is a pressing problem. Testing may involve long periods of exposure to high temperatures and high radiation in various cooling media to determine dimensional stability and resistance to corrosion. Much remains to be learned about the behavior in reactors of even the more common materials.

Three of the metals which have come into prominence with the atomic age are zirconium, hafnium, and beryllium. All have specific properties which make them useful, particularly in reactors using natural or slightly enriched uranium. They

also have their limitations.

Zirconium appears to have important applications in future reactors because of its low cross section for thermal neutrons, which is the physicist's way of saying that thermal neutrons pass through it readily without being absorbed and thus consumed. When alloyed with 1.5 percent tin and small quantities of iron, nickel, and chromium, it has fair strength at high temperatures and excellent resistance to corrosion.

The alloy is used as a cladding for uranium fuel elements in power reactors and as a structural member of fuel element assemblies. Uranium and its alloys generally have poor corrosion resistance; cladding is required to overcome this and to contain the fission products. Low temperature reactors have used slugs canned in aluminum, which also has good nuclear properties but a much lower melting point. Zirconium's first important application was in the prototype submarine reactor and the later model used in the Nautilus. At the present time, metal production is small, perhaps 250 tons per year, but with increasing demand, this production rate will almost certainly double or treble over the next few years. The price of about $40 per pound for zirconium sponge will come down as output goes up. Melting

and rolling to strip approximately doubles the $14 figure.

Zirconium's favorable nuclear properties were not recognized until about six years ago, principally because all of the metal available for examination up to that time was contaminated with a small amount of hafnium, which has a high neutron cross section and readily stops neutrons.

Zircon, a silicate of zirconium, is the principal raw material. Many deposits are known and it should be readily obtainable in the quantities desired. Hafnium is present in all zircon, averaging about two percent on a metal basis. Over half of the zircon going into United States industry, at present about 45,000 tons per year, is imported from such countries as Australia and Brazil, with United States production on the order of 16,000 tons. United States reserves in Florida, Idaho, California, and Oregon are estimated at some 7 million tons of zirconium. World reserves should be several times this figure. The present price of zircon is $60 per ton.

The control of a reactor is obtained through the use of high cross section materials which are inserted into, or withdrawn from, the core. Hafnium, which was accumulating as a useless by-product of zirconium production, proved to be excellent for

reactor control because of its high neutron cross section, resistance to corrosion which eliminated the need for cladding, high melting point, fabricability, and long reactor life. Early interest centered on cadmium or boron alloys and compounds but these require cladding for strength and for corrosion resistance. Cadmium has the disadvantage of a low melting point, 321 degrees C. Boron alloys have the disadvantage of brittleness. In view of these disadvantages, some new designs are based on the use of hafnium. Other materials having high cross sections are also being investigated.

Materials known as moderators are needed in reactors to slow down neutrons emanating from the fissionable material, scatter them, and increase the probability of collision with the uranium or other fertile material--thus sustaining the chain reaction. Carbon, which is extensively used in plutonium-producing piles, and beryllium and its oxide, are the only good solid moderators. Other moderators are water, heavy water, and organic compounds containing hydrogen, deuterium, and carbon.

Beryllium's excellent nuclear properties have led to its use or consideration in a number of reactor designs. In addition, it is light in weight and has a high melting point. Unfortunately,

in the purity normally obtainable, it is nonductile and has poor corrosion resistance to water at high temperatures. Nevertheless, the advantages suggest application to reactors in which high temperatures are contemplated, where weight is important and cost is a secondary consideration.

However, beryllium is expensive. In the form of vacuum-cast billets, costs range from $50 to $75 per pound, depending upon production rate. In finished, machined shapes, the cost per pound may be substantially higher, depending on the amount of machining, grinding, etc. required.

The only commercial source of beryllium is beryl, a beryllium aluminum silicate, occurring as scattered crystals in pegmatites. The beryl crystals are hand sorted to make a fairly clean beryl product carrying on the order of 10 percent beryllium oxide. Both demand and price have fluctuated widely over the last five years. At present beryl is selling at about $400 per long ton.

Most of the beryl is produced as a by-product of mining operations for other products such as feldspar and mica. These, in turn, are in irregularly distributed masses within the pegmatite. Mining is thus a gophering operation with the miners attempting to

follow and mine the richer zones. Reserves are difficult to estimate, although some attempts have been made based on experience factors.

United States reserves in pegmatites are thus estimated at 15,000 tons of beryl, of which about half is considered recoverable. Several hundred thousand tons might be obtained from mining known low-grade domestic deposits if economically and technically feasible recovery processes could be worked out.

