Ar 442

3
28/73 LA-5351-MS

A Monitor for Radioactive Gas
in the LAMPF Accelerator Beam Channel

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87544

MASTER

UNITED STATES
ATOMIC ENERGY COMMISSION
CONTRACT W-7405-ENG. 36

INSTITUTION OF THE UNIVERSITY OF CALIFORNIA

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or 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.

Printed in the United States of America. Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy \$4.00; Microfiche \$0.95

LA-5351-MS

UC-41

ISSUED: October 1973

A Monitor for Radioactive Gas in the LAMPF Accelerator Beam Channel

by

Morris J. Engelke

Harvey I. Israel

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or 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.

MASTER

A MONITOR FOR RADIOACTIVE GAS IN THE LAMPF ACCELERATOR BEAM CHANNEL

by

Morris J. Engelke and Harvey I. Israel

ABSTRACT

Beam loss in accelerator structures and target areas gives rise to radioactive gases formed by interaction of secondary particles in air. A method of monitoring the air in the LAMPF accelerator beam channel using a 51.5-liter ion chamber is described. A method for control of these radioactive gases is discussed.

I. INTRODUCTION

The Clinton F. Anderson Meson Physics Facility (LAMPF) is a linear proton accelerator composed of a Cockcroft-Walton accelerator injector, the beam-transport system, the accelerator proper, the beam switchyard, and experimental areas.

Proton injection from the Cockcroft-Walton accelerator is at 750 keV. The first part of the accelerator operates at 201 MHz to raise the proton beam to an energy of 100 MeV. The rest of the accelerator operates at 805 MHz to bring the beam to its design energy of 800 MeV.

Beam pulses can be as long as 500 μ sec with a peak current of 17 mA and a repetition rate of 120 pps. Beam loss has been estimated to be 100 nA/m in the 61-m-long, 201-MHz section and 2 nA/m in the 732-m-long, 805-MHz section. Experience has shown that beam loss in accelerator structures and target areas will give rise to radioactive gas formed by the interaction of secondary particles in air. The principal types of radionuclides thus generated are well known, and their potential radiation hazard has already been estimated.¹⁻⁵ Radioactive gases thus formed will be predominantly ¹³N, ¹⁵O, ¹³C, and ⁴¹Ar. The half-

lives of all but argon ($T_{1/2} = 1.83$ h) are 20 min or less.

In the beam channel, it is sufficient to monitor the air for gaseous radioactivity and permit its release only when the detection instrument shows essentially no more than two to three times normal background activity. The gas can be analyzed in greater detail if conditions warrant. The time required for the air activity to decay to background levels will be short compared to decay time of the induced activity in accelerator structures. Thus, personnel occupancy will be governed by the radiation emanating from accelerator components in the beam channel, not by radioactive air concentrations.

The beam channel will have barriers to isolate the air at the beginning of the 201-MHz section and at the end of the 805-MHz section. These barriers will not necessarily be airtight, but they will minimize natural leakage and convection. Portable air samplers with provisions for drawing the air from the beam channel to the detector and returning it to the beam channel are located in the service corridor, 30 ft above the beam channel. This air is monitored for radioactive gases and ozone.

Fig. 1. The Kanne air-monitoring system.

A Kanne-type air-ionization instrument is used to monitor the beam-channel air for radioactive gases, and a Mast Development Company detector is used to measure ozone.

II. THE KANNE CHAMBER

Figure 1 is a block diagram of the Kanne air-monitoring system. This is a mobile unit mounted on a four-wheeled, industrial-type wagon for movement to areas where air measurements are desired (Fig. 2). A filter has been placed ahead of the chamber to remove dust. The chamber is composed of concentric cylinders in which the air passes by a deionizer before entering the sensitive volume of the chamber. When the air at the rate of $0.00142 \text{ m}^3 \text{ sec}^{-1}$ ($3 \text{ ft}^3 \text{ min}^{-1}$) passes into the 51.5-liter sensitive volume of the chamber, it is forced to pass first down one side and then up the other side of the chamber before discharge. The current produced by ionization within the Kanne chamber is measured by a picoammeter and continuously recorded.

