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MTA QUARTERLY PROGRESS REPORT

December, 1952, January, February, 1953

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1. ACCELERATOR DEVELOPMENT PROGRAM

C. M. Van Atta

Introduction

The decision of the Atomic Energy Commission not to proceed with construction of an A-12 production MTA (12.25 megacycle, 0.5 ampere of 350 Mev deuterons for Pu production) has altered considerably the objectives of the MTA accelerator development program. Instead of concentrating exclusively on the optimum design and operating requirements of a 12.25 megacycle machine, as was necessary as long as construction of such a machine seemed imminent, the major effort in the past six months has been on the more fundamental questions of the best type of accelerator and the most economical choice of frequency compatible with rf tube and circuit development.

Since the diameter of the vessel is inversely proportional to the frequency, and the exciting power at a given gradient is inversely proportional to the square root of the frequency, it has long been obvious that an accelerator designed for higher frequency than the 12.25 megacycles chosen for the A-12 design would be less expensive both in construction and operating cost. However, at the time of initiation of the A-12 design, and continuing until quite recently, the frequency of 12.25 megacycles was as high as seemed to be immediately feasible. Two developments of the past year have raised considerably the practical limit on frequency:

1. Progress in the MTA rf program which raises the limit of frequency at which high d.c. to rf power conversion efficiencies can be attained at power levels of the order of one megawatt CW per tube.

2. The development of the "strong focusing" principle first brought into prominence by the Brookhaven group.

During the past year RCA has succeeded in improving the A2332 developmental power tube to the point where reliable performance at 12.25 megacycles with good conversion efficiency up to a power level in excess of one megawatt has been demonstrated by operational tests at UCRL. In these tests also the design of suitable oscillator (or amplifier) circuits have been developed and tested. More recently UCRL tests carried out at 50 megacycles have shown high conversion efficiencies up to an output of about 275 kilowatts continuous wave, at which point the tests were limited by overheating of circuit components, which are now being changed to permit carrying the tests on to higher power levels. As a result of recent progress it is now believed that the new design RCA A2332 tube with ceramic to copper seals will operate with good efficiency at frequencies up to 50 megacycles.

For frequencies in excess of 50 megacycles it appears that a tube of the "resnatron" type will be required. Continued research on this type of tube at UCRL has gone favorably with the expectation that there would be no great

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difficulty in developing a high power resnatron type of tube for operation at 100 megacycles or higher frequency if desired.

When the choice of 12.25 megacycles was made for the A-12 accelerator design, the decision was also based upon the aperture attainable with the solenoidal magnetic field focusing, then an essential element of the design. It was found, for example, that the magnet power required for a machine operating at 24 megacycles was so great that a suitable design could not be devised which could be fit inside the small-dimensional drift tubes appropriate for the 25 megacycle machine. Substituting magnetic "strong focusing" in place of the solenoidal magnetic focusing, however, reduces by a large factor the power required for focusing, so that with strong focusing considerably higher frequency accelerator designs become entirely feasible.

At UCRL the beam dynamics and rf geometry of a 48 megacycle accelerator incorporating magnetic strong focusing has been studied with particular attention to the low energy end of the machine where the design tends to be more difficult. Since the results of these studies indicate the feasibility of such a machine, preliminary engineering design studies are now being undertaken at UCRL to determine in some detail the features of the low energy end of such a machine, with the expectation that a short portion of the "pre-accelerator" may soon be built and tested at UCRL.

Concurrently with the UCRL accelerator development program, CRDC is carrying out a preliminary mechanical design and economic study of the cost of cavity type accelerators as a function of the frequency. The design features of both 50 and 100 megacycle machines will be worked out in sufficient detail to permit good estimates of costs and to compare them with that of a 12.25 megacycle machine. On the basis of operating experience with the 12.25 megacycle Mark I machine at Livermore, the performance of the proposed 48 megacycle pre-accelerator at UCRL and the CRDC economic study now in progress, it is expected that a low production pilot model accelerator of essentially full energy will eventually be proposed for construction at Livermore.

2. HIGH FREQUENCY PROGRAM

W. R. Baker

Up to the present time, it has been generally accepted that frequencies higher than approximately 20 megacycles were not practical in the MTA linear accelerator program because of the requirements of the magnetic focusing system and limitations of the power tubes then available. Twelve megacycles was the value actually agreed upon in order to have a reasonable margin of safety.

Recently, however, a new and greatly improved means of focusing has been devised that removes the old limit and makes higher frequencies desirable. Higher frequency means a smaller, and hence more economical machine.

The recent excellent performance of RCA A-2332 type shield grid power tubes at 12 megacycles gave rise to hopes that these tubes would also perform well at higher frequencies. In the last report it was stated that 1100 kilowatts of continuous 12 megacycle power was obtained from one of these tubes at 80 percent efficiency.

An extrapolation of known data from this tube indicates that the high frequency limitations are in seal heating and in grid heating. The former trouble can in all probability be corrected by the use of a new type of ceramic-copper seal that is now in the process of development at the factory. The latter represents a more basic type of limitation, and is estimated to lie approximately in the region of 50 megacycles. Some uncertainties about possible parasitic conditions arising from internal tube resonances have now been cleared up, and experiment indicates that this problem can be eliminated rather easily by choosing an operating frequency that does not fall in the same range. By actual experiment, 50 megacycles plus or minus 2 megacycles was satisfactory.

