866

709239

SOME PRESENT AND ANTICIPATED USES OF ATOMIC ENERGY

Remarks Prepared by N. H. Woodruff
Oak Ridge Operations, U. S. Atomic Energy Commission
for presentation to Cincinnati Post,
Society of American Military Engineers
Cincinnati, Ohio - March 5, 1954

Sam Sapirie, the Manager of the Commission's Oak Ridge Operations, asked me to bring you his greetings and to express again his thanks to the Corps of Engineers, particularly the Ohio River Division, for the help which has been given us. Many of you will recall that the Corps has assisted us in many very important site selection problems in the past. I am aware of two further "assists" which the Corps has been to us within the past two months. We never seem to be in a position to do our jobs on a reasonable schedule but are called upon to get or make things that should have been on hand yesterday. When our schedules are tight, we have learned that the Corps will understand this fact and furnish assistance promptly. You have been most helpful.

I was somewhat relieved upon the receipt of Gen. Strong's letter indicating the subject on which tonight's talk would be based. I had imagined that a suitable talk would have been how we are managing the present 2 billion dollar expansion of the gaseous diffusion facilities, or how we are wiring in the 5600 MW of electricity necessary to make the plant go. Since I am not an engineer, I could see myself getting into "hot water" very fast with this group.

Tonight I will try to cover some of the present and anticipated peacetime uses of atomic energy. As usual, on such general topics, I will not be able to cover all uses or even perhaps those in which you are interested. Therefore, if you have questions at the end of the talk I will be pleased to try to answer them. I will probably have to say "I don't know" to some of your questions for two reasons; first, I do not have the information on hand, or second, if I did know, by answering, I might precipitate a security meeting at which I would be the center of attention. I like to avoid being in the center of such sessions.

I do find myself somewhat embarrassed by not being able to tie up a compact picture of peacetime atomic energy in the allotted time because of widespread use and growth possibilities. I find myself with only a partly done job, much like the farmer out in Oklahoma who owned quite a large ranch with oil possibilities. This farmer had received many calls from representatives of oil companies trying to get him to sell the oil rights to his place and had been subjected to a lot of heavy pressure.

After thinking over the propositions, he decided that perhaps the best thing he could do would be to hire a consultant to advise him whether to sell or use some of his money to sink a well. The consultant was hired and advised the farmer not to sell but to do the drilling himself. The farmer accepted the advice, sank his well and hit a black, liquid "jackpot".

At the next oil producers' convention the farmer met his consultant and tried to reward him again for his advice. But the consultant refused by saying he had been adequately paid and deserved nothing more. But, after a great deal of prodding by the farmer, the consultant agreed that it would be nice if he had a new set of golf clubs. How many clubs are there in a set, the farmer wanted to know. "Nine" replied the consultant, to which the farmer said, "Good, I'll get them for you immediately". They parted and the consultant did not see or hear from the farmer until they met at the next year's meeting. The farmer came up and in an embarrassed fashion, said, "I bet you think I am not going to give you those clubs. Boy, I have had a terrible time. I found six good ones but finding three more for sale with swimming pools is a damned hard job".

In an effort to give an appreciation of the peacetime applications of atomic energy, I will use a series of slides which I believe will assist in developing a logical but not necessary complete picture. The first slide (FIGURE 1), presenting a typical fission reaction of a uranium atom, will be helpful in reviewing fundamental concepts on which all applications are based.

To bring about the fission of a U-235 atom, it is necessary for the atom to absorb a neutron (a fundamental physical unit of mass with no charge and which is believed to be a part of all atoms except the hydrogen atom). I will dismiss the origin of this initial neutron with the statement that there are a number of ways to generate neutrons without having fission. When the neutron is absorbed by the U-235, it takes on such an excited state that it fissions, which simply means it splits into two fragments which are new and lighter - weight atoms and are known as fission products. The splitting of U-235 does not break in the same pattern each time, consequently a variety of new atoms are formed. Generally, the initial fragments are radioactive, meaning that these atoms will give off particles or gamma rays, and will change themselves in other atoms and eventually reach a stable or non radioactive form. You will note that the slide shows this fact. These fission products, or new formed, radioactive atoms, have many important applications, which will be discussed later.

