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R WASHINGTON DC MAY 8 1943

DR F H DEMPSTER

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PLEASE SEND PHOTOSTATIC COPIES OF DOCUMENTS LISTED IN YOUR MEMORANDUM TO CAPT LAVENDER TODAY.

FOSTER YORK

250AM8

July 19, 1943

TO: F. York

FROM: L. Szilard

If I understand correctly, one of the most important questions in evaluating the patent situation is the question whether my disclosures of February 1940 would have enabled a man, skilled in the art, to built a chain reacting pile. It is my contention that this is ao, and I told you that I believe I could bring out this fact if I were permitted to put questions to various men whom you have heard in connection with this matter. It seems to me that by going through a form of mock trial in which witnesses could be cross-examined by me on one hand, and by someone representing the opposite point of view on the other hand, we could develop a rather clear picture. A transcript of such a mock tril could then be sent to Captain Lavender for close study of the case. I am listing in the following, a number of points which I think I could establish by such a procedure.

1. I submit that the disclosures which are available in the form of postmarked photocopies dated February 21, 1940 and which are substantially identical with A-55, teach a man skilled in the art how to built a lattice of uranium in graphite that will have a multiplication factor larger than 1. In particular this disclosure teaches that uranium metal spheres of 5 cm radius can be used for building a lattice that will be operative. It also teaches that uranium metal spheres of 8 cm radius can be used to build up a lattice which will be operative a_t 900°C. The disclosure further teaches that an operative lattice can be built from spheres between cm radius by using a ratio of uranium to carbon which is given by equation 33a. It subsequently recommends a weight ratio of uranium to graphite of 3200 for spheres of 5 cm radius.

The radius of 5 cm at room temperature and 8 cm at 900°C are arrived at in the following way:

Equation 26 shows, at a glance, that the most favorable conditions will be obtained by making ε as large as possible. Equation 20a gives ε as a function of the radius of the uranium sphere and by using the cross sections and other values given in the paper (please note that μ or α do not enter into the expression of defining ε) one can calculate the value of R for which ε becomes a maximum. One then that the maximum occurs at room temperature for a radius slightly above 5 cm. The same calculation gives at 900°C a radius of about 8 cm.

Equation 25 teaches that the best uranium to carbon ratio is obtained if we have one half of the neutrons which are lost absorbed by graphite, and, accordingly, the other half which is lost absorbed by uranium at resonance. This condition which is correct with very good approximation leads to equation 33a if we use for the resonance absorption, the approximate formula given by equation 9. Equation 33a gives for the size of spheres contemplated in the disclosures, a ratio of uranium to carbon for which the lattice is operative. In comparison with equation 33a, equation 36 is less accurate since it represents an approximation for very large values of ε as it is clearly stated in the text.

2. I submit that a man, skilled in the art, who had read the February 1940 disclosure would have had no difficulty on the basis of the knowledge then available to determine the critical size at which the chain reaction becomes divergent by empirical methods.

Ever since the discovery of the neutron emission of uranium in March, 1939, physicists have been trying to devise a system which will give a multiplication factor larger than 1; but nobody ever expressed any fear that if such a system is found it would be difficult empirically to determine the critical dimensions. For this purpose, there were three methods which were readily available and all of them were discussed, and some of them published at that time.

a. The first method which is the crudest makes use of the fact that if a neutron source is placed in the center of a sphere which contains material that has a multiplication factor above 1, the neutron radiation emanating from the sphere will be more intense as a neutron radiation which would come from the neutron source in the absence of the sphere. If the chain reacting system is made larger and larger, the neutron radiation will approach infinity as will come close to the critical radius.

b. A more refined method which was known by men skilled in the art was to surround a potentially chain reacting sphere with water or paraffin, putting the neutron source in the center of the sphere and compare the number of neutrons which are absorbed in the water with a number of neutrons which are emitted by the source alone. According to whether the number absorbed in the water around the chain reacting layer is larger or small than the number emitted by the

s source the multiplication factor can be taken as larger or smaller than unity and in case the multiplication factor is larger than unity, the critical radius can be computed from the results of such measurements.

c. By measuring the neutron density inside the potentially chain reacting sphere, one can determine whether or not the multiplication factor is larger than 1 and if so, the approximate critical radius can be deduced.

In support of my contention under this point, I wish to state the following:

At a metting of an advisory comittee to the uranium committee which was held under the official chairmanship of Urey at the request of Dr. Brinks, and in which Pegram, Bride, Fermi, Wigner, myself and others participated, a consensus of opinion was reached that the critical dimensions could be determined by making measurements on a lattice containing about 40 tons of graphite and a corresponding amount of uranium on the assumption that the quantity may represent perhaps 1/5 of the quantity required to make the chain reaction going. There was a consensus of opinion that the physicist could, by making measurements on such an intermediate scale as we then called it, determine the approximate value of the critical dimensions. This proves that, in the opinion of men skilled in the art, the empirical determination of the critical dimensions was considered as a natural way of proceeding. Incidentally, the so-called exponential experiment was mentioned at the meeting by Fermi as one of the possible methods by means of which the intermediate scale pile could be investigated.

That such an intermediate scale pile could be investigated by measurements performed outside the pile in water or paraffin wax was common knowledge and an example for such measurements can be found in the paper by Halban, Joliot, Kowaski, Journ de Phys. 10 pp. 428-429 (1939). This paper is quoted in A-55.

