



3 4456 0360924 5

ORNL-1163

Physics

9a

THE PREPARATION OF THIN
AND OF THICK TARGETS TO BE BOMBARDED
BY POSITIVE PARTICLES



CENTRAL RESEARCH LIBRARY
DOCUMENT COLLECTION
LIBRARY LOAN COPY

DO NOT TRANSFER TO ANOTHER PERSON

If you wish someone else to see this document, send in name with document and the library will arrange a loan.

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
CARBIDE AND CARBON CHEMICALS COMPANY
A DIVISION OF UNION CARBIDE AND CARBON CORPORATION



POST OFFICE BOX P
OAK RIDGE, TENNESSEE

ORNL 1163
Physics

This document consists of
24 pages. Copy 9 of
291 copies. Series A.

Contract No. W-7405-Eng-26

ANALYTICAL CHEMISTRY DIVISION

M. T. Kelley, Director

C. D. Susano, Associate Director

THE PREPARATION OF THIN AND OF THICK TARGETS TO BE BOMBARDED

BY POSITIVE PARTICLES

Rene A. Bolomey

Date Issued

 1957

OAK RIDGE NATIONAL LABORATORY
Operated by
CARBIDE AND CARBON CHEMICALS COMPANY
A Division of Union Carbide and Carbon Corporation
Post Office Box P
Oak Ridge, Tennessee



3 4456 0360924 5

INTERNAL DISTRIBUTION

- | | |
|---|-----------------------|
| 1. G. T. Felbeck (C&CCC) | 27. S. C. Lind |
| 2-3. Chemistry Library | 28. F. L. Steahly |
| 4. Physics Library | 29. M. T. Kelley |
| 5. Biology Library | 30. K. Z. Morgan |
| 6. Health Physics Library | 31. J. S. Felton |
| 7. Metallurgy Library | 32. A. S. Householder |
| 8-9. Training School Library | 33. C. E. Winters |
| 10. Reactor Experimental Engineering School | 34. D. S. Billington |
| 11-14. Central Files | 35. D. W. Cardwell |
| 15. C. E. Center | 36. E. M. King |
| 16. C. E. Larson (K-25) | 37. E. O. Wollan |
| 17. W. B. Humes (Y-12) | 38. G. H. Clewett |
| 18. L. B. Emlet | 39. D. D. Cowen |
| 19. A. M. Weinberg | 40. P. M. Reyling |
| 20. E. H. Taylor | 41. M. J. Skinner |
| 21. E. D. Shipley | 42. L. M. Nelson |
| 22. A. H. Snell | 43. W. M. Good |
| 23. F. C. VonderLage | 44. H. E. Banta |
| 24. R. C. Briant | 45. J. L. Dial |
| 25. J. A. Swartout | 46. R. E. McHenry |
| 26. A. Hollaender | |

EXTERNAL DISTRIBUTION

- 47-291. Given distribution as shown in TID-4500 under Physics Category.

THE PREPARATION OF THIN AND OF THICK TARGETS TO BE BOMBARDED
BY POSITIVE PARTICLES

Rene A. Bolomey

Thick and thin targets of aluminum, boron¹⁰, boron¹¹, nitrogen¹⁵, deuterium and tritium have been prepared in this laboratory during the past year and a half. The aluminum and boron targets were made by evaporating the metals on various target mounts placed under a large bell jar which could be evacuated and maintained at a pressure of 2 to 4 x 10⁻⁶ mm Hg. Nitrogen, deuterium and tritium targets were made by absorbing the gases on tantalum or zirconium in a quartz and glass apparatus.

I. Aluminum and Boron targets

No difficulty was encountered in evaporating aluminum, but such was not always the case with boron. Aluminum has a low melting point (658.7°C) and the element was in a granular form. Boron on the other hand melts at about 2300°C. The elemental boron employed existed as a fine amorphous black powder which has poor heat transfer properties in a vacuum and could be heated only by radiation.

Apparatus. A schematic diagram of the system employed for the evaporation of aluminum and boron is represented in Figure 1. The design of this system and the supervision of its construction is the work of Dr. H. E. Banta of the instrument division of ORNL. He should be consulted for more complete details of the evaporator than can be presented in this report. A few features of the apparatus may, however, be mentioned here. All pumping leads from the booster pump to the bell jar and cold traps has a minimum diameter of two inches. The booster pump insured a proper backing vacuum for the diffusion pump so that the latter could handle the outgassing of all of the constituents in the bell jar at a sufficiently rapid rate to maintain a good vacuum at all times during an operation. The cold trap

