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Radiation Levels at the
Los Alamos Tandem Accelerator Facility

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ABSTRACT

Radiation surveys were made of the Los Alamos tandem accelerator facility. The radiation levels of primary concern for health and safety were the gamma radiation levels at the vertical accelerator and neutron levels around the tandem accelerator and at the control slits and target. Gamma radiation of over 4,000 R/h was found, and neutron levels were found greater than 25 Rem/h. These measurements were made inside the biological shield; no detectable radiation was found in areas of normal occupancy.

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INTRODUCTION

Inquiries from other laboratories, as well as our own interests, led to an extensive radiation survey of the Los Alamos tandem accelerator facility. Two electrostatic accelerators, one vertical and one tandem, make up the essential parts of the facility (Fig. 1). The vertical accelerator was built by LASL and has been in productive operation for ~2,100 hours each year since 1951. The high potential terminal of the vertical machine can be charged up to 8 MeV. When a singly charged ion, for example a proton, is accelerated from the charged terminal to the ground potential end of the machine, the ion will acquire an energy of 8 MeV. Particle beams of protons, deuterons, tritons, helium, and oxygen ions are commonly accelerated. Either steady or pulsed beams are available. Over the years, the vertical accelerator has been used primarily for neutron experiments, with several nuclear reactions producing neutrons either for steady neutron beams or for pulsed, time-of-flight experiments.

A tandem accelerator was purchased from High Voltage Engineering Corporation of Massachusetts. This accelerator can be operated independently, and is located in a concrete building with sufficient radiation shielding to prevent interference caused by both machines operating simultaneously. The same variety of particles can be accelerated with the tandem as with the vertical accelerator, and proton energies of 16 to 17 MeV can be readily obtained. The tandem is used primarily for charged-particle experiments, in which

Fig. 1. Los Alamos tandem accelerator facility.

thin targets of various materials are directly bombarded with the accelerated particles and studies are made of scattered particles, secondary reaction particles, and properties of the target and residual nuclei.

The two accelerators are frequently used in series. When this is done, negative ions and electrons are accelerated in the vertical machine at the same time. These electrons impinge on defining slits and give rise to bremsstrahlung radiation, which causes a high gamma radiation about the vertical accelerator. The bending magnet at the base deflects the electrons, and only the negative ion beam is injected into the tandem accelerator. Additional energy is then added to the negative ion beam, giving an accelerated particle a maximum possible energy of 20 to 23 MeV. In steering the beam straight through, i.e., when the beam is not energy-analyzed, some intensity is lost as a result of the particle striking various beam-tube components. This gives rise to bremsstrahlung radiation as well as neutron production from the disintegration of the accelerated particles and from (p,n), (d,n), and (t,n) reactions.

There are 18 beam tubes in the experimental areas, so that multiple use can be made of the facility. Shielding is designed so that an experiment may be set up in one area while the beam is on target in another. This gives rise to personnel traffic-control problems and potential radiation exposures. The primary purpose of this radiation survey was to provide radiation exposure information for traffic-control planning. Secondary purposes were to document

radiation levels at specific locations, and to provide information for response to inquiries from organizations acquiring tandem accelerators.

PROCEDURES

Measurements were made with injection particle energies of 6 MeV for protons and 7, 7.5, and 8 MeV for deuterons. A beam intensity of 8 μ A was used on all particles except during the 8 MeV deuteron run, which was at 3 μ A. The tandem accelerator added 13 and 15 MeV of energy. Typical beam currents straight through were from 2.5 to 3.0 μ A, and on the injection stop from 9.0 to 9.6 μ A.

In the areas of interest on the first and second floors of the vertical accelerator, radial lines were marked off in 10-ft intervals, extending from the bases of the magnets to the perimeter of the building. On the first floor these radial lines were extended to the radiation fence in 10- and 20-ft intervals. The distance from the magnet base to the fence varies from 150 to 175 ft. Because the hallway leading to the vertical accelerator is along the side of the tandem accelerator and has minimal 18-in. concrete shielding, it was extensively monitored at intervals of 5 ft.

The entire tandem accelerator roof was marked off in 20-ft squares to observe the effect of the roof shield. Areas of interest in the tandem accelerator room were marked so that the radiation levels would be well known. Some of these readings were taken directly, while others were observed by looking at the survey instrument through a transit. For

the 8-MeV deuteron run, a concrete shield was constructed about the transit to reduce exposures to the observers.

