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SAMPLING PROGRAM FOR AIRBORNE RADIOACTIVITY

31 January 1965

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Fifth U.S. Army Medical Laboratory
St. Louis, Missouri

SAMPLING PROGRAM FOR AIRBORNE RADIOACTIVITY

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Veterinary Division

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TABLE OF CONTENTS

	Page
INTRODUCTION	2
SAMPLING EQUIPMENT	
a. Staplex Model TF-1A Sampler	3
b. Gelman Model 16002 Sampler	5
c. Shelter	7
d. Filter Media	10
e. Time Meter	10
TECHNIQUES	
a. Collection	11
b. Preparation and Counting	11
c. Gamma Spectrometry	12
CALCULATIONS	
a. Volume Sampled	13
b. Activity and "Uncorrected" Concentration	14
c. Sample Age and "Corrected" Concentration	16
CONCLUSIONS AND RECOMMENDATIONS	20
LIST OF SUPPLIERS AND MANUFACTURERS	24
REFERENCES	25
APPENDIX I: Preparation of Standards	27

LIST OF FIGURES

1.	Staplex Model TF-1A High Volume Sampler	4
2.	Gelman Model 16002 High Volume Sampler	6
3.	Exterior View of Shelter	8
4.	Interior View of Top of Shelter	9
5.	Fission Product Age - Calculated From Way-Wigner Equation	18
6.	Atmospheric Radioactivity, 1963 and 1964	21
7.	Laboratory Data Sheet for Air Samples	22
8.	Typical Program Report	23

INTRODUCTION

The air sampling program being conducted by the Fifth US Army Medical Laboratory is patterned after that developed by the US Public Health Service for the National Air Sampling Network. Certain of the techniques have been modified or changed in order to simplify the procedures and adapt them to local facilities and instrumentation.

The basic program involves the collection of particulate matter from a known volume of air. The collector is a high volume sampler equipped with a glass fiber filter. The gross beta radiation emitted by a known fraction of the sample is measured in an appropriate instrument, and the concentration is calculated for the sampling period.

A decision to initiate sampling was made on 1 September 1961, with the resumption of atmospheric nuclear testing. The first sample was obtained on 11-12 October 1961. Since that time, approximately 900 samples have been collected. This represents an average operating rate of seventy-five per cent.

Many phases of the program have been modified as knowlege and experience have increased. These changes have included the type of filters employed, shelter design, timing, sample preparation techniques and measurement of air flow rates. This report is a description of the equipment and procedures currently in use. No attempt is made to discuss the theoretical aspects such as fission product formation and decay, properties of gases and aerosols, etc. Instead, a list of references is provided for those desiring additional information on these subjects.

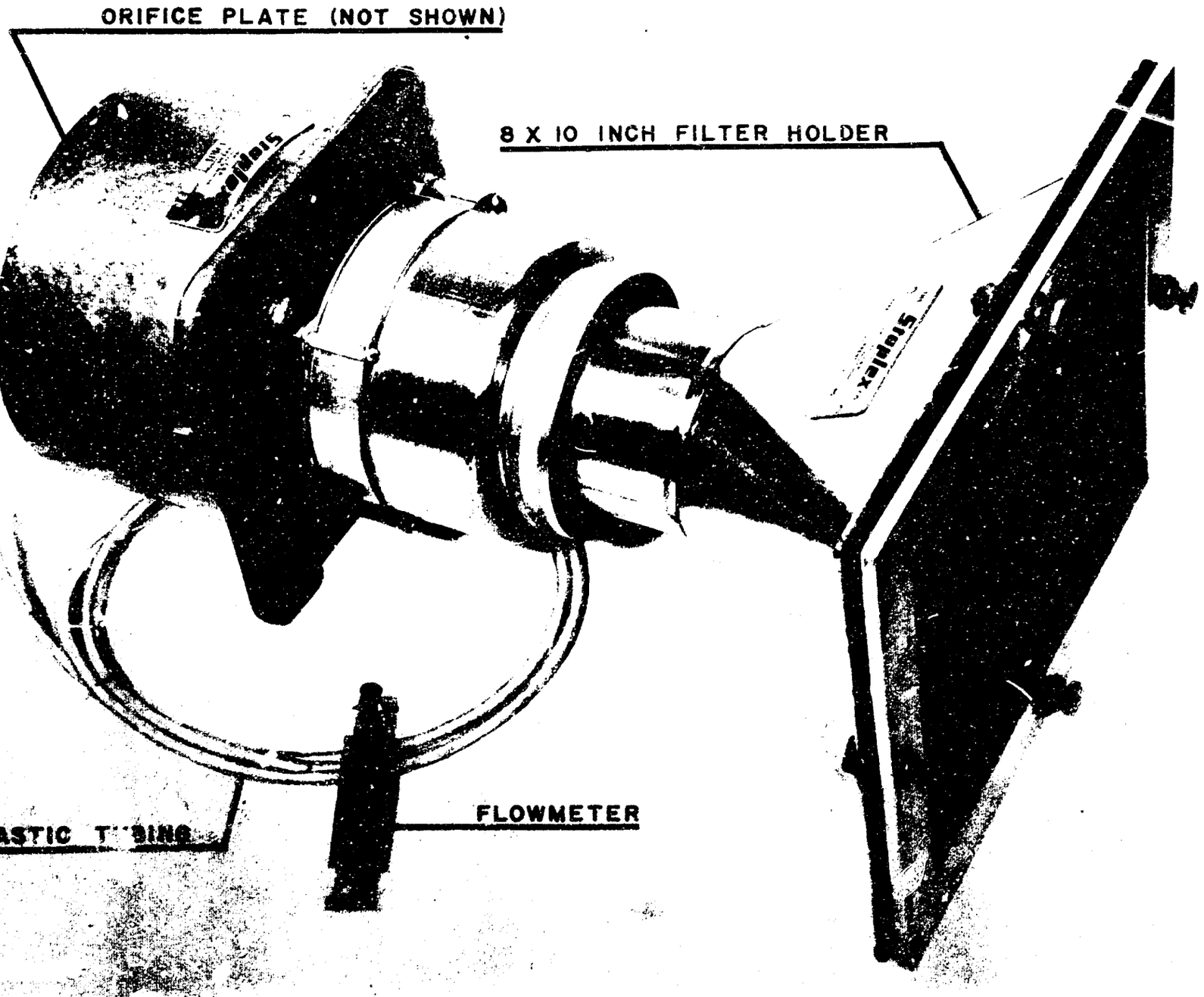


FIG. 1: Staplex Model TF-1A High Volume Sampler

DEPARTMENT OF THE ARMY PHOTOGRAPH

SAMPLING EQUIPMENT

The samplers used by this laboratory are the Staplex Model TF-1A[1]*, and the Gelman Model 16002[2]. They are shown in Figures 1 and 2 respectively. Both are equipped with adapter assemblies for 8 X 10 inch filters. Performance and reliability of each sampling unit have been good. A number of other samplers with similar performance characteristics are commercially available[3,4,5].

a. Staplex Model TF-1A

This unit consists of a modified Electrolux axial flow centrifugal blower assembly. The average sampling rate is 50-55 CFM. With the unit in operation continuously, the only maintenance required has been brush or motor replacement. New brushes are necessary every 1,500 to 2,000 hours. The life of the motor is limited by wear of the armature and bearings, and has averaged 5,600 hours. Brushes (and motors with slight modification) may be obtained at Electrolux dealers, if necessary. In order to replace the brushes, the entire unit must be removed from the shelter and disassembled.