In 1953, the peak year, world beryl production amounted to 8,300 tons, of which 8,000 tons were imported into the United states. The United States production amounted to only 750 tons in this period. Most of the imports were from the Union of South Africa, Rhodesia, Brazil, and India.

Reactor uses could annually require more beryl than the world has produced in any year to date. Programs dealing with military reactors designed around the use of beryl should be based on careful estimates of the quantities likely to be required, together with forward planning to meet these requirements. These steps are essential to a sound program. The alternatives to forward planning are sky-high prices and short supply. A long-term market at a guaranteed price would probably be an effective way to stimulate

greater production, but a substantial lead time would be required to meet any very large demand.

Fewer problems are likely to be encountered in achieving uranium production at levels to meet future requirements. Uranium is the mainstay of both the military and industrial atomic energy programs. Thorium, which can be converted into fissionable U-233, may become important. When and to what extent is still a matter for conjecture.

Uranium is not a newly discovered metal. Identified more than 150 years ago, it was mined on a small scale as early as 1850 at Joachimstal in Bohemia and used to make orange pottery glazes and to color glass. It was still used for such purposes up to a few years ago. As a matter of fact, you may have some bright-colored pottery of pre-war vintage around the house which will give a measurable kick on a Geiger counter. The Joachimstal deposits, in what is now Czechoslovakia, are still being mined and are a source of supply to Soviet Russia.

In the United States, carnotite deposits containing both uranium and vanadium were first mined about 1900. At that time, mining was principally carried on for the uranium, from which radium was extracted. The rich Shinkolobwe mine in the

Belgian Congo came into production about 1922 and virtually monopolized the uranium and radium markets until 1931 when production began at the Eldorado mine, a newly discovered pitchblende deposit in northern Canada on Great Bear Lake, close to the Arctic Circle. However, although there was little demand for uranium, the Colorado mines were sporadically operated for vanadium.

When the atomic bomb project came into being, both the Shinkolobwe mine in the Belgian Congo and the Canadian Great Bear Lake mine had suspended operations, and activity at the Colorado mines was directed largely toward vanadium. However, large quantities of uranium had been accumulated above ground at both the Shinkolobwe mine and at the Eldorado mine in Canada. From these stocks and from the re-treatment of uranium-bearing tailings accumulated in Colorado from past vanadium operations came the quantities of uranium needed to carry out the wartime atomic bomb project.

Early in World War II during the development of the atomic bomb, the United States and the United Kingdom joined in uranium procurement. Uranium purchases are made through the Combined

Development Agency, directed by the United Kingdom Atomic Energy Authority and the United States Atomic Energy Commission. The Agency's activities are confined to contracting for production from sources other than those in the United States, the United Kingdom, and Canada.

When the Atomic Energy Commission began to function in 1947, the bulk of our uranium was coming from the Congo, some was being produced from the lone Canadian deposit near the Arctic Circle, and a little uranium was being recovered from our own western carnotite deposits. It was obvious that most of our eggs were in one basket.

Before the end of 1947, the prospect of devoting a major share of our resources to the peaceful application of the atom had faded,along with the prospect of adequate international controls over the manufacture of atomic weapons. We still had a monopoly, but energetic action was necessary to hold our lead. Spurred by the Russian development of the atomic bomb, Congress authorized successive program expansions and appropriated the huge sums needed for plant, equipment, and operating expense. The uranium, to feed the fissionable material production plants costing billions of dollars, had to come from new sources. It was necessary to

find and bring into production new mines at home and abroad and to develop suitable processes for recovering uranium from low-grade ores such as the South African gold ores. Lead time was short and a vigorous effort was called for.

The Shinkolobwe mine in the Belgian Congo continues to be an important source of supply. Since the beginning of operations in 1922, it has been the world's largest individual producer of radium and uranium. Its production is, in a large measure, responsible for the development of our weapons stockpile and without it we could not have come so far so fast.

At Shinkolobwe, the uranium occurs mainly as pitchblende in irregular veins and high-grade bunches in or adjacent to steeply-dipping quartzites. Although early operations were from superficial and relatively shallow workings, mining now extends to a depth of about 600 feet. Early shipments were hand-picked pitchblende ore containing 50 percent to 60 percent uranium oxide. Some of the current output is hand-picked material, but the bulk of production is shipped as gravity concentrates and chemical precipitates resulting from the acid leaching of lower grade ores and tails from gravity concentration.