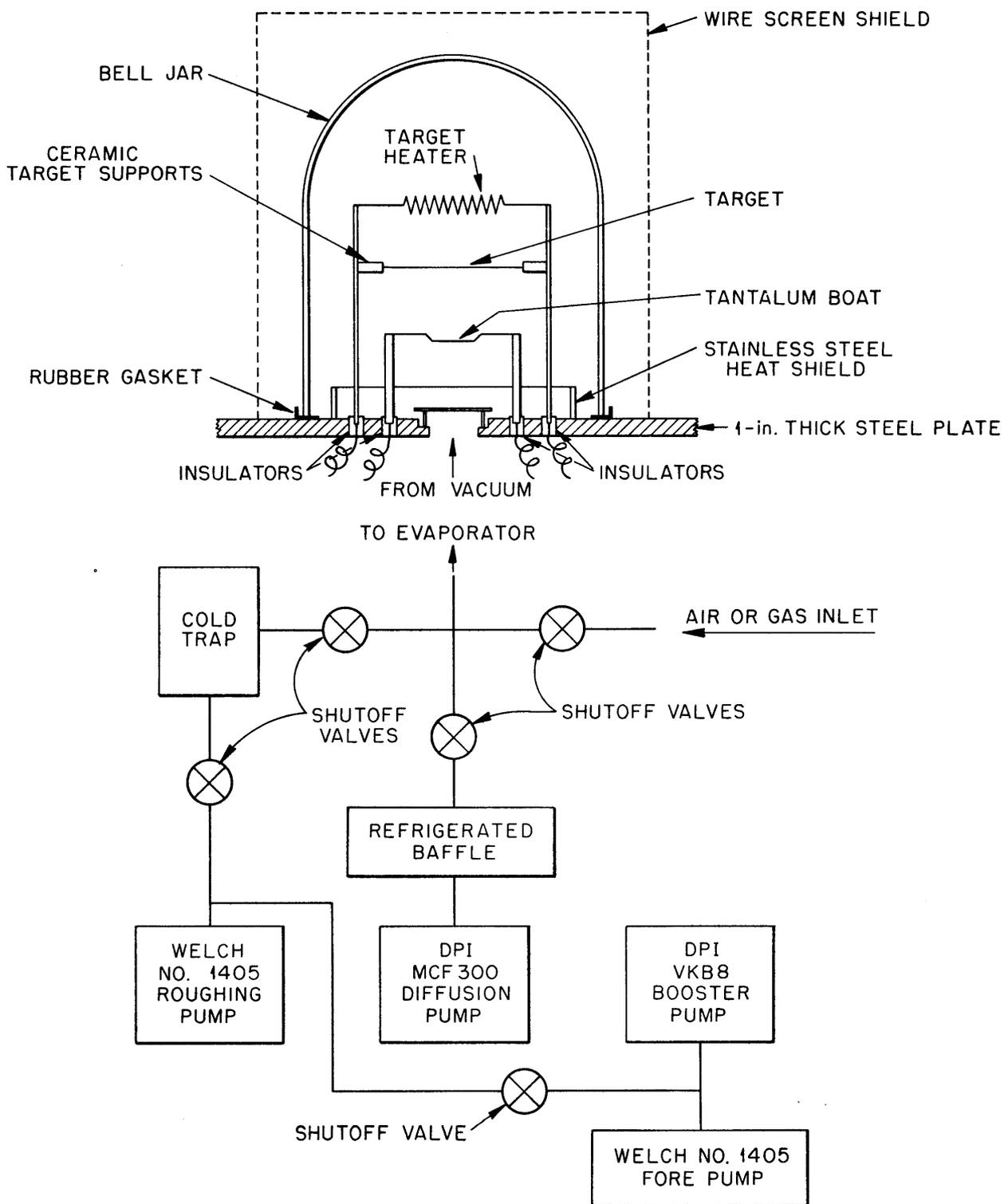


Fig. 1 - Evaporator

and refrigerated baffle helped materially in this respect. The roughing pump made it unnecessary to cool the diffusion and booster pumps between operations so that all parts of the apparatus could be kept ready to operate at a moments notice. In less than twenty minutes the initial vacuum inside the bell jar could be reduced from atmospheric pressure down to the 10^{-6} mm Hg range. The target heater consisted of a tantalum filament that could be employed in connection with electron bombardment to outgas the target. The tantalum boat into which was placed the aluminum or the boron for evaporation was 0.007" to 0.010" thick by 1/4" to 1/2" wide and 2" long. It was connected to large copper electrodes which afford little resistance to the high currents employed.

The SS heat shield was a strip of polished stainless steel ring 1/16" thick by 2" wide and about 1/2" to 1" less in diameter than the internal dimensions of the bell jar. Its function was to shield the small amount of the rubber gasket which protruded inside of the bell jar and which otherwise would have outgassed considerably due to its black body properties.

Preparation of the target blanks and evaporation technique.

Various materials including stainless steel, silver, copper, and tantalum were employed as backing surfaces for the targets. Silver and copper were chosen for their heat conduction properties. Stainless steel and tantalum were tried because they could be easily outgassed without running into the danger of melting them. In the case of most silver, stainless steel and copper supports these materials were silver soldered on a small copper heat exchanger through which either water or other suitable coolant could be passed to protect the target from heat damage

while it was bombarded in a Cocroft Walton accelerator with a $100 \mu d$ beam of positive particles of 100 or more Kev in energy. This design was dictated by the physical requirements of the experiment to be performed. Other target blanks were made of discs of tantalum .001" to .010" thick and $1 \frac{1}{8}$ " in diameter. These could be sandwiched in between the vacuum system of the Cocroft Walton or the van der graff and the target cooling system by means of a suitable designed holder and O rings. Unfortunately some of the targets which were silver soldered to the heat exchanger contained boron from the soldering flux. These were very hard to clean and showed the boron resonance curve superimposed on the aluminum curve in the case of thin aluminum targets.

All target blanks were polished by hand and kept flat with very fine abrasive paper, then with jewelers rouge. They were then degreased with carbon tetrachloride or ethyl ether and rinsed in nitric acid, distilled water, chromic acid and distilled water until entirely free of acid. In the case of stainless steel it was found advantageous to give the blank a flash nickel coating by electroplating nickel from a nickel sulfate bath. This treatment seemed to insure a good surface for the adhesion of both aluminum and boron. When great care in cleaning the targets was not taken, non adherent films that flacked off easily especially after bombardment in the Cocroft Walton were frequently observed. Evaporation of the Al and B on Tantalum supports seemed to give good adherent films in all cases providing the supports were free from grease and thoroughly outgassed.

Aluminum could be melted and evaporated easily in the apparatus mentioned above. The evaporation was probably not complete due to some alloy formation with the tantalum boat but the error did not seem appreciable so that simple geometric considerations could be employed to

calculate the amount of aluminum required to obtain a film of the desired thickness. The advantage of the low melting point of aluminum was however frequently offset during bombardment of the target with a high current beam in a Cockcroft Walton even though the targets were kept cold. The immediate surface of the target during bombardment was undoubtedly quite hot even though the average target temperature was cold. The result was that targets would burn up unless the beam was diffused over the target area or its current density kept low. Whenever experiments required high beam intensities and thin targets were not required it was found advantageous to employ aluminum foils a few mils thick instead of evaporated targets.

Amorphous boron required quite a bit of care during the outgassing procedure as may be inferred from the fact that it exists as a fine powder. The procedure employed therefore was to increase the voltage on the boat very slowly keeping the pressure quite low (5×10^{-5} mm Hg or less). If this precaution was not taken the outgassing occurred explosively in various portions of the powder with the result that a fair amount of the powder was blown about in the bell jar. As outgassing proceeded the fine powder formed various agglomerates of boron over the filament. As the temperature was increased sufficiently high to melt these boron agglomerates, the pressure inside the bell jar would fall rapidly to the 10^{-6} or even down to the 10^{-7} mm Hg region and these agglomerated would melt and evaporate one by one. In those cases where the pressure reached the 10^{-7} mm Hg region melting and evaporation was most rapid and complete. The decrease in pressure noted just before the agglomerates melted reached a certain minimum value and remained at this value until the few agglomerates melted and evaporated then the pressure rose again to the initial pressure of the system until other agglomerates were ready to melt and the drop in

pressure was noticed again. For good results it was found best to evaporate the metal from an initial pressure of 1 or 2×10^{-6} mm Hg with the filament at full heat. If this was not done, the filament had to be cooled and reheated a few times during a run in order to completely evaporate the boron as otherwise the temperature of the bell jar, bottom plate and copper leads would increase sufficiently to cause these parts to become further outgassed due to the length of time required to evaporate the boron at the higher pressure.