Flow measurement is accomplished by reading the pressure drop across a fixed orifice plate in the exhaust stream. The flowmeter (sometimes called a "visifloat") however, is small and somewhat difficult to use. It must be removed from the unit and remotely located with a

*NOTE: THE LISTING OF PRODUCTS OF MANUFACTURERS DOES NOT INDICATE A SPECIFIC ENDORSEMENT OF A PRODUCT, BUT ONLY INDICATES THAT THESE PRODUCTS ARE USED IN THIS LABORATORY AND MEET THE SPECIFICATIONS ESTABLISHED FOR THE APPLICATION DESCRIBED.

length of plastic tubing (See Fig. 1). It also requires thorough cleaning and recalibration periodically. If left connected to the unit continuously, the reading will show a steady decline over a period of weeks. In order to reduce the frequency of calibration, it is normally connected only when a reading is being taken. When necessary, the meter is calibrated using a 4 inch Orifice Plate Calibration Meter[3].

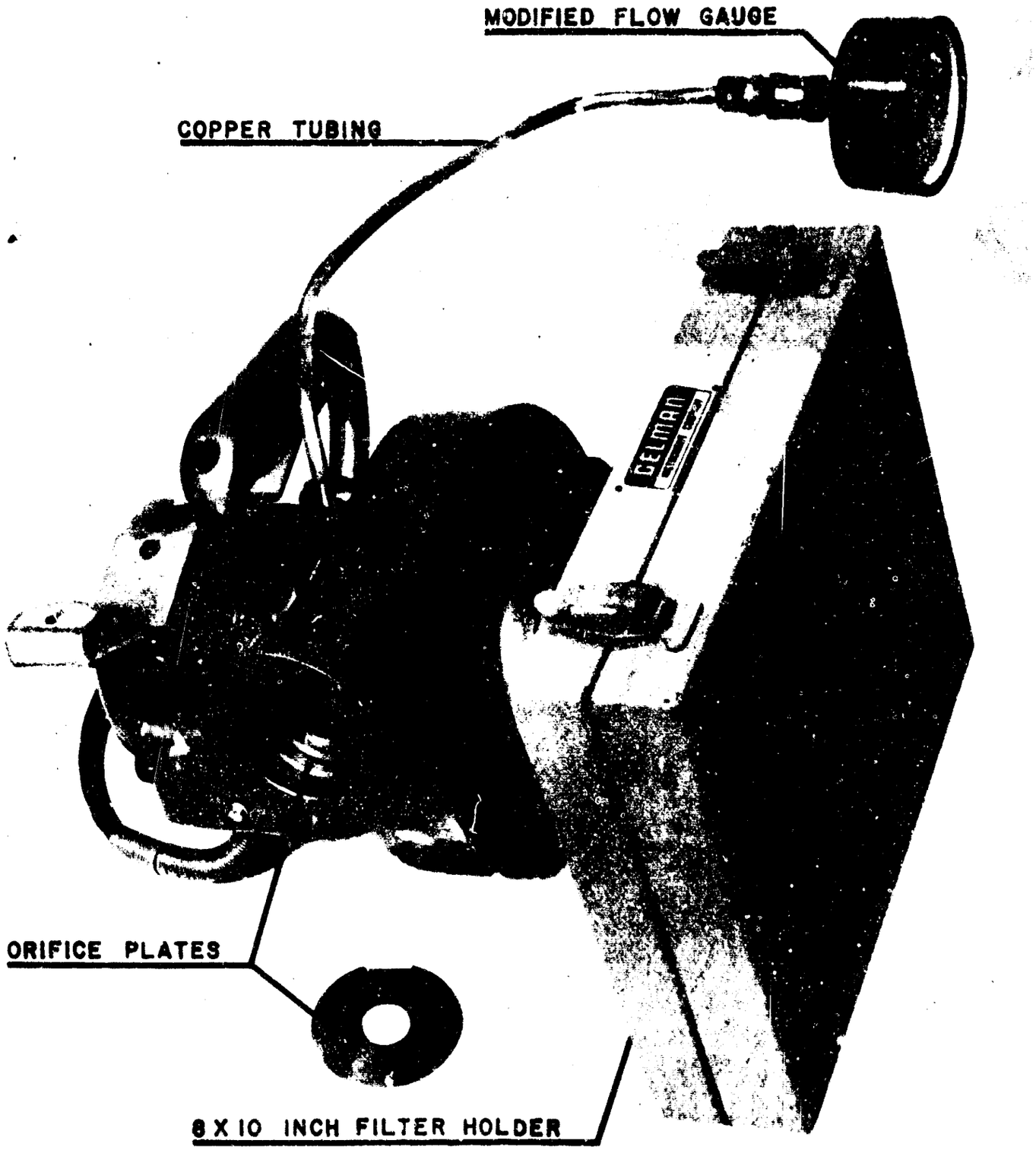
Studies are presently being made to determine whether this meter can be replaced with a calibrated pressure gauge. Initial results show that, to avoid excessive cost, it will be necessary to use a modified orifice plate, with a consequent change in air flow rate.

The sampler is somewhat sensitive to changes in line voltage. A 10 volt change will cause approximately a 6-8% change in flow over the range of 100-130 volts.

b. Gelman Model 16002

This sampler utilizes a radial flow centrifugal type blower. The flow rate is somewhat higher than that of the axial flow types, with an average of 70-75 CFM. Brush replacement can be conveniently accomplished without removing the unit from the shelter. Brush and armature/bearing life, averaged over a number of replacements, is approximately 500 and 3,300 hours respectively.

