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ASSESSMENT OF THE RADIATION DOSE DUE TO FALLOUT*

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Lemont, Illinois

October 1959

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*This work was performed under the auspices of the U. S. Atomic Energy Commission.

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the primary source of world-wide deposition.

Of the many radioelements produced in the fission process, Sr^{90} and Cs^{137} have been examined most thoroughly because of their high fission yield, long radioactive half lives, and chemical properties which readily permit entry into the biosphere, including man himself. Many factors relevant to the processes whereby these radioisotopes enter the food chain and are deposited in the human body have been qualitatively assessed (2,3). The body burdens of Sr^{90} and Cs^{137} have been measured as a function of time, and thus the radiation doses arising from such internal deposition may also be determined (4,5). A second source of radiation also exists, namely that which is due to gamma-emitting fission products external to man, yet capable of delivering to man, a dose often manyfold greater than that due to Sr^{90} and Cs^{137} combined. This presentation will be concerned with this external dose, its measurement, variation with time, and how it compares with the dose from natural background radiation.

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isotopes present in the soil. The standard reference spectra, one for each isotope, permit setting up the fraction of the total counting rate occurring in each spectral region, there being as many regions

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the distribution in depth within the soil may also be determined empirically. The dose arising from these various fission products may be calculated under the assumption that the activity is spread

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with an appropriate ionization chamber at various times during 1959. In order to compare calculated and empirical dose rates one must bear in mind that the measured dose contains a component due to natural radioactivity and to cosmic radiation. The dose from U, Th, and K^{40} may be calculated from Hultqvist's equations using the concentrations of these radioelements determined from gamma-ray spectrometry (9). The dose from cosmic radiation was taken from the literature and expressed in μrad/hour. Table III shows the calculated dose for April 1959, totaling 19.2 μrad/hour, contrasted with a measured dose rate of 18.5 μrad/hour. Agreement of a similar order was observed during the succeeding spring and summer months, lending support to both the method of calculation and to the method of measuring fission product concentration.

As previously stated, these dose rates pertain to the unshielded situation. The actual dose to which an individual is exposed must take into account shielding, time spent out-of-doors, and the like. Again use was made of an ionization chamber to determine the dose rate indoors and outside. Within the accuracy of measurement, a shielding factor of 5 was found for fallout radiation (i.e. the dose due to

A unique situation exists at the present time for the study of fallout mechanisms. Testing of nuclear weapons has stopped, and there is no further injection of fission debris into the stratospheric resevoir, so that it should now be possible to obtain values for fallout rate and stratospheric storage time. Furthermore, since no new activity is being produced, there is some justification for hoping that future levels of radioactivity and radiation may be predicted within reasonable limits. To this end monthly soil samples have been collected at Argonne since March 1959, and from these samples fallout rates for each radioisotope mentioned have been determined. Interpretation is complicated by the fact that a portion of the fallout at Argonne comes from tests conducted by the US and UK in the Pacific area and a portion from Russian tests carried out in the far North. The stratospheric storage times and consequently the fallout rates appear to be substantially different for debris coming initially from these two locations (11,12).

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The best fit to our data is obtained upon assuming that 60-75% of the fallout is due to Russian tests having a storage time of 6 to 9 months with the remainder coming from Pacific tests with a storage time of 4 years. This proportionation appeared to continue throughout the summer of 1959. On this basis it is possible to compute the initial amount of any isotope in the reservoir at the time of detonation. For example, the Cs^{137} content of the reservoir according to these data was 6.0 megacuries in October 1958. For this same date, air and rain sampling indicated 4 megacuries of Sr^{90} in the reservoir (13). Using the Cs/Sr ratio of 1.6, one obtains 6.4 megacuries of Cs^{137}. The initial reservoir content of the other fission products measured are in agreement with that of Cs^{137} according to the fission yields of these isotopes.

Encouraged by the consistancy of these findings, estimates of the future levels of external radiation and integral dose from such radiation were made under the assumption that testing is not resumed. It is to be emphasized that these figures actually pertain only to the Argonne site and its immediate surroundings, although the similarity in Sr^{90} deposition at Argonne and at other localities throughout the

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North Central and Northeastern United States implies that comparable fallout levels exist over this area, which contains roughly one half the population of the country. Figure 3 indicates the variation of gamma dose rate from all fission products, as well as that due to Cs^{137} alone, starting in 1957. Extrapolation to future levels is done