Extensive exploration has uncovered additional reserves,

and it is safe to predict that the mine will be an important source of uranium for some years ahead.

The story of South Africa's uranium actually began about 1923 when uraninite was identified in the Witwatersrand gold ores. The small uranium content made the identification of little interest until about 1945, when the Manhattan Engineer District, predecessor to AEC, looked into these ores as a possible source of uranium. However, practically no information was available at that time on the grade and extent of the uranium mineralization. Later, a major program of sampling the underground exposures and accumulated tailings piles was undertaken. Preliminary information looked promising and research on extraction methods was begun in Government laboratories in the United States, the United Kingdom, and South Africa to devise means of economically recovering the relatively small quantities present in the gold tailings. I should mention here that most of the ores being treated contain less than a pound of uranium per ton of ore.

The research was successful and a process was developed which was applicable not only to South African ores but also has found application in all of the major uranium recovery plants throughout the world. In South Africa uranium extraction begins

where gold recovery operations end. The ore which has been mined, hoisted, crushed, ground, and cyanided to remove the gold is then pumped to the uranium plant where the uranium is dissolved in dilute sulphuric acid. The mixture of ore and pulp is filtered to give a clear solution containing the uranium. This clear liquor is run through columns filled with beads of a strong-base ion exchange resin, which has the property of selectively grabbing the uranium and letting the bulk of the other elements in solution pass by. Next, the resin is treated with nitric acid which takes off the uranium, resulting in a relatively pure concentrated solution from which the uranium can be precipitated by neutralization of the acid. This precipitate, when dried at 450-500 degrees C., yields a black oxide of uranium which will carry 75-80 percent uranium oxide.

To give some idea of the size of the total operation, when all of the 16 plants authorized are completed, they will treat on the order of 18 to 20 million tons of tailings annually. Plant cost, including acid production and auxiliary facilities, is estimated at close to $100 million. For the most part, uranium is a by-product with income from gold bearing all mining, crushing, and grinding costs, but in a few instances reefs have been found too low in gold

to be worked for that metal alone but were relatively high in uranium. Uranium production is coming mostly from the newer mines which have reserves for 25 to 40 years of operation. Others are under development and it seems safe to predict that South Africa will be a leading producer of uranium for many decades.

Small production operations are under way at Radium Hill in South Australia and at Rum Jungle, about 80 miles south of Darwin in the Northern Territory. Uranium at Radium Hill occurs as davidite, a refractory uranium-titanium-thorium-rare earths mineral, which requires digestion in hot sulphuric acid at high concentration. This unique ore is mined from narrow veins persistent to depths of at least 1200 feet. With minor variations, filtering, ion exchange treatment, and precipitation follow the practice outlined for the South African plants. However, prior to chemical treatment, the ores are concentrated to about 30 pounds of uranium oxide per ton by gravity methods and by flotation.

At Rum Jungle, the ores are being mined by open-pit methods. The uranium mineral, uraninite, is associated with copper. Treatment is by acid leach, followed by ion exchange and conventional precipitation methods.

Active exploration in Australia has turned up new deposits which appear capable of exploitation. Continued search should turn up still others and it is reasonable to expect that Australia will continue to be a supplier of uranium for many years.

In Portugal, the Urgeirica mine operated by a British company has, for the past several years, accounted for minor uranium production in terms of the Free World's requirements. France also has developed sources of supply which may result in substantial production.

In a number of European and Latin American countries prospecting is being carried on, mostly on a Governmental basis. A large number of uranium occurrences have been reported, some of which will no doubt be found capable of providing uranium at competitive cost. It can be expected that the controls which many Governments have placed on the prospecting for and exploitation of uranium deposits will be gradually relaxed. As in the United States, Canada, and Australia, widespread participation by private enterprise in the search for uranium should have spectacular results.

Russia, of course, is largely an unknown. However, there is little chance that Russian production is equal to that of the Free World or even to that of the United States.

Canadian discoveries in the past 18 to 24 months have been of major significance. Earlier I mentioned the Eldorado mine at Great Bear Lake, which has been in operation since about 1931. This mine continues to supply uranium, along with the Beaverlodge mine, in the Lake Athabasca area of northern Saskatchewan, which came into production in the spring of 1952. As a result of finding additional reserves, work is in progress to more than double the already sizable mill on the Beaverlodge property. Both mines are owned and operated by a Canadian Government organization, Eldorado Mining and Refining Limited. Widespread activity in the Lake Athabasca region has turned up a number of other deposits. One large ore treatment plant has been built by Gunnar Mines Limited and is already in operation. At least one more plant is in the planning stage which will probably treat ores from a number of smaller mines.