There are other basic derivatives of fission which I should like to point out. At the time of fission, the neutron-activated U-235 gives rise to other neutrons, in the actual process to the fissioning atom gives rise on an average to two and a half neutrons. These neutrons can be used:

(1) to activate other U-235 atoms to fission which in turn produces additional neutrons to support a chain or continuing reaction in uranium provided there is enough U-235 present.

(2) To bombard or irradiate materials. When the atoms of most elements are subjected to this bombardment or irradiation, they will become radioactive, thus generating radioactive isotopes. Many of our more useful radioisotopes are produced from neutrons not used to maintain the chain reaction.

(3) to produce fissionable material. For example, when U-238 uranium (which occurs in nature in the ratio 140 atoms to 1 U-235 atom) absorbs a neutron, it will go through a radioactive chain and is transmutted (change from one element to another) into Plutonium 239 which will also undergo fission and may be used as a weapon

material or as a fuel for a reactor. Also Thorium 232 can be made to produce U-233 which is also fissionable. Because each atom of U-235 gives off two and a fraction neutrons and one neutron can cause a naturally occurring non-fissioning atom to be changed into one capable of being fissioned, this introduces the very interesting possibilities of generating more fissionable material than is being used up - the so called breeding principle. I will say more about this later.

(4) to study fundamental nature of matter. This use perhaps does not have as much appeal to the public in general as the last two uses. However, these neutrons are the ones that will open the doors for future developments in the atomic energy field and will give us increased knowledge on the basic principles of how matter is made up and possible guides for future practical applications. These neutrons are also most helpful in generating information to engineer more efficient use of all the derivatives of the fission reaction.

Continuing our review lessons, you will note that considerable number of gamma rays are emitted. These rays are closely akin to x-rays and have and are being used in experimental studies of physics, chemistry, biology, engineering, and other sciences.

The last item, though not clearly shown on this slide, is the generation of heat. What one does with heat that comes off is a matter of desire and the ability to engineer for specific purposes. At Hanford in 1943, the desire was the fastest possible production of plutonium for weapons; the heat was dissipated in the easiest engineered possibility which was cooling with water, and subsequently dumping heat and water into the Columbia River.

Having reviewed the fundamentals of the fission reaction, let's turn our attention to the device in which the reaction can be successfully sustained and worked with safely (Use Figure 2). All successfully operated reactors have (1) sufficient fissionable material that neutrons from one fissioning reaction will initiate one or more others, that is a critical mass of fissionable material must be present, (2) controlling mechanisms or techniques which will assure that increases in number of fissioning atoms will not become so great that an accident occurs, (3) adequate shields to protect worker from radiation hazards, (4) arrangements for the removing heat from the device, and (5) usually, materials which will slow down the newly emitted neutrons so that their capture by other fissionable atoms will be efficient; these are called moderators. In this area, becuase of presently approved security classification, I can not divulge the present status of reactor development to the fullest extent. However, this next and the three slides on reactors will, I hope, be of interest to you. FIGURE 2 is a schematic diagram of the graphite reactor at Oak Ridge National Laboratory. This reactor was built in 1943 as prototype for the Hanford Plutonium reactor and has made significant contributions to peacetime America because of the research work it permits and the production of about 85% of the radio-isotopes that have been used by non-Commission installations.

It is one of a number of designs of the heterogeneous type of reactors, meaning that the uranium fuel elements containing the fissionable U-235 is distinct from the neutron moderators. The moderating material in this reactor is carbon, actually carbon blocks containing holes into which approximately one by four inch aluminum-clad uranium rods are placed. The purpose of the moderator is to slow down the velocity of emitted fission-produced neutrons to speed at which they will be more efficiently absorbed.

One can see the 7 foot thick concrete walls used to keep neutrons, beta and gamma rays from working area about the pile. All reactors must be shielded to protect the workers from the radiations.

