ORNL TECHNICAL INFORMATION DIVISION
Y-12 TECHNICAL LIBRARY
Document Reference Section
LOAN COPY ONLY
Do NOT transfer this document to any other person. If you want others to see it, attach their names, return the document, and the Library will arrange the loan as requested.
UCN-1624
(3 5-60)

DECLASSIFIED
CLASSIFICATION CHANGED TO: TID-1177
BY AUTHORITY OF: DBS by Marie Carbonell
BY:

MUC-LAO-18
This document consists of 5 pages and 3 pgs. Outline ~~figures~~
No. 5 of 18 copies, Series
ML

NOTES ON MEETING OF APRIL 28, 1944

9:00 - 10:30 209-Eck

Present: Fermi, Allison, Wigner, Smyth, Szilard, Morrison, Watson, Feld, Hogness, Young, Weinberg, Creutz, Cooper, Vernon, Ohlinger

The first speaker was Mr. P. Morrison; his comments follow: If we view the chain reaction merely as a source of unspecialized energy, it goes directly into competition with the many existing large scale prime movers and fuel sources. Economics are then paramount. It is Mr. Morrison's opinion that we should not move in that direction for some time to come, but should attempt to exploit the particular properties of the chain reaction as a concentrated source of a highly special form of energy. Power simply as kw hours should appear at most as a by-product. *

The following data was gathered from the Bureau of Mines bulletins and other sources and correlated by Mr. Morrison.

In 1941 the average yearly power produced by the major sources was as follows:

Water	25×10^6 kw
Gas and Petroleum Products	340×10^6 kw
Coal	470×10^6 kw
	835

The first item covers mostly government and private utilities and private industrial power developments. Of the power produced from the second fuel source, about 40% was from gasoline in all its uses. Of the power produced from coal, about 10% was used in public utilities, about 10% for coke and chemical uses, about 20% for railroad transportation, and the balance of about 60% for other miscellaneous uses including domestic and industrial fuels. Of the above total figures for the world power production, the U.S. consumed about 35% of the coal-produced power and about 60% of the petroleum-produced power.

Cost figures for the above power, while not on a strictly comparative basis, are interesting. The figures below are all per megawatt hour.

Government hydropower	-	$1.20
Private hydropower	-	2.00 to 2.50
Most efficient coal-steam plants	-	0.80
City consumer	-	30.00
Large industrial consumer (firm power)	-	4.00
Rjukan	-	0.40

[redacted]

(Energy, not mechanical power)		$200.00
TNT	-	~~$2.00~~
Hi-octane gas	-	4.50
Motor fuel	- ~	2.00

The first item is based on the cost of the power at Boulder Dam at the bus-bar face on a guaranteed consumption continuously throughout the 24 hour day and includes the cost of the original equipment, maintenance, etc. The figure for the coal-steam plant is based on the fuel cost only and does not include the equipment, maintenance, etc. As Mr. Szilard pointed out, these two cannot be compared and, as Mr. Fermi observed, it is the 80¢ figure of the coal-steam plants with which we must compete in the production of power.

As Mr. Morrison noted in a recent memorandum, the approximate abundance of tubealloy and thorium in the top crust (5 to 8 km thick) of the earth is as follows:

Tubealloy	4 ± 2 ppm	(found mostly in granite and does not include sands, etc.)
Thorium	12 ± 4 ppm	(found mostly in sedimentary rocks)

The most efficient gold extraction plant yet constructed has been able to dig the rock, crush it, treat it, etc. to recover the gold for about $7.00 per ton. Crushing rock requires about 100 kw hours per ton when the rock is reduced to particles of about 1 mm^3 in size. Therefore, Mr. Morrison estimates that we could afford to work the rock for power (based on using the 25, not the 28), if necessary, providing the abundance of the tubealloy was not less than 5 to 10 ppm. It has been estimated that there are about 10^{14} - 10^{15} tons of natural tubealloy to be found in rock in the earth's crust and about 10^8 tons in sea water (the concentration in sea water is about 10^{-9} gms of tubealloy per gm of water).

The richest occurences of natural tubealloy in the world are at the following locations. All figures are very rough estimates based on incomplete and often reluctant surveys by the producers. All tonnage figures are tons of tubealloy and not ore.

U.S.	(mainly Colorado vanadium ores or Carnotite, having a content of about 1% tubealloy. Estimated at 3,000 tons of tubealloy available in 1925.)	about 5,000 tons in sight.
Czech	(also about 1% content)	about 1,000 tons remaining.