It is rather difficult to calculate the exact amount of boron that should be employed to produce a target of a certain thickness as part of the mass may have been exploded from the boat due to too rapid outgassing or may alloy with the boat. At times it seemed impossible to melt and evaporate all of the boron as some of the agglomerates seem to refuse to make contact with the tantalum boat. Also there is the possibility that boron forms sufficient alloy with the boat metal to cause the boat to burn up. This has been found to be the case when attempting to make thick targets by evaporation.

As in the case of aluminum targets a high current beam in the Croft Walton especially if focused to a spot tended to evaporate the boron from the surface of the target. But this effect on thin boron targets was not as marked as it was in the case of the aluminum targets.

II. Deuterium and tritium targets.

The thin and thick targets of deuterium and tritium were made on films of evaporated zirconium while the very thick targets of these isotopes were made by absorbing the gases on either .002" zirconium foils or on such foils melted on tungsten or tantalum blanks. Tungsten backings were found to be too brittle for proper sealing of the vacuum

system while the tantalum supports made of 0.010" to .030" foils were quite pliable and made good seals with O rings. Tantalum, however, also forms a hydride.

Apparatus. The all-glass apparatus shown in Fig. 2 was constructed to handle tritium gas. All stopcocks were of the mercury seal high vacuum type. Stopcocks whose barrel had to be maintained in a horizontal position were of the type which could be sealed with mercury at both ends of the barrel. Mercury was however placed in the front compartment while the rear compartment was kept connected to an evacuated system from which tritium could be recovered if necessary. The cold trap was equipped with a ground joint so that it could be dismantled for cleaning. The whole vacuum system could be evacuated to 1×10^{-6} mm Hg by a MCF300 type DP1 diffusion pump containing octoil S. This pump was backed with a duoseal #1405 Welch fore pump.

Two additional pumping systems each of which included a small mercury diffusion pump, a toeplar pump, a gas burette and a mercury manometer were employed to circulate the tritium gas from one part of the system to the other. One of these systems (A Fig. 2) was employed to collect a known volume of tritium at a known pressure from the storage bottle and to dispense this gas either to the target system or to 100 ml break off seal bottles which were employed for long term storage of tritium or back to the temporary storage bottle through the pumping system B Fig. 2. The first system was also employed to recover and measure the uncombined tritium. The other system (B Fig. 2) was employed to recover excess tritium from the first system. It was also employed to outgas the tritium purifying system and to dispense tritium from the purifying system or from an outside source.

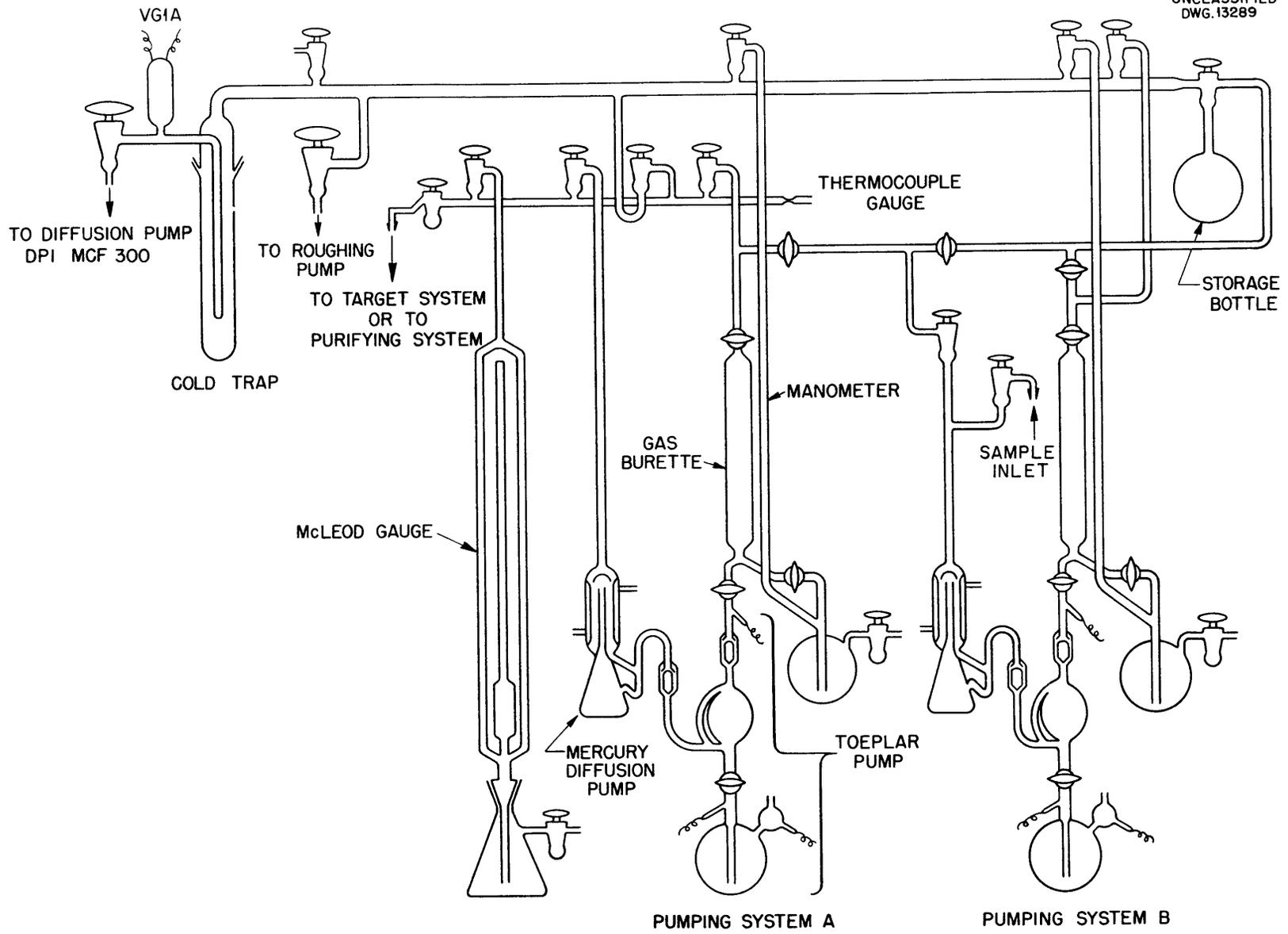


Fig. 2-Gas Dispensing and Recovering System

This last system (B Fig. 2) was omitted from the deuterium and nitrogen systems as these latter two gases are cheap enough and need not be so completely recovered. Otherwise the apparatus employed for these gases was the same as that employed for tritium.