A slight disadvantage of this unit is its requirement for intermittent operation. The air being sampled does not pass through the motor compartment, thus a separate fan is mounted directly on the armature shaft for cooling. Since this does not provide an adequate



DEPARTMENT OF THE ARMY PHOTOGRAPH

FIG. 2: Gelman Model 16002 High Volume Sampler

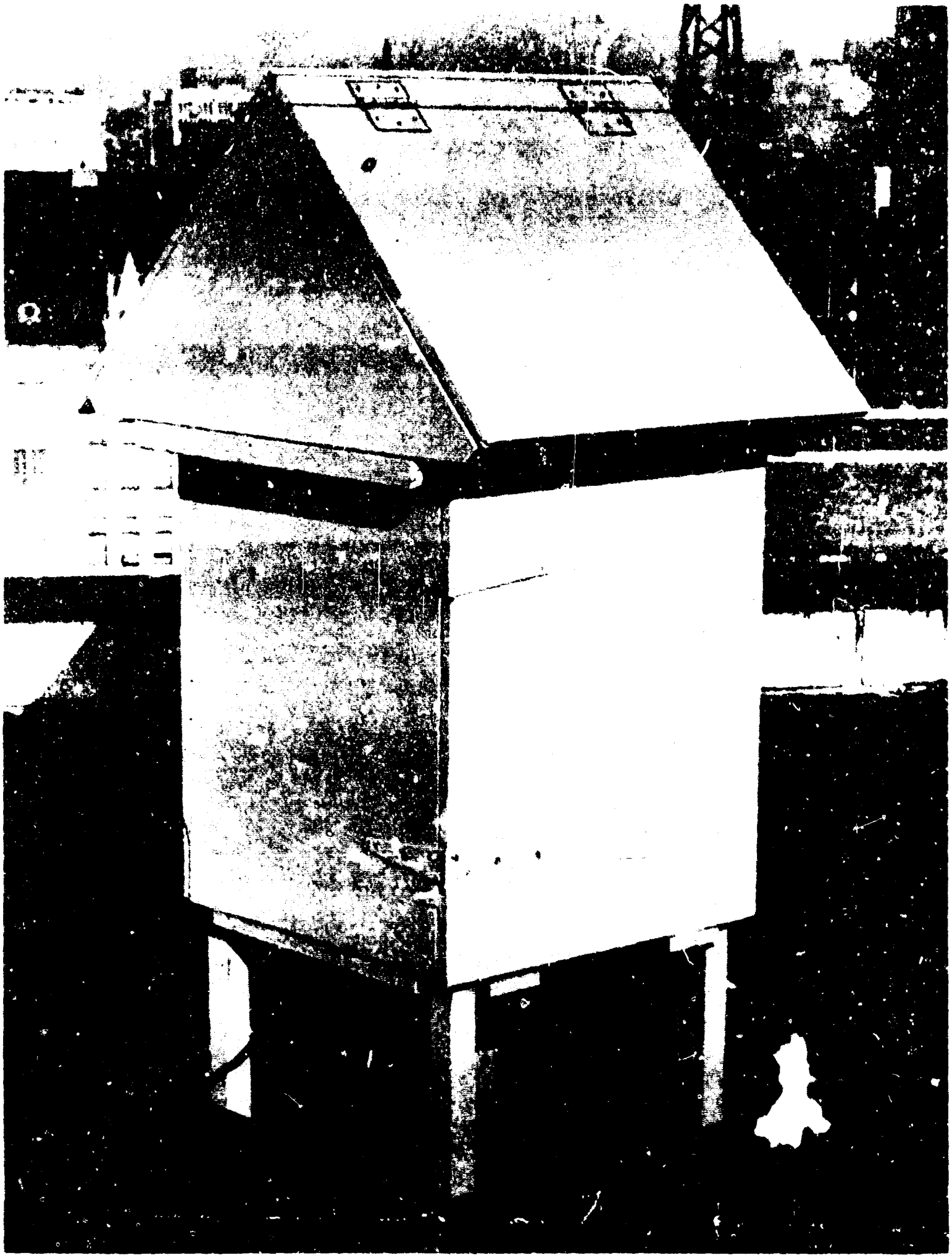
supply for continuous sampling, it is necessary that the motor be stopped after six to eight hours and allowed to cool for a short time. In order to accomplish this, a Tork Model 8001 Automatic Time Switch[6] has been provided. This is a sequential timer, settable at 15 minute intervals over a 24 hour period. As presently used, it allows the blower to operate for five and one-half hours, after which it is off for a thirty minute cooling period. This sequence is repeated four times each day. The resulting loss of sampling time slightly offsets the increased air flow.

The flow rate is conveniently and accurately measured by means of a calibrated pressure gauge and interchangeable orifice plates. When received, this gauge was calibrated in inches of water. A chart was furnished for conversion of the reading to cubic feet per minute. To simplify the process, a new dial face was prepared and calibrated directly in CFM. A similar change has been made by the manufacturer, and all samplers are now equipped with a gauge reading directly in CFM. It was also necessary to relocate the gauge for convenience in reading. This was accomplished using 1/4 inch copper tubing and compression fittings (See Fig. 2).

The flow rate of this sampler also is affected by changes in supply voltage. The change in flow is approximately 9-11% for a 10 volt change over the range of 100-130 volts.

c. Shelter

The shelter for the sampler is shown in Figures 3 and 4. It was constructed from 3/4 inch exterior plywood and is installed on the roof



DEPARTMENT OF THE ARMY PHOTOGRAPH

FIG. 3: Exterior View of Shelter

of a ten-story office building. The location is the Northwest corner of the roof, at a distance of 40 feet from the nearest building air effluent. It is a modified form of the type available commercially[5] and used by the USPHS.

Air is drawn upward through the shelter inlets at a velocity of 55 feet per minute. It is then pulled downward through the horizontal filter and exhausted at the base of the unit. The inlets on two sides are provided with hinged doors which partially restrict the opening. These are closed for use with the Staplex unit which has a lower air flow rate. The purpose is to maintain a constant inlet velocity, which results in a uniform size distribution of the collected particles.

d. Filter Media

The filters used are MSA-1106BH[3]. These are glass fiber mats which have been flash fired to remove the organic binder. Their retentivity for Airborne Fission Products is in excess of 99.8%[4].

e. Time Meter

An elapsed time meter[7] is used to record the running time of the blower. This meter is connected in parallel with the motor and records up to 100,000 minutes in increments of 0.1 minute. It is reset to zero each time the filter is changed.