In support of the condition mentioned under a. in this section, I am submitting exhibit A which contains a disclosure that is available in postmarked photocopies stamped March 9, 1939. In connection with the question of this section, the following facts may also be pertinent. The existence of the critical dimensions and the variation of the thermal neutron density inside a potentially chain reacting sphere was first disclosed by me filed in England in 1934. There is subsequently disclosed by me as shown in exhibit B which is available in postmarked photocopies stamped March 9, 1939. Following that these last were published by F. Perrin in 1939 at a time when they were considered to be known by men skilled in the art. The neutron density goes in a potentially chain reacting spherical body with

$$\frac{\text{Sin } r/A}{r}$$

If the multiplication factor is larger than 1 and with

$$\frac{e^{+r/A} - e^{-r/A}}{r}$$

If the multiplication factor is smaller than 1. The latter case holds for graphite from which we have removed all the uranium. An important quantity is the length A and my letters to Fermi in July and also A-55 gives a method

how to determine A by measuring the thermal neutron density inside a phere. This method is described on pages 24 and 25 in A-55. It is described in connection with graphite only, and it is not explicitly stated that it can also be used for graphite-uranium systems. The general principle of this method which was new at the time of its disclosure in July 1939 was applied by Fermi to a rectangular system for the purpose of measuring the absorption of graphite in April, 1940 and the application of this method to uranium-graphite system was proposed by Fermi in June, 1940 at the above-mentioned conference.

July 23, 1943

TO: F. York

FROM: L. Szilard

~~After Captain Lavender left Chicago,~~ Lately I had a conversation with Dr. Dempster from which I saw that the interpretation of various pertinent points in A-55 is controversial. I am now going through A-55 with Dr. Dempster, and I believe that Dr. Dempster will be in a position by Tuesday of next week to reevaluate this disclosure.

It is my contention that a man skilled in the art of inducing radioactivity by means of neutrons was in the position to build a chain reacting pile on the basis of my disclosure February 1940. These disclosures consist essentially in a paper sent to Physical Review on February 14, 1940 and corrected pages which were written between February 14 and February 21, 1940 and which are availalbe in the form of photocopies stamped February 21, 1940 by the U.S. Post Office. This question really falls into two parts:

(a) Does the disclosure teach how to make a lattice which has a multiplication factor larger than 1, and does it give the order of magnitude for the critical radius of a chain reacting unit?

(b) Was a man skilled in the art in the position, in 1940, to determine by known measurements on a structure which was not as large ~~enough to constitute a chain reacting unit~~ as the critical size whether the multiplication factor was larger than 1 and how large the structure would have to be made in order to reach the critical conditions.

3.) 4.) A third question which may be pertinent is whether it was known what amount of impurities could be tolerated in the chain reaction unit.

Before going into detail, I wish to emphasize the following general point of view: Ever since the discovery of the neutron emission of uranium in March 1939, it was recognized that as an important problem to find a structure which will have a multiplication factor larger than 1. Many people expressed doubt whether this was at all possible, and numerous suggestions were discussed and published. Nobody expressed any doubt, however, to my knowledge, concerning the question whether, if we had a composition and structure giving a multiplication factor above 1, we would be able to determine the critical dimensions at which the unit would become chain reacting. It was taken for granted that this would be the case and I am attaching a number of exhibits which support this contention, that this was a prevailing view at the time.

Concerning A-55, I have written a memorandum which I have forwarded to Dr. Dempster for his comment, and I am, therefore, summarizing here my contentions in connection with A-55.

1. A-55 gives the recipe for calculating a radius for the uranium sphere and a ratio of graphite to uranium at which the multiplication factor of the lattice will be close to the maximum possible value. The formulae given for room temperature, 5 cm as the radius of the uranium spheres at a density of 15 gms/cc; and give for 900°C a radius of 8 cm. The corresponding ratios

of uranium to carbon can be calculated from the formulae given in the paper. For 5 cm spheres, a weight ratio of 10 to 3 is (explicitly) recommended. ~~No ratio is recommended for 8 cm spheres at 900°C but the formulae would give a weight ratio between 3.8 to 1 and 4.1 to 1.~~

A-55 gives for 5 cm spheres an approximate value for the critical radius of 250 cm. It is my contention that it is obvious from the limits of error given in the paper to the various quantities involved that this radius is also given only within certain limits of error which would include the radius at which the chain reaction according to our present knowledge would actually reach the point ~~of diversion~~ (critical).

Critical size

2. It is my contention that men skilled in the art were fully aware of methods which enabled them to determine the critical size by empirical methods, that is, by measurements on structures which are smaller than the critical size. → Mrs II

At an official meeting held under the chairmanship of Professor Urey in June 1940, it was acknowledged after discussion in which Wigner, Fermi, Breit and I participated, that the critical dimensions can be empirically determined (with reasonable certainty) by measurements on a structure which contains about 1/5 as much material as would be needed to reach the point of diversion. A recommendation was adopted that measurements on such an intermediate scale should be made. Exhibit C corroborates this statement. It is the draft of a letter written by me to Fermi six days after the Washington meeting, ~~and~~ which contains a ~~note~~ record stating that this draft was not actually sent to Fermi. ~~It~~ The latter distinguishes between a semi-large scale experiment ~~that is~~ for the performance on structure approximately 1/5 of the amount containing materials

at which the chain reaction might become divergent; and a large scale experiment ~~that is an amount close~~ to be performed on a structure containing materials to the amount at which the chain reaction might be very close expected to become divergent. I submit that from this disclosure, it is evident that it was out intention to proceed in an empirical manner and the disclosure explicitly states the the nuclear constants should be measured while waiting for the arrival of the material needed for the semi-largescale experiment.