This reactor is air cooled. Air, at the rate of 100,000 cubic feet per minute, is blowed through the reactor to remove the heat and permit satisfactory operation. This reactor in normal operation liberates 3500 to 3800 kilowatts of heat/day. However, the air cannot be used directly for heating purposes because there is a considerable amount of short-life radioactivity produced in the air as it blows through the reactor. The approximate size of this reactor can be judged by the to-scale figures of the workers on the ramp. These reactors are quite expensive, for example, this relatively low-powered prototype cost approximately $3,500,000 in 1944.

However, the heterogeneous type reactor (FIGURE 3) can be built for much less cost. For example, at Oak Ridge there is in operation a low-power, relatively low cost research reactor, commonly called the "Swimming pool".

The reactor is submerged in a pool of water 20 feet deep, 20 feet wide, and 40 feet long, in which it can be moved about. The entire facility was constructed for less than $250,000, exclusive of fuel cost. Of this amount, the reactor core itself cost only $58,400, the rest of the cost being for concrete work, the building and auxiliary equipment. The reactor uses fuel elements which had already been designed for the Materials Testing Reactor, a large and more powerful research reactor at the National Reactor Testing Station at Arco, Idaho. The water in the pool acts as the neutron moderator as well as a medium by and through which the heat is removed from the fuel elements by convection.

This "swimming pool" reactor has a continuous, full power load rating of 10 kilowatts. About $6\frac{1}{2}$ pounds of U-235 equivalent is used as fuel.

This reactor has proved to be an economical and safe producer of radiation for certain purposes. For these reasons, as well as low cost, simplicity and performance, it is one of several types of reactors which is suitable for use at schools and other research and training institutions.

The Commission has recently approved the loan of approximately 8 pounds of U-235 to Pennsylvania State University for use in swimming pool reactor which that Institution will build.

The reactor is an assembly of movable fuel elements placed on end in an aluminum grid. It is suspended by an aluminum framework from which is called the reactor bridge, which spans the pool. The bridge rests on wheels fitted to rails along either side of the pool, so that the reactor can be moved along a center line the length of the pool.

The reactor has a variety of uses in addition to its principal role as an aid in the testing of shields. It enables students and other investigators to perform critical experiments, study neutron distribution and, within limits, study the effects on reactor operation of various patterns of arrangement of the fuel elements.

The second general type of reactor, the homogeneous variety, is illustrated by FIGURE 4. In this case the active uranium is a form of a solution, which the solvent, the water, acts as a moderator. Reduced to its simplest form, it is pot in which there is sufficient uranium in solution to cause the fission reactor to become self-sustaining or as the trade knows it, to become "critical".

From the pot a stream of hot fluid is pulled off and sent to the heat exchanger in which steam is produced. This steam then can be used to heat buildings, drive electric generators, or any other things which steam would be useful. It is necessary to have this heat exchanger in the system to confine the radioactivity of the reactor fluid.

In February 1953, the Oak Ridge National Laboratory operated the first experimental pilot plant. FIGURE 5 is sketch of the facilities in which the experiment was accomplished. This facility generates about 150 kilowatts of electricity from 1000 kilowatts of heat. The electricity generated at full power is approximately that estimated to be needed for 50 average five-room dwellings. On the extreme right of the figure, you will note the electrical generator. I would like to add that this experimental model, and the electricity produced, has not caused the Tennessee Valley Authority to grow any grey hairs.

Seriously, this was an experiment. It helped to define the problem areas and point out the direction in which the next steps of development should go. In comparing the diagram on the previous slide, to the experiment, you can see that much of the simplicity has vanished. However, the basic experiment was successful, now comes the tedious work of engineering a plant that works and will last long enough to be competitive with other electrical generating facilities. Much development work remains to be done.

Realistically, it will be a very difficult job to make reactors, as we know them today, competitive with contemporary generating facilities, particularly in this part of the country where we can build and operate hydro and coal electrical generating plants to produce electricity in neighborhood of 4 and 5 mils per kilowatt hour. However, in areas of this country where electrical energy is 2 or 3 times the above price, atomic energy may in the next few years be competitive. In any event, atomic energy will add a terrific reserve to our power economy, for whenever we have a need.