Radiation measurements were made by five two-man teams. Each team was equipped with gamma and neutron portable survey instruments. Radio contact between monitoring teams and the control room was maintained so that readings by all teams would be taken under similar conditions. Also, measurements were recorded in the control room from the radiation levels shown by the in-place gamma and neutron detectors located throughout the facility.

INSTRUMENTATION

The tandem accelerator radiation monitoring system consists of neutron and gamma detectors permanently installed at locations throughout the building. This provides rapid visual and recorded information at the control room and other locations, as well as audio and visual alarms in the experimental area.¹

Neutron measurements are made with counters consisting of a lithium iodide crystal surrounded by a sphere of polyethylene to moderate the neutrons. The detector response for a 10-in. sphere is proportional to the tissue damage from neutrons below 10 MeV.² These detectors have a logarithmic readout from 1 to 10^4 mRem/h. An 8-in. sphere (called a "Cow") is used as a portable instrument for neutron detection because, with its integral, battery-operated electronics, it weighs considerably less than the 10-in. sphere. A 10-in. sphere on a movable chassis (called a "Rover") was also used.

The gamma detectors installed in the building use aluminum air-ionization chambers having a volume of about 600 cc. These detectors have a logarithmic readout ranging from about 2 mR/h to 10 R/h. The Victoreen Radector and the Eberline E-112B were used as portable instruments for gamma detection. For known high level, gamma ray intensities, CaF_4 thermoluminescent dosimeters were planted at areas of interest. Detector stations and radiation levels are given in the appendix.

RESULTS

Figure 2 shows radiation measurements taken on the first floor of the vertical accelerator. Measured gamma radiation varied from 2 mR/h at the fence to a high of 8 R/h close to the magnet. Neutron radiation levels ranged from normal background to a high of 260 mRem/h. The highest radiation levels, measured with CaF_4 thermoluminescent dosimeters, were found on the third floor (Fig. 3). The radiation from the third floor shines down toward the first floor (Fig. 4). Variations in radiation levels are attributed to accelerator hardware and building structures, which have a shielding effect. Figure 5 shows that measurements along radial lines are also affected by shielding. Radiation in the hallway is predominantly neutrons contributed by the tandem accelerator. All these measurements were made with portable survey instruments.

Figure 6 shows the survey of the roof of the tandem accelerator building. The highest readings are at the

Fig. 3. Radiation measurements taken with thermoluminescent dosimeters in the vertical accelerator building (floor plan view).

RADIATION ALONG VERTICAL ACCELERATOR BEAM TUBE

Fig. 4. Radiation measurements taken with thermoluminescent dosimeters placed along the vertical accelerator beam tube.

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GAMMA RADIATION, mR/h
NEUTRON RADIATION INSIGNIFICANT
FIRST NUMBER, PROTON RUNS
SECOND NUMBER, DEUTERON RUNS

Fig. 6. Radiation survey taken on the roof of the tandem accelerator building.

vertical accelerator building wall, which is made of thin metal and affords no shielding; hence, these readings were from the vertical accelerator and not the tandem accelerator.

An attempt was made to measure the neutron radiation levels when all the beam was defocused at the stripper of the tandem accelerator and the machine was operated at 7.5 MeV. Rover instruments were placed beside the tank center, about 1 ft from the tank wall. The Rover instruments indicated a radiation level of >25 Rem/h.

A more extensive radiation survey was not made because additional exposure to the surveyors was undesirable. The exposures the surveyors did receive, which were within acceptable limits, contributed data to the personnel traffic-control study. All surveyors wore film badges containing a beta-gamma film (DuPont 555) and a neutron monitoring film (Kodak Type B). The four highest gamma exposures ranged from 850 to 120 mRem, with all other gamma exposures under 100 mRem. The highest neutron film-badge exposure was 40 mRem. Additional radiation survey data were obtained from in-place monitoring stations, shown in Fig. 7.

Recently, three types of experiments have been made, using accelerated triton beams with energies greater than 20 MeV and intensities more than $1 \mu\text{A}$ on target. For these experiments, neutron intensities of about 10^{11} /sec were produced at the beam stop, which produced a radiation level of 10 Rem/h at the inside surface of the shield wall. Even under these conditions, negligible neutron intensities were measured outside the shield walls, except near the doors.