In order to appraise the performance of the present A-2332 at 50 megacycles, it was necessary to resort to a very elaborate seal cooling system and to develop completely new circuit components. The B1 resonant load that had been used at 12 megacycles had to be abandoned and a new type of low Q water load substituted. The result of 50 megacycle measurements to date, is a maximum of 275 kilowatts continuous wave at 10 kilovolts plate voltage, and 70.5 percent efficiency. An arbitrary limit of 10 kilovolts is being observed, because of seal heating, until an improved cooling system is completed. It is expected that the efficiency will be better at higher plate voltage, and that an output of one megawatt will be practical.

3. BEAM DYNAMICS IN STRONG FOCUSING LINEAR ACCELERATORS

G. Culler, M. Good, F. N. Holmquist, H. P. Kramer and L. Smith

The study of beam dynamics in the low energy region of a linear accelerator incorporating strong focusing has resulted in a tentative design for a pre-accelerator operating at 48 mc. The repeat length is taken to be $(3/2)\ \beta\lambda$, to allow room in the drift tubes for the focusing magnets, and the drift tubes are mounted on the end of 1/4-wave lines, as in the earlier design of Brobeck. With a constant 2 in. bore, the machine would seem capable of accelerating a beam of the order of 100 ma. current.

A synchronous phase of 60° has been chosen in order to get a large initial phase acceptance. By the time the ions reach the million volt range, the damping should be sufficient to let the bunches be accepted by a big accelerator operating at 30° or less synchronous phase. Differential analyzer studies are in progress to determine the acceptance of the machine in phase, initial velocity, and initial radial displacement and divergence.

Drift tube lengths and voltages have been computed for gradients of 150 kv/ft. and 300 kv/ft. up to a deuteron energy of about 1 Mev, although the best starting energy for the main accelerator is not yet known. The necessary lengths are 20 and 10 ft. respectively.

An analytical study has been made of the orbits of particles in the strong focusing fields, with the rf effects represented by an average defocusing force, to determine starting conditions and strength of focusing fields which will result in the smallest radial excursions of the ions. The best starting point, i.e., the best length for the first magnet, depends on the initial divergence of the beam, but in general the orbits are improved by using strong focusing fields somewhat weaker than those necessary for periodic orbits. This latter conclusion seems to be borne out by the differential analyzer work.

Finally, a study is in progress of the effect of slow changes in strong-focusing parameters to determine whether and to what extent one can influence the radial dimensions of the beam. This may be of practical importance in either sense--to help confine the beam during acceleration, or to spread it out as it approaches the target.

4. SPIRAL BEAM BUNCHER EXPERIMENTS

Written by S. A. Colgate

Work performed by A. J. Schwemin and D. Parmentier

During the last quarter the spiral accelerator beam buncher has advanced to the stage of giving quantitative results.

A magnetically separated single mass proton beam was injected at 10 kv with variable angular momentum. The original design specifications were:

1. D.c. central rod potential: 50 kv.
2. Angular momentum such that r min/r max: 0.45.
3. Injection energy: 40 kv.
4. Energy gain per rf gap: 10 kv.
5. Number of gaps: 10.
6. Peak rf to ground 10 kv at beam threshold (i.e., transit time factor of 50 percent).
7. Phase acceptance unknown, but assumed large if synchronous phase angle was of the order of 30° i.e., if the peak rf voltage to ground was greater than 12 kv.
8. Bunching within 80°.
9. Unknown energy spectrum.
10. Beam stability assumed to be reasonably sensitive to less than a minimum central rod voltage of 40 kv.
11. The effect of a radial central rod support at high and low energy ends of machine is unknown.
12. Injection current sufficient to make meaningful d.c. current measurements.

The results were: A phase acceptance of 60 ± 5 percent was attained with the following conditions:

1. D.c. central rod potential: 30 to 40 kv.

2. Angular momentum varied over half the region of d.c. dynamic stability. At minimum angular momentum, i.e., when r min of beam orbit is just greater than the central rod radius, the phase acceptance drops off to 50 percent with optimum rf voltage.

3. Injection energy: 10 kv.

4. Energy gain per rf gap: 10 kv.

5. Number of gaps: 11.

6. The accelerated beam comes through at a minimum rf voltage of 8.5 kv and peak phase acceptance occurs at 10 to 11 kv. This optimum rf is slightly less for lower central rod voltage and for greater angular momentum. The phase acceptance falls to about half maximum value for an rf voltage of about 15 kv. In general, however, the phase acceptance is not very sensitive to rf value.

7. The width of the bunch was about 40°, i.e., 10 percent.

8. The energy spectrum showed the major fraction of the beam to be monoenergetic to ± 5 percent, at about 100 kv. There was some evidence for a small fraction (less than one-quarter) of the beam coming through monoenergetic at around 70 kv, but less than one-half of this beam would have been included in the phase acceptance figures, because the accelerated beam was always measured through an aluminum foil 170 micrograms/cm^2 thick.

9. A single central rod support removed about one-sixth of an azimuthally uniform beam at the low energy 40 kv end. The fraction removed at the high energy 100 kv end was less than one-tenth. It therefore seems perfectly feasible to support a central rod up to quite high beam energies, i.e., two supports for 10 Mev.

10. No attempt was made to try to find the optimum injection energy in relation to the first two or three gap rf voltage, but it is assumed that the conditions used were not necessarily optimum in so far as phase acceptance is concerned.

In conclusion the beam buncher has given a large phase acceptance angle for conditions considerably more modest than the design ones. The transit time factor proved larger than 50 percent. The central rod voltage could be considerably less than the designed value, meaning that the energy gain per gap could be doubled without requiring too high a central rod voltage. The angular momentum could be varied over a wide range without effecting the phase acceptance, and the much greater stability of the beam at high energy implies that the gap voltage could be increased with energy allowing something like a constant voltage gradient with no attendant beam loss.