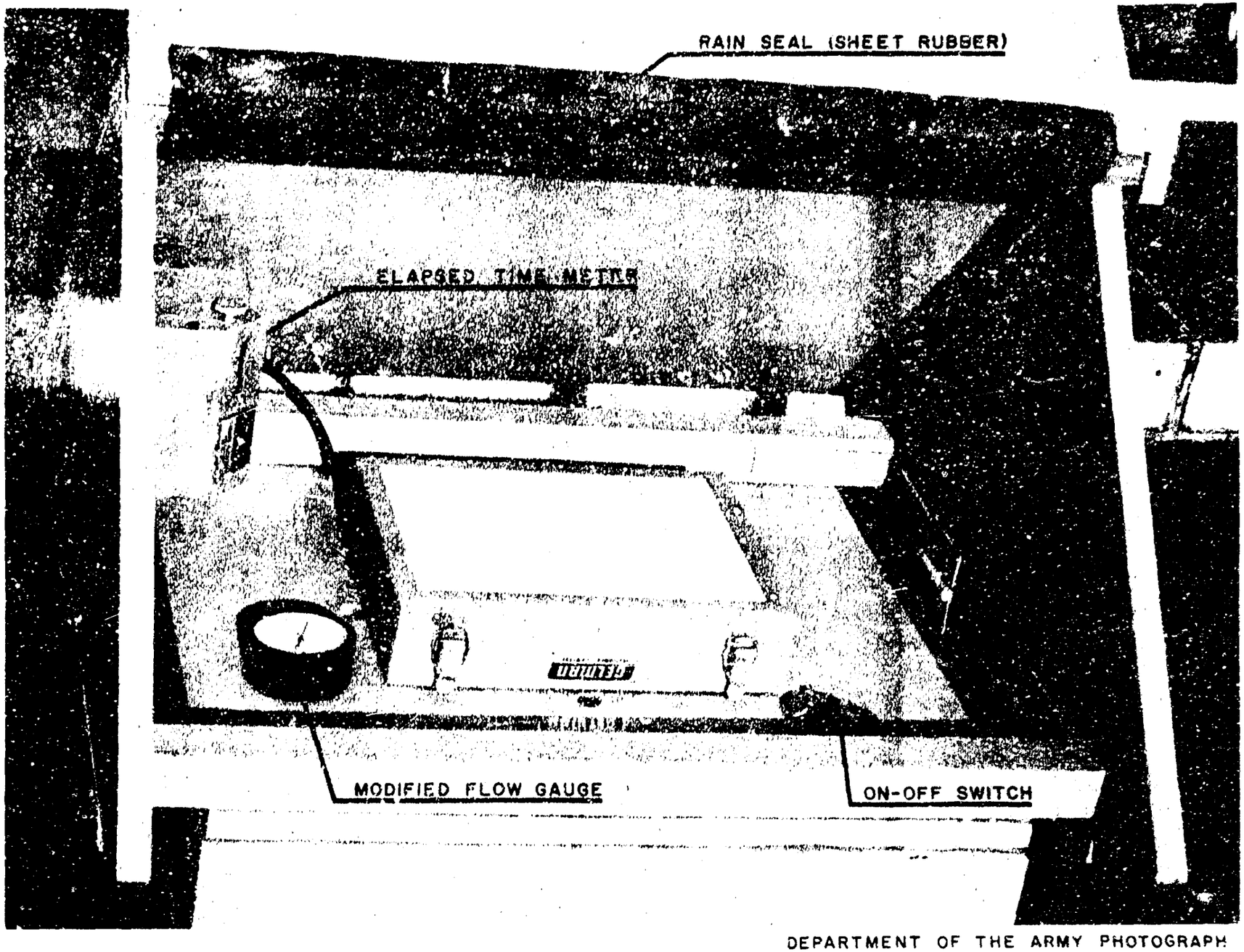


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FIG. 4: Interior View of Top of Shelter

TECHNIQUES

a. Collection

Filters are placed on the sampler between 1300-1400 hours each day. The elapsed time meter is set to zero, and a reading is taken of the air flow rate. A similar reading is taken when the filter is removed on the following day. The sampling time, as recorded by the elapsed time meter, is also noted.

b. Preparation and counting

Each sample is numbered immediately upon being returned to the laboratory. A circle is then removed from near the center of the filter mat with a 1-7/8 inch diameter Hand Mallet Die[8]. After being placed on a two inch diameter stainless steel planchet, it is sprayed thoroughly with anti-static compound[9] and placed in a dessicator. Each sample is left in the dessicator for three days to allow natural activity resulting from Rn-220 and 222 daughter products to decay[8].

The instrument used to measure the activity of the samples is an Internal Proportional Converter, Nuclear Measurements Corporation Model PCC-11A[10]. The count information is registered by a Decade Scaler, NMC Model DS-1A, which also supplies the necessary high voltage. The counting gas supplied to the converter is type P-10, a mixture of 90% Argon and 10% Methane[11]. Resolving time of the system is 3 microseconds.

Following the initial three day decay period, the sample is counted for a selected period of time, depending on its activity. During the

final 30 seconds of flushing, an estimate is made of the gross counting rate. Using this estimate, and suitable nomographs[C], the counting time is chosen to yield a 95/100 Error of 5% for the net sample counting rate. The maximum time for any sample however, is 40 minutes. A 55 minute background count is taken twice each day. Nominal background values are 25-28 counts per minute.

A similar count is made four to six days later. This allows a correction factor to be calculated for the time elapsed between sample collection and the first count (See page 16).

c. Gamma Spectrometry

Selected samples are also subjected to qualitative gamma spectrometric analysis. This is usually performed during periods of atmospheric nuclear testing, when the amounts of activity collected are relatively large. The samples are prepared by removing 10-12 circles from the filter mat. They are placed in a uniform stack and the top circle is inverted. The stack is then wrapped with plastic film (Saran Wrap).

For analysis the sample is centered on the face of a 3" X 3" Sodium Iodide (Tl) detector. The detector and preamplifier are contained in a lead cave with four inch thick walls. The instrument used to measure the spectra is a DD_2 non-overloading linear amplifier (ORNL-Q/1593). High voltage is provided to the system by a Victoreen Model 683 Power Supply[12].

CALCULATIONS

a. Volume Sampled

During the sampling period, as particulate matter accumulates on the surface of the glass fiber mat, the flow rate gradually diminishes. The magnitude of the decrease will depend on a number of factors, such as particulate size and concentration, ambient temperature and humidity, and fluctuations in supply voltage. Since it is impractical to repeatedly measure the flow, an average value is determined from the initial (F_1) and final (F_2) flow rates. This average is multiplied by the sampling time (T) in minutes, to find the total volume of air sampled (V_t).

$$V_t = \frac{F_1 + F_2}{2} (T) \qquad \text{Equation 1}$$

In order to calculate the gross beta concentration, the volume of air (V_c) passed through the counted sample must be determined. This is found by first relating the area of the counted sample (2.76 square inches) to the active area of the filter (set a 63 square inches for both samplers.

$$r = \frac{2.76}{63.0} = 4.38 \times 10^{-2} \qquad \text{Equation 2}$$

The fraction (r) of the total area is then multiplied by the total flow V_t, to find the number of cubic feet of air V_c which has passed through the counted portion. The result is converted to cubic meters.

$$V_c = (V_t)(r)(2.83 \times 10^{-2})$$
$$= (V_t)(1.24 \times 10^{-3}) \qquad \text{Equation 3}$$

b. Activity and "Uncorrected" Concentration

The measured net sample counting rate (A_1) from the initial count, is corrected for self absorbtion, backscatter and instrument efficiency and is converted to picocuries (pc). One Picocurie equals 2.22 disintegrations per minute.

$$pc = \frac{A_1}{(E)(2.22)} \qquad \text{Equation 4}$$

In Equation 4, all factors influencing the detection of the beta particles have been combined into one term (E), called the Total Counting Efficiency. The magnitude of E was established using sources of Sr^{90}-Y^{90} in secular equilibrium. This standard was selected chiefly because the range of beta particles emitted, approximates the wide variety of beta energies arising from mixed fission products of various ages. Other advantages are its availability, long half-life and well defined radiochemical properties[D].