My contentions concerning the Washington meeting in June 1940 are ~~found~~ further corroborated by exhibit D which is taken out of a memorandum written by Pegram and dated August 14, 1940. I have marked on the margin the pertinent passage. I am also enclosing a photocopy, exhibit E, showing the official natural of the Washington meeting. I wish to state further that the following methods were available and known to men skill in the art of inducing radioactivity by means of neutrons, exploring a potentially chain reacting unit which was smaller than the critical size.

(a) Measurements of the neutron radiation emanating from the structure. This is, for instance, disclosed in exhibit B which is available in the form of a photocopy stamped March 9, 1939 by the U.S. Post Office. Exhibit B proposes to determine the critical size empirically by means of neutron radiation emitted from the structure.

(b) Measurements of the neutron density inside the chain reacting structure. The ~~loss~~ laws governing the neutron density inside a ~~xinx~~ structure which is potentially chain reacting ~~in~~ but not large enough to reach the

point of diversion was disclosed for the first time, I believe, by me as shown in Exhibit A which is available in the form of photocopies stamped March 9, 1939 by the U.S. Post Office. There are also subsequent publications disclosing these losses, one of them by F. Perrin in the summer of 1939.

It was quite well-known in 1939 to men skilled in the art that by measuring the neutron density inside the structure one can observe whether or not the multiplication factor is larger than 1 and determine the approximate size of the divergent chain reacting unit.

Measurements of the neutron density inside a chain reaction structure were, for instance, published by Joliot in a paper which is quoted in A-55.

(c) That by measuring the thermal neutron density within a system in which the thermal neutron density obeys the diffusion equation by means of making the thermal neutron density zero along a closed surface by the introduction of cadmium and by measuring the change in the thermal neutron density inside the space as delimited by the closed surfaces and that from such measurements, one can deduce the length which characterizes the pertinent properties of the medium in which the diffusion of neutron take place was disclosed by me in letters to Fermi in July, 1939 and is also disclosed in A-55. This principle can be used for determining the critical dimension, which in the case of uranium spheres would be simply $\pi \times A$. At the Washington meeting in June 1940, Fermi explicitly proposed the use of this principle for determining the critical size and described shortly the method which at present is called exponential experiment. This same method has been applied in April 1940 by Fermi to determine the length A in graphite which did not contain uranium.

(d) It was well-known to men versed in the art that by surrounding a potentially chain reacting unit with paraffin, water or a manganese-sulfate solution one can slow down all the neutrons emanating from the structure and by measuring the neutron density outside the structure, can determine whether or not thenumber of neutron generated by the pile increases with increasing size of the structure. Such measurements are, for instance, published by Joliot and quoted in A-55. Such a measurement is also mentioned in a letter written by Fermi to Pegram in July, 1939. It is my contention that ~~every man~~ men skilled in the art knew ~~of~~ that this method was available and that the application of this method was quite obvious and did not require any ~~mention.~~ invention

3. It is my contention that it was known as early as July 1939 how much neutron ~~absorption~~ absorbing impurities we can safely tolerate. I was, in this respect, in touch both with the National Carbon Company and the U.S. Graphite Company, ~~since~~ in July 1939, I was not quite satisfied with the .1% ash and the vanadium content of the ash of the graphite, offered by the National Carbon Company. The U.S. Graphite Company offered us graphite which had only .05% ash and which contained a much smaller percent of vanadium than the National Carbon Company graphite. It is my contention that the absorption cross sections of all elements that occur as impurities in either graphite or uranium were sufficiently well-known at the time to enable us to ~~raise~~ work out a specification for purity.

I wish to draw attention to the fact that ~~of the materials~~ the neutron absorption of the total amount of impurities which are dispersed in

the chain reacting structure, and that it is immaterial whether these impurities are in the graphite or in the uranium. To be quite precise inasmuch as the thermal neutron density in the uranium is slightly smaller than in the graphite, the harmful effect of the impurity contained in the uranium is slightly less ~~less harmful than~~ in the uranium than in the graphite. There was one great difference between the graphite and uranium, however. Uranium was available in the form of soluble salts like, for instance, uranium nitrate which would be easily purified by recrystallization or ether extraction, both methods being well-known and a number of other methods for purification are described in chemistry books. Graphite, however, cannot be brought into solution and there are not methods described in the books by which graphite could be purified. It was, therefore, our first concern to see whether pure graphite could be obtained.

In addition to this, we were informed in 1938 that uranium oxide, ~~with its impurities~~ 99.5% pure, ~~and its main impurity~~, silicon and iron, was commercially available and marketed by the Canadian Radium Mines. Pure uranium metal had been previous manufactured by the Westinghouse Company from uranium nitrate. Uranium nitrate itself was commercially available ~~xxxxxxx~~ and its purification and conversion into oxide do not meet with any difficulty for a trained chemist.

Myself was not in touch in 1939 with the Can. but later

455 grams at room temp
$(k\eta - 1) = \frac{1}{p}$ or $\mu\eta = 1.125$ This value
is the closeness of this value to 1 sets a limit to the

thermal neutron cross section
of the total amount of impur-
ities which can be tolerated
without appreciably decreasing
the useful range.

July 26, 1943

TO: F.-York

FROM: L. Szilard

Lately I had a conversation with Dr. Dempster from which I saw that the interpretation of various pertinent points in A-55 is controversial. I am now going through A-55 with Dr. Dempster, and I believe that Dr. Dempster will be in a position by Tuesday of ~~next~~ this week to reevaluate this disclosure.