In September of last year, the North Carolina State College at Raleigh completed a small reactor of the homogeneous type on its campus. The Commission supplied the necessary uranium. This reactor has the same general purposes (except for shielding experimentation) of the swimming pool reactor described earlier. The North Carolina State reactor was designed and built by the college and is the first reactor in existence in this country not built by Government money. Interesting enough, a private textile company put up the bulk of the money which the College used in building the reactor.

During our brief consideration of reactor types, I noted the use of reactors for experimental and development purposes and for the production of isotopes (Figure 6). In addition to the demonstration of electrical power from the heat of homogeneous reactor experiment, I would like to indicate other highlights of developments in use of reactor heat.

In 1951, the British, making use of their experimental reactor at Harwell, their atomic energy research center, were successful in heating an 80 office building. One of their major problems was to get reactor heat into water without making the water dangerously radioactive. This is accomplished by means of one or more secondary heat exchanger systems, in which the heat is removed by one fluid and then transferred to a second or third which is used to carry the heat to the desired locations. This sounds easy but it requires absolutely leak tight systems. Otherwise, the secondary systems will become contaminated with radioactivity and will be unsafe. The British, because of coal, oil and other fuel prices, have more compelling economic reasons for pushing such developments. It was estimated that savings in coal bills would pay for the heating installation within about five years.

The Argonne National Laboratory has built and put into operation at Arco, Idaho ~~in~~ during late 1951 ~~of last year, the reactor, known as~~ the Experimental Breeder Reactor. This experimental reactor, like the homogeneous reactor experiment, was a small reactor in terms of power and costs and was constructed to develop further information and technique. It was the first reactor (December 21 & 22, 1951) in this country to give a real demonstration of the production of electricity from reactor heat, by driving a generator with 250 kilowatts capacity. In this reactor a liquid metal, a mixture of sodium and potassium, is employed to remove the heat from the reactor core and transfer the heat to a separate circuit of liquid metal.

The heat from the second circuit is used to make steam for electrical generators. This series of heat exchanger insures that radioactivity will not get into steam generation systems.

The reactor gains its name from the fact that it has a blanket of U-238 which is immediately around the core and in which Plutonium 239 will be generated. You will recall that Plutonium 239 is also a fissionable material. The design makes it possible to produce at least as much fuel as is being burned up in the core. Both achievements of the Experimental Breeder Reactor are significant steps in reactor utilization.

Also within the past year, work was started on one of the Hanford Plutonium producing reactors to develop a system which would use the reactor heat for heating process buildings. It is estimated that this system will pay for itself in a little over seven years through savings in fuel bills.

Although not properly classified as a peacetime effort, one cannot pass by the Navy-AEC development of engineering a reactor for the propulsion of a submarine. Viewed in prospectus, there is no fundamental reason why reactors could not be used to propel other large mobile units. However, it will be extremely difficult or impossible to engineer a reactor to an automobile, for example, because of the shielding that would be required.

With the summary which is presented in Figure 6, I should like to turn our attention to uses of radioisotopes.

During the discussion on reactors, I noted on how these radioisotopes are produced. I will not spend further time on this point. If there are questions, I will be glad to try to answer them at the conclusion of the talk.

Radioisotopes are useful (FIGURE 7) because they emit radiations (1) which will bring about certain changes in physical and biological materials (or radiation affect material), (2) which follow certain definite known patterns of behavior when reacting with matter (or materials affect radiation) and (3) which can be detected with suitable instruments (or radiation traces material).

Earlier while discussing reactors, it was noted that because of radiations, heavy shields were required to protect the reactor workers. However, under controlled conditions these radiations can be put to useful work. The two most significant type of radiations are beta and gamma rays. The first ray is actually very light nuclear particle, equivalent to an electron, emitted from the heart of a radioactive element. This particle does not travel far through matter and can be stopped with a small amount of shielding. The second radiation, gamma rays, are electro magnetic waves very closely akin to an x-ray with which you are familiar. These rays are penetrating and require considerable shielding dependent on the quantity of radiations being emitted.