The beam loss that occurred evidently occurred entirely at the low energy end of the machine. A detailed report will be written.

5. DYNAMICAL PROPERTIES OF MARK I

J. F. Waddell

Work continues on the paper "Time Quantization in Feedback Systems". Two of the experiments have been re-performed using refined techniques with very satisfactory agreement between experimental results and theory. The theoretical work and writing is probably three-fourths complete. Consideration is being given to presentation of this paper at either the National Electronics Conference or the West Coast meeting of the Institute of Radio Engineers next summer, in addition to publication in the literature.

After a long delay, time was obtained on the Mark I accelerator for further testing of the rf regulator. It was found satisfactory save for one aspect - the energy stored in the filter reactor due to high oscillator current before the regulator comes into range causes a severe overshoot which the regulator is unable to control.

A conference was held with CRD personnel, at which time it was decided to effect certain changes in the return-loop amplifiers which will keep these units in operating range at all times. Two advantages are gained thereby -

(1) A time delay due to the necessity of de-saturating the amplifiers after the rf voltage output from the cavity comes into regulating range is eliminated.

(2) There is at all times, after rectifier start, a closed loop for frequencies greater than zero (formerly there was no loop closure at all until d.c. loop closure was effected by de-saturation of the amplifiers).

It was also decided to install a phase-retard angle meter on the operator's desk, which will indicate the Power Supply No. 1 operating condition at all times, making manual control of the induction regulation feasible under rf regulation.

The changes noted above are being effected, and it is anticipated that the testing on Mark I will be performed by the end of March.

6. MECHANICAL DESIGN

W. M. Brobeck

During this period an average of two members of the Mechanical Engineering Department was employed on the MTA Project as compared with six members during the immediately preceding quarter and twenty members during the quarter nine to six months ago. Their work consisted primarily of liaison with CRD on engineering and procurement problems of the experimental program and incidental design work and engineering studies on the long range MTA program. The latter were of the following major categories:

(1) Strong-foucsing studies. A three-dimensional electrolytic tank was designed for the study of end effects on strong-focusing electrodes and for fields between accelerating electrodes. Design studies were initiated on magnets for electrodes at the low energy end of an accelerator to determine practical limits on fields and sizes.

(2) Fifty megacycle test amplifier. Design assistance was rendered to the experimental groups.

(3) Resnatron development. Design assistance was rendered the experimental groups.

7. TARGET PHYSICS PROGRAM

Cross Section for Producing One Neutron for Uranium Bombarded by 190 Mev Deuterons

Walter E. Crandall
CRD

George P. Millburn
UCRL

In attempting to explain the yield of neutrons from targets bombarded by high energy deuterons, an important quantity is the cross section for producing one neutron, σ_{1n}. Recently measurements of σ_{1n} were made with uranium targets ranging from 1/16 in. to 3 in., all 2 in. by 2 in. square, bombarded by 190 Mev deuterons.

The neutrons were detected by using the $MnSO_4$ tank described in UCRL-2063, which has an 18-inch blanket of $MnSO_4$ surrounding the target. The deuteron beam was measured by an ionization chamber. If N neutrons are produced by a target of thickness t (less than one range) bombarded by D deuterons, then the cross section for producing one deuteron may be defined as

$$\sigma_{1n} = \frac{N}{Dt} \qquad (1)$$

or if t is in centimeters and σ_{1n} in barns,

$$\sigma_{1n} = \frac{NA}{DtA_o\rho} \times 10^{24} \qquad (2)$$

where A is the atomic mass number and ρ the density of the target, and A_o is Avogadro's number.

The ratio N/D is usually measured directly in using the $MnSO_4$ tank. The cross section so defined is obviously an average for the energies of deuterons present in the target. In the present experiment this quantity was measured for energies from 190 to 0 Mev and is shown in Fig. 1 as a function of the mean deuteron energy.

The number of neutrons produced per incident deuteron was measured for targets the following thickness: 0, 1/16, 1/8, 1/4, 1/2, 5/8 (one range), 1, 2, and 3 in. The incident beam diameter was about 0.75 in. and the beam was centered on the targets. The deuterons which passed through the target hit the back of the experimental area about 10 ft. behind the tank. These deuterons produce neutrons which are detected by the tank, and their effect was subtracted

from the measured ratio N/D for targets up to one range by assuming its variation to be

$$\left(\frac{N}{D}\right)_{Bdg} = \left(\frac{N}{D}\right)_o \frac{(R_o - t)}{R_o} e^{-\sigma t} \qquad (3)$$

where $(N/D)_o$ is the ratio for no target, R_o is the range of 190 Mev deuterons, t is the target thickness, and σ is the inelastic cross section for deuterons (3.45 barns). Eq. (3) should be approximately correct, for the yield N/D varies about as the square of the energy at this energy, and the range varies in almost the same way, so $N/D \sim R$ where $R = R_o - t$ is the range of the deuterons which strike the back of the cave.

To compute σ_{ln}, the differences between adjacent points were divided by the differences in thickness in units of 1/16 in. and $e^{-\sigma t}$ to correct for the deuteron attenuation. Then σ_{ln} follows from (2) with t = 1/16 in. and $\rho = 18.6$ gm cm^{-3}. The mean energy was then calculated.