ITALICIZED NUMBERS(*71/56)- GAMMA RADIATION, mR/h
 REGULAR NUMBERS(21/89)-NEUTRON RADIATION, mRem/h
 FIRST NUMBER, PROTON RUNS
 SECOND NUMBER, DEUTERON RUNS

Fig. 7. Radiation levels recorded from the in-place monitoring system.

CONCLUSIONS

The radiation levels reported here should be considered as being only a few typical cases from an infinite range of possibilities with these accelerators. Although high gamma and neutron radiation levels are found in controlled areas where people are not allowed, the shielding around the tandem accelerator is adequate for the radiation levels measured. However, a serious radiation exposure is possible. Continued vigilance and training are necessary to ensure that all personnel know the safety rules and abide by them.

REFERENCES

1. Hiebert, R. D., Jennings, H. K., Engelke, M. J., Henkel, R. L., and Lang, H. J., "Area Radiation Monitor System," Inst. Elec. Electron. Engrs. Trans. Nucl. Sci. 12, No. 3, 721 (1965).
2. Bramblett, R. L., Ewing, R. I., and Bonner, T. W., "A New Type of Neutron Spectrometer," Nucl. Instr. Methods 9, 1 (1960).

APPENDIX

In order to obtain radiation levels at various locations around the tandem accelerator when it is running, portable survey instruments were placed at 1- and 5-ft intervals in the tandem accelerator room and the tunnel underneath. Detector stations 1-25 were located in the tandem accelerator room; stations 26-47 were located in the tunnel under the tandem accelerator room and the reaction room. Figures 8 and 9 show these locations. Stations 1-6 were positioned radially from the tank to the wall at 1-ft intervals. Stations 7-25 and 26-47 were parallel to the beam axis at 5-ft. intervals. Readings from these stations are listed in Tables I to V.

Fig. 8. Stations where radiation survey instruments were located on the first floor of the tandem accelerator building.

Fig. 9. Stations where radiation survey instruments were located in the basement of the tandem accelerator building.

TABLE I-A

RADIATION LEVELS UNDER THE TANDEM ACCELERATOR ROOM AND THE REACTION ROOM
WITH THE BEAM STOPPED IMMEDIATELY AFTER 90° IMAGE SLITS

Particle: Proton Vertical energy: 6 MeV Tandem energy: 13 MeV

Beam intensity: Straight through 2.5 μ A
Injection stop 9.6 μ A

Neutrons were measured with a Cow on the floor.
Gammas were measured with a Radector and an E-112B.

Station (a)	Gamma	Neutron
	Radiation Level mR/h	Radiation Level mRem/h
26 (b)	1	4
27	5	4
28	2.5	7
29	2.5	15
30	4	30
31 (c)	7	50
32	10	100
33	20	150
34	15	200
35 (d)	15	250
36	15	250
37	12	250
38	10	250
39	9	200
40	5	100
41	4	50
42	9	50
43	10	100
44 (e)	10	200
45	10	350
46 (f)	10	350
47	10	200

(a) Refer to Figs. 8 and 9
for station locations.

(c) End of tank.
(d) Tank center.

(e) 90° magnet.
(f) Beam stop.

(b) End of tunnel.

TABLE I-B

RADIATION LEVELS IN THE TANDEM ACCELERATOR ROOM
WITH THE BEAM STOPPED IN THE REACTION ROOM

Beam intensity: Reaction room $\sim 1.5 \mu\text{A}$

Other data are the same as in TABLE I-A.

<u>Station</u>	<u>Gamma Radiation Level mR/h</u>	<u>Neutron Radiation Level mRem/h</u>
7(a)	2	125
9	7	100
11	6	150
13(b)	-	~ 500

(a) Beside wall, near injector-control slits.

(b) ~ 10 ft from center of tank.

TABLE II-A

RADIATION LEVELS IN THE TANDEM ACCELERATOR ROOM
WITH THE BEAM STOPPED IN THE REACTION ROOM

Particle: Proton Vertical energy: 6 MeV Tandem energy: 15 MeV

Beam intensity:	Straight through	2.5 μ A
	Injection stop	9.0 μ A
	Reaction room	1.5 μ A

A Cow was placed on top of a Rover, about 5 ft above the floor.

<u>Station</u>	Neutron Radiation Level (a) <u>mRem/h</u>
15	500
17	700
19	900
21	>3,000
23	~2,000
25	1,200

(a) Average of Cow and Rover readings.