Fig. 2. The mobile Kanne chamber and Mast O_3 detector unit.

The Kanne chamber has been extensively used to measure ^3H concentrations in air.^{5,6} This type of instrument has been used to monitor more energetic gaseous radioisotopes successfully with reduced efficiency. If the gas is not a pure β emitter, the contribution to the current from interaction of γ 's, and eventually of conversion and auger electrons, must be taken into account. The physical dimensions of the Kanne chamber make experimental determination of the backscatter and absorption of higher energies of betas or electrons very difficult. Elsewhere, ^{85}Kr has been used to calibrate ionization-type instruments and proportional counters.^{7,8} There is an overresponse to

Fig. 3. Kanne-chamber calibration to ^{85}Kr .

most radioactive gases if ^{85}Kr has been used as a calibration standard.⁸ This is true for radioactive gases, such as ^{11}C , ^{13}N , and ^{15}O , that are positron emitters. Sensitivity calculations for the Kanne-type ionization chamber show that the ^{85}Kr sensitivity is 85% that of ^{41}Ar .^{6,7}

Because of high ozone concentrations at the Electron Prototype Accelerator, it was originally thought that the same conditions might be true for LAMPF.¹⁰ This has not been so; ozone has not been detected in the beam channel. The ozone detector used is discussed in the appendix.

III. CALIBRATION PROCEDURE

A 1-Ci ^{85}Kr source was acquired so that the Kanne chamber might be calibrated to this β emitter ($E_{\text{max}} = 670$ keV). The source was encapsulated in a 12.5-cm³ glass vial at standard temperature and pressure. This source was subsequently mixed with a nitrogen carrier to produce a 54- $\mu\text{Ci}/\text{cm}^3$ mixture. At the LASL Occupational Health Laboratory, a 16-m³ airtight chamber was used for calibration. All quot parts of the ^{85}Kr concentration were introduced into this chamber, and air was drawn from it to the Kanne instrument and returned. Figure 3 shows the result of these measurements.

IV. OPERATING INFORMATION

As shown above, the Kanne chamber can be used to detect radioactive gas in air. The background of 1.5 to 2×10^{-13} A is due

Fig. 4. Kanne-chamber response to gamma radiation.

to naturally occurring radioactivity. This limits the low-level measurement to 2×10^{-6} $\mu\text{Ci}/\text{cm}^3$ of ^{85}Kr . The maximum permissible concentration of these radioactive gases can be calculated,¹¹ and it varies from 2 to 3×10^{-6} $\mu\text{Ci}/\text{cm}^3$. Before the beam-channel air is to be vented, a reading of $<5 \times 10^{-13}$ A must be obtained on the Kanne instrument. This number is two to three times normal background and relative to ^{85}Kr is like 2×10^{-6} $\mu\text{Ci}/\text{cm}^3$.

For operational checks, ^{60}Co or ^{137}Cs sources are available and they have been used for this purpose by cross-reference to a well-calibrated Victoreen 440 rf survey instrument (Fig. 4). For some unknown reason, the slopes in Figs. 3 and 4 are not the same.

V. DISCUSSION

This monitoring procedure has been in use for several months and has proved very practical for measuring radioactive air in the accelerator beam channel. Its real value is in determining when to vent so as not to exceed acceptable limits for discharge of radioactive gases.

Accelerator radiation background can be a problem where very sensitive monitoring equipment is used to measure radioactive gas concentrations. The normal background is shown on the right in Fig. 5.

Fig. 5. Kanne chamber response to radioactive gases in the accelerator beam channel.