The target making assembly is shown in Fig. 3. The various parts of the apparatus were lubricated with silicone grease and held together by atmospheric pressure acting on the evacuated parts. A weighed sample of zirconium was placed on a .050" tungsten button and heated with a 5 Kw induction heater until outgassed at a bright yellow temperature. Simultaneously the target support .001" thick was heated to bright red heat by passing current through it. Tungsten and tantalum were tried as target supports. Tungsten was too brittle to be of much value and tantalum absorbed enough of the isotope to result in the formation of infinitely thick targets. Silver and aluminum were also tried with moderate success. At present H. E. Banta and J. B. Dial are employing platinum as a backing material with good results. It was rather difficult to evaporate zirconium metal by this method as the induction heater furnished just enough power to attain this end with very little energy to spare. A more powerful induction heater or resistance heating as performed by Lillie, A. B. and Conner, J. P. (NP 1860 Task order I Nuclear Physics October 1, 1950; RSI 22, 210 (1951)) would have been better. The fact that the targets produced in this laboratory never were in contact with air from the time the component parts were outgassed prior to the evaporation of zirconium until after the adsorption of the isotope is an advantage not realized when utilizing the apparatus employed by Lillie and Conner. The apparatus of Lillie and Conner requires a transfer of the target support containing a thin film

of zirconium from the evaporation chamber to a tritium administering apparatus. This transfer introduces air which adsorbs on the surface of the zirconium and requires that the tritium be adsorbed directly on the zirconium after evacuation. Outgassing of the thin zirconium film by heating in vacuo prior to the addition of tritium would fix much of the adsorbed air with resultant poor yields in the formation of zirconium hydride.

Purification of Tritium. Finely divided uranium was employed to purify tritium (R. E. Graves, A. A. Rodrigues, M. Goldblatt, and D. I. Meyer, RSI 20, 579 (1949) Newton, A. S., Warf, J. C., Spedding, F. H., Johnson, O. Johns, I. B., Nottorf, R. W., Ayres, J. A. Fisher, R. W., and Kent, A. Nucleonics 4, 17 (1949)). Two types of chambers were employed for this system. Each has some merits. One was made of stainless steel and the other was made of pyrex glass. These are shown in Fig. 4. The stainless steel bottle could be filled by removing the sylphon bellows and the baffle arrangement below the valve. Freshly cleaned uranium metal could be introduced down the inner tube. Above this was added some pyrex glass wool then the baffle and the valve assembly. Care was taken that no uranium particles were left above the baffle assembly as they could prevent the valve seat from working properly. The system was then evacuated immediately to minimize surface oxidation of the uranium.

The pyrex glass bottle was equipped with a high vacuum stopcock, a fine cinkered disc to prevent powdered uranium from reaching other parts of the system and a side tube employed to add the uranium to the bottle. Freshly cleaned uranium was added to the bottle the side arm was then sealed with a clamped rubber pressure tube. The system was