There is one other term I would like to define. It is isotope. In nature most chemical elements are made up of atoms of different weights, for example, I mentioned Uranium 235, the fissioning atom and Uranium 238, the one that did not fission but from which plutonium could be made. The numbers used are actually difference in the relative weight of the atoms. In chemical reactions, Uranium 235 and 238 behave alike. So let us think of an isotope as one member of a specific chemical element family which has different weight from those of sister members. If it happens to give off radiation, it is spoken of as an radioisotope. Each radioisotope has a set of radiation and chemical properties which help to define it.

Previously, it was noted radiations from radioisotopes can be detected with suitable instruments. Since detections are possible, one introduces radioactive atoms of a particular kind into any given system and find out where they go. That is these isotopes act as tracers. For example, I have several dimes in my hand. One of these dimes spent a few seconds in the Graphite Reactor at Oak Ridge and, because of neutron bombardment became radioactive - actually a radioisotope of silver. With a suitable instrument I can pick this dime out from the group, even though to the eye it has an appearance identical to the others.

FIGURE 8 will show a practical application of the tracer technique in the field of diagnostic medicine as well as use of radiation as a therapeutic tool. Radioactive iodine (I-131) will follow the path of normal iodine in the body. In the normal individuals, iodine will concentrate by a factor 5,000-10,000 times in the thyroid gland than elsewhere in the body. If the concentration does not occur, the gland is not functioning properly. This fact can be used as a diagnostic aid to the physician. It has been used for this purpose on infants and small children, where it is not feasible to give basal metabolism. In all such cases a very small amount of radioiodine is used. The quantity of radiation coming off is not enough to cause any damage, just as the amount of x-ray used in many diagnostic pictures does not cause discernible damage.

In case of cancer of thyroid gland, there is always the possibility of cancerous thyroid spreading to other parts of the body. If the misplaced cancerous thyroid tissue is growing and has not lost its ability to use iodine, radioiodine will be picked and concentrated. Then, with the proper instrumentation, other sites of growth can be located.

I noted earlier that radiation will affect matter. Now, if a large dose of radioiodine is used, the thyroid and thyroid-like tissues in concentrating the radioiodine will receive large amounts of radiations. In fact, so much that all the tissue may be killed by it. Since the radioisotope is concentrated in the thyroid and thyroid-like tissue, the normal tissue does not receive a damaging amount of radiation. Some of you may recall the article of about 18 months ago, which Time ran on a 15 year old Kentucky youngster. When this boy was ten, a growth in his neck was diagnosed as cancer of the thyroid. He had a series of x-ray treatments and a surgical operation which did not gain control of the growth. Further, additional such treatments were considered to be useless. He was later referred to the Medical Division of the Oak Ridge Institute of Nuclear Studies for treatment with radioiodine. In his case the treatment by radioisotopes appears to be eminently successful. He is growing satisfactorily, approaching 6 ft. and at his last periodical examination showed no sign of the disease.

I would like to caution you not to make any general conclusion that here is a cure of cancer. A few cases of thyroid cancer have been handled successfully by the radioiodine procedure. Many cases of thyroid cancer do not respond to this treatment. Also, fortunately, there are relative few cases of thyroid cancer. Further, we know of no other examples where radioactive materials can be concentrated in cancerous tissue to the extent noted in this case.

FIGURE 9 shows an industrial application of tracer technique. This application was developed by the California Research and Development Corporation. By being able to define more exactly the interfaces of two types of petroleum product,(such as gasoline, diesel fuel and stove oil) flowing through a pipeline, the amount of discard for reprocessing can be materially reduced. The above organization estimates they are affecting a 500 barrel savings at each interface by use of this technique in place of other procedures based on specific gravity measurements. The radioactive technique is routinely practiced in the Salt Lake Products Pipe Line which operated between Salt Lake City, Utah and Pasco, Washington, a distance of over 500 miles.

Slide 58-A

FIGURE 10 illustrates another modification of tracer technique. In this case the piston rings were made radioactive by insertion in a reactor and, as the engine operated, the amount of wear was determined from the radioactive iron in the oil. The procedure permits measurements of wear so small as not to be detected by other methods. The procedure was used to evaluate lubricating properties of various oils on the market and to give indications how to make better oils. Also, is furnished hither-to unknown information of the wearing process. However, the big advantages in using this technique are the savings in time and manpower. In a test program which required $35,000 and 4 years using radioactive piston rings, would have required about $1,000,000 and 60 years to perform. By exercising a little imagination you can see that this general technique has many, many other applications.