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dose respectively. The whole body dose is composed of an external

component arising from Cs^{137}. An additional source of radiation to bone exists due to the presence of Sr^{90}. The external dose was computed using two assumptions; (A) a shielding factor of 5 for all radionuclides, and (B) a shielding factor of 5 and a weathering factor of 2 for Cs^{137}. The internal dose from Cs^{137} also involved two assumptions; (C) the Cs^{137} body burden is proportional to fallout rate, and (D) the Cs^{137} body burden is proportional to the accumulated Cs^{137} deposition. Depending upon the assumptions considered, the 30 year dose lies between 42 and 113 mrads and the 70 year dose between 48 and 170 mrads. Investigations at Argonne have shown little weathering

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indefinitely at this rate. The genetic and lifetime doses under these circumstances are presented in Table V with the dose from natural sources shown for comparison. Continuous testing will result in an increase in whole body irradiation amount to some 6% over that coming from natural background.

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The methodology described and utilized in this work has made it possible to obtain a measure of the dose arising from gamma-emitting fission activity on the ground. Evaluation of the whole body dose to man from such sources has been made through the use of shielding factors applied to this gamma radiation. The present situation in which nuclear weapons testing is no longer being carried out will lead to a genetic dose of 52 mrads and a lifetime dose of 62 mrads to roughly one-half of the population of the United States, an increase of approximately 1% over that arising from natural radiation. The continuous testing of nuclear weapons at the rate occuring between 1954 and 1959 would result in an increase of the whole body dose of some 6% over that occurring naturally.

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9. B. Hultqvist, "Studies on Naturally Occurring Ionizing Radiations," Kgl. Svenska Ventenskapsakad. Handl. 6(4), no. 3 (1956).

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10. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. General Assembly Official Records: Thirteenth Session, Supplement no. 17 (A/3838), New York (1958).

11. W. F. Libby, "Radioactive Strontium Fallout," Proc. Nat. Acad. Sci., U. S. 42: 365-390 (1956).

12. E. A. Martell, "Atmospheric Aspects of Strontium-90 Fallout," Science 129(3357): 1197-1206 (1959).

13. W. F. Libby, "Stratospheric Fallout Particularly from the Russian October Series," USAEC, TID-5556, May 1959.

14. M. Eisenbud, "Deposition of Strontium-90 through October 1958," Science 130(3367): 76-80 (1959).

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Gamma-Ray Emitting Fallout Radioactivity

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Isotope	1957 May	1957 July*	1957 October	1958 April	1958 July	S
Zr^{95}-Nb^{95}**	180	195	230	200	95	3
Cs^{137}	35	34	37	45	60	
Ru^{106}	175	180	180	170	150	2
Ru^{103}	175	200	240	130	35	
Ce^{141}	110	120	140	60	15	
Ce^{144}	240	260	275	250	215	2
Totals***	1095	1184	1332	1055	665	1

* Soil collected 40 miles from the Argonne site gave
any contamination from the reactors at Argonne is c

** Assuming Zr^{95}-Nb^{95} to be in equilibrium.

*** Totals include activity due to both Zr^{95} and Nb^{95}

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TABLE II

Dose Rate due to Fallout at Argonne National Laboratory in μrad/hour

	1957			1958			1959					
Isotope	May	July	October	April	July	Sept.	March	April	May	June	July	August
Zr^{95}-Nb^{95}	1.14	1.23	1.46	1.27	0.60	2.00	4.64	6.22	6.62	5.82	4.80	
Cs^{137}	0.09	0.08	0.09	0.12	0.15	0.21	0.32	0.34	0.36	0.37	0.38	
Ru^{106}	0.15	0.15	0.15	0.14	0.13	0.18	0.53	0.69	0.75	1.00	1.03	
Ru^{103}	0.35	0.41	0.49	0.27	0.07	0.17	0.69	0.48	0.39	0.25	0.18	
Ce^{141}	0.01	0.02	0.02	0.01	0.01	0.01	0.13	0.07	0.06	0.04	0.03	
Ce^{144}	0.04	0.05	0.05	0.04	0.04	0.05	0.21	0.27	0.28	0.31	0.33	
Total	1.78	1.94	2.26	1.85	1.00	2.62	6.52	8.07	8.46	7.79	6.75	

Natural Background = 11.12 μrad/hour

TABLE III

Calculated and Measured Gamma-Ray Dose Rate One Meter above Ground at Argonne National Laboratory April 1959

	Calculated	Measured
Thorium	2.53 μrad/hour	
Uranium	2.65	
K^{40}	2.77	
Cosmic Radiation	3.17	
Fallout	8.07	
Total	19.19 μrad/hour	18.48 μrad/hour

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Integral Dose for

Time Interval	External (A)*	(B)
30 years	42	32
70 years	52	40

* Assumption (A) Shielding factor of

" (B) Shielding factor of

" (C) Cs^{137} body burden p

" (D) Cs^{137} body burden p

** Percentage of background dose.

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TABLE V

Probable Values of Whole Body Dose in mrads

Conditions	30-year Dose	70-year Dose
Tests continue for 5 years beyond 1959	79 (2.1%)*	95 (1.1%)
Tests continue indefinitely	234 (6.2%)	546 (6.2%)
Natural Background	3750	8750

* Percentage of Background Dose.