Also shown is the instrument response to gamma radiation resulting from beam spill along the accelerator structure. This is distinguished by the rapid fall off contrasted to the slower, more gradual decay of radioactive gases (left side of Fig. 5). The half-lives of the isotopes of interest were drawn through the straight sections of the decay curve. Agreement with radioactive gases expected and those measured is good. When there is no beam spill, normal background measurements persist.

ACKNOWLEDGMENTS

The Kanne-chamber air sampler was constructed by Harry W. Craig and Tony H. Salazar. We very much appreciate the assistance of Bernard C. Eutsler and Robert N. Mitchell in calibrating this instrument.

REFERENCES

1. A. C. George, A. J. Breslin, J. W. Haskins, Jr., and R. M. Ryan, "Evaluation of the Hazard from Radioactive Gas and Ozone at Linear Electron Accelerators," Proc. U.S. AEC 1st Symp. Accelerator Radiation Dosimetry and Experience, 1965, CONF-651109, p. 513.
2. A. Rindi and St. Charalambus, "Airborne Radioactivity Produced at High Energy Accelerators," Nucl. Instr. Methods **47**, 227 (1967).
3. H. Vialettes, "Gas and Dust Activation in the Target Room of the Saclay Electron Linac," 2nd Intern. Conf. Accelerator Dosimetry and Experience, 1969, SLAC, CONF-691101.
4. M. J. Engelke and J. R. Parker, "Generation of Radioactive Air and Noxious Gases," LASL internal memo (1967).
5. K. R. Kase, "Radioactive Gas Production at a 100 MeV Electron Linac Facility," University of California Radiation Laboratory report UCRL-14662 (1966).
6. J. E. Hoy, "Operational Experience with Kanne Ionization Chambers," Health Phys. **6**, 203-210 (1961).
7. J. J. Fitzgerald and W. E. Borelli, "Determination of the Efficiency of Kanne Chambers for Detection of Radiogases," Knolls Atomic Propulsion Laboratory report KAPL-1231 (1954).
8. G. W. Martin, J. B. Smathers, and R. D. Neff, "A theoretical Analysis of Proportional Counter Response vs LET," Health Phys. **22**, No. 1, 73-77 (1972).
9. U.S. Department of Health, Education and Welfare, Public Health Service, Radiological Health Handbook, PB 121784R, 1960, p. 155.
10. J. R. Parker and M. J. Engelke, "High-Intensity Electron Accelerator Radiation Hazards," in *Health Physics Operational Monitoring*, Vol. I, C. A. Willis and J. S. Handloser, Eds. (Gordon and Breach, New York, 1972), p. 179.
11. Report of Committee II on Permissible Dose for Internal Radiation, 1959, Health Phys. **3**, 6-28 (1960).

APPENDIX

OPERATION OF THE MAST OZONE METER

The mobile Kanne chamber and Mast O₃ detector unit is shown in Fig. 2.

PRINCIPLES OF OPERATION*

The concentration of O₃ in air is measured by the Mast O₃ meter or Mast micro-coulomb detector. The air sample comes into intimate contact with a thin film of sensing solution on an electrode. The O₃ concentration is determined by the oxidation-reduction of KI in the sensing solution. An electrical current directly proportional to the mass per unit time of O₃ entering the sensor is produced. The meter output

may (1) be read directly from a dial in parts per million per volume, or (2) be recorded as a voltage and converted to parts per million per volume by calibration.

The Mast meter's normal operating range is 0 to 1 ppm/vol. However, with proper selection of range resistors, it is possible to record O₃ concentrations in the 0- to 0.1-ppm/vol range. (The Threshold Limit Value for occupational exposure to O₃ is 0.1 ppm/vol.) The natural background of O₃ is roughly 0.01 to 0.02 ppm/vol, and it is possible to detect O₃ concentrations ~0.01 ppm/vol above this background.

*Instruction Manual for Mast Model 724-2 Ozone Meter, Mast Development Company, Davenport, Iowa (1969).