It is my contention that a man skilled in the art of inducing radioactivity by means of neutrons was in the position to build a chain reacting pile on the basis of my disclosure February 1940. These disclosures consist essentially in a paper sent to "Physical Review" on February 14, 1940 and corrected pages which were written between February 14 and February 21, 1940 and which are available in the form of photocopies stamped February 21, 1940 by the U.S. Post Office. This question really falls into ~~two~~ three parts:

(1) Does the disclosure teach how tomake a lattice which has a multiplication factor larger than 1, and does it give the order of magnitude for the critical radius of a chain reacting unit?

(2) Was a man skilled in the art in the position, in 1940, to determine by known measurements on a structure which was not as large as the critical size, whether the multiplication factor was larger than 1 and how large the structure would have to be made in order to reach the critical conditions.

(3) Is it an invention to make a chain reactinn in a structure in which the multiplication factor is larger than 1 but if the structure is smaller than the critical size?

(4) A fourth question which may be pertinent is whether it was known in 1940 what amount of impurities could be tolerated in the chain reacting unit.

Before going into detail, I wish to emphasize the following general point of view: Ever since the discovery of the neutron emission of uranium in March 1939, it was recognized as an important problem to find a structure which will have a multiplication factor larger than 1. Many physicists ~~agreed~~ expressed doubt whether this was at all possible, and numerous suggestions were discussed and published; but to my knowledge, nobody doubted that, if we had a composition and structure giving a multiplication factor above 1, we would be able to determine the critical dimensions ~~at which~~ of the unit ~~would become divergently chain reacting;~~ it was taken for granted that this could be done and ~~I am attaching a number of exhibits which support the contention, that~~ this was a prevailing ~~point of~~ view, at the time.

Concerning A-55, I have written a memorandum which I am forwarding to Dr. Dempster for his comment, and I am, therefore, summarizing here my contentions in connection with A-55.

A-55

1. A-55 gives the recipe for calculated a radius R for the uranium sphere which forms the lattice element and a ratio of graphite to uranium at which the multiplication factor k_∞ of the lattice will be close to the maximum possible value. The formulae give for room temperature, R=5 cm as the radius of the uranium spheres at a density of 15 gms/cc; and give for 900°C a radius of R=8 cm. The corresponding ratios of uranium to carbon can be calculated from the formulae given in the paper. For 5 cm spheres, a weight ratio of 10 to 3 is explicitly recommended.

A-55 gives for 5 cm spheres ($k_\infty \approx 0.6$ and $(\eta\varepsilon - 1) = \frac{1}{5}$ (with $\mu = 1.07$) and $l =$) an approximate value for the critical radius of 250 cm. It is my contention that it is obvious from the limits of error

some of the constants
with modern values while
leaving the others unchanged and then
[illegible] a comparison of N 55 [illegible] on the
face that such a procedure leads
to ~~absurd results.~~ wrong conclusions.
~~Appeals to those known~~

given in the paper to the various quantities involved that this radius is also given only within certain limits of error which would include the radius at which the unit would according to our present knowledge, would actually reach the critical point.

A55 gives for the constants a definite set of values which have been so adjusted as to give the approximately correct ratios for U, C and the approximately correct multiplication factor for room temps.

Critical Size

2. It is my contention that men skilled in the art were fully aware of methods which enabled them to determine the critical size by empirical methods, that is, by measurements on structures which are large but smaller than the critical size.

It is not permissible to apply the reasoning given

In order to prove this point, the best method appears to be to submit affidavits by men skilled in the art who, in 1940, were interested in inducing radioactivity by neutrons. I am staisfied that I can submit any number of affidavidts on this point, and I rather doubt whether any nuclear physicists standing would attest under oath his incompetence by asserting that he would not have been able to determine the critical szie by empirical methods.

However, there is already an almost official recognition of my point of view which consists in the following:

On June 13, 1940, there was a meeting in Washington, the official nature of which is illustrated by Dr. Urey's letter dated June 7, 1940 which I enclose. At that meeting, there was a consensus of opinion that empirical measurements carried out on about 1/5 of the critical mass would enable us to determine with good accuracy the approximate size at which the critical conditions will be reached. Experiments carried out on that scale were at that time called experiments on an intermediate scale whereas empirical determination of the critical sizw on a mass which was below the critical mass, but close to it were called large scale experiments. The meeting unanimously recommended that the critical size be determined by experiments carried out on an intermediate scale and

I remember Lind Fermi Wigner Brett and I in the discussion and supported his view.

The recipe given in A55 uses these constants only in certain combinations. It is not permissible to obtain some of the constants alone, in these combinations

material corresponding to about 1/5 of the expected critical size should be put at our disposal by the Government. 5 to 10 tons of uranium metal and 50 to 100 tons of graphite were named as needed for the intermediate scale experiment. I personally ~~felt~~ considered it as reasonably ~~sure~~, certain that 5 times this amount, namely 50 tons of metal and 500 tons of graphite will be sufficient to reach the critical dimensions; and that ~~perhaps~~ half this amount would be sufficient for a large scale experiment which comes close to the critical dimensions and ~~would~~ give us as much scope as we ~~would~~ might desire to have for experimentation.

Information concerning the above mentioned meeting and its recommendations are contained in the letter written by Professor Pegram to Rear Admiral Bowen a few days after the meeting on July 19, 1940. Professor Pegram writes, "The idea has been developing that an intermediate experiment on a scale larger than experiments under A preceding, but not large enough to give a chain reaction could probably be used to obtain measurements bearing directly upon the chain reaction and the amount of material to be used to maintain such a reaction, and that this would in a sense be a method of short-circuiting, so to speak, some of the tedious experiments for measuring the constants of uranium. In its conference last Thursday, the scientific committee came to the conclusion that it would recommend that an experiment be done right away using not less than one-fifth of the material that would be estimated as necessary for maintaining a chain reaction.