[redacted]

Congo	(of five sites total, one was estimated in 1925 at not less than 5,000 tons of ore having 20% tubealloy content)	about 5,000 tons in sight.
Canada	(although other deposits undoubtedly exist, the known deposits containing 20 to 50% tubealloy content ore have)	about 5,000 tons.
Russia	(1 to 2% tubealloy content Carnotite vanadium ore deposits)	not less than 3,000 tons in sight.

Total about 20,000 tons of tubealloy in sight.

A similar table of the distribution of thorium throughout the world follows. This is found almost entirely in monazite sand having about 5 to 11% thorium content.

U.S.	(mainly in North Carolina with a small amount in Idaho and Florida)	about 1,000 tons.
Brazil	(on the coast)	about 8,000 tons.
British India		about 150,000 tons.
Netherland East Indies		may have about 5,000 tons.

If we were to use the entire U.S. and Canadian resources of tubealloy (10,000 tons) using a γ of 0.9 and utilizing only the 25 and not the 28, we would have an equivalent replacement factor of only nine months for the total power consumption of the U.S. or about ten years for the hydropower.

The second speaker was Mr. Szilard who continued his discussion from the previous meeting. He recapped first the three possibilities as he saw them:

(1) Unseparated tubealloy ⟶ 49 production

(2) Enriched tubealloy ⟶ 49 production

(a) slow chain reaction

(b) fast chain reaction

(3) Enriched tubealloy ⟶ <u>no 49 production</u>

[redacted]

On the basis of Morrison's report, Mr. Szilard felt that the tubealloy should be utilized more efficiently, i.e., using the 28 and not just the 25. However, since the power production indicated in item (3) above is a long term proposition, he did not intend to discuss this phase at great length at this time.

In item (1) above, heat is only a byproduct and not the primary object. Concerning item (2), Szilard proposed answering the question - if an amount A of 49 were invested, how long would it be until 2A of 49 were obtained. In a fast chain reaction, if two tons of enriched ore containing 10% of 49 were used in the core surrounded by 28 at the rate of 125,000 kw, then 2A of 49 would be produced in 4½ years. In order to have any practical significance, this time should not be very much larger and the readjustment of the material should be easy during the time of operation.

Considering first the slow chain reaction: assume a μ_{49} (neutrons emitted in fission/neutrons absorbed) equal to 2.0 - 2.2. Szilard struck out the latter figure when Fermi stated that the μ_{49} is probably lower than μ_{25}. With $\mu = 2$, just as much 49 is being produced as is being destroyed. In a slow chain reaction this might be improved by using the fission of 28 mixed with 49 but this is not very effective in a slow chain reaction because even from large lumps embedded for instance, in graphite, many neutrons escape, are slowed down, and do not produce fission. Since the super-plutonium (40-10) formed might be fissionable, there is, say, a fifty-fifty chance that we can improve μ to a $\mu_{eff} = 2.5$.

Considering the fast chain reaction, the situation is more favorable. With a low concentration of 49 in the mixture with 28, experiments have shown that ε might be raised to 1.2. In addition, there is a high energy tail producing an (n, 2n) reaction which may give a 2½% increase in μ (based on observations of Turkevich).

(The value μ has been defined as the number of neutrons produced/number absorbed in 49. Szilard uses ν_0 defined as the number of neutrons produced/number of fissionable atoms used up.).

In a fast chain reaction, even if 40-10 is not fissionable, Szilard felt that it is probably true that the branching ratio for 40-10 moves in a favorable direction, or that ν_0 may be taken as $\nu_0 = 2.5$. He felt strongly that there is a very good chance that Pu^{240} is either fissionable in the thermal region or at least that the branching ratio can be counted upon to decrease by a factor of 3 as one goes from thermal energies to, say, 1 Mev. (Fermi pointed out that the branching ratio of 49 is greater than that for 25.)

The arguments for this belief is in part based on the rule of thumb $(\Delta M/M) - (2\Delta Z/Z)$ (see also Morrison in Project Handbook, Chapter IV B 1.1) which gives a rough indication of the fission threshold and is partly based on the belief that, with increasing neutron energy, the time required for fission decreases whereas the time required for radiative

[redacted]

capture remains constant. Szilard therefore assumes that, in a mixture of 238 and Plutonium, $\varepsilon \nu_0 = 1.2 \times 2.5 = 3.0$ neutrons emitted per thermally fissionable atom destroyed and this would mean that there is a net gain of one thermally fissionable atom per similar atom destroyed.

Referring to item (3), Szilard emphasized one possibility, i.e., the burning of Plutonium in a slow reaction and absorbing the neutrons by bismuth to give Polonium. Of the heat dissipated when Plutonium is destroyed to give Polonium, only about 3% would be stored in the Polonium. However, this energy will be available for use free of γ radiation and could be used for driving airplanes, etc.