These developments alone would provide a substantial boost in Canada's uranium output. However, recently discovered deposits in the Blind River area will yield greater production and will be capable of supplying uranium in large quantities for a long time. This area is located just north of Lake Ontario between Sudbury and the Soo. Here extensive uranium deposits have been found

in pre-Cambrian conglomerates containing on the order of 0.1 percent uranium oxide. The deposits are somewhat similar geologically to the South African gold-bearing reefs. One plant in the 1000-ton-per-day class is already in operation. Construction is already under way on three additional plants, each of which will treat several thousand tons of ore per day. Some production is also expected from eastern Ontario, where one moderate sized plant is also under construction. The foregoing by no means exhausts Canada's potential, and many other properties capable of production are likely to be turned up.

The Blind River operations, particularly, are supported by substantial reserves, and it can be predicted with considerable assurance that large-scale uranium production will be forthcoming from this area for several decades at least.

In this review of uranium sources I have left our domestic operations until last. They are of major importance from the standpoint of national interest, and also domestic developments have been the most spectacular. In seven years, starting with almost negligible production, scant reserves, and uncertain prospects at best, the United States has become one of the world's leading uranium producers. We are moving out in front in the

production race. We hope to continue in first place but may find ourselves part of the time in close competition for that position. Our success is a tribute to the American system of free enterprise and to the effectiveness of the profit incentive. Mining operations are entirely in private hands and only one of the nine mills now in operation is government-owned.

At the beginning of 1948 there was practically no uranium mining or prospecting. Ore deposits commonly contained a few hundred to a few thousand tons of ore and in 50 years of mining and prospecting for uranium and vanadium, only two or three had been found which contained 100,000 tons or more. By 1955, there were probably more people looking for uranium inthe United States than for all other metallic minerals combined. There are now a dozen or more 100,000-ton ore bodies, and we also have some multi-million-ton deposits.

The mainspring of this activity was the Commission's establishment of a guaranteed price for uranium in ore over a long period. This period has been extended several times and now runs to March 31, 1962. Collateral undertakings by the Commission have included exploration for and development of ore deposits, geologic studies, the development of prospecting

methods and tools, and the development of improved uranium recovery processes. Expenditures by the Commission now total some $46 million on exploration and related activities and about $12 million on metallurgical research.

Special instruments and techniques have been developed for use in exploring for radioactive materials. New metallurgical processes for extracting uranium from ores have increased recoveries and reduced the cost of production.

Exploration and production have extended far beyond the original Plateau area, with important production coming from Colorado, Utah, New Mexico, Arizona, Wyoming, and South Dakota. Exploration has also been active in Washington, Oregon, California, Nevada, and Texas. One deposit of possible commercial significance is being explored on the Prince of Wales Island, Alaska. Minor occurrences of uranium have been found in nearly every state.

New mills are under construction and nearly all existing mills in the United States have been expanded one or more times to keep pace with increased ore availability. This all adds up to an industry which is thriving and is still in a period of rapid growth. However, most production operations are geared to a maximum production over the next few years, and many deposits will be mined out in a

relatively short time.

To maintain a high production rate from the types of deposits now being exploited, there must be a continued high discovery rate. If prospecting and exploration were to stop today, reserves would be rapidly depleted and by 1962 we would be in little better position than we were in 1948 when the program got under way.

Prospecting and exploration will continue so long as there is an assured commercial or Government market. If the market is primarily dependent on Government requirements, a guaranteed minimum price for uranium over a considerable period is a must. The period should be long enough to cover at least several years for exploration and five years for production. Should the military demand cease or be drastically curtailed before the demand for uranium for power has reached substantial proportions, the expected high levels of domestic output could be maintained only by Government stockpiling. We are unable to predict the size and duration of the military demand and many unknowns are involved in trying to determine the rate of growth of nuclear power. But on the basis of studies made about a year ago, it may be 1970 or even 1980 before substantial tonnages of uranium will be required.

These estimates may well be too pessimistic because a tremendous effort, governmental and private, is going into studies of reactor designs and components. Out of these studies competitive power reactors may come sooner than expected. They are already competitive in areas of high-cost fuels.