The materials needed for such an intermediate experiment would be:

50 to 100 tons of graphite . . . . $25,000 to $50,000
5 to 10 tons of uranium metal at $8.00 a lb . . . . $80,000 to 160,000

The figures just given are doubtless too high. The carbon has been figures at $500 a ton, the rate paid for the graphite we have at present. It can probably easily by obtained for $400 a ton or less. The figure of $8.00 a lb for metallic uranium is the lower figure given here last week by Mr. Alexander, who thought that in ton lots it would not be difficult to furnish metallic uranium at $15.00 to $12.00 a lb, or possible $8.00. Chemical opinion seems to be that it ought to be possible to purchase uranium at $5.00 a lb, but perhaps that is a little too optimistic.

It is believed that this intermediate experiment which would be on the way of the final experiment might well furnish results that would make feasible a fairly accurate calculation of the amount of uranium and carbon necessary to sustain the chain reaction. The same materials could, of course, be used as far as they would go in setting up the final experiment.

If the intermediate experiment is to be done the question will arise as to whether it would be better to do it here or to do it in some place where it can be more carefully guarded."

In support of the contention that I myself clearly expressed myself in favor of determining the exact critical dimensions empirically by means of intermediate scale or by means of large scale experiments, I draw attention to the following: ~~my letter to Fermi dated July 8, 1939.~~ On July 4, 1940, I wrote Fermi as follows: "According to present plans, $90,000 would be requested for buying materials for the intermediate experiment and I believe our policy should be to give the intermediate scale experiment the right of way before the general survey of nuclear constants." In a letter written to Fermi June 19-1940, which is a blank in my files ~~and~~ but which was not mailed I wrote the following: " Nr (1)

In a letter dated July 8 1939 I wrote Fermi " Nr (2)

Still earlier in a disclosure (the enclosed Exhibit B) available in the form of a photocopy stamped March 9th 1939 by the ~~P~~ U.S. post office I discuss the empirical determination of the critical size.

In the following, I am listing a number of methods ~~and~~ known to men skilled in the art of inducing radioactivity b means of neutrons ~~in 1940~~ which were available in Feb. 1940 ~~and in ordinary use by~~ for the purpose of determining empirically the critical size by measurements ~~in~~ of structures which are smaller than the critical size, the most trivial are being that listed under (d)

At an official meeting held under the chairmanship of Professor Urey in June 1940, it was acknowledged after ~~the~~ discussion in which Wigner, Fermi, Breit and I participated, that the critical dimensions can be empirically determined with reasonable certainty by measurements on a structure which contains about 1/5 as much material as would be needed to reach the point of diversion. A recommendation was adopted that measurements on such an intermediate scale should be made. Exhibit C corroborates this statement. It is the draft of a letter written by me to Fermi six days after the Washington meeting, which contains a note stated that this draft was not actually sent to Fermi. The letter distinguishes between a semi-large scale experiment to be performed on a structure containing approximately 1/5 of the amount of material at which the chain reaction might become divergent; and a large scale experiment to be performed on a structure containing materials very close to the amount at which the chain reaction might be expected to become divergent. I submit that from this disclosure, it is evident that it was our intention to proceed in an empirical manner and the disclosure explicitly states that the nuclear constants should be measured while waiting for the arrival of the material needed for the semi-large scale experiment.

My contentions concerning the Washington meeting in ~~July~~ June 1940 are further corroborated by exhibit D which is taken out of a memorandum written by Pegram and dated August 14, 1940. I have marked on the margin the pertinent passage. I am also enclosing a photocopy, exhibit E, showing the official nature of the Washington meeting.

I wish to state further that the following methods are available and known to men skilled in the art of inducing radio activity by means of neutrons exploring a potentially chain reacting unit which was smaller than the critical size:

(a) Measurements of the neutron radiation emanating from the structure: This is, for instance, disclosed in exhibit B which is available in the form of a photocopy stamped March 9, 1939 by the U.S. Post Office. Exhibit B proposed to determine the critical size empirically by means of neutron radiation emitted from the xtxmtx xtt structure.

(b) Measurements of the neutron density inside the chain reacting structure: The laws governing the neutron density inside a structure which is potentially chain reacting but not large enough to reach the point of diversion was disclosed for the first time, I believe, by me as shown in Exhibit A which is available in the form of photocopies atamped March 9, 1939 by the U.S. Post Office. There are also subsequent publications disclosing these laws, one of them by F. Perrin in the summer of 1939.

It was quite well-known in 1939 to men skilled in the art that by measuring the neutron density inside the structure one can observe whether or not the multiplication factor is larger than 1 and determine the approximate size of the divergent chain reacting unit. Measurements of the neutron density x inside a chain reaction strutture were, for instance, published by ~~xmix~~ Joliot in a paper which is quoted in A-55. (Journ. de Physique 1939) 5-K and 11-K

In my letters to Fermi in July 1939, ~~and also on pages 5 and 11. which Fermi refers in the last paragraph (see also last paragraph in Fermi's letter to Anderson, exhibit F)~~ and on page 24 of this in A-55, I disclosed a method for determining a length A which is characteristic for a system in which the thermal neutron density obeys the diffusion equation. This method consists ~~in xdetexmxinx~~ity

in determining the thermal neutron density along a closed surface and at one point in the interior of the space which is enclosed by the closed surface. The thermal neutron density is then reduced to zero along the closed surface by introducing cadmium, and the thermal neutron density is again measured at the said point in the interior.

