~~TOP SECRET~~

23 April 1945

MEMORANDUM FOR THE SECRETARY OF WAR

ATOMIC FISSION BOMBS

I. PURPOSE OF DEVELOPMENT

The successful development of the Atomic Fission Bomb will provide the United States with a weapon of tremendous power which should be a decisive factor in winning the present war more quickly with a saving in American lives and treasure. If the United States continues to lead in the development of atomic energy weapons, its future will be much safer and the chances of preserving world peace greatly increased.

Each bomb is estimated to have the equivalent effect of from 5,000 to 20,000 tons of TNT now, and ultimately, possibly as much as 100,000 tons.

The entire program is known as the "Manhattan District Project" and at times as either the "DSM Project" or the "Tubealloy Project".

~~TOP SECRET~~

II. EXPLOSIVE MATERIALS

The Nature of the Explosive Materials. Either of two materials, plutonium, (a new element not found in nature but transmuted from uranium and the existence of which is not generally known) and uranium-235, is used as the explosive substance.

Natural uranium, like all elements, is composed of different kinds of atoms called isotopes. One of these is uranium-235 (U-235) which comprises 0.7% of all uranium, another is uranium-238 (U-238), which makes up about 99.3% of the whole.

An atom is made up of neutrons, electrons and protons. In this development we are interested in the neutrons. When a free neutron, from outside the atom, strikes an atom of U-235, the collision causes the atom to break into two parts freeing more neutrons and releasing a relatively large amount of energy. This splitting of an atom is known as fission. If the neutron does not hit a U-235 atom, but instead, meets a U-238 atom, it may be captured by the U-238 which is then transmuted into plutonium.

Methods of Manufacturing the Explosive Materials.

a. Uranium-235. As there is no chemical difference between the various isotopes of an element the process for separating out

The U-235 must be done physically rather than chemically. We have developed three methods whereby the separation can be carried out.

Gas Diffusion Method. Uranium fluorine gas is pumped continuously through porous membranes which tend to permit the U-235 atoms to pass through while holding back the U-238 atoms. The U-238 is thus gradually eliminated as the gas passes through a long series of such membranes. The gas at the end of the series contains a high percentage of U-235.

Thermal Diffusion Method. A uranium fluorine liquid compound in a long vertical pipe is sandwiched between a hot surface and a cold one. The U-235 portion of the compound becomes slightly richer at the top of the pipe where it accummulates. It is then drawn off at regular intervals.

Electromagnetic Method. A uranium chlorine salt is vaporized, then the atoms are electrically charged, and projected through a strong magnetic field which causes their paths to curve. The U-235 atoms, being lighter in weight, follow a sharper curved path than do the U-238 atoms and it is thus

possible to collect them separately in a small receiver. In order to get the desired purity, it is necessary to repeat the process using the receiver material from the first operation as a feed for the second.

Combination of Methods. Any one of these three methods could be used alone to carry the separation to the desired purity, and to date we have so used the electromagnetic method. However, we have found it best to use a combination of the three and this we are now beginning to do as the various sections of our gas diffusion plant are completed. The gas diffusion and thermal diffusion plants feed material, partly enriched in U-235, to the electromagnetic plant where the final concentration is performed.

b. Plutonium. There is a chemical difference between uranium and plutonium so that once a portion of uranium is transmuted into plutonium the separation can be done chemically.

Graphite Pile Method. Rectangular pieces of graphite are stacked to form a large cubical block called a pile. A large number of tubes extend through this pile. In these tubes are placed a number of cylinders of uranium, jacketed with aluminum. Neutrons are constantly emitted from the U-235 portion of the uranium. In the pile when these free neutrons strike a U-235 atom, that atom is disintegrated, energy is released and additional neutrons

are freed. Some of these are captured by U-238 atoms and by transmutation plutonium is produced. Others strike U-235 atoms and thus perpetuate the chain. The graphite is essential to the process as it slows down the speed of the neutrons so that an excessive proportion are not captured by the U-238. After about three months the uranium cylinders are removed and the plutonium which has been formed is chemically separated.