The Sr^{90}-Y^{90} used to prepare the standards was a Nuclear Chicago Model 188550 Certified Solution Standard[12]. The concentration was stated to be within $\pm 3\%$ of the true value.

In the preparation of any counting standards, the principal objective is to duplicate, as closely as possible, the physical, chemical, and radiological properties of the sample to be measured[E]. In the present case therefore, it is not sufficient merely to evaporate a known volume of the standard onto a planchet. The method that was selected for this program was to precipitate an aliquot of the standard, in the presence of a known amount of carrier, as Strontium Carbonate. The

quantity of carrier was chosen to yield a weight of precipitate equal to the particulate matter collected in an average air sample. Since this value is quite variable depending on the physical location of the sampler, it must be determined separately for each installation.

A study of 60 samples collected over a period of months revealed that the average deposition on the filter was approximately 0.6 mg/cm^2. Since the active area of the standards was selected as 15.5 square centimeters (1.75 inch diameter), the required weight of Strontium Carbonate precipitate was 9.3 milligrams. Allowing for a slight loss, 6.0 milligrams of elemental Strontium carrier was added as the nitrate (14.5 mg Strontium Nitrate).

Following complete formation of the precipitate, it was filtered through a 1-7/8 inch diameter circle of clean glass fiber mat. The filtration was carried out in a Gelman Model 2200W stainless steel funnel[2]. The filtrate was collected for use in evaluating the yield. The detailed procedure used in preparing the standards is contained in Appendix I.

When the standards were measured in the Proportional Counter, the Total Counting Efficiency E, was found to be 0.639. Using this value, Equation 4 may be written as

$$pc = (A_1)(0.705) \qquad \text{Equation 5}$$

The activity of the counted sample is then divided by the volume of air which it represents (from Equation 3). The result is the average "Uncorrected" concentration (C_u) of gross beta activity for the sampling period.

$$C_u = \frac{pc}{V_c}$$ Equation 6

c. Sample Age and "Corrected" Concentration

The "age" of a fission product mixture refers to the time elapsed since its formation in a reactor or a nuclear detonation. Due to the abundance of components, a varying half-lives, the mixture does not follow the decay pattern given by a single radionuclide. Instead, the following relationship has been determined by Way and Wigner[F]:

$$(A_x) = (k)(T_x)^{-1.2}$$ Equation 7

Where: A_x = Beta activity at time T_x

k = Constant (Activity at T_x = 1)

T_x = Elapsed time since formation (age)

Equation 7 has been confirmed by subsequent investigators[G,H], and is generally regarded as a simplified method for the prediction of the decay of fission product mixtures less than 200 days old. It may also be expressed in a modified form:

$$(A_1)(T_1)^{1.2} = (A_2)(T_2)^{1.2}$$ Equation 7a

If we let T_1 in Equation 7a represent the age of the mixture at the time of the first count, then T_2 will be equal to $T_1 + \Delta t$, where Δt represents the time between the first and second count. A_1 and A_2 will be the activities at the first and second counts respectively. Solving the equation for T_1, we obtain:

*NOTE: THE METHODS OUTLINED HERE ARE [illegible] MANUALS PUBLISHED BY THE [illegible].

$$T_1 = \frac{\Delta t}{\left[(A_1/A_2)^{0.833}\right] - 1}$$ Equation 8

Solutions to Equation 8 have been plotted in Figure 5.

Using either Figure 5 or Equation 8, the age of the fission products making up the sample may be determined. When this has been accomplished, the decay correction factor is found for the time elapsed between the mid-point of the sampling period and the first count. This can also be done either graphically, or by use of the following modification of Equation 8:

$$\frac{A_c}{A_1} = \left[\frac{T_1}{T_1 - \Delta t_1}\right]^{1.2}$$ Equation 8a

In Equation 8a, the factor A_c represents the activity at the time of collection, and Δt_1 is the time elapsed between the mid-point of the collection period and the first count.

If the graph is used, the factor is determined by following the decay curve for the proper age, to the time (Δt) elapsed between the middle of the sampling period and the first count. The subscripts 1 and 2 of the activity ratio will now represent the time of collection and the first count respectively.

It must be remembered that this will be a <u>different</u> age curve than that used previously, since the sample was not as old when it was collected as it was when it was counted for the fist time. The time between the middle of collection and the first count must be subtracted from the age at the first count to find the new age curve.