By applying this principle to a chain reacting mixture, one can determine the critical dimensions of a sphere which is simply the product $R = \pi A$ and at the Washington meeting in June 1940, Fermi explicitly ~~proposed the use of~~ this principle for determining the critical dimensions. The specific form ~~in~~ which Fermi ~~proposed~~ to apply this principle is at present calle "the exponential experiment" ~~and Fermi gave a short descritpion of the exponential experiment which he proposed at the Washington meeting in June 1940.~~ An exponential experiment has been actually performed by Fermi ~~for the first time~~ in April 1940 for the purpose of determining the length A in the limiting case of graphite which ~~did not contain any uranium.~~

~~At the Washington meeting in June 1940,~~ Fermi explicitly ~~proposed~~ the use of this principle for determining the critical size and described shortly the method which at present is called exponential experiment. Such an exponential experiment has been performed in April 1940 by Fermi to determine the length A in graphite which did not contain uranium.

(d) It was well-known to men versed in the art that by surrounding a potentially chain reacting unit with paraffin, water or a manganese-sulfate solution one can slow down all the neutrons emanating from the structure and by measuring the neutron density outside the structure, can determine whether or not the number

of neutron generated by the pile increases with increasing size of the structure. Such measurements are, for instance, published by Joliot and quoted in A055. Such a measurement is also mentioned in a letter written by Fermi to Pegram in July 1939, It is my contention that men skilled in the art knew that this method was available and that the application of this method was quite obvious and did not require any invention.

3. It is my contention that in view of the state of the knowledge in February 1940, a structure which is large, but not quite as large as the critical size and which has a multiplication factor larger than 1, would have consitutted a useful device for inducing radioactivity ~~my~~ by means of neutrons and for producing fission products. A publication of Joliot, for instance, describing a chain reacting unit in which the multiplication factor is smaller than 1 and in which the radioactivity is induced by means ~~of neutrons and~~ a neutron source ~~is~~ placed in the center of the structure, ~~and~~ Joliot demonstrates that the total number of neutrons produced in the system is very much larger than the ~~sum of neutron~~ number of the neutrons emitted by the source. A uranium-carbon structure which has a multiplication factor larger than 1 is a great improvement in this respect over Joliot's structure even through the structure remains ~~is~~ below the critical size.

Impurities

4. It is my contention that it was known as early as July 1939 how much neutron absorbing impurities we can safely tolerate. I was, in the respect, in touch both with the National Carbon Company and the U.S. Graphite Company in July 1939. I was not quite satisfied with the .1% ash and the vanadium content of the ash of the graphite, offered by the National Carbon Company, and the U. S. Graphite Company offered us in July 1939 graphite which had only .05% ash and

which contained a much smaller ~~percent~~ fraction of vanadium than the National Carbon Company graphite. It is my contention that the absorption cross sections of all elements that occur as impurities in either graphite or uranium were sufficiently well-known at the time to enable us to write a specification for purity.

I wish to draw attention to the fact that what matters is only the neutron absorption of the total amount of impurities which are dispersed in the chain reacting structure, and that it is immaterial whether these impurities are in the graphite or in the uranium. To be quite precise let us ~~state~~ add that inasmuch as the thermal neutron density in the uranium is slightly smaller than in the graphite, the harmful effect of the impurities ~~contained~~ is slightly less in the uranium than in the graphite.

There was one great difference between the graphite and uranium, however. Uranium was available in the form of soluble salts like, for instance, uranium nitrate which would be easily purified by recrystallization or ether extraction, both methods being well-known and a number of other methods for purification which are described in chemistry books. Graphite, however, cannot be brought into solution and there are not methods described in the books by which graphite could be purified. It was, therefore, our first concern to see whether pure graphite could be obtained.

In addition to this, we were informed in 1939 that uranium oxide, 99.5% pure, the impurities ~~derived~~ being mainly silicon and iron, were commercially available and ~~marketed~~ made by the ~~Canadian Radium Mines~~ Eldorado Gold Mines. I had no direct contact with ~~the Canadian Radium Mines~~ Eldorado in 1939, but I ~~visited~~ saw Mr. Lubear and discussed with him the question of the purity of the Belgian uranium oxide and also obtained samples from him in 1939. I also made inquiries concerning the purity of uranium oxide through Mr. Krewer ~~by~~ but I do not have ~~those~~ my old ~~fact~~ files at present in Chicago, so ~~that I cannot let up such information as may be contained in them.~~ available

Pure uranium metal had been previously manufactured by the Westinghouse Company from uranium nitrate. Uranium nitrate itself was commercially available and its purification and conversion into oxide do not meet with any difficulty for a trained chemist. Uranium metal has been produced prior to 1939 from urnium tetrachloride by means of reducing uranium tetrachloride with calcium metal. Prior to 1939 calcium metal was imported into this contry from France and this calcium metal was of a very high degree of purity. Samples of this French calcium tested by us showed that the boron content of the French calcium was not appreciable. The uranium itself may be purified in the process of transforming it into the uranium tetrachloride.

As to the total neutron absorption of the impurities which can be tolerated in the chain reacting unit dispersed throughout the structure whether in the graphite or in the uranium A-55 sets an upper limit in the following manner. It is obvious that the factor of the thermal neutrons absorbed of the impurities is the same as if the capture cross section of carbon were increased by the neutron absorbed of the impurity calculated per carbon atom in the structure. This leads to a change in A and a corresponding change in qm. Since page 20 of A-55 gives the room temperatures

~~A = 43.5 cm for $\delta_c(C) = 0.005$~~

$(\eta\varphi - 1) = \frac{1}{8}$ or $\eta\varphi \cong 1.125$

and this corresponds to R = 250 cm

It is computed from the formulae given in A-55 that an amount of impurity which would raise the absorption cross section per carbon atom from .005 to .006 already gives a large increase in the critical mass of the chain reacting sphere, and, therefore, constitutes an upper limit for the neutrons absorbed of impurities which must not be exceeded if we do not want to waste material by considerably increasing the critical size of the chain reacting unit.