This review of uranium production illustrates the fact that uranium is much more plentiful than at one time supposed. Although uranium is fairly plentiful in the earth's crust, it was erroneously assumed that commercial concentrations might be rare. One of the important lessons to be drawn from the information gathered during the past seven years is that commercial uranium deposits of considerable size may be found in many areas and under a variety of geological conditions.

Some conclusions also can be drawn on world uranium resources although it is evident that future prospecting of those regions of the globe which are virtually unexplored should greatly augment known supplies. On the basis of present developments and geological evidence, it is estimated that uranium resources of the producing nations of the western world are in excess of one million tons. This is uranium which can be mined and produced at moderate

cost from the types of deposits now being worked, at an average of about $10 per pound uranium oxide in a high grade concentrate. Some of this production might be profitable at a price of less than $10.

For the long-range future, we can count on being able to recover uranium from the vast low grade deposits of uraniferous phosphates and shales which are plentiful in the United States and are also known to occur in extensive deposits in other parts of the world. In the United States alone these materials carrying on the order of one-tenth of a pound uranium to the ton are estimated to contain between 6 and 7 million tons of uranium. World resources in this type of deposit may be several times that figure. When it is considered that 100 tons of uranium is equivalent to one million tons of coal, using present technology, these resources represent a seemingly inexhaustible supply of fuel. If breeding is successful, fuel supplies would be stretched by a factor of ten or more.

By the time these low-grade materials are needed, breeding may make the presently estimated recovery cost of between $30 and $50 per pound of uranium look reasonable when it is considered that one ton of uranium may do the work of ten. There is a prospect of even much greater efficiency. Sir John Cockcroft of the United

Kingdom Atomic Energy Authority, in a paper given at Geneva before the Industrial Conference on the Peaceful Uses of Atomic Energy envisaged that by the year 2000, if breeding is fully developed, one ton of uranium may be made to yield the energy of one million tons of coal.

I have so far only touched on thorium. There is a difference of opinion among physicists on the application of this fertile material to the production of industrial power. At present nearly all the reactor designs are based on uranium, natural or enriched.

As to the adequacy of supply, plants now in operation can produce several hundred tons of by-product thorium annually in refined salts using monazite from the placer deposits of India, Brazil, the United States and from the monazite vein deposits of the Union of South Africa. Production could be greatly expanded if more thorium were required.

Monazite is a mineral commonly mined and processed for its rare earth content with thorium as a by-product. In addition to carrying 50-55 percent total rare earths, it also contains from 4 to 8 percent thorium oxide. India has estimated its resources at more than 2 million tons of monazite, carrying upward of 150,000 tons of thorium oxide. Brazilian reserves are stated to be on the

order of 70,000 tons monazite, containing 4,000 tons of thorium oxide. Deposits of lesser importance are found in many other countries. United States' resources are estimated at 250,000 tons of monazite, containing about 10,000 tons thorium oxide. Much of this domestic monazite could be mined only at excessive cost.

Substantial additional quantities of thorium could be obtained annually as a by-product of some Canadian uranium operations if a market existed. Also thorite veins are known which might be sources of production. A search for thorium deposits as intensive as that which has been made for uranium could be expected to turn up important additional quantities.

I have a few slides which I would like to run through rather rapidly. I think I am using up a little more than my allotted time.

(Slide 1)

This map shows the principal producing areas of the world. I mentioned earlier the Great Bear Lake mine up close to the Arctic Circle, operating since around 1931. Another recent operation has been at Beaverlodge mine since 1952.

In southern Canada, just north of Lake Athabaska, there is a plant there and a rather large deposit. There are a large

number of deposits along the river which may be traced for some 70 miles on the surface, not all uranium bearing, but the uranium deposits alone have been found commercially interesting.

At present there is no production from Peru, Chile, or Argentina, but deposits have been found which indicate radioactivity is present and something of value may be turned up.

The only other places where production is coming from are in southern France, Portugal, the Shinkolobwe mine in South Africa--some 2,000 miles from the coast where shipments originate for the United States. The Shinkolobwe mine is operated by the United Kingdom. The gold mines of South Africa are a large producing source of uranium.

In Australia, we have the Rum Jungle deposit, which I mentioned earlier, in the northern territory, and the Radium Hill deposit in South Australia. This is a large deposit which unquestionably will be a source of uranium in the future.

(Slide 2)

This map shows the Australian deposits. We have the Rum Jungle deposits in the northern territory, and this incidentally is one of the poorest areasclimatically that you can find anywhere--

high humidity; heavy rainfall during part of the year; high temperatures generally. South Australia is almost a complete desert. There is where the Radium Hill operation is found. The other numbers on the map refer to various prospects that have been either partially explored or are still under exploration.