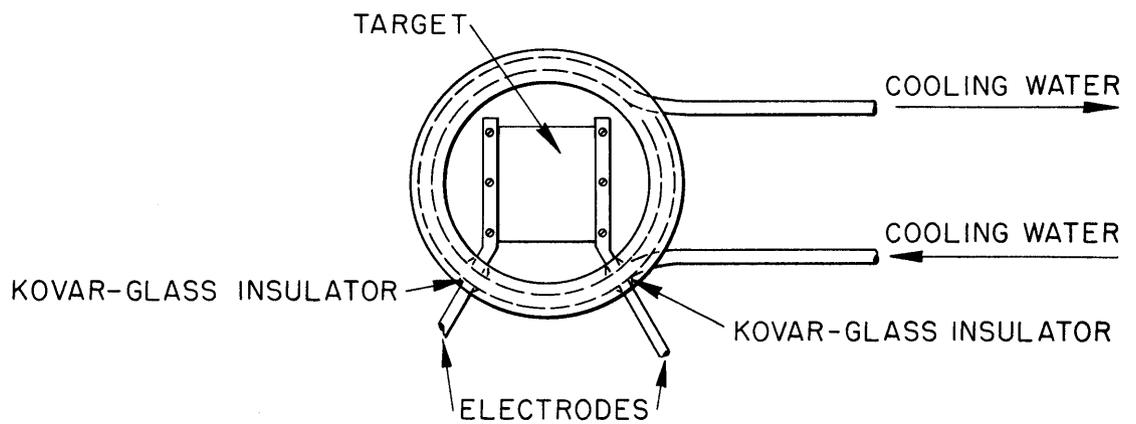
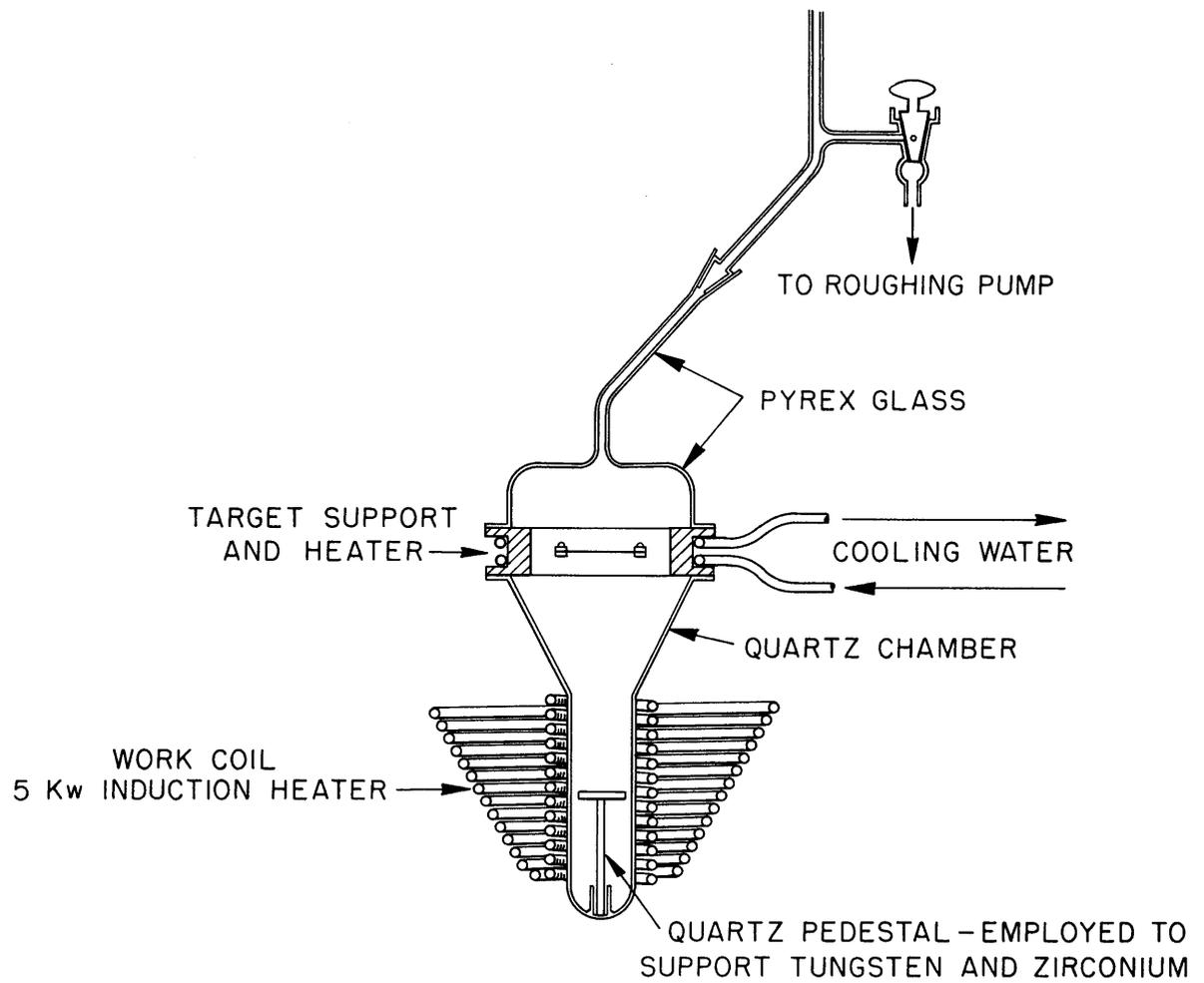
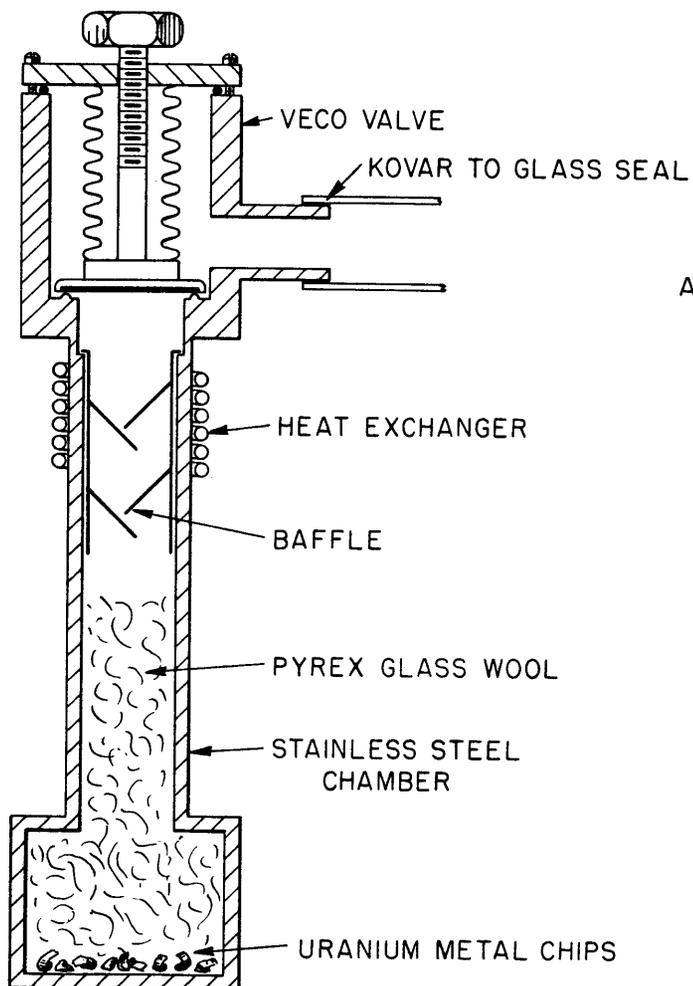
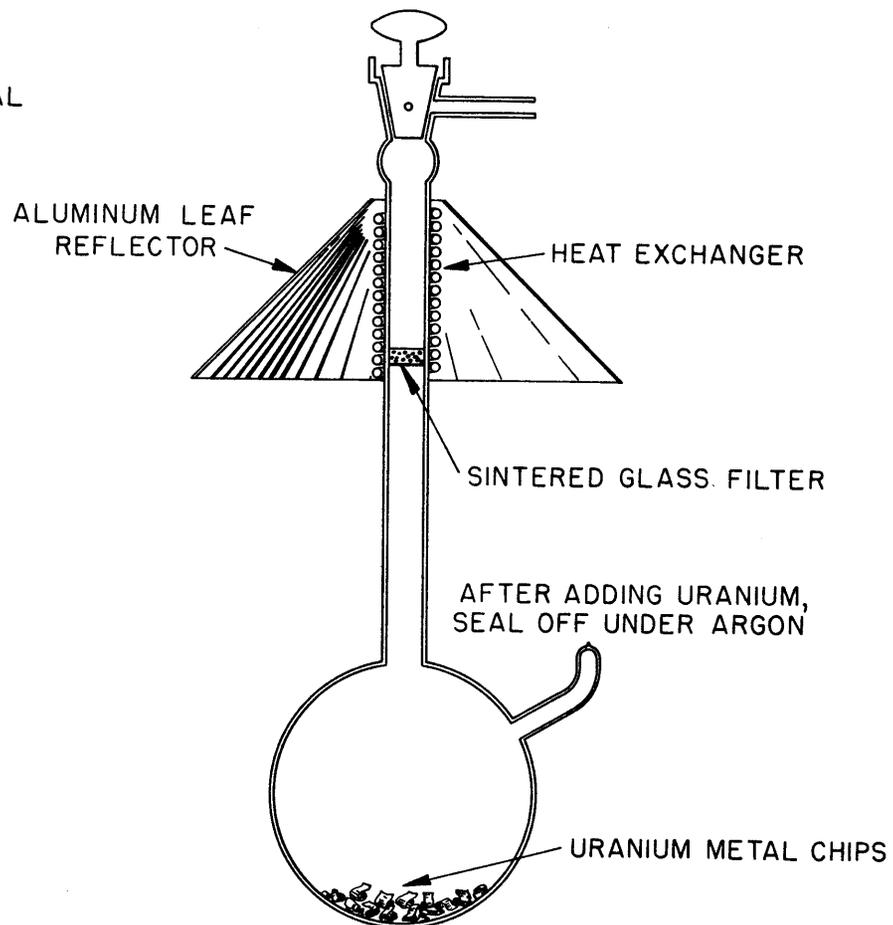