These calculations neglect entirely the effects of secondary multiplication and the neutrons produced by the fast effect. Dr. Frank Adelman performed calculations which included these effects, but the experimental data is not accurate enough to warrant applying the corrections (of the order of two or three per cent). Neglecting these effects should give too high a value for σ_{ln} as computed above, especially for the thick targets (low mean energies).

Previous measurements of σ_{ln} gave a value of about 28 ± 2 barns for deuterons of about 180 Mev mean energy. This figure is corrected from 34 as originally published. At the time these experiments were performed, no data on the angular distribution of neutrons from the target were available so that a measured asymmetry between the forward and backward yield was thought to be real. Since angular distribution measurements with BF_3 counters have shown the distribution to be symmetrical for thin targets, it is believed that the asymmetry must have been due to scattered deuterons. The $MnSO_4$ tank used in the earlier experiments had only a 4-inch diameter tunnel, compared with the 12 in. by 13 in. tunnel in the present tank. Earlier measurements on the 1/8 in. uranium target in the present tank gave $\sigma_{ln} = 29 \pm 2$ which agrees with the older data.

Results are shown in Fig. 2.

Energy Spectrum of Deuterons Stripped from He^3 and the Resultant Neutron Yield

F. L. Adelman

The attenuation curve of the deuterons stripped from He^3 has been measured with a Faraday cup by Crandall et al (Fig. 3). The corresponding curve at 190 Mev was fit by assuming that the deuterons were monoenergetic, with only three possible processes taking place:

(1) Attenuation of the deuterons with a cross section $\sigma_1 = 3.45$ barns, independent of deuteron energy;

(2) Production of stripped protons of half the energy with a cross section $\sigma_2 = 1\text{-}1.5$ barns, independent of deuteron energy; and

(3) Attenuation of these stripped protons with a cross section $\sigma_3 \cong 5\text{-}15$ barns, independent of proton energy.

The latter value has no physical significance, but rather serves to correct the calculation for too large a value of σ_2 at lower energies. The fit is insensitive to σ_3.

For the "320" Mev deuteron beam, it was immediately obvious that a single value of the energy would not suffice to fit the attenuation curve. Therefore, a fit was attempted using various incident energies and adjusting their relative importance to obtain the best fit. The parameters chosen were: $\sigma_1 = 3.45$ barns, $\sigma_2 = 1.5$ barns, and $\sigma_3 = 5$ barns. Straggling is sufficiently small so that its only effect is to reduce the intensity at the end of the range to half its value without straggling. The best fit obtained is shown in Fig. 3, and the inferred energy spectrum appears as Fig. 4.

While the curves agree well (the probable error on the upper points is 1 percent), relatively large variations in the relative intensities of the components cause only small variations in the fit. Therefore, the spectrum is probably not good to better than 10 percent. It is believed, however, that the sharp high energy cutoff, the long but not intense low energy tail, and the broad main peak are not far off as to either location or relative importance.

If one were to vary the cross sections used, undoubtedly a better fit could be obtained. In particular, a 1 percent increase in σ_1 would be expected to improve the fit at the points marked with an asterisk without significantly changing the spectrum. The effect of varying these quantities, however, has not been investigated, as the credibility of the result would be very much in doubt.

The lowest energy component used in the calculation was at 207 Mev. The tail probably continues below this point, but, judging from the variation of intensity with steering magnet setting, it does not appear that the tail extends

below about 170 Mev. On this assumption, the mean energy of the beam is about 300 Mev. The effective energy for neutron production is about 305 Mev, as the yield increases rapidly with energy.

In order to compare the extrapolation of UCRL-1958 with the experimental result for this spectrum, an estimate of the extrapolated external yield was made. A somewhat more recent version of the total yield extrapolation was used, which gave the total yield at 320 Mev as 12.5 neutrons/deuteron (UCRL-1958 shows 11.6). Upon the assumption that 16.4 percent of the total yield was internal at 190 Mev (for a 1 ft. cube target), 17 percent at 275 Mev, 18 percent at 350 Mev, and 19 percent at 425 Mev, the estimated external yield of Fig. 5 was found. Integrating this against the spectrum of Fig. 4 gave the yield as 8.8 - 9.1 neutrons/deuteron (depending upon whether the lower energy cutoff was at 170 Mev or at 210 Mev). Since the experimental value of 8.9 ± 0.3 for a 1 ft. cube is in excellent agreement, it is reasonable to assume that the extrapolation used here is not too far off. The total yields predicted by this extrapolation are 14.7 at 350 Mev, 28.8 at 500 Mev, and 50.1 at 700 Mev.

Neutron Yields from Laterally Infinite Targets

Walter E. Crandall
CRD

George P. Millburn
UCRL

The majority of the data on neutron yields produced by bombarding targets with high energy particles has been collected for one-foot square targets (UCRL-2063). Chemistry experiments on the internal yield have shown that these targets are not large enough laterally with respect to the beam diameter to show the total capture to be expected in a production target, but that a two-foot square target shows little capture near the edges. Thus experiments are now being performed with two-foot square targets.

The targets are placed in a specially constructed tank which has a 3 x 3 x 2 foot cavity surrounded on all sides by a 12-inch layer of $MnSO_4$ except in the backward direction where there is a 15-inch layer (see Fig. 6). The $MnSO_4$ stops 90 percent or more of the neutrons emitted from a Ra-Be source so that little error is made bacause of differences in the energy spectra of the source and target neutrons.

The primary targets used were uranium, beryllium, and beryllium with aluminum to simulate the effect of NaK. All primary targets were two feet square, and the aluminum was inserted in the ratio of 0.250 in. for each inch of beryllium. The secondary targets were uranium and uranium with aluminum in the ratio of 0.188 in. for each 1.125 in. of uranium.