(Slide 3)

This map shows the structure of the ore at Radium Hill. There are a series of narrow seams, somewhat in echelon formation. The mine has been carried down to the number four level and mining is now being done at about 600 feet.

(Slide 4)

This is an aerial shot of the Radium Hill camp. It is pretty arid, pretty desolate country. Water is pumped in from Broken Hill to the east.

(Slide 5)

This is a shot taken at Rum Jungle at the beginning of the open pit operation. It is now the source of production for a moderate sized mill. The ore here contains both uranium and copper in commercial quantities, copper being recovered as well

as uranium. There is only one other deposit like it in the world.

(Slide 6)

This map shows the location of the Great Bear Lake mine at the top of the map. It also shows the location of Beaverlodge property at Lake Athabaska. The principal purpose of presenting the slide is to illustrate how freight moves. It is a distance of around 1200 miles by water from Great Bear Lake to the head of the rail line at the waterway at the bottom of the map. The material is carried by water and undergoes several portages before it gets to its final destination. In addition, the lake is frozen over for all but 2-1/2 months in the summer, so all freight going in and coming out must be moved in that period of time. At Beaverlodge they have about three months for lake and river transportation.

(Slide 7)

This is a picture of Port Radium, Great Bear Lake operation, in the winter where they get temperatures down to 60 below zero.

(Slide 8)

Summer time looks a little better.

(Slide 9)

This map shows the Beaverlodge district. The two black

lines on this geological map show the major fault structures. All the ore in that area is shown to be associated with faults, along this hanging wall, either cluster along those faults or in minor faults. The entire area is heavily impregnated with mining minerals which run 25 percent uranium.

(Slide 10)

This is a picture of the development in the Beaverlodge area and the construction of a mill. The mine is in that part of Canada where most of the area seems to be covered by water when you travel through there. It is obvious that with a pontoon plane you would get around readily.

(Slide 11)

This map shows the general location of a number of mines and camps on the Witwatersrand mine in South Africa. The distance from the upper right, swinging around in an arc to the lower left, is about 150 miles. The mines are principally -ahable for gold, with uranium largely as a by-product.

(Slide 12)

This looks like a grave but it's not. That is the interior of the big hole and the old tailing dump, hydraulicked out, and sent through the uranium recovery plant. In some cases the old dump

was found to have sufficient quantities of uranium, but for the most part, the tailings from Witwatersrand contained too little uranium to make them worth while. These dumps are quite a picture on the Johannesburg landscape, covering many acres.

(Slide 13)

This is a view of one of the uranium recoveryplants, one of the smaller ones.

(Slide 14)

This is still another plant. In the central part are the agitating plants where the material is agitated with sulphuric acid. I have some interior shots to show you.

(Slide 15)

This is also a series of agitating plants. The ore is agitated by the introduction of high-pressure air through the sulphuric acid for a given period of time until as much uranium as can be dissolved is in solution.

(Slide 16)

This shot shows the filter floor of one of the medium sized plants. These filters are 14 feet in diameter and the larger plants may have as many as 28 or 30 of them. The mixture of ore and uranium bearing solution is pumped through these filters, the

solids removed, and the clear liquor then goes into the ion exchange thorium plant.

(Slide 17)

This is a precipitation portion of a plant where the solution has been taken off of ion exchange resins and place in a precipitating tank with ammonia to gives ammonia dilunate (?) which is heated and shipped to the United States.

(Slide 18)

This is the slide showing how in one plant they use a candle filter to remove uranium precipitate from the separation tanks. These filters are immersed in solution and suction applied; then they reverse the process, take it out of that tank and put it under light pressure.

(Slide 19)

This is a picture of a uranium plant; also shows some of the tanks on the side.

(Slide 20)

This portion of the plant shows slurries being fed at the top of a rotary drum. The filter is dropped down, goes through a rotary steel belt, and filters through the furnace. From this furnace it goes to another furnace where temperatures are from

400 to 500 degrees. It comes out black instead of yellow. It is packed in five-pound drums and shipped to the United States.

(Five-minute break)

COLONEL NYQUIST: Mr. Faulkner has a few more slides.

MR. FAULKNER: I will run through these rapidly and then go to the questions.

(Slide 21)

This shows the rough distribution of uranium in the four principal producing states. The newest state to come into major production is New Mexico, down near Grants, about the center of the state, just north of Albuquerque. Anaconda turned up a large deposit and has a new mill which has been operating about a year. Another one is under construction.