I

"I saw Professor Pegram yesterday and discussed with him the situation. He had a letter from Admiral Bowen which he wanted to answer right away.

I told professor Pegram thatin my personal opinion the se mi - large scale experiment for which you have suggestedusing 5 tons of uranium metal ought to have the right ofway before everything else and that weshould not hesitate to place an order for this amount of metal; and perhaps as much as 50 tons of graphite. I have no doubt that this material will be needed in any case and will have to be ordered sooner or later. Clearly, it will be impossible for us to say with certainty even if we succeed in measuring all nuclear constants involved rather accurately within a year that a chain reaction with slow neutron cannot be made to work. Consequently, if we defer ordering thismaterial we would only lose time but not save any money."

I/

II.

~~Sorry to bombard you with so many letters about carbon.~~ This is just to tell you that I have reached the conclusion that it would be the wisest policy to start a large scale experiment with carbon right away without waiting for the outcome of the absorption measurement which was discussed in my last two letters. The two experiments might bedone simultaneously. The following can be said in favor of this prodedure:

A chain reaction with carbon is so much more convenient and so much more importantfrom the point of view of applications than a chain reaction with heavy water or helium that we mustknow in the shortest possible time whether we can make it go. This can be decided with certainty in a relatively short time by a large scale experiment, and therefore this experiment ought to be performed. If we waited for the absorption measurement we wouldlose three months, and in case the result is positive we would still not know with a 100% certainty the answer with respect to the question of the chain reaction.

I thought that perhaps 50 tons of carbon and 5 tons of uranium should be used as a start."

UNITED STATES
ATOMIC ENERGY COMMISSION
OFFICE OF CHICAGO DIRECTED OPERATIONS
P. O. Box [redacted] 5207
CHICAGO 80, ILLINOIS

IN REPLY REFER TO:

CPD:DMH (S-506)

September 21, 1951

Dr. Leo Szilard
Prof. Biophysics Inst. Radiobiology and Biophysics
University of Chicago
6200 Drexel Avenue
Chicago, Illinois

Subject: RE-EXECUTION OF AND OATH FOR CASE S-506, SERIAL NO. 596,465

Dear Dr. Szilard:

We are enclosing herewith an oath in connection with the case identified above for re-execution by you.

You had previously executed an oath for this case on May 2, 1945, but due to the length of time that elapsed between the date of execution and the date of filing, the Examiner has requested that a new oath be executed and filed in the U. S. Patent Office.

Please sign the oath at the place indicated with a metal tab, being careful that you sign your first name in full and otherwise have your signature correspond with the manner in which your name is typed in the body of the oath. Please be sure to have your signature notarized.

Please return this oath to us when it has been properly executed.

Very truly yours,

Foster York, Chief,
Chicago Patent Group

Enc.

5650 Ellis Avenue

October 3, 1951

Your reference:
CPD:DMH (S-506)

Mr. Foster York, Chief
Chicago Patent Group
U. S. Atomic Energy Commission
Post Office Box 5207
Chicago 80, Illinois

Dear Mr. York:

Enclosed herewith is the signed and notarized copy of the Oath for case S-506, serial no. 596,465.

I trust that you will find this copy satisfactory.

Very truly yours,

Leo Szilard

sds
Enclosure

5650 Ellis Avenue

November 7, 1951

Mr. Foster York
U. S. Atomic Energy Commission
Post Office Box 5207
Chicago 80, Illinois

Dear Mr. York:

I am returning to you enclosed the material which you sent me November 6, 1951. As you see, I have executed the affidavit. Since I am not equipped here to handle any secret documents, I would appreciate it if no further documents were sent to me in the future. Instead, I suggest that an appointment be made over the telephone and that someone come to see me with the documents. It may then be possible to settle the matter in short order and the documents can be taken back immediately. As I said before, I have no place to keep secret documents.

Sincerely yours,

LS.

Leo Szilard

LS/sds
Enclosures

material sent to L. S. under registry # 477656

UNITED STATES
ATOMIC ENERGY COMMISSION
OFFICE OF CHICAGO DIRECTED OPERATIONS
P. O. Box [redacted] 5207
CHICAGO 80, ILLINOIS

IN REPLY REFER TO:

CPD:JAH:dmh

November 19, 1951

Dr. Leo Szilard
Institute of Radiobilogy and Biophysics
University of Chicago
5650 Ellis Avenue
Chicago 37, Illinois

Subject: CASE S-348

Dear Dr. Szilard:

We wish to thank you for your cooperation in signing and returning the affidavit in connection with the subject case. Your suggestion that similar matters concerning classified subject matter be handled personally rather than by mail will be followed in the future.

As to the classification of the subject matter of the affidavit, this was necessitated because of the enclosure of photostats of pages of project reports and the Clinton Project Hand Book which were classified secret. It would involve just too much time and trouble to go through all the rigmarole required to have these reports declassified, even if it could be done.

Very truly yours,

Foster York

Foster York, Chief,
Chicago Patent Group

UNITED STATES
ATOMIC ENERGY COMMISSION
CHICAGO OPERATIONS OFFICE
P. O. Box 6140A
CHICAGO 80, ILLINOIS

NEW MAILING ADDRESS
POST OFFICE BOX 299
LEMONT, ILLINOIS

CPD:lo

January 21, 1953

Mr. Leo Szilard
1155 E. 57th Street
Chicago 37, Illinois

Re: Case No. S- 10564
Serial No. 323,451
Filing Date December 1, 1952

Dear Mr. Szilard:

Your patent application identified above has been filed in the United States Patent Office. You no doubt will receive from the Patent Office a notice of issuance of an order of Secrecy under Public Law 256 and with the order a printed Form D-18, which includes under Item 2 information as to the tender of the application for the use of the United States Government. You will also receive a receipt to be filled in and returned to the Patent Office.