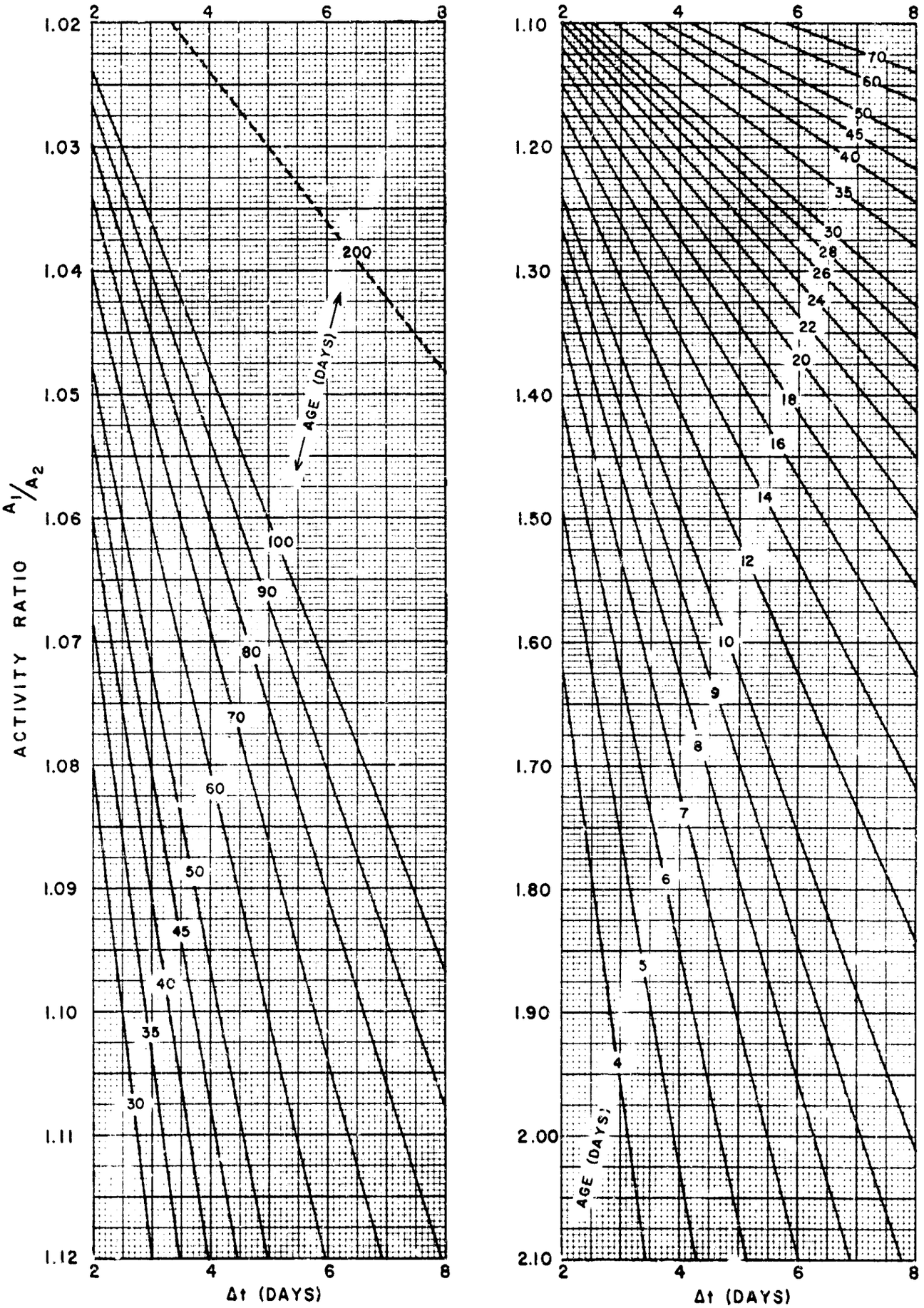


FIG. 5: Fission Product Age - Calculated From Way-Wigner Equation

Finally, the "Corrected" Concentration (C) is calculated by multiplying the "Uncorrected" Concentration by the new activity ratio.

$$C = (C_u)\left(\frac{A_c}{A_1}\right) \qquad \text{Equation 9}$$

It should be noted that, for very old fission product mixtures (>100 days), the activity ratio rapidly approaches unity. This means that the decrease in activity between the two counts is very slight. For this reason, no age determination or decay correction is attempted for samples greater than 100 days old or less than 1 picocurie per cubic meter. Also, when the sample consists of both fresh and aged fission products, Equation 8 will not yield the true date of formation. It will however, give an apparent age, which may be used to determine an approximate decay correction factor.

CONCLUSIONS AND RECOMMENDATIONS

The program as presently constituted is adequate for the routine determination of airborne radioactivity. The results derived from the procedures employed may be correlated with those obtained by various other agencies having similar programs. Improvements may still be made in certain phases, notably determination of air flow rates, regulation of supply voltage to the sampler, and use of improved instrumentation. Consideration is also being given to the use of positive-displacement blowers equipped with constant speed motors as suggested by Lockhart and Patterson[J].

It is recommended that the program be continued in order that personnel may retain proficiency with the equipment and procedures involved. It is also recommended that the improvements mentioned above be thoroughly investigated, and incorporated if possible, into the existing methods.

The regular reports, now being distributed at four week intervals to interested agencies, should also be continued. In the event of a resumption of atmospheric nuclear testing, the frequency of distribution should be increased to biweekly. If possible, additional information should also be included, such as gamma spectral data or a listing of nuclear detonations.

LABORATORY DATA SHEET FOR AIR SAMPLES

NUMBER:

DATE & TIME ON:

DATE & TIME OFF:

A. VOLUME OF AIR SAMPLED

1. INITIAL FLOW RATE = _____ cu ft/min.
4. SAMPLING TIME = _____ min.
2. FINAL FLOW RATE = _____ cu ft/min.
5. TOTAL VOLUME SAMPLED = (A-3) (A-4) = _____ cu ft.
3. AVERAGE FLOW RATE = (INITIAL + FINAL) / 2 = _____ cu ft/min.
6. VOLUME IN COUNTED SAMPLE = (A-5) (1.24×10^{-3}) = _____ . _____ cubic meters

B. RADIOACTIVITY IN COUNTED SAMPLE

1. NET C/M AT _____ days = _____ Gross - _____ BG = _____ c/m x 0.705 = _____ pC
2. NET C/M AT _____ days = _____ Gross - _____ BG = _____ c/m x 0.705 = _____ pC
3. ELAPSED TIME BETWEEN COUNTS = _____ days.
6. AGE OF SAMPLE WHEN COLLECTED = _____ days.
4. ACTIVITY RATIO = $\frac{(B\text{-}1)}{(B\text{-}2)}$ = _____
7. DECAY CORRECTION FACTOR FOR _____ days = _____ .
5. AGE OF SAMPLE AT FIRST COUNT = _____ days.

C. CONCENTRATION OF GROSS LONG-LIVED RADIOACTIVITY IN AIR

1. UNCORRECTED CONC. = $\frac{\text{Activity (B-1)}}{\text{Volume (A-6)}}$ = _____ pC / CuM = _____ . _____ pC/M^3
2. CORRECTED CONC. = $\frac{C\text{-}1}{B\text{-}7}$ = _____ = _____ . _____ pC/M^3

D. GAMMA SPECTROMETER DATA (Samples >15 pC/M³)

1. INTEGRAL ACTIVITY ABOVE 30 KEV = _____ net c/m on _____ (date)
2. COUNTING CONDITIONS:
3. RADIONUCLIDES IDENTIFIED:

Ce^{141} _____ $Ba\text{-}La^{140}$ _____ I^{131} _____ _____ _____

Ru^{103} _____ $Zr\text{-}Nb^{95}$ _____ Cs^{137} _____ _____ _____

E. DUST

1. WT. OF FILTER + SAMPLE = _____ Grams
3. WT. OF SAMPLE = [(E-1) - (E-2)] 10^6 = _____ Micrograms
2. WT. OF FILTER = _____ Grams
4. CONCENTRATION = (E-3) / (A-3) (0.0283) = _____ uG/M^3