<u>Slide 36A</u>

FIGURE 11 gives uses of fission products. In luminescent points, the radioisotope Strontium 90 is usually used. It is a replacement for radium having these advantages (1) is is cheaper, per equivalent light unit, (2) the chemical matrix lasts several times as long and (3) there are no gamma radiations to worry about.

Static electricity causes many difficulties in industry handling paper, textiles, etc. Radium and naturally occurring polonium have been used in the past. Co 60, Sr 90, and other isotopes are cheaper and, in some cases, easier to handle.

In Radiography, a number of radioisotopes are finding use. These man-made radio-materials are replacing radium because of price, and x-ray machines, because of adaptability to specific problems and of cost. There are almost 200 firms using Cobalt 60 for radiographical purposes at the present time.

In thickness gage, new lines of control instruments are developing. Many isotopes can be used and the particular one selected will depend on the specific job to be done. Usually a radioactive source of a gamma emitting material is placed on the opposite side of a sheet of material from a suitable detecting instrument. The amount of radiation which reaches the detecting instruments varies inversely to the thickness of the intervening sheet. With proper calibration the thickness of the sheet can be determined from the radiation which passed through the sheet without stopping the roller to make a mechanical measurement and with an accuracy of between 1/2% and 2%. In most rolling operations, one of the acute problems is to keep the roller so adjusted that the proper thickness of the sheet or foil is formed. The gage permits instanteous readings and suitable adjustments to be made promptly. In some cases, adjustments are made automatically by rigging the controls on the rollers so that impulses from the gage will make the adjustments. This basic application has been used to control thickness of rolled plastics, rubber sheet, roofing, aluminum, copper, steel, tinplate and amounts of various materials added onto the rolled materials. There are currently three companies engaged in the manufacture of these controls - General Electric Company, Industrial Nucleonic Corporation and Tracerlab.

The last use noted on FIGURE 11 is only in the investigative stage. There is a possibility that beta and gamma rays may find a use in the preservation of foods and the sterilization of drugs. There are a number of interesting studies underway which may develop this use. To achieve sterilization extremely large quantities of radiations must be applied; some of the recent studies indicate that much smaller doses of radiation will increase the shelf life of foods without any apparent harm to the commodity. Although we do not know of any case where radiation has caused the development of harmful constituents in food, this aspect of the problem has not been explored fully. It is very doubtful that harmful materials will be found even with the very large doses of radiation. This application will permit food preservation without heat, freezing or drying; therefore, it appears attractive particular for materials which are temperature - sensitive. Except of heat sensitive items (such as some drugs) the application must stand the test of economic competition from other preserving techniques.

Another example of radiation effecting materials, is the teletherapy unit, shown in FIGURE 12. To date all such machines have used Co 60 a man-made isotope have the gamma rays which approximate those of radium. The idea is not new as it had been tried with radium but expense and limited availability of radium deterred its full development. The machine will contain in the order of 1000 curies of Co 60, which may be purchased slightly over $5,000. The radiation from such machines is approximately equivalent to a 2 million volt x-ray machine and can be built for about one half to one-third of x-ray machine.

Since I have only been able to indicate a few of the radioisotope applications, Figure 7 will also serve as a summary of the general uses. The slide is specifically prepared for industrial users, however, the principles are applicable in any field of endeavor. Radioisotopes have and are making real contributions in science, industry, agriculture and madicine.

In August 1946, the Manhattan District, make the first shipment of radioisotope to a non-project users. At present, we are making about 1000 shipments a month and do not see that the growth curve is flattening off to any degree.

In conclusion, I hope that I have successfully demonstrated to you that atomic energy has much to offer in addition to effective military weapons. It has been showing many peacetime applications. Further applications will be developed as reactors are engineered into electric power plant, heating systems, and into moving machines and as our imagination puts radioisotopes into more and more uses.