DECLASSIFIED

[redacted]

U. S. ATOMIC ENERGY COMMISSION

[redacted]

AEC FORM 94 (MAR. 19, 1947)

~~RESTRICTED DATA~~

~~This [illegible] restri[illegible] [illegible] of 1946. Its transmit[illegible] disclosure [illegible] tent[illegible] manner to an unauthorized [illegible]son is prohibited.~~

	TO	INITIALS	DATE
1	Griffith		
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
	FROM		

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

RESTRICTED DATA
This document contains restricted data as defined in the Atomic Energy Act of 1946. Its transmittal or disclosure of its contents in any manner to an unauthorized person is prohibited.

[redacted] [redacted]

AB-1013 UCRL-781

THIS DOCUMENT CONSISTS OF 4 PAGES.
NO. 3 OF 14 COPIES. SERIES B.

DECLASSIFIED

MEETING HELD JUNE 27, 1950 ON MARK II TARGET PROBLEMS

Present: UCRL: Alvarez, Hansen, Latimer, Perlman, Reynolds, Street, Van Atta*, York

CRDC: Cope, Crandall, Gaylord, Kent, Powell

AEC: Ball, Dean, English, Fidler, Hageman, Langmuir, Thomas

* Consultant

Van Atta outlined the target problems as follows: The process to be utilized will involve the bombardment of a target material with high energy deuterons in which neutrons will be produced both by the spallation reaction and by stripping process on the deuterons themselves. This latter process will yield neutrons of much higher energy than will the spallation reaction. In order to utilize efficiently these two different neutron spectra it will be necessary to provide for both a primary and a secondary target.

Presently available data indicate that with deuterons of 350 Mev the multiplication factor obtainable for neutron production is 9 to 1. Another possible target arrangement is to use a primary target of beryllium backed up by a target of uranium. By such a target arrangement it is expected that one could approach the neutron yield obtained by the direct bombardment of the uranium itself. A test chamber is now being completed which is roughly a 4-foot cube tank with a 1-foot square channel running through it in which various target arrangements can be placed and subjected to measurement of their over-all neutron yield.

Tests will be made both on targets in which the uranium is disposed at normal incidence to the beam and also target arrangements in which the beam impinges on the uranium at a large angle. Because of the difference in neutron spectra in the lateral and forward directions, the secondary uranium target will be differently designed for use in these two regions. Targets slated for immediate test will be plain uranium followed by uranium bonded to copper or steel and backed up in turn by cooling water. Thorium will also receive study as an alternate target material in the event that problems in uranium metallurgy preclude its satisfactory use. The uranium, due to its unfortunate crystal structure, is extremely sensitive to damage both from radiation and from thermal cycling. The importance of the damage due to the thermal cycling has not been estimated but may not prove to be severe since the thermal cycle will involve temperature variation of only about ± 30 degrees Centigrade.

A third target material of possible interest is heavy water. This material would not give the same intrinsic neutron production as is obtainable with the heavy metals but would have the advantage of providing a fluid target material from which the heat may be easily dissipated; would provide a target material in which essentially the entire beam energy may be dissipated; and, further, would yield neutrons largely of

DECLASSIFIED

CLASSIFICATION CANCELLED (OR CHANGED TO [redacted])
(INSERT APPROPRIATE CLASSIFICATION)
BY AUTHORITY OF TID-1339 2/28/67
(PERSON AUTHORIZING CHANGE IN CLASSIFICATION)
BY B J Blackburn 6/1/67
(SIGNATURE OF PERSON MAKING THE CHANGE, AND DATE THEREOF)

[redacted]

DECLASSIFIED

high energy in the generally forward direction. These favorable characteristics may conceivably dictate the use of a heavy water target if the geometry required for heat removal of the heavy metal targets decreases their efficiency excessively. Also to be investigated, if obtainable, will be a 5 percent molybdenum-uranium alloy which is said to have a cubic crystal lattice and should be therefore much less susceptible to damage from radiation and thermal cycling.

Among the first things to be measured will be over-all neutron yields of various target materials and target geometries. Also to be measured will be the neptunium production in the secondary target, since this will give a measure of the slow neutron multiplication in the secondary target. Finally, the thermal neutron flux distribution throughout the tank will be measured for the more promising target arrangements.