III. THE WEAPON

The weapon, using either U-235 or plutonium, is a large highly complicated aerial bomb. In this bomb, quantities of either U-235 or plutonium are brought together at an extremely rapid rate into one mass which then explodes. No explosion can take place unless a minimum amount of material, known as the critical mass, is brought together. To avoid an ineffective explosion or fizzle, this amount must be brought together at a high rate of speed. The final shape affects the critical mass, a sphere being the most favorable. Density also has an important effect, the denser the material the less the critical mass. We now have designs for two types of bomb.

a. The Gun Type. In this bomb a short barreled smooth bore 6½" gun and a target near the muzzle are contained in the bomb. The gun shoots a projectile of U-235 into the target of

the same material, thus forming a more than critical mass which it is estimated will explode with a force equivalent to that of from 8,000 to 20,000 tons of TNT.

b. The Implosion Type. In this bomb, a small sphere of plutonium is surrounded by a much larger sphere of high explosives. When the high explosives are detonated, the plutonium is compressed into a still smaller sphere of much greater density which because of the greater density becomes super-critical and explodes. It is estimated that the bomb will explode with a force equivalent to that of from 4,000 to 6,000 tons of TNT.

The implosion method is the more difficult but when perfected will probably be the better and will be used for U-235 as well as for plutonium. The gun method cannot be used for plutonium because spontaneous neutron emission would cause a fizzle before the projectile was properly seated in the target.

IV. PLAN OF OPERATIONS

Our operation plans are based on the gun type bomb, the first of which, without previous full scale test (and we do not believe this will be necessary), should be ready about 1 August 1945. The second one should be ready before the end of the year and succeeding ones at approximately sixty day

intervals thereafter.

Our previous hopes that an implosion type of bomb might be developed in the late spring of 1945 have now been dissipated by scientific difficulties which we have not as yet been able to solve. The effects of these difficulties are that the bomb will require more material and we will get less explosive effect per pound of weight. We should have sufficient material for the first implosion type bomb to be tested in the United States in the early part of July. A second test, if necessary, can be held by the 1st of August and if our scientific progress continues as expected we should be prepared to drop one of these bombs every ten days starting the latter part of August.

While our plan of operations is based on the more certain, more powerful, gun type bomb, it also provides for the use of the implosion type bombs as soon as they become available. The target is and was always expected to be Japan. A composite group of the 20th Air Force has been organized and specially trained and equipped. The initial echelons are about to leave for the overseas base.

V. GENESIS OF THE PROJECT

The production of atomic energy from the disintegration of atoms was the subject of speculation in scientific

circles for many years. It was not until 1939 however, when the fission of uranium was discovered, that the obtaining of tremendous amounts of atomic energy became a real possibility.

In late 1939 the possibility of using atomic energy for military purposes was brought to the attention of President Roosevelt. He appointed a committee to look into the possibilities. This led to scientific research first on a limited scale and then on a full scale basis. Various committees of scientists reviewed the prospects and as a result efforts were intensified. Shortly after December 1941 the research and development work was given an all-out status and was placed under a special group of outstanding American scientists in the Office of Scientific Research and Development. By the middle of 1942, the progress was such that it appeared feasible to initiate plans for the construction of production plants. In the meantime, President Roosevelt had appointed a general policy group to advise him on the matter. This group consisted of Vice President Wallace, Secretary of War Stimson, General Marshall, Dr. Bush and Dr. Conant. In June of 1942, this group recommended a great expansion and acceleration of the work and the assignment of the construction phases to the Corps of Engineers of the War Department. President Roosevelt approved the recommendations

and the Manhattan District was created to handle the program.

By September 1942 it became evident that the project was of great magnitude and extremely difficult of accomplishment. The Secretary of War selected Major General L. R. Groves to take direct executive charge of the program. Since that time General Groves has devoted his entire time to the work. At the same time the President's General Policy Group appointed a Military Policy Committee consisting of Dr. Bush or his alternate Dr. Conant as Chairman, Lieut. General W. D. Styer and Rear Admiral W. R. Purnell to plan military policy relating to the project. General Groves sits with this Committee and acts as its Executive Officer in carrying out its policies.

The many completely unknown phases of the possible methods of producing the explosive materials led to a decision in December 1942 to proceed towards the construction of three major plants -- the electromagnetic and the gas diffusion now located at the Clinton Engineer Works in Tennessee and the graphite pile now located at the Hanford Engineer Works in the state of Washington. It was thought that at least one of the methods would develop insurmountable difficulties that would necessitate its abandonment. While great difficulties were encountered they were surmounted and no one method developed such a superiority that the others could be safely abandoned. In

the summer of 1944, progress in the thermal diffusion research indicated the wisdom of constructing a small plant using this method to serve as a feeder for the electromagnetic plant.