Kindly execute and return the receipt to the Patent Office but do NOT tender the invention in this application to the Government as stated in Form D-18 because you have already assigned the invention to the Government as represented by the United States Atomic Energy Commission. A tender by you to some other Government agency would only complicate matters in view of the fact that you have already assigned the invention to the Government.

Very truly yours,

Foster York

Foster York, Chief
Chicago Patent Group

UNITED STATES
ATOMIC ENERGY COMMISSION
CHICAGO OPERATIONS OFFICE
~~P. O. Box 6140A~~ 5207
~~CHICAGO 80, ILLINOIS~~
NEW MAILING ADDRESS
POST OFFICE BOX 299
LEMONT, ILLINOIS

SYMBOL: CPD: SJW April 9, 1954

Dr. Leo Szilard
c/o Mr. A. N. Spanel
International Latex Co.
350 Fifth Avenue
New York, New York

SUBJECT: CASE S- 1578 , SERIAL NO. 664,732

Dear Dr. Szilard:

A Notice of Allowability was received from the U. S. Patent Office for your patent application identified above, entitled

REACTORS

and executed by you on April 8, 1946.
This normally means that whenever the application is declassified, the application will issue as a patent, at which time you will be notified and sent a copy of the issued patent.

Your courtesy and assistance to the members of the staff of the Patent Branch in connection with the prosecution of this application are appreciated.

Very truly yours,

Foster York

Foster York, Chief
Chicago Patent Group

UNITED STATES
ATOMIC ENERGY COMMISSION
CHICAGO OPERATIONS OFFICE
P. O. Box 59
LEMONT, ILLINOIS

NEW MAILING ADDRESS
POST OFFICE BOX 299
LEMONT, ILLINOIS

CPD:lo

June 8, 1954

Dr. Leo Szilard
c/o Mr. A. N. Spanel
International Latex Co.
350 Fifth Ave.
New York, N. Y.

Re: Case No. S- 2247
Serial No. 668,110
Filing Date May 8, 1946

Dear Dr. Szilard:

Your patent application identified above has been filed in the United States Patent Office. You no doubt will receive from the Patent Office a notice of issuance of an order of Secrecy under Public Law 256 and with the order a printed Form D-18, which includes under Item 2 information as to the tender of the application for the use of the United States Government. You will also receive a receipt to be filled in and returned to the Patent Office.

Kindly execute and return the receipt to the Patent Office but do NOT tender the invention in this application to the Government as stated in Form D-18 because you have already assigned the invention to the Government as represented by the United States Atomic Energy Commission. A tender by you to some other Government agency would only complicate matters in view of the fact that you have already assigned the invention to the Government.

Very truly yours,

Foster York

Foster York, Chief
Chicago Patent Group

UNITED STATES
ATOMIC ENERGY COMMISSION
CHICAGO OPERATIONS OFFICE
P. O. Box 59
LEMONT, ILLINOIS

April 26, 1955

CPD:CET:hc

Dr. Leo Szilard
c/o Mr. A.N. Spanel
International Latex Co.
350 Fifth Avenue
New York, New York

Subject: DECLASSIFICATION OF DOCUMENTS

Dear Sir:

This is to inform you that the following documents, MUC-PA-7513 and MUC-PA-7579, addressed to you, have been declassified. Accordingly, you should remove classification markings therefrom.

Very truly yours,

Foster York

Foster York, Chief
Chicago Patent Group

UNITED STATES
ATOMIC ENERGY COMMISSION
CHICAGO OPERATIONS OFFICE
P. O. Box 59
LEMONT, ILLINOIS

June 6, 1955

CPD:EC:es

Dr. Leo Szilard
c/o Mr. A. N. Spanil
International Latex Company
350 Fifth Avenue
New York, New York

Subject: PATENT NO. 2,708,656

Dear Mr. Szilard:

This office takes pleasure in forwarding a copy of the above-identified patent which, as you will note, issued on May 17, 1955 based on application Serial No. 568,904.

Your courtesy and assistance to the members of the staff of the Patent Branch in connection with the prosecution of this application are appreciated.

Very truly yours,

Foster York

Foster York, Chief,
Chicago Patent Group

Enc. (1)

The Quadrangle Club
The University of Chicago
Chicago 37, Illinois
September 6, 1956

Mr. Foster York, Chief
Chicago Patent Group
United States Atomic Energy Commission
Chicago Operations Office
P. O. Box 59
Lemont, Illinois

Dear Mr. York:

Many thanks for your letter of August 24th in which you wrote me about Case S-10,565; Serial No. 323,452. I wonder if you could inform me what this case is about? Is this my application relating to the fast reactor or, if not, to what subject matter does it relate?

I wonder if it would be possible for you to send me a list of all applications which you have filed for me, indicating the following:

1.) Who are the co-inventors, if any?

2.) Is the application pending, abandoned, or granted; and if granted, is it declassified or not?

3.) What is the subject matter of the application? On this point I do not need any detailed statement that might violate the requirements of secrecy, but merely a sufficient indication of what it is all about to enable me to identify the application from memory.

I shall appreciate your kindness in furnishing me with this information.

With best wishes,

Very sincerely yours,

m

Leo Szilard