The results are shown in Fig. 7. The errors shown are relative to this set of data only. For comparison with other data, the errors should be increased to 5 percent, and on an absolute basis the errors should be taken as about 10 percent.

Data was taken at the same time on pure beryllium targets with a 12 in. by 15 in. cross section and varying in depth from 4 in. to 22 in. The results are shown in Fig. 8.

Beam Monitoring Device

John Ise, Jr.

The new helium-filled ion chambers discussed in the last quarterly report have been completely tested in the past three months and have shown that recombination is no longer a problem, the effective multiplying factor of these chambers being completely independent of the cyclotron beam level and also of the high voltage applied to the ion chamber as long as this voltage is greater than about 100 volts. In addition to the original all metal-and-glass ion chamber using copper gaskets, a second smaller chamber has been modified using the same type of foil suspension as the larger chamber. In this type of suspension the foils are crimped tightly between two grooved copper rings, eliminating the need for cements which might poison the chamber gas and cause recombination. The second chamber, after very careful cleaning of all interior surfaces and insulators, was filled through a liquid nitrogen-charcoal trap with carefully purified helium, and has so far shown no recombination whatsoever, in spite of the rubber gaskets in contact with the chamber gas.

The new Faraday chamber has likewise been extensively tested and used both in attenuation measurements and in ion chamber calibration. Results have been highly gratifying, showing that with proper selection of electrometer tubes, VX-10 thermal shorting switches, condensers, and operating voltages, cyclotron currents of 10^{-14} ampere can be followed through hundred-fold attenuation measurements, i.e., down to currents of 10^{-16} ampere, with uncertainties of perhaps 10 percent at these very low beams.

A full report of the construction and operation of these instruments has been written and is being issued as a UCRL report.

He^3 Purification System

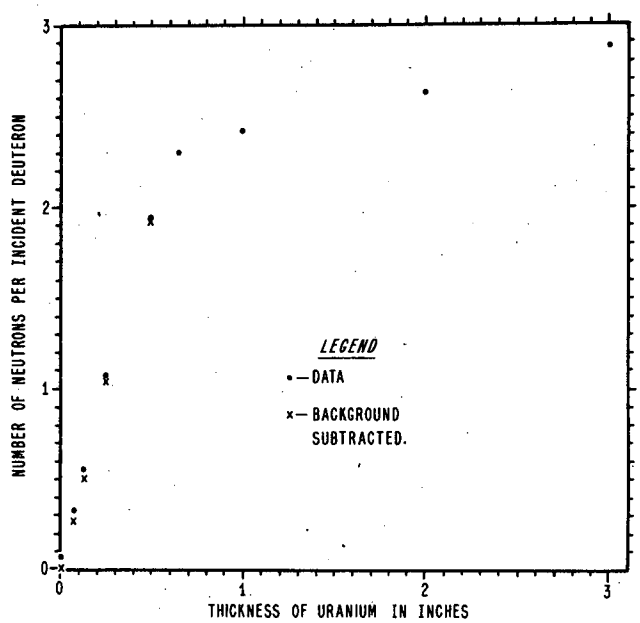
John Ise, Jr. and George P. Millburn

During the first few weeks of the past three months the emphasis of the MTA target program continued to be placed on the production of and experiments with the beam of 320 Mev deuterons from He^3 stripping. During this period cyclotron runs with 320 Mev deuterons were made practically weekly. These

runs all showed a loss of helium smaller than that which could be read on the gauges used in the purification system. A new dual purification system, much more carefully engineered and designed to use both the 4 percent He^3 and the 95 percent He^3, incorporating numerous safety factors to prevent loss of He^3 in any conceivable emergency, has been built, tested and shaken down for a week of simulated running with ordinary (atmospheric) helium. This system is now considered ready for operation with the 95 percent He^3.

The sporadic difficulties with the shaft seal on the 100 CFM Kinney pump became worse until finally the packing glands were burning out at an alarming rate. The pump was dismantled, the old scored shaft replaced, and the packing gland seal replaced with an oil-lubricated graphite disc similar to that used with such success in the small Kinney pumps in the purification system. This new seal has only recently been developed by the Kinney Mfg. Co. for use on the 100 CFM Kinney pumps. Several runs were made using this new arrangement, with recovery line vacua five times lower than previously obtainable, when the graphite ring cracked, and the shaft leak reappeared. Upon disassembly it seemed likely that the previous assembly had not been made correctly, the retaining assembly for the graphite ring having slipped.

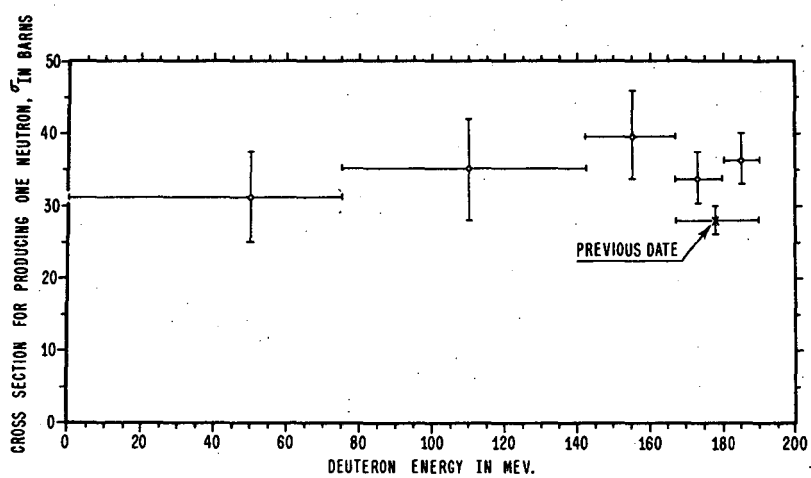
The pump was reassembled with a new graphite ring, tested thoroughly, and is now being set up outside the cyclotron building in its permanent location. This has necessitated new vacuum plumbing, and electrical connections, most of which have been made, so that runs with He^3 should recommence in a few weeks.