Thomas asked if the neutron production per deuteron of 9/1 is the maximum that can be obtained with any target material. Van Atta said they are not prepared to answer that question definitely. The neutron ratio of 9/1 is instead a figure which it seems can be reasonably well approached with realistic target designs with a deuteron energy of 350 Mev. Alvarez mentioned that it may turn out that the optimum beam energy may be less than 350 Mev. Latimer pointed out also that the neutron yield in the secondary target used in conjunction with a primary heavy water target is not yet known. Van Atta said that in using light materials such as lithium or beryllium as a primary target there will be an increased yield of high energy stripped neutrons, and the over-all neutron yield then becomes more dependent upon the fast fission multiplication in the secondary target. English inquired as to the ratio between neutrons produced by stripping and those produced by fission or spallation in the primary target. York said that the neutrons produced by the stripping process after multiplication in the secondary target are about 1/3 of those produced by the direct fission and spallation processes. To summarize, the various target arrangements being considered are the following:

1. V-shaped target.

2. Flat target in which the deuteron beam might pass through relatively little uranium.

3. A rotating wheel covered with thick uranium and water cooled.

4. Fluidized powdered uranium oxide. Thin walled stainless steel tubes with the heat removal being accomplished outside the primary target.

5. Uranium sheets encased in stainless steel cooled with water.

6. Molten uranium target.

There is also a possibility of uranium tubes encased in thin stainless steel tubes disposed as in a boiler tube arrangement and cooled by passing water through them. Targets of this latter type appear capable of design in which at least 90 percent of

DECLASSIFIED

[redacted]

the deuteron energy is expended in the uranium metal. The beam energy lost in the water would yield some neutron production, so that an over-all energy utilization for neutron production as high as 95% of that for pure uranium might be obtained. These various target arrangements will be very carefully studied in order to justify those which are most promising for detailed investigation.

One additional problem to be solved is that involving the intensity distribution of the beam as it leaves the accelerator. Recent calculations by Panofsky indicate that the beam intensity at the center may be 30 or 40 times the average beam intensity and this may require some sort of sweeping of the beam over the target arrangement in order to avoid excessive local heating. Van Atta said that his preliminary calculations on using a scatterer for this purpose do not look very promising since it does not appear possible to maintain the scatterer in a solid state by depending upon radiation cooling alone. Alvarez suggested that a rotating wheel might be used as a scatterer. Van Atta said that two foils with helium at low pressure flowing between them for cooling might also be feasible. Van Atta said Brobeck had suggested rotating the beam by passing it through a rotating magnetic field. Calculations on this suggestion indicate that a plateau of intensity on the target can be obtained out to the radius of the circule which is being swept out. There is also a possibility of sweeping of a rectangular, rather than a circular, area by using crossed magnetic fields oscillating at different frequencies. Langmuir asked what was the total area to be bombarded. Van Atta said that the area of the beam, if rotated over a circular pattern, would cover a circle approximately 6 feet in diameter and that the plateau would extend over a diameter of about 3 feet.

Thomas inquired as to what steps can be taken to test various target materials for radiation damage. Alvarez said that the 60-inch cyclotron could be used and could prove satisfactory for this purpose. Latimer said that the radiation damage to uranium caused by the fast neutron reactor at Los Alamos has proved to be more severe than had been expected.

Delete

Van Atta said one additional problem that will require study will be that of neutron moderation and utilization and the design of the tertiary target. Also to be developed is the chemistry for the extraction of tritium and, lastly, the problem of shielding. This latter problem appears to be one which should be deferred until a specific target design has evolved. At that time whatever is necessary to ensure safety can be done. Van Atta said that Brobeck has taken one of these typical target suggestions and has worked out a preliminary design of a target structure. Although this layout is very exploratory, Brobeck has attempted to anticipate the problems of maintenance and repair of the primary and secondary targets and the removal of sections of the tertiary target for tritium recovery. Similar preliminary sketches of other target arrangements will soon be drawn up so that the engineering problems of each arrangement can be studied more effectively.