Fig. 3 - Target-making Assembly.



STAINLESS STEEL SYSTEM



PYREX SYSTEM

Fig. 4 - Uranium Tritide Purifying Apparatus.

then alternately evacuated and filled with argon and the side arm was sealed off with a torch. This method of sealing was employed to prevent small particles of uranium which adhered to the walls of the tube from catching on fire and falling into the main mass of uranium.

Uranium metal chips were employed for this work as these were available. They were suspended in distilled water and the finely suspended particles were decanted. Twenty percent nitric acid was then added and the particles were stirred slowly with a glass rod. When about 90% of the particles obtained a metallic luster or when gas was evolving from the surface of the metal. Distilled water was added and the acid was decanted. The particles were repeatedly suspended in fresh distilled water until free of acid. Then they were washed three times with 95% alcohol, twice with diethyl ether, transferred to the reaction flask and evacuated immediately. If the metal was vacuum dried instead of using the intermediate alcohol and ether rinses drying took too long and the metal surfaces blackened appreciably.

The uranium was then activated in situ by making the hydride of normal hydrogen and decomposing it at 300 to 400°C. in a good vacuum. This process was repeated up to three times. As activation proceeded the temperature initiating reaction between uranium and hydrogen decreased from about 50 to 250°C. depending on the sample down to room temperature. The rate of reaction also increased so that it was found advisable to control the rate of hydrogen addition by controlling the pressure of the incoming gas as the reaction is exothermic. Also as the sample became more activated it was capable of taking up greater quantities of hydrogen.

More recently the freshly cleaned uranium metal was activated

by through outgassing at 400 to 450°C. until the pressure reached a final steady value of 2×10^{-6} mm Hg. at this temperature. The sample was then cooled to room temperature. Under these conditions it was found that the addition of hydrogen would start at room temperature. The first addition was usually preceded by a lag period lasting about 5 minutes if no heat was applied to start the reaction. Then the pressure started to fall off slowly at first then with ever increasing rapidity. The temperature of the reaction as reflected by an iron constantan thermocouple placed in the heating mantle increased very rapidly to about 200°C. At this point the rate of hydrogen addition was controlled and hydrogen was added until the pressure of the system remained constant at about one atmosphere for at least 30 to 60 minutes, the temperature of the flask being at room temperature. Once the end point had been reached the hydride was dissociated at 350° to 400°C. until the pressure returned to 2×10^{-6} mm Hg. The next addition of hydrogen starting with the flask at room temperature showed no lag period. Typical values of pressure time relations for this second hydrogen addition are as follows:

T (min.)	0	1	2	4	6	9	12	16	90
P (μ)	10^5	10^3	950	400	240	110	70	40	25

The uranium hydride was then dissociated at 350°C. to 400°C. to a final pressure of 2×10^{-6} mm Hg and the powdered active uranium was ready to receive tritium.

Procedure. The procedure employed for making thick targets of tritium or of deuterium was essentially that described by Graves et al (RSI 20, 579 (1949)). These authors employed .030" thick tungsten discs upon which zirconium was melted by means of an induction furnace. In other experiments they employed .001" to .004" thick tantalum sheets.

Tritium was then sorbed directly on the outgassed zirconium or tantalum after heating the metals to sufficiently high temperatures to initiate hydride formation. In the case of tantalum these authors heated the outgassed metal to 1900°C. in the presence of tritium held at an initial pressure of 2 to 5 mm Hg. and allowed the metal to cool to room temperature. The brittleness of tungsten makes it undesirable as a backing material when it is to be employed in conjunction with O rings to seal the vacuum at the bottom of the accelerator tube. Tantalum hydride is also quite brittle although the metal itself is quite pliable. Even though tantalum cannot be considered the most suitable backing material it was tried with success for this purpose. This metal is supposed to have its maximum absorptive power for hydrogen at about 600°C. (Espe, W. Powder Met. Bull, 3, 100 (1948); CA 43, 2877)). The tantalum in contrast to zirconium samples employed in this laboratory showed insignificant uptake of deuterium or of tritium as measured from pressure volume measurements when the thoroughly outgassed metal was heated to a dull red heat in the presence of the hydrogen isotope at a pressure of 5 mm. Hg. The counting rate of a thin film of tantalum treated with tritium in this manner indicated that tritium had been sorbed by the metal. Tantalum films from .010" to .025" treated in this manner remained pliable and non brittle indicating that no significant hydride formation took place. The films, however, were somewhat warped due to the high temperature employed to outgas the metal.

Zirconium metal discs 0.002" thick and 1 1/8" in diameter were employed for this work. These discs were outgassed and fused on tungsten or tantalum discs .025" thick and 1 1/8" in diameter according to the method employed by Graves et al (RSI 20, 579 (1949)). At

times the zirconium discs with no backing metal were outgassed in the field of the work coil of the induction heater operating at full power. Under these conditions the zirconium was heated to a bright orange red glow and no melting occurred as there was insufficient metal to produce sufficient coupling to increase the temperature of the zirconium to the melting point.