YIELD vs URANIUM THICKNESS FOR 2 INCH BY 2 INCH TARGETS BOMBARDED BY 190 MEV. DEUTERONS.

SECRET MU - 5771

Figure 1



CROSS SECTION FOR PRODUCING ONE NEUTRON IN URANIUM vs DEUTERON ENERGY.

SECRET MU - 5770

Figure 2

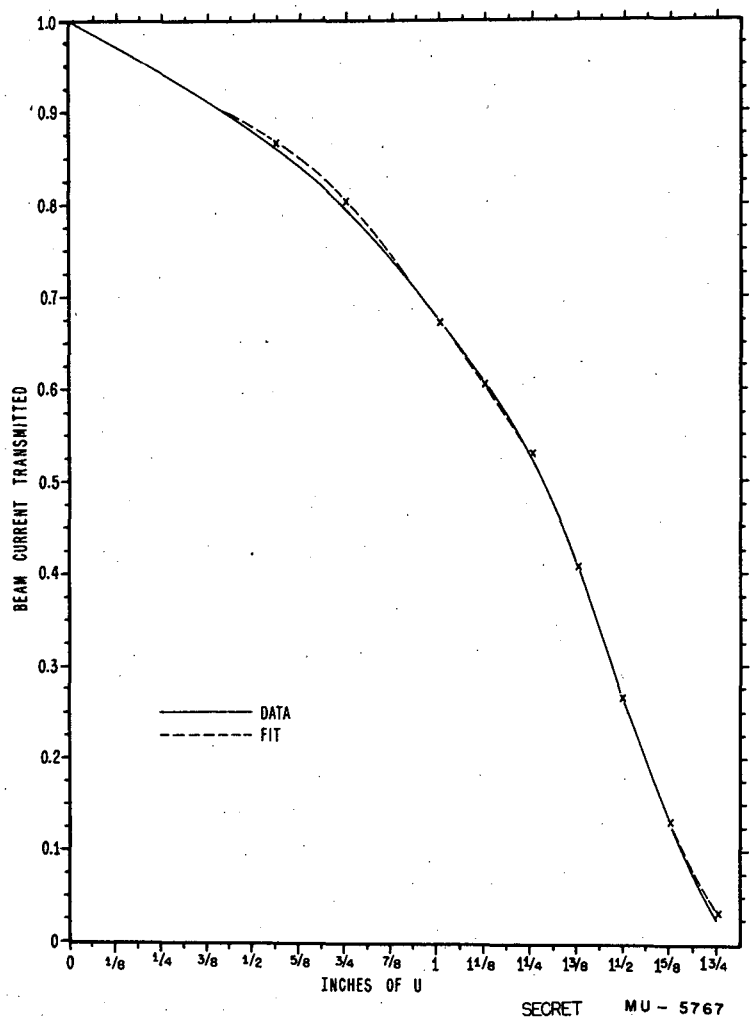

1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
BEAM CURRENT TRANSMITTED
DATA
FIT
0
1/8
1/4
3/8
1/2
5/8
3/4
7/8
1
1 1/8
1 1/4
1 3/8
1 1/2
1 5/8
1 3/4
INCHES OF U
SECRET
MU - 5767

Figure 3

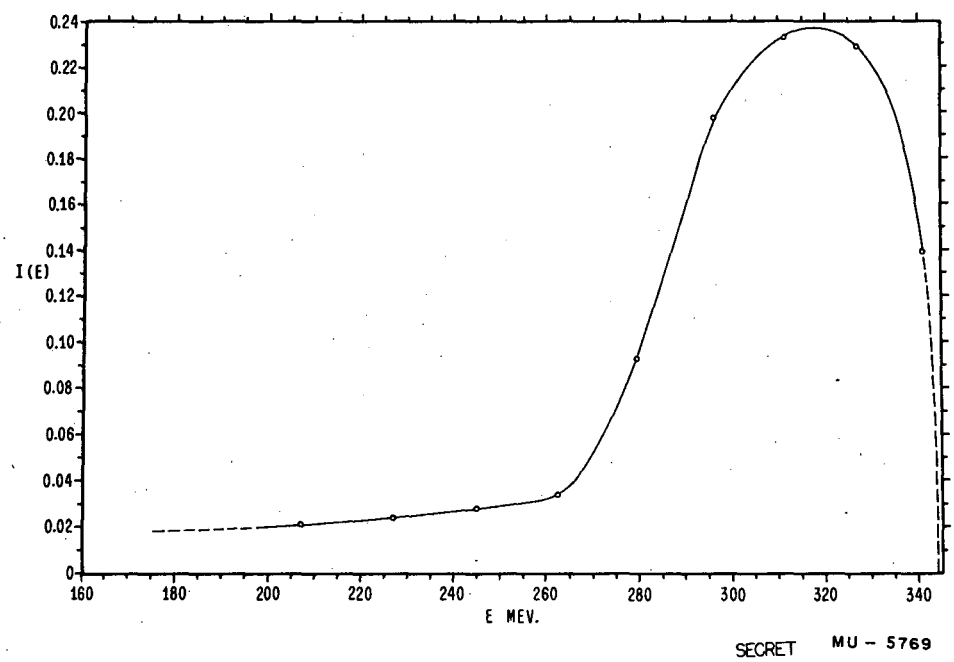

0.24
0.22
0.20
0.18
0.16
0.14
I(E)
0.12
0.10
0.08
0.06
0.04
0.02
0
160
180
200
220
240
260
280
300
320
340
E MEV.
SECRET
MU - 5769