Latimer says that with regard to the design of the Mark II we have about six months' leeway in which to firm up ideas as to the most fruitful approach to the problem. Following this period a rather rapid schedule will have to be followed on its engineering and construction. Commissioner Dean inquired as to the nature of

assumptions regarding target design which had been made in estimating the production of a gram of neutrons per day or one kilogram of tritium per year. Alvarez says that the general assumption made was that the target could be designed to make reasonably efficient use of the neutrons produced by the stripping, spallation, and fission processes in the target. English asked whether or not consideration had been given to the use of uranium deuteride or other specific uranium compounds. Van Atta said that no specific consideration had been given to this compound but that experiments would be conducted to evaluate the effectiveness of several specific uranium compounds as well as the metal. Thomas inquired as to how obtainable in practice would be the ion currents that had been estimated, to which Alvarez replied that all of our estimates have been on the low side. He pointed out that we are planning initial operation with a 1/5 duty cycle and there is no reason why this cannot be increased to a 100-percent duty cycle if adequate power and cooling are provided. He pointed out that one ampere current run with a 100-percent duty factor and with a neutron multiplication factor of 10 would yield 10 moles of neutrons per day. We are talking about running with a 1/20 ampere, which means we will be able to produce a half gram of neutrons per day. However, an average current of 0.1 ampere appears very readily obtainable so there should be no question at all about getting one gram of neutrons per day. The power bill for this rate of production would be about $6,000,000 per year, which would give approximately one kilogram of tritium. Latimer pointed out that there is still considerable uncertainty as to the suitability of uranium as the primary target material.

Thomas inquired as to the order of magnitude of the neutron flux that would be produced in the neighborhood of the primary target. York said that with a 50-ma beam the flux would generally exceed 10^{12}. It will not be 10^{12} all through the target region and, as a matter of fact, if it were required to be of that magnitude for efficient utilization one would have to sacrifice about 10 percent of the neutrons. Perlman said that these figures apply to the use of normal water as a moderator, but that if heavy water were used as a moderator this figure could be significantly increased. Street said that the amount of lithium required as target material could be reduced by using heavy water as the moderator. Latimer pointed out that we have an urgent need for a good theoretical physicist with a thorough background in pile technology who can evaluate these target arrangements in terms of over-all neutron economy.

Alvarez said that the power consumption on the Mark II accelerator with a 1/5 duty cycle will be about evenly distributed between skin losses in the liner and the beam itself. He said if the injected beam current were increased the additional power fed into the cavity would go almost entirely into the beam, whereas if the duty factor were increased to 100% the power lost in the liner would go up by a factor of only 3 or 4. Latimer said that there is a possibility of running the target at very high temperature and using the outcoming coolant to generate useful power which could be used to offset the increased power requirement due to increasing the duty factor.

Attached as an appendix is the text of a letter from Dr. S. Intermeyer to Professor Latimer, dated June 26, 1950, with regard to Mark II target problems.

Russell H. Ball

RESTRICT[redacted] DAT[redacted]
This document contains restrict[redacted] defined in the Atomic Ener[redacted] Its transmittal or the di[redacted] of its contents in any man[redacted] an unauthorized person is prohibi[redacted]

[redacted]

RE[redacted]

AB-1013

UCRL-781

DECLASSIFIED

THIS DOCUMENT CONSISTS OF 3 PAGES.
NO. 3 OF 14 COPIES. SERIES C.

APPENDIX TO
MINUTES OF MEETING HELD JUNE 27, 1950 ON MARK II TARGET PROBLEMS

"After I saw you, I had the pleasure of discussing with Van Atta, York, and Rohrbeck.

"Generally, it appears that gamma activities will require shielding the entire machine, while approximately 16 ft. of concrete shielding will be required around the target. Roughly 60,000 cubic yards of concrete would be needed to shield the machine. Thus shielding requirements are more severe than for a reactor. Reactors are much smaller and require about 10 ft. of concrete shielding.

"If water is used as a coolant, the entire cooling system will also require shielding on account of O-16 activity. This reaction is O-16 (n,p) $\longrightarrow$ N-16 (7.6 sec - 6.3 Mev gamma). The threshold of this reaction is 9.2 Mev and the cross section for very fast neutrons might be 100 times greater, and this would require about 7 ft. of concrete around the cooling system.

"As we discussed, the central problem is the high density of heat production in the target.

"If all the heat is produced in the first 5 cm depth in a one meter diameter target which dissipates 40,000 kw, then about 1,000 kw is released in each liter of target. This is about twice the highest power density contemplated for reactors and is many times higher than the heat production in any natural uranium reactor.

"I was originally persuaded that the subcritical feature of the machine would permit operation at marginal heat fluxes as failure might be less serious. On further thought, it is not clear that your machine differs from a reactor in respect to coolant failure hazards.