VI. RESEARCH, PRODUCTION AND MANUFACTURING INSTALLATIONS

Clinton Engineer Works. This is a Government reservation of about 59,000 acres located 18 miles west of Knoxville, Tennessee which was acquired in the autumn of 1942. Two large plants for the production of U-235 by the electromagnetic and the gas diffusion methods are located here as well as a small experimental graphite pile plant for the manufacture of plutonium and a small thermal diffusion plant. The isolated location was necessitated primarily by the need for adequate safety distances; the isolation has assisted in the maintenance of secrecy. It was necessary to construct a Government-owned and operated town (Oak Ridge) within the reservation. The people of Oak Ridge live under normal conditions in modest houses, dormitories, hutments and trailers and have all the religious, recreational, educational, medical and other facilities of a modern small city. Construction workers now employed at the Clinton Engineer Works total about 32,000, and operators about 47,000. The population of Oak Ridge proper and adjoining temporary construction camps within the reservation is approximately 78,000. This includes the workers and their immediate families. The re-

mainder live in the surrounding communities.

Hanford Engineer Works. The plant for the production of plutonium by the graphite pile method is situated at the Hanford Engineer Works, a Government reservation embodying some 430,000 acres and located at an isolated, semi-desert site 15 miles northwest of Pasco, Washington. The site was acquired early in 1943. Isolation from existing populated communities of any size was a requisite, to provide the necessary safety distances. The Government-owned and operated town of Richland is contained within the reservation area. It is similar to Oak Ridge but much smaller in size. Construction at the Hanford Engineer Works is essentially complete and only operating personnel and their immediate families now reside there. Operating personnel at the Hanford Engineer Works number about 6500. The present population of Richland is approximately 17,000.

Los Alamos. A highly secret research and experimental laboratory for the fabrication of the weapon is located at a site 25 miles northwest of Santa Fe, New Mexico. Persons employed at this site number approximately 6100 and a small temporary Government-owned and operated community has a population of about 5800.

Other Manufacturing Plants. Heavy water present in natural water in the ratio of about 1 part in 7000 is produced at three plants in the United States and at one in Canada as a substitute slowing down medium for the pile method of producing plutonium,

to be used in place of graphite, in the event the graphite method should develop insurmountable technical difficulties. Heavy water also has characteristics which will probably ultimately be used to increase greatly the destructive effects of the atomic bomb. It is planned to develop its potentialities in this regard after the present fundamental work on the weapon is accomplished.

Expansions to Existing Plants. Additions were required to the plants of a number of industrial firms in the United States to effect the rapid manufacture of specialized equipment, the refining of uranium ores and the development and production of special new chemicals.

Research. Columbia, Chicago, California, and a number of other Universities throughout the United States and many industrial firms contributed materially in developing and supplying special equipment, materials and processes used by the project.

Operators. The graphite pile plant is operated by duPont, the electromagnetic by Tennessee Eastman and the gas diffusion by Union Carbide.

VII. AID FROM OTHER GOVERNMENT AGENCIES

There is complete understanding and cooperation with the Navy. Its facilities have been drawn upon freely and a number of its officers occupy key positions in the work.

The Office of Scientific Research and Development, the National Selective Service, the War Manpower Commission, the War Production Board, the Office of Censorship and other

agencies have rendered invaluable aid.

VIII. SCIENTIFIC REVIEW

Throughout the course of the program we have had the key phases of the work reviewed by the best available scientists and industrial leaders.

IX. EXTRAORDINARY SECURITY MEASURES

Because of its tremendous importance President Roosevelt personally ordered extraordinary secrecy and security measures for all phases of the project.

However, in order to maintain security during consideration by Congress of the necessary appropriations, President Roosevelt approved the informing of a limited number of the members of the Congress of the general purposes of the project. These members were:

Senators Barkley, Thomas of Oklahoma, Bridges and White, also Speaker Rayburn, Majority Leader McCormack and Minority Leader Martin.

It was inevitable that during the course of such a project public curiosity would be aroused and that citizens would make inquiries of Members of Congress. In all such instances known to us the members were most cooperative in accepting the statement of the War Department that military security prevented the disclosure of vital information. However, the War Department did give all information which it felt would not violate security.

Appropriate reports have been made from time to time to President Roosevelt through General Marshall and the Secretary of War. These reports, delivered personally, were handed back to General Groves so that there is but a single repository for these highly secret papers. To preserve secrecy, we avoid using outside of the project many revealing words such as plutonium, U-235, atomic, transmutation, fission and the like. These words have also been banned in the voluntary code of censorship.