(Slide 22)

This is a picture of the area around Grants, New Mexico, where the first find was made by Anaconda. This may turn out to be a little bigger than expected. This is mined by the open pit method.

(Slide 23)

This shows some superficial working in one of the areas near Blind River, a small mine, containing a few thousand tons of uranium. There is one of the prospectors.

(Slide 24)

This is a picture of the Happy Jack mine, which is the copper-uranium type similar to the one in Australia. The ore contains 1.4 percent uranium oxide and 3 to 4 percent copper.

(Slide 25)

This particular slide illustrates how in some parts of the plateau we run into structures and sub-surface channels of old river beds. An accumulation of carbon helped prospectors in that location by doing geological mapping and plotting sub-surface contours to find channels that go into an area where deposits are known to exist.

(Slide 26)

This is another view of the Happy Jack mine in southern Utah. The odd fact about this mine is that there was no waste taken out. Everything taken out was ore shipped direct to be processed.

(Slide 27)

This picture was taken at the Navajo Indian Reservation. There the uranium was in layers that went up and down. There was a very limited amount horizontally. This is one of the newer deposits which will run to many millions of tons.

(Slide 28)

This shows some small shallow workings.

(Slides 29 and 30)

This shows an AEC prospecting exploration camp where the people live when they are out on the desert. They stay out there most of the summer.

(Slide 31)

This is a prospecting rig, portable type, developed out there. It runs on tracks to get over the rough terrain. It is used to put down drill holes.

(Slide 32)

This is a picture of a service piper cub, inside out. The observer is loading the center portion. Up to the right you can see some of the recording apparatus.

(Slide 33)

This shows some of the prospecting by airplane. These planes fly very close to the rims of the canyon, sometimes with wings practically scraping the rim. We have lost one or two planes, but no people yet. The reason for the close flying is that, if you fly at high altitudes, you cannot differentiate between a large area of high grade ore and a low grade area. After the

planes locate the deposits, they must be checked by ground reconnaissance parties. Many deposits have been found by this means.

QUESTION: I read that the price for ordinary uranium, based on no profit or loss on the part of the United States, was about $40 a pound. One of the means to supplement natural resources seems to be by the recovery of fissionable material from the reactors. How does the price of recovery vary from that price of $40 for ordinary uranium?

MR. FAULKNER: I am sorry I can't answer your question. This is out of my field. I do know that the recovery of spent fuels is one of the major problems being tackled today. There must be improvements in metallurgical techniques, and the cost of recovery may vary depending on how you reuse the fuel and if it is cheaper to throw it away rather than reprocess it.

QUESTION: I am not sure I understood you correctly during your talk, but I got the impression that you stated there is little significance in the USSR uranium production, that their deposits are not as great as ours. Did I misunderstand you?

MR. FAULKNER: No, I said that. What I said was that it would seem unlikely that the uranium production of the USSR

was as great as that of the Western World and probably would not equal our own in this country. This is based on the best information we can get. Obviously, our information is not complete.

QUESTION: Actually, then, would I be right in tabbing that as a surmise?

MR. FAULKNER. That is more a surmise. I think I would let it go at that.

QUESTION: It sounded to me like if we wanted to go into commercial power plant production we are going to be limited by finding rare metals safe to use to build the piles.

MR. FAULKNER: I mentioned that beryllium may turn out to be in short supply. Most of the materials available are in ample quantity. Beryllium can be used as a moderator. Graphite is a very satisfactory moderator. There is no shortage of that. So far as I know, the metal should not be a limitation unless we design around some of these very scarce ones.

QUESTION: Would you care to comment on the dangers that are involved in mining uranium and processing it, and shipping it, and so on?

MR. FAULKNER: Yes. The health hazards in the

uranium mines are not considered great, provided there is adequate ventilation. In the first place, there is not enough radioactive material in the mines to give a direct radiation hazard. There is quite an accumulation of lithium gas. However, adequate ventilation answers the problem. In the mills there is no problem unless you actually digest the uranium (if you were to eat it), if you take reasonable care in changing your clothing and washing when you go off the shift.

QUESTION: What is thepolicy of the United States relative to importing radioactive material versus using domestic resources?

MR. FAULKNER: At the present time we are using all the supplies we can get, both domestic and overseas. I would assume that the policy would be to utilize domestic resources to the extent available in the future. Right now we need all we can get and are using it all.