"The fission product activity in the target will be comparable with the activity in a reactor, while the consequences of coolant failure will be the same (possible melting of fuel and release of gaseous activities). In enriched reactors, boiling coolant ordinarily reduces reactivity and stops the pile.

"I was told that a very high heat flux (3 kw per sq. in. or 1,500,000 Btu/sq. ft. hr or 110 cal/cm^2 sec) was assumed in the target design. I believe this is much too optimistic. We normally limit ourselves to about 20 cal/cm^2 sec (270,000 Btu/sq. ft. hr). This is about three times Hanford heat flux. If we accept this figure, we find that the transfer surface required for 40,000 kw is about 500 square feet. This is hard to provide in a uranium target one meter in diameter and 5 cm deep. Furthermore, as Dr. York pointed out, the center of the target must dissipate much more heat than the average. This makes the problem even more difficult.

"With uranium targets, moreover, consideration must be given to removal of fission

CLASSIFICATION CANCELLED (OR CHANGED TO S[redacted]
(INSE[redacted]
BY AUTHORITY OF TID-1339 2/28/67
(PERSON AUTHORIZING CHANGE IN CLASSIFICATION)
BY [signature] 6/1/67
(SIGNATURE OF PERSON MAKING THE CHANGE, AND DATE THEREOF)

DECLASSIFIED

DECLASSIFIED

DECLASSIFIED [redacted]

product beta-gamma heat after shutdownd due to power failures. This heat may be several percent of operating power and must be removed without electrically driven pumps.

"While neither this problem nor any other is hopeless, it is apparent that liquid targets should be used if at all feasible, even if they involve slight losses in neutron conversion. As you know, large reductions in performance would be tolerated in reactors if they could be constructed of fluids. It seems much easier to use a fluid system in your case.

"Dr. York mentioned that Bi was about 60% as good as uranium. I would accept this loss if it were the only alternative. However, light materials, such as Be and D_2O, have been found to be almost as good as uranium. If this is confirmed, I should certainly recommend use of a D_2O tank as a target. I realize the problems involved. They are:

(1) Irradiation damage to tank lid from deuterons
(2) Decomposition of D_2O
(3) Activity of D_2O

"Offhand, none of these problems seem crucial. I should think that a double tank lid should be used and leaks detected between the lids. Light metals, such as Al or possibly Be, might be used for the lids.

"Decomposition of D_2O would be roughly proportional to the energy released in the D_2O. For a 30,000 kw reactor, about 750 kw are released in D_2O and about 0.01 pounds of D_2O are decomposed per hour. In your case, the decomposition rate would be about $\frac{1}{2}$ pound per hour, which is fairly high. Catalyst chambers would be required to recombine the D_2 and O_2.

"The coolant activity would be high, but not much more so than with an H_2O-cooled uranium target.

"Pumping rates would not be excessive, say 4,000 gpm for a temperature rise of 70°F (40°C). Presumably the D_2O could also be used to cool the binary and tertiary targets. Similar arguments might apply to other liquid targets (such as Li) if they move efficient neutron producers.

"One aspect of your project that interests us very much is the possibility of using this machine as an experimental neutron source. My rough calculations indicate that 1/10 mole of neutrons per day, produced in a large tank of D_2O, would lead to a thermal neutron flux between 10^{14} and 10^{15}. Such a machine might not even require fissionable elements, so that it would not contain fission products, yet it would provide experimental facilities at highest neutron fluxes attainable anywhere. To duplicate this would require at least a $15,000,000 reactor and because of possible hazards, such a pile could not be located near any large city. Thus, even if your project should not produce the desired quantity of neutrons, it still might lead to a very useful result.

"I enjoyed talking to you last week and we hope you will continue to keep us informed

SECRET [redacted] DECLASSIFIED

DECLASSIFIED

of your progress since we feel that your work may have important bearing on reactor technology.

"Kindest regards."

Distribution of Series C:
1B to W. Brobeck, UCRL
2B to Information Division, UCRL
3B " " " " appendix 3/c
4B " " " "
5B " " " "
6B to W. M. Latimer, UCRL
7B to J. Norton, UCRL
8B to W. B. Reynolds, UCRL
9B to J. Q. Cope, CRDC
10B to A. Hildebrand, CRDC
11B to W. E. Elliott, AEC
12B to H. A. Fidler, AEC
13B to K. S. Pitzer, AEC
14B to A. Tammaro, AEC

DECLASSIFIED