X. COLLABORATION WITH GREAT BRITAIN

Before the project came under the War Department, scientific information was interchanged with the United Kingdom. We did not consider the informal arrangements in existence to be as advantageous as they should have been to the United States and suspended the interchange until a formal agreement was signed at the Quebec conference in August 1943 by President Roosevelt and Prime Minister Churchill. The salient provisions of the Quebec Agreement were:

1. This weapon would never be used by one against the other;

2. It would not be used against a third country except by mutual consent;

3. Information concerning this weapon would not be communicated to third parties except by mutual consent;

4. The British disclaimed any interest in commercial or industrial aspects beyond what might be considered by the President of the United States to be fair, with any postwar arrangements to be dealt with in terms specified by the President;

5. To effectuate collaboration to bring the project to fruition. This was to be done under the guidance of a Combined Policy Committee in Washington composed of the Secretary of War, Dr. Bush and Dr. Conant for the United States, Field Marshal Sir John Dill and Colonel J. J. Llewellyn for the United Kingdom* and Mr. C. D. Howe, Minister of Munitions and Supplies for Canada. This committee was to supervise generally the entire project and to settle any questions that might arise on the interpretation of the agreement and to arrange for full interchange of information in the particular fields in which both countries were engaged. Design, construction and operational information was not necessarily to be exchanged.

XI. PROCUREMENT OF URANIUM

Uranium is not a widespread element in recoverable amounts. The only known moderately substantial sources of ore,

*Colonel Llewellyn was replaced by Sir Ronald Campbell in December 1943 and the latter in turn was replaced by the Earl of Halifax. The late Field Marshal Sir John Dill was replaced by Field Marshal Sir Henry Maitland Wilson.

and the ones on which we are now drawing, occur in the Belgian Congo, northern Canada and the Colorado plateau of the United States. The Belgian Congo deposits greatly exceed in richness and in magnitude the others.

In order not to use up all of the uranium ore in the United States and Canada and at the end of the present war find all known sources on the American continent practically depleted, steps were taken to insure an uninterrupted and adequate supply from the Belgian Congo.

The Quebec Agreement was implemented in June 1944 by another agreement executed by President Roosevelt and Prime Minister Churchill. This agreement created the Combined Development Trust to handle the procurement of fissionable elements not within the territorial limits of the contracting powers. The Trust has available funds in the sum of $25,000,000.00, one half advanced by each of the signatory powers. The Trust operates under overall policies set by the Combined Policy Committee which appoints the members of the Trust. These are:

United States Representatives

Major General L. R. Groves, U. S. Army, Chairman

Mr. George L. Harrison, Special Assistant to the Secretary of War, President, N. Y. Life Insurance Company, former Governor and President of the

Federal Reserve Bank of New York

Dr. Charles K. Leith, eminent geologist, now Chief of the Metals and Minerals Branch, War Production Board

British Representatives

Sir Charles Hambro, Deputy Chairman, former member of the British Mission for the Procurement of Raw Materials, former Director of the Bank of England

Mr. Frank G. Lee, member of United Kingdom Treasury Delegation in Washington

Mr. George C. Bateman, Canadian member of Combined Production and Resources Board and experienced mining operator.

A careful study of the Constitution of the United States, the pertinent decisions of the Supreme Court and the lesser Federal courts, and the long usage of agreements by other Chief Executives, as far back as the administration of President Washington, clearly established the power of a President to enter into such an arrangement.

In furtherance of their policy of gaining control of uranium ores throughout the world, the Governments of the United States and the United Kingdom entered into an agreement with the Government of Belgium in September 1944. It provided

for the purchase and immediate exportation of a large quantity of uranium ore from the Belgian Congo and for the control under certain conditions of the ore in that territory for an additional ten year period. It also provided that at the proper time and after the cessation of hostilities the agreement would be submitted by the signatory governments for proper formalization under the fundamental law of the respective powers. Ambassador Winant signed for the United States, Mr. Eden for the United Kingdom and Mr. Spaak for Belgium. The new Secretary of State (Mr. Stettinius) was informed of the general situation soon after he took office.

XII. PROCUREMENT OF THORIUM

Thorium, another of the elements, has properties similar to uranium. Consequently, several new agreements to obtain complete control of thorium ores are presently anticipated. One of these has been discussed by the Secretary of State with President Vargas of the United States of Brazil and another is contemplated with the Government of the Netherlands. It is also expected that another agreement will be entered into by the United Kingdom with the Indian State of Travencore.