Figure 4

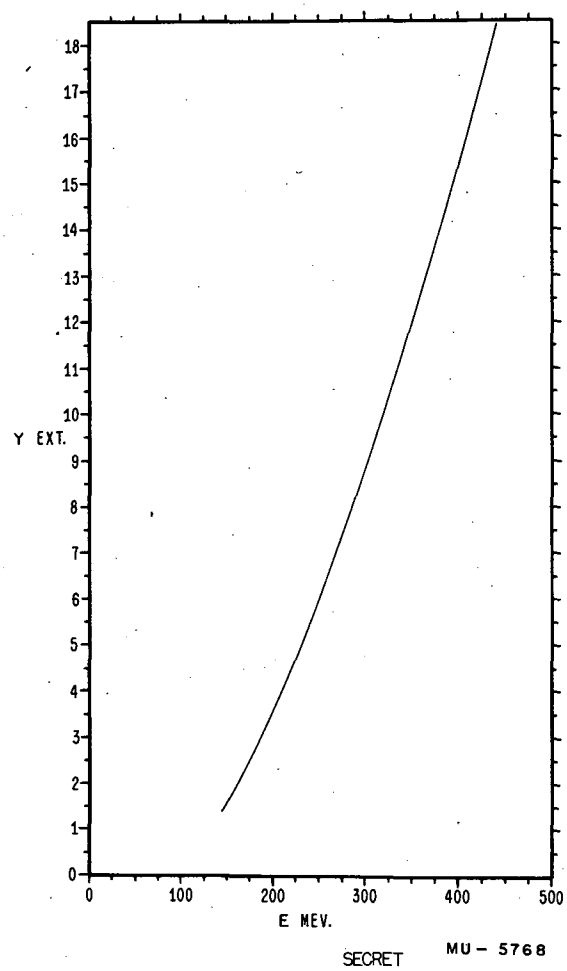

Y EXT.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
0
100
200
300
400
500
E MEV.
SECRET
MU- 5768