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in 1958.

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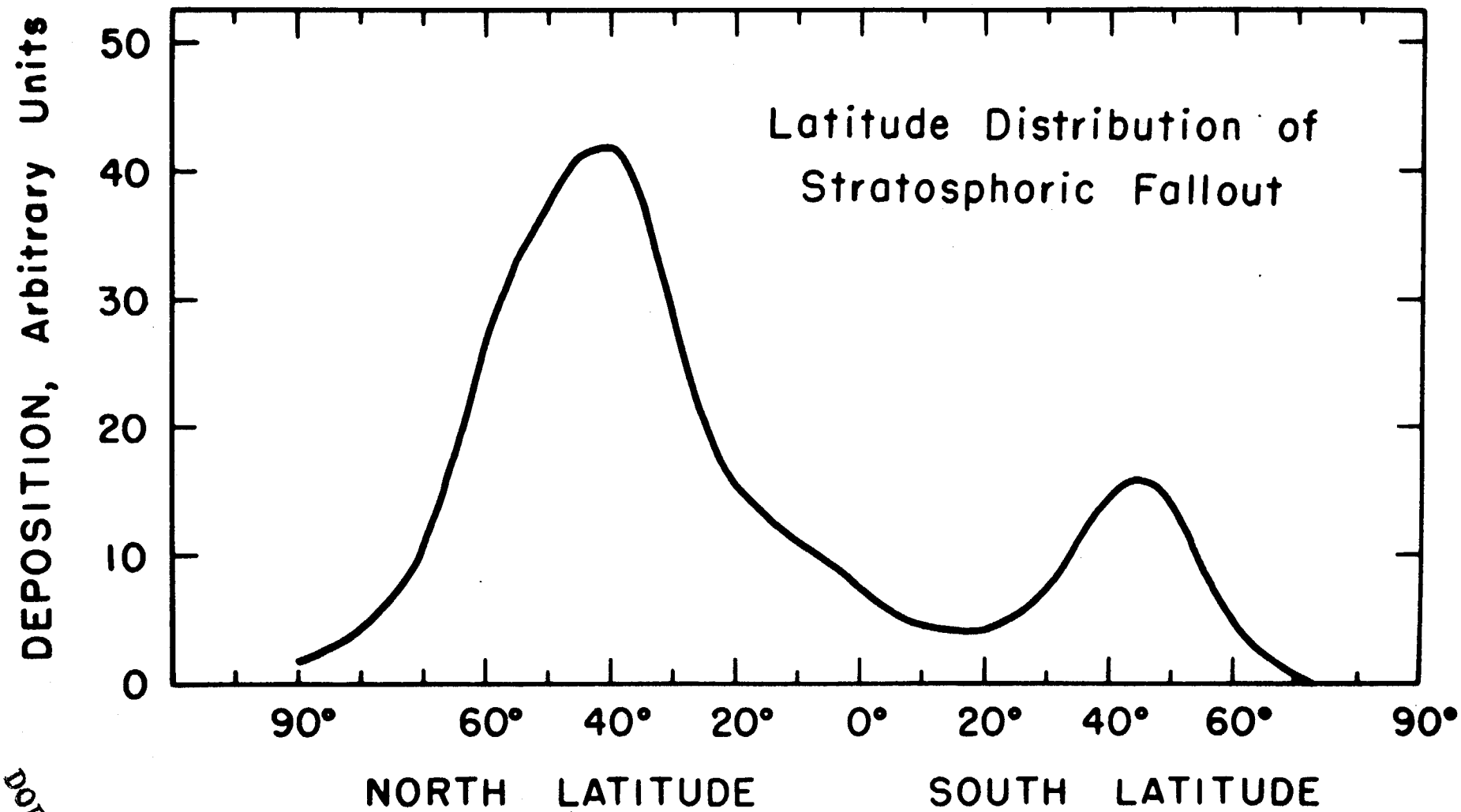

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Fig. 1