FIG. 7. Laboratory Data Sheet For Air Samples

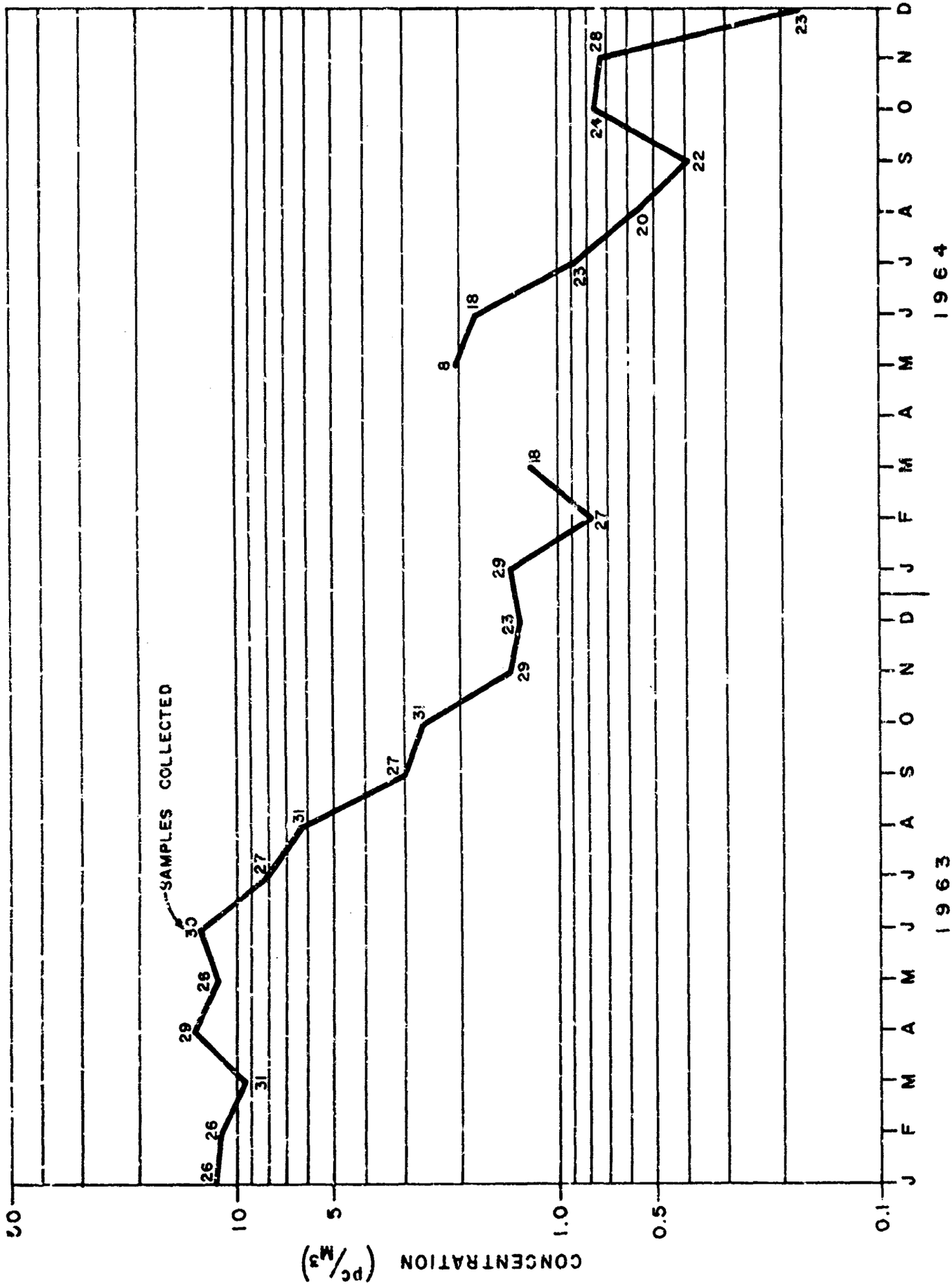


FIG. 6: Atmospheric Radioactivity – 1963 and 1964

HEADQUARTERS
FIFTH U. S. ARMY MEDICAL LABORATORY
TWELFTH AND SPRUCE STREETS
ST. LOUIS, MISSOURI 63102

ALUML-RB

11 January 1965

SUBJECT: Atmospheric Sampling Program

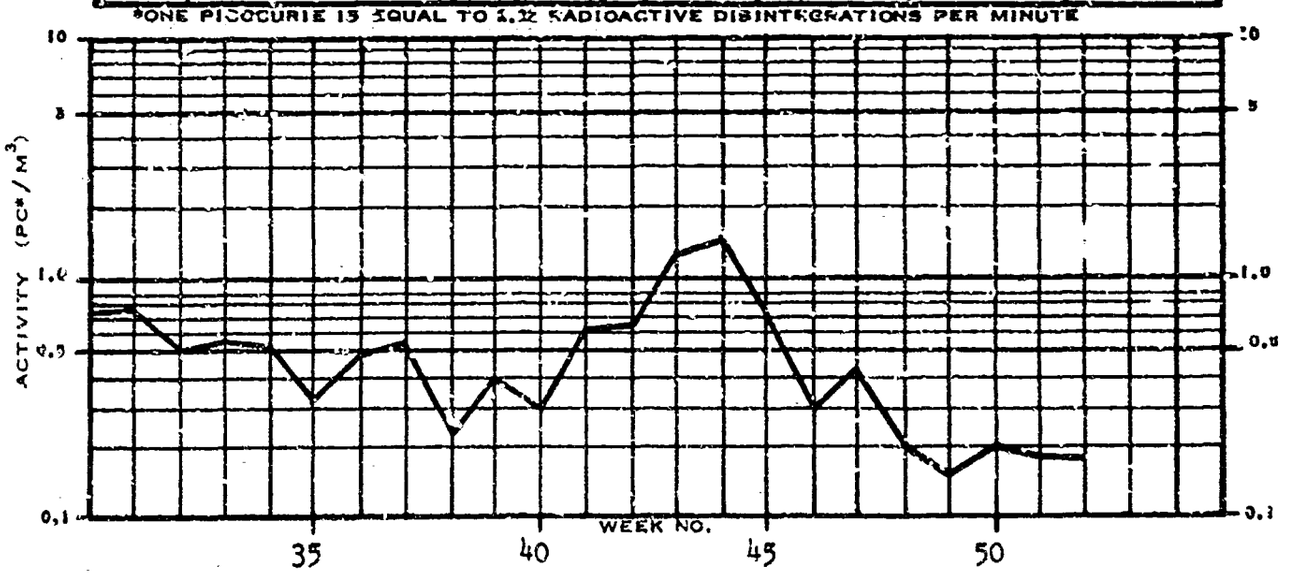
TO: All Concerned Agencies

THE FIFTH U.S. ARMY MEDICAL LABORATORY IS CONDUCTING PERIODIC SAMPLING OF THE ATMOSPHERE TO DETERMINE LEVELS OF BETA RADIOACTIVITY. A HIGH VOLUME AIR SAMPLER IS USED WHICH DRAWS 70,000 - 80,000 CUBIC FEET OF AIR THROUGH AN 8 X 10 INCH GLASS FIBER FILTER IN A 24 HOUR PERIOD. A REPRESENTATIVE SAMPLE IS PREPARED FROM THE FILTER AND MEASURED AT 3 AND 8 DAYS AFTER REMOVAL FROM THE UNIT. THE AVERAGE NET BETA RADIOACTIVITY IN PICOCURIES* PER CUBIC METER IS THEN CALCULATED FOR THE SAMPLING PERIOD.