Figure 5

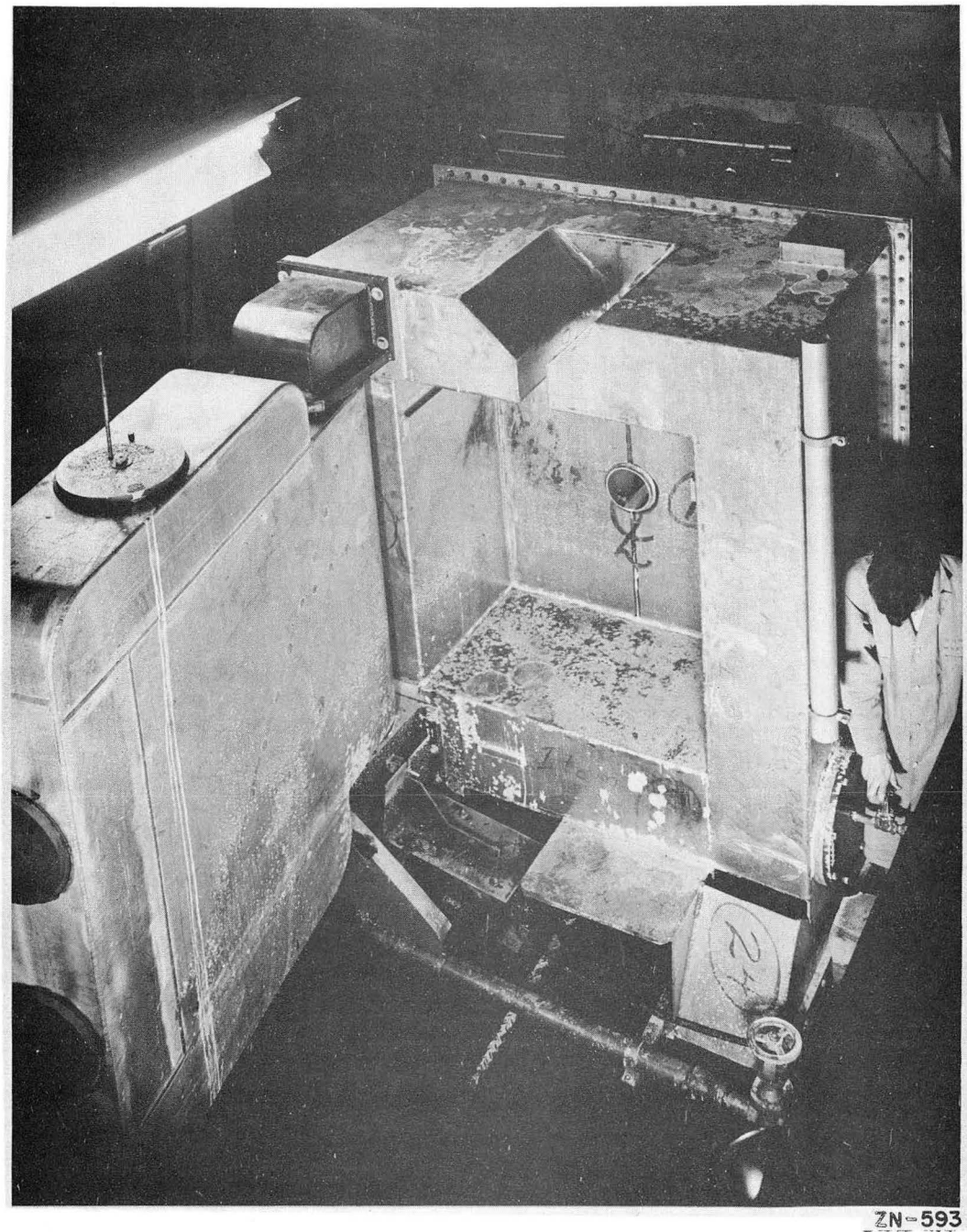


Figure 6

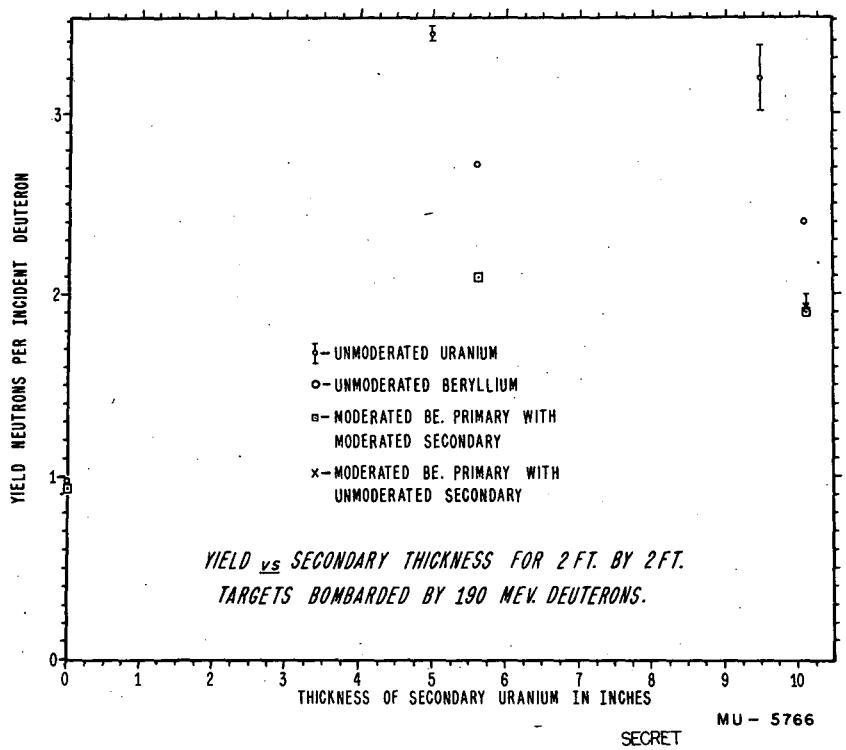
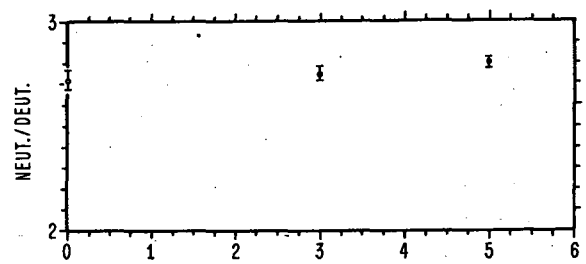

YIELD NEUTRONS PER INCIDENT DEUTERON
THICKNESS OF SECONDARY URANIUM IN INCHES
0
1
2
3
4
5
6
7
8
9
10
I-UNMODERATED URANIUM
o-UNMODERATED BERYLLIUM
⊡-MODERATED BE. PRIMARY WITH MODERATED SECONDARY
x-MODERATED BE. PRIMARY WITH UNMODERATED SECONDARY
YIELD vs SECONDARY THICKNESS FOR 2 FT. BY 2 FT. TARGETS BOMBARDED BY 190 MEV. DEUTERONS.
MU-5766
SECRET

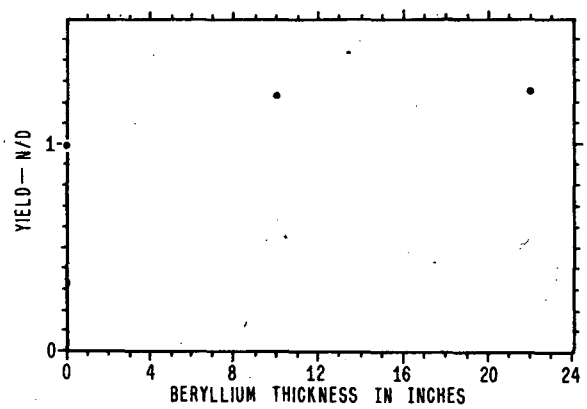
Figure 7

DECLASSIFIED



SEPARATION OF PRIMARY AND SECONDARY TARGETS IN INCHES.
PRIMARY: 4 IN. BE.
SECONDARY: 5⅝ U. TARGETS 2FT. BY 2FT. 190 MEV. DEUTERONS.

YIELD vs SEPARATION OF PRIMARY AND SECONDARY TARGETS.



YIELD vs THICKNESS OF BERYLLIUM FOR 12 IN. BY 15 IN TARGET BOMBARDED BY 190 MEV. DEUTERONS.

SECRET MU-5765

Figure 8

SECURITY INFORMATION DECLASSIFIED

SECRET
SECURITY INFORMATION