TABLE II-B

RADIAL RADIATION FALLOFF IN THE TANDEM ACCELERATOR ROOM

Neutrons were measured with a Rover.

Measurements were made radially from the tank.

The wall and room background influence the radial falloff.

Other data are the same as in TABLE II-A.

<u>Station</u>	<u>Neutron Radiation Level mRem/h</u>	<u>Approximate Distance from Tube ft</u>	<u>Normalized 1/R² Intensity</u>
2	250	10	200
3	300	9	-
4	300	8	300
5	300	7	-
6-1/2 (a)	375	6	450

(a) Vertical ladder on tank.

TABLE II-C

RADIATION LEVELS UNDER THE TANDEM ACCELERATOR ROOM AND THE REACTION ROOM

Neutrons were measured with a Cow on the floor.

Other data are the same as in TABLE II-A.

<u>Station</u>	<u>Neutron Radiation Level mRem/h</u>
33	175
35 (a)	200
37	200
44	200
45	400

(a) Tank center.

TABLE III

RADIATION LEVELS UNDER THE TANDEM ACCELERATOR ROOM AND THE REACTION ROOM
WITH THE BEAM STOPPED IN THE REACTION ROOM

Particle: Deuteron Vertical energy: 6 MeV Tandem energy: 15 MeV

Beam intensity: Straight through 3.0 μ A
Injection stop 7.2 μ A
Reaction room 2.5 μ A

Neutrons were measured with a Cow on the floor.

<u>Station</u>	<u>Neutron Radiation Level mRem/h</u>
26	20
28	40
30	100
32	250
34	350
35 (a)	400
36	350
40	200
42	50
44	50
46	60

(a) Tank center.

TABLE IV-A

RADIATION LEVELS IN THE TANDEM ACCELERATOR ROOM
WITH THE BEAM STOPPED IN THE REACTION ROOM

Particle: Deuteron Vertical energy: 7 MeV Tandem energy: 15 MeV

Beam intensity: Straight through 3.0 μ A
 Injection stop 7.5 μ A
 Reaction room 1.8 μ A

Neutrons were measured with Rover instruments.
Gammas were measured with a Radector and an E-112B.

<u>Station</u>	<u>Gamma Radiation Level mR/h</u>	<u>Neutron Radiation Level mRem/h</u>
10	50	700
11	65	900
12	100	2,000
13	200	2,000
14	350	11,000
15	-	11,000
16	200	4,500
17	170	2,500
18	200	2,500
19	250	3,500
20	-	4,500

TABLE IV-B

RADIATION LEVELS IN THE TANDEM ACCELERATOR ROOM
WITH THE BEAM DEFOCUSED ON THE STRIPPER

Other data are the same as in TABLE IV-A.

<u>Station</u>	<u>Gamma Radiation Level mR/h</u>	<u>Neutron Radiation Level mRem/h</u>
Roof above tank center (a)	4.5	4.5

(a) Through 3 ft concrete.

TABLE V-A

RADIATION LEVELS AT THE INJECTION END OF THE TANDEM ACCELERATOR
WITH THE BEAM STOPPED IN THE REACTION ROOM

Particle: Deuteron Vertical energy: 7 MeV Tandem energy: 15 MeV

Beam intensity: Straight through 3.0 μ A
Injection stop 8.6 μ A
Reaction room 2.5 μ A

Neutrons were measured with a Cow on the floor.

<u>Station</u>	Neutron Radiation Level <u>mRem/h</u>
7	400
8	425
9	500

TABLE V-B

RADIATION LEVELS AT THE INJECTION END OF THE TANDEM ACCELERATOR

Neutrons were measured with a Rover.

Other data are the same as in TABLE V-A.

<u>Station</u>	Neutron Radiation Level <u>mRem/h</u>
28	600
About 5 ft from beam axis:	
Midway between injection slits and stop	750
Against wall, about 5 ft from slits	1,000
Beside injection stop	600

TABLE V-C

RADIATION LEVELS AT THE INJECTION END OF THE TANDEM ACCELERATOR
WITH THE BEAM STOPPED AT THE INJECTION STOP

Neutrons were measured with a Rover.

Other data are the same as in TABLE V-A.

<u>Station</u>	Neutron Radiation Level <u>mRcm/h</u>
Beside injection stop	375