IN THE ABSENCE OF ATMOSPHERIC NUCLEAR TESTING, REPORTS ARE PREPARED AT FOUR WEEK INTERVALS. DURING PERIODS OF TESTING, THE FREQUENCY OF REPORTING IS INCREASED. WEEKLY AVERAGES ARE CALCULATED FROM SUNDAY THROUGH SATURDAY. MONTHLY AVERAGES EXTEND FROM THE FIRST THROUGH THE LAST CALENDAR DAY.

WEEK NO.	INCLUSIVE DATES	NO. OF SAMPLES	ACTIVITY LEVELS (PC*/M³) HIGH	LOW	AVERAGE	AGE (DAYS)
49	12/6 - 12/12	5	0.21	<0.10**	0.15	#
50	12/13- 12/19	5	0.25	0.14	0.20	#
51	12/20- 12/26	5	0.25	0.14	0.18	#
52	12/27- 1/2	5	0.20	0.15	0.17	#
--	December	23	0.27	<0.10**	0.18	#

*ONE PICOCURIE IS EQUAL TO 2.22 RADIOACTIVE DISINTEGRATIONS PER MINUTE



COMMENTS:

\# Age of "high" sample not measured if less than 1.0 pc/M³.

** Concentration is not calculated for samples less than 0.10 pc/M³. A value of 0.05 pc/M³ is assigned for calculation of weekly average.

FIG. 8: Typical Program Report

LIST OF SUPPLIERS AND MANUFACTURERS

1. The Staplex Company; 777 Fifth Avenue, Brooklyn 32, New York
2. Gelman Instrument Company; P. O. Box 1448, 600 South Wagner Road, Ann Arbor, Michigan
3. General Metals Works; 8368 Bridgetown Road, Cleves, Ohio
4. Union Industrial Equipment Corporation; Port Chester, New York
5. Mine Safety Appliances Company; 201 North Braddock Avenue, Pittsburgh, Pennsylvania
6. Graybar Electric Company; 600 South Taylor Street, St. Louis, Missouri
7. H. T. Sell Company; 3305 Washington Avenue, St. Louis, Missouri
8. Unexcelled Die & Supply Company; 1407 Marcus Avenue, St. Louis, Missouri
9. Merix Chemical Company; 2234 East 75th Street, Chicago, Illinois
10. Nuclear Measurements Corporation; 2460 North Arlington Avenue, Indianapolis, Indiana
11. The Matheson Company; P.O. Box 966, Joliet, Illinois
12. The Victoreen Instrument Company; 5806 Hough Avenue, Cleveland 3, Ohio
13. Nuclear Chicago Corporation; 333 East Howard Avenue, Des Plaines, Illinois

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APPENDIX I

Preparation of Standards

Reagents:

Strontium carrier 6.0 mg-Sr/ml as $Sr(NO_3)_2$

Strontium-90 standard solution $\cong 10^3$ dps/ml

Sodium carbonate 0.1 N

Sodium hydroxide 0.1 N

Aerosol solution 1% (Optional)

Ethanol 95%

Anti-static solution

Procedure:

1. Add 1.0 ml of Strontium carrier to 20 ml of water in a 50 ml beaker (Note 1).
2. Add 250λ of Sr-90 standard solution from a micropipette.
3. Add 2 drops of 0.1 N NaOH and heat to near boiling.
4. Add 2 ml of 0.1 N Na_2CO_3 and digest at room temperature for one hour (Note 1).
5. (Optional) Add 2 drops of 1% Aerosol and swirl gently.
6. Filter, with suction, through a 1-7/8 inch diameter circle of MSA-1106BH glass fiber mat in a Gelman Model 2200W funnel. Collect the filtrate in a large test tube placed in the filtering flask.
7. Wash the beaker with 5 ml of water and add wash to the funnel.
8. Wash filter with 5 ml of 95% Ethanol and draw air through it for 1-2 minutes.
9. Carefully remove the filter, place on a stainless steel planchet and dry in an over at 110°C for two hours.
10. Spray thoroughly with anti-static solution and place in a dessicator for two weeks (Note 2).
11. Count to a 95/100 Error of 2% in the Internal Proportional Counter used to measure air samples.
12. Transfer filtrate to a 50 ml beaker, using 5 ml of water to wash the tube. Slowly evaporate to 2 ml on a hot plate.

13. Transfer filtrate to a stainless steel planchet, using 1 ml of water to rinse the beaker. Evaporate to dryness under an infra-red lamp and store in a dessicator for two weeks (Note 2).

14. Count filtrate as in Step 11. If count rate is near backround, use a maximum time of 30 minutes.

15. Repeat Steps 1 through 14 for triplicate samples.

16. Add 250λ of Sr-90 standard solution from a micropipette to each of 3 stainless steel planchets. Spread by adding distilled water from a dropper. Evaporate to dryness under an infra-red lamp.

17. Count as in Step 11 and determine average count rate.

18. Calculate yield for each sample.

$$Y = 1 - \left(\frac{N_2}{N_3}\right) \qquad \text{Equation I-1}$$

Where: Y = Yield factor
N_2 = Net counts/minute from Step 14
N_3 = Average net counts/minute from Step 17

19. Calculate Total Counting Efficiency for each sample.

$$E = \frac{N_1}{(Y)(D)} \qquad \text{Equation I-2}$$

Where: E = Total Counting Efficiency
N_1 = Net counts/minute from Step 11
D = Disintegrations/minute of standard added in Step 2

20. Determine average of results from Step 19. Substitute this value for E in Equation 4.

Notes:

1. The amounts of Strontium carrier and Na_2CO_3 specified are sufficient to provide a precipitate "thickness" of 0.6 mg/cm^2. They should be varied as necessary, depending on the "thickness" of the air samples to be measured.

2. Since the Strontium-90 and Yttrium-90 will not precipitate as a perfect equilibrium mixture, a delay of two weeks will allow the proper proportions to be established. The filtrate samples may then be discarded after counting and the standards retained for future use.