XIII. FOREIGN ACTIVITIES

a. Allies. Great Britain was previously covered in Section X.

Russia. The Russian Government since early 1943 has

evinced a strong interest in our activities and through its diplomatic, information and espionage groups in the United States has made efforts to secure particularized information concerning the project. These activities have been carefully watched by our specialized Army Intelligence and the Federal Bureau of Investigation.

France. The French Government occupies a peculiar position in that some of the first patents, of doubtful validity in the United States as well as in other countries, are held by the French Government. The British Government made certain commitments to the French Government which were most embarrassing to the United States. These British commitments were taken up by the Secretary of War with President Roosevelt who discussed them with Prime Minister Churchill at Malta last February and I understand, made a satisfactory adjustment.

b. Enemy.

Germany. Germany has a number of scientists eminent in the atomic field. Since 1941, reports have continuously emanated from neutral countries that Germany was about to use an atomic bomb of tremendous force. The enemy efforts were clothed in such secrecy that it was impossible to discover the true facts. We did learn that Germany had confiscated and re-

moved 1200 tons of partially processed uranium from Belgium and had reduced some of it to pure metal; that 29 laboratories and 31 corporations in 54 cities were engaged on work connected with the project and that there was every indication that Germany since 1943 was showing a deep interest in the development of atomic energy. Our forces in Germany have just captured about 1100 tons of the missing uranium material and a plant used to reduce the ore to metal has been destroyed. There would no longer appear to be any possibility that Germany could use an atomic bomb in this war.

Japan. As far as is known, there is no prospect that Japan could develop an atomic bomb for use in the present war.

XIV. PATENTS

With a few exceptions, the United States and the United Kingdom will have exclusive control of all essential patents in the entire field and non-exclusive rights to all non-essential patents. The few exceptions are those filed prior to the initiation of the project and ownership or rights are being sought on these.

XV. FUNDS

Funds for the Manhattan District were made available from two sources: "Engineer Service Army" and "Expediting Production of Equipment and Supplies". The total amount of all expenditures to 31 March 1945 was: for Construction - 1148

millions, for Operations - 345 millions, Total - 1493 millions. The estimated cost to 30 June 1945 is: for Construction - 1465 millions, for Operations - 485 millions.

The work has been of such an unprecedented nature that it has not been possible in the past to make even reasonable estimates in advance. The estimates for the fiscal year 1946 will prove more accurate. They amount to 195 million for construction, mainly for rounding out the existing operating plant at Clinton Engineer Works and 697 millions for all operations. If the war ends before June 1946, appreciable savings will result. Otherwise the total to be expended by 30 June 1946 will be 2842 millions of which 1660 millions will be for construction and 1182 millions for operations.

XVI. POSTWAR PLANS

While the project's primary mission is the development of atomic bombs for use against Japan the tremendous and far reaching implications of the future cannot be and have not been overlooked. Atomic energy if controlled by the major peace-loving nations, should insure the peace of the world for decades to come. If misused it can lead our civilization to annihilation.

The urgencies of war have prevented full consideration of the postwar developments of atomic energy but it is evident that the United States must maintain the leadership in the field

of atomics which it now holds.

There must be continuous, vigorous and extensive research and development of the possibilities of atomic energy including the use of radioactive substances. This will entail:

a. Full cooperation with the United Kingdom.

b. The continued procurement and movement to American and British control of available world supplies of uranium and thorium.

c. The improvement and operation of the most efficient manufacturing processes.

d. The improvement of the bomb.

e. The development of military power applications such as to engines of naval vessels.

f. The development of commercial and industrial power if that proves feasible.

g. The development of biological, medical and industrial applications of the radioactive substances.

h. Fundamental research so as to retain our present lead in the field.

The Secretary of War, with the approval of President Roosevelt, asked Mr. Harrison to prepare tentative plans for the postwar period. The latter considers that these plans envisage the goals set forth above together with a policy for the

control of uranium and thorium within the United States. Mr. Harrison recommends the establishment of a select committee of particular qualifications to recommend action to the executive and legislative branches of our government when secrecy is no longer in full effect. The committee would also recommend the actions to be taken by the War Department prior to that time in anticipation of the post-war problems. This committee would be assisted by panels of specially qualified scientists, Army and Navy personnel and other persons.

L. R. GROVES,
Major General, U.S.A.

ATOMIC FISSION BOMBS

Contents