QUESTION: What controls will be exercised to see that uranium in the Western World is not shifted into Russian hands?

MR. FAULKNER: Most of the governments friendly to the West have enacted laws which prescribe that all uranium must be sold to the government or exported under government license. So

most agreements with foreign producers run with the United States Government and the government concerned with respect to exports. Now commercial contracts, of course, take into account the needs of the commercial producer, but so far as we can tell, no uranium is going from countries in which we are interested to the USSR.

QUESTION: I think you indicated that the approximate cycle should be about seven years for full exploration and five years for development.

MR. FAULKNER: I meant to say several years, two or three or four. You need time to find the deposit, develop it, get it ready for mining, and a reasonable time to get your money back.

QUESTION: Is there any indication that a guaranteed market will be extended beyond the 1962 figure that you mentioned?

MR. FAULKNER: That's a good question. I haven't any answer to it. All I can say is this: The problem is under study in an attempt to find out what the military demand may be in the future and what the commercial demand may look like. We have to firm that up some more. An announcement will be made as soon as it is possible to do so, I would expect within the next six months.

QUESTION: What is the depletion rate allowed on a uranium mine?

MR. FAULKNER: At the present time it is 27-1/2 percent.

QUESTION: Against 15 on minerals?

MR. FAULKNER: That is correct.

QUESTION: If we can jump to 1970 or 1980 when you anticipate industrial use might be extensive, do we have enough known deposits or resources to maintain, say, a maximum industrial base utilizing atomic power, at the same time maintaining our military weapon system?

MR. FAULKNER: That is a very difficult question to answer. You might look at it this way: It seems the stockpile of atomic weapons must some day be adequate. If the material is not used up, it can keep almost indefinitely. It can be re-formed, re-worked, and made into new kinds of weapons. The assumption is that at some stage, whether 1970 or before, there would be sufficient fissionable material in the stockpile to take care of military needs. This assumption may turn out to be false. If there is a very substantial demand for uranium for military and commercial uses, we might have to go to low-grade sources,

which I mentioned. There is no shortage. There is plenty of it. The difficulty of getting it out may be large.

QUESTION: Why is it we hear that it only takes a small amount of uranium to power industrial plants and that it has quite a long life, half life, whatever the term is? I can't understand how we use it. Doesn't it continue for a tremendously long period of time?

MR. FAULKNER: This is out of my field. There is quite a lot of information on the decay rate of uranium. It is a very long time before it reaches half life. But in the reactor, what you are doing is converting one material into another with the use of heat. So you are not depending on the natural decay rates at all. Actually, you are consuming material in the sense of changing it from one material into another by this heat process.

QUESTION: You indicated in your talk that the production of uranium was growing quite rapidly. I don't know whether you can answer this question or not. Can you indicate what percentage of uranium is being used for military uses and what percentage of it is being used for commercial purposes and experimentation?

MR. FAULKNER: I have no figures on that, but I can tell you this, that the tonnage being used for commercial and experimentation purposes is very small, an insignificant portion of our

total take. It would be a matter of a few percent.

QUESTION: It appears that our deposits of uranium have been made in the Rocky Mountain area. Do you feel that the Appalachian Mountains may have any prospects?

MR. FAULKNER: We have learned to be cautious about saying what areas are no good because uranium, as I mentioned earlier, has been turned up under a large variety of geological conditions. Radioactivity has been reported from the Appalachian Mountains, but the quantity so far is not sufficient to warrant exploration. Our attention has been on the places where it is known to occur in quantity and where commercial deposits exist. Uranium has been reported from Maine, North Carolina, South Carolina, almost every state in the Union, and, and it could very well be that uranium deposits might turn up in the Appalachian area, but the chances are they would not be as good as from the West.

QUESTION: I think we all know the stockpile figures on the military atomic weapons. They are classified very highly. My question is in relation to whether or not the shipments of uranium ore both within the United States and the imports from foreign countries have any direct relation to what might be in

the stockpile figures? Is there some direct relationship between these two things or not?

MR. FAULKNER: I will answer that question this way: The total take of uranium, annual import and production, has been going up on a very sharp curve. These materials do, of course, contain U-235 and may be converted to produce plutonium, and the amount of uranium you get is a measure of the total weapon capacity. I think that is true. But as far as the relation of imports in any one year to the stockpile, I am afraid I can't answer that question.

COLONEL NYQUIST: Mr. Faulkner, on behalf of the College, thank you for returning to the school and giving us this very instructive lecture on a very important subject. Thank you.