Better targets were obtained with thicker backing materials as coupling was better and heating of the discs was more uniform. Blanks made of .060" tungsten or tantalum produced nice smooth target surfaces while those made of .020" or less tended to be rough and were often characterized by a central area of unfused zirconium.

The addition of deuterium or of tritium was performed under the conditions specified by Graves et al, with the exception that the temperature was maintained at a dull red heat until the gas pressure became constant for a minute or two. It was felt that a higher temperature would induce appreciable hydride formation in the backing material when tantalum was used. The targets took up from 6.8 to 7.7 Std. ml. of hydrogen irrespective of the presence, absence or type of backing material. The more thoroughly outgassed was the sample the greater was the uptake. In the case of those samples of zirconium where no backing was employed tritium or deuterium gas was readily taken up by the target but the sample had to be outgassed for a considerably longer period of time than was required by those samples backed with .060" tantalum or tungsten in order to insure "reasonable" uniformity of the target. The term "reasonable" is employed here to denote that none of the targets were uniform but tended to become more uniform with longer periods of outgassing. At the time these data were obtained the target

analyzer was not made. In its place we employed a crudely constructed system that would give us an approximate distribution of tritium over the face of the target. Therefore, the curves presented in Fig. 6 represent the general trend of what was found. The same general type of activity distribution was obtained with targets that were backed with tantalum or tungsten than was obtained with those that were not backed.

Another form of thick target containing no backing material was made. A sheet of zirconium .002" thick and two inches wide was shaped in the form of a cylinder 1 1/8" in diameter. The distribution of tritium along the length of the cylinder is roughly represented in Fig. 7. The induction heater was operated at full power. The temperature although quite high was far from sufficient to melt the zirconium. A slight amount of buckling was present at the region of highest activity indicating that the outgassing as well as the absorption temperature was highest in this region of the target.

Target Analysis. In the case of thick tritium targets it was easy to count X-rays coming from the targets. By employing an end window GM counter, a 1/4" thick aluminum plate containing a 1 mm hole in the center and a position indicating device (schematically shown in Fig. 5) one can obtain a fair idea of the distribution of tritium on the surface of a target. The target position indicating device (Drawing No. Q951-7) was designed by A. W. Prichard. By means of this device one can move the target back and forth past the hole a known number of millimeters and rotate the target a known number of degrees about its center. Another method that may be of advantage especially with thin targets involves the use of radioautographs.

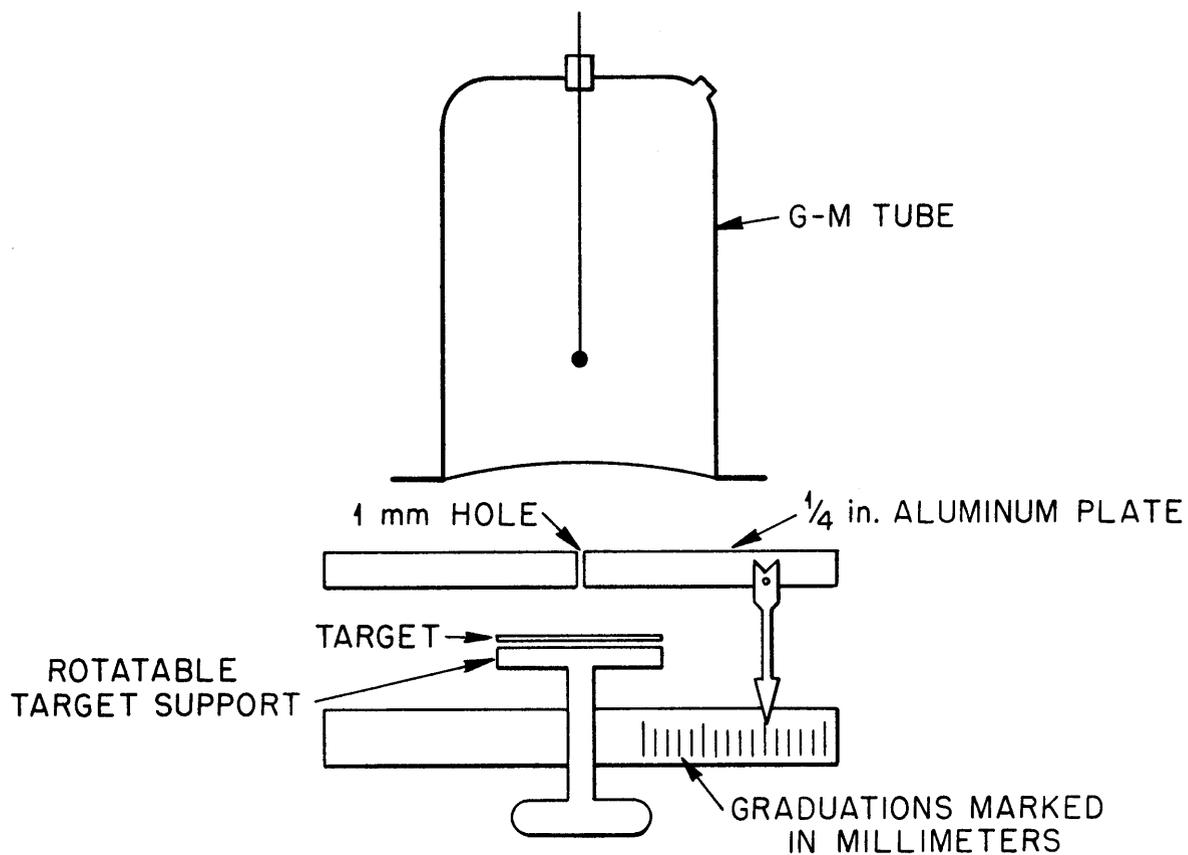


Fig. 5 - Target Analyzer (For Details of Construction See Dwg. Q951-7).