In the discussion following, Fermi questioned the estimated value of $\nu_0 = 2.5$ on the ground that it might be too optimistic and pointed out that there is a long range future in developing the full utilization of 28 and thorium.

Wigner questioned the feasibility of the rotating disc arrangement described at the previous meeting on the ground of poisoning and questioned the $4\frac{1}{2}$ year investment return. He felt this would probably be more nearly 10 to 20 years by which time, as Mr. Morrison suggested, we may be burning water.

After discussion, Szilard expressed his view that item 2a is of more immediate concern than 2b.

Mr. Morrison suggested that more work should be done on the nuclear development of thorium because of its greater availability and also suggested experiments to obtain ν_{23} and other useful constants.

Mr. Ohlinger explained very briefly an outlined program, of which a copy is attached hereto. This program for consideration of future trends in the laboratory work, is a compilation of the independent results of the "homework" requested at an earlier meeting. It has been assembled to give a majority concensus of the classification of possibilities.

In general, the outline is first divided into three main groups based on the use to which a pile would be put. Thereafter, the potentialities are subdivided for easy consideration. An open discussion of this outline will occur at the next meeting on Friday, May 5th.

[redacted]

I. POWER PRODUCTION (49, 25, or 23 consumed)

A. Purpose of power (in order to determine following)

1. Physical size and mobility

a. Large stationary piles (slow chain react. or group of fast chain react.) such as for central stations

b. Medium mobile (or sta.) piles (slow chain react. or group of fast chain react.) such as for boats or locomotives

c. Small mobile piles (fast chain react.) such as for planes or cars

2. Power output range, e.g.

a. over 10^6 kw

b. between 10^3 - 10^6 kw

c. less than 10^3 kw

B. Utilization of Energy

1. Direct

a. Electrical removal (including thermocouple type)

b. Working fluid absorbing heat directly

(1) Direct liquid vaporization in pile to operate turbine, etc.

(2) Gas cooling with or without gas turbine

(3) Endothermic chemical reactions, e.g., $2H_2O \rightarrow O_2 + 2H_2$

2. Indirect Energy removed by circulating

a. the metal

b. the moderator (if any)

c. the coolant

II. ISOTOPE PRODUCTION (49 or 23 produced)

(Since its purpose is well defined and there are no limitations on size, lack of mobility and power produced, except by the operating potentialities of the design chosen, these factors are not outlined here.)

[redacted]

A. 49 Production

1. Slow chain reaction (thermal neutrons) using normal U

   a. Homogeneous piles moderated with

      (1) P-9

      (2) P-9 + H_2O

   b. Heterogeneous piles moderated with

      (1) Graphite - improvement in operation and utilization of present piles (X and W) and design new improved piles

      (2) P-9 } Also require a separation process to recover P-9

      (3) P-9 + H_2O }

      (4) Be

      (5) BeO

   c. Cooling accomplished by moving

      (1) the metal (UF_6, molten U, solutions)

      (2) the moderator (P-9, P-9 + H_2O)

      (3) a separate coolant (H_2O, P-9, liquid Bi or Bi-Pb alloy, diphenyl)

2. Enriched piles (enriched with 49 or 25)

   a. Slow chain reaction as outlined above

   b. Fast chain reaction as outlined below

3. Fast chain reactions (no moderator)

   a. Homogeneous piles

   b. Heterogeneous piles

   c. Cooling accomplished by

      (1) Liquid Bi as coolant

      (2) Liquid Na as coolant

      (3) Using U molten and moving it [redacted]

B. 23 Production

1. Reflectors

Comment: If power produced in making 49 can be used practically, this constitutes another case, - a combination of I and II.

III. RADIATION SOURCE (High levels of intensity)

(Since the purpose is well defined and size, mobility and power produced are not criteria, they are not outlined here. However, such a pile must be flexible with the ability to reach high levels of intensity and expose materials or take measurements with ease. Flux and not total power important here. Most suitable of piles defined in II to be chosen as experimental machine. Routine metal removal is not important.)

PROBLEMS COMMON TO ALL PILES (or a large number of them)

1. Shielding
2. Reflectors

[redacted]

MAY 1944
Clinton Laboratories
Central File
Room

RECEIVED
MAR 22 1949
OAK RIDGE NATIONAL
LABORATORY
CENTRAL FILE

RECEIVED
APR 2 1949
OAK RIDGE NATIONAL
LABORATORY
CENTRAL FILE