UNCLASSIFIED
DWG. 13293

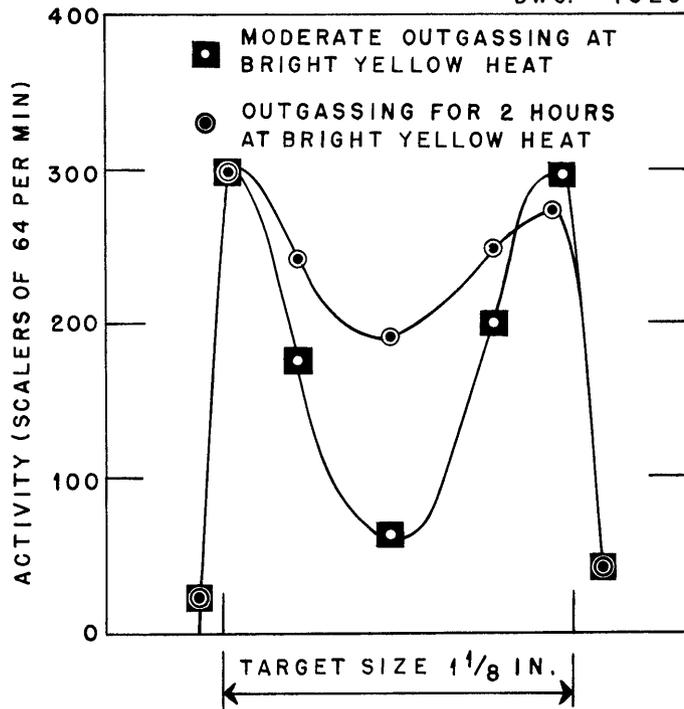


Fig. 6 - Distribution of Tritium Over Face of Flat Disk

UNCLASSIFIED
DWG. 13294

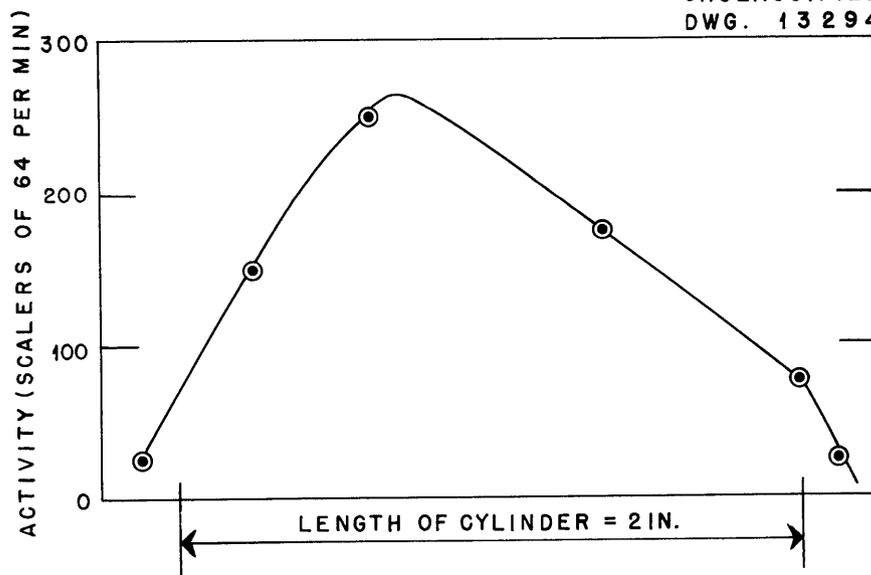


Fig. 7 - Distribution of Tritium Over Face on Longitudinal Axis of Cylindrical Target

The stability of the targets after they were made is of interest. Grives et al (P.S.I. 20, 579 (1949)) were of the opinion that zirconium hydride targets are stable at room temperature but stated that targets should be kept cool during bombardment. Zirconium hydride appears to be a solution instead of a saline type of hydride or a definite compound (Fitzwilliam, J., Kaufmann, F. and Squire, C. J. Chem. Phys. 9, 678 (1941); Schumb, W. C., Sewell, E. F., Eisenstein, A. S. JACS 69, 2029 (1947)). One should expect that zirconium hydride has a small but definite vapor pressure at room temperature and that it should undergo a slow but steady decomposition. For all practical purposes thick tritium or deuterium targets can be considered stable in that these targets will contain appreciable quantities of the hydrogen isotope for a long time under proper care. Also tritium or deuterium lost from the surface of the target may be expected to be replaced from that present in the sub layers of the zirconium. Thin targets on the other hand may be expected to have much shorter lives than do the thick targets. At room temperature tritium is continually lost to the atmosphere. A target was made by fusing .002" zirconium to .030" tungsten. Tritium to the extent of about 20 curies was absorbed by the zirconium which was then allowed to cool to room temperature and the excess tritium was recovered until a pressure of 3×10^{-6} mm Hg. remained in the system. About an hour or two later the target was placed in a methane flow counter. The initial counting rate of the background was about 16 cpm. The target contained enough tritium to jam the counter. It was, therefore, removed a background count was attempted again but the counter remained jammed due to tritium which

became adsorbed on the walls of the counter chamber. Two weeks later this same target was placed in a fresh counter chamber with the result that the background increased from an initial counting rate of 15 cpm to over 700 cpm. The target was then placed in an evacuated chamber which was pumped down once a week over the week end to a good vacuum. Gas from this chamber was sampled with an evacuated ionization chamber from time to time and monitored for activity; after six months tritium was still appearing in the atmosphere of the chamber and as far as the Cocroft Walton was concerned the target was still infinitely thick. We have at present no evidence that the deuteride loses deuterium in this manner although it may be expected to do so.

One of these targets (1 1/8" in diameter) had been bombarded with 100 μ d beam of 170 Kev H² for over an hour and showed no loss in activity. The beam was spread over the whole area of the target which was air cooled. The neutron counter surrounded with about 10" of paraffin and placed about 15 ft from the target registered about 1 x 10⁵ cpm. This target has been used since many times with very good results. If, however, a 100 μ d beam is accidentally focused to a bright spot on a target, the target life seems to be only a few seconds and the operator might as well look for a fresh target.

Nitrogen targets were made in the same manner as were the tritium targets. Tantalum and zirconium take up large quantities of nitrogen forming very brittle nitrides. Some success was, however, realized in attaining good targets by forming the nitride on thin films of zirconium evaporated on platinum or silver supports.

SUMMARY

Methods for making thick and thin targets to be bombarded by positive particles have been described. The target elements studies were Al^{normal}, B¹⁰, B¹¹, N^{normal}, H², H³.

ACKNOWLEDGEMENT

The author wishes to express his gratitude to the members of the high voltage laboratory for their cooperation and fine "esprit de corps" during the development of these methods; and to Dr. M. T. Kelley and Mr. S. A. Reynolds of the Analytical Division for their interest in the problem, and for the opportunity provided to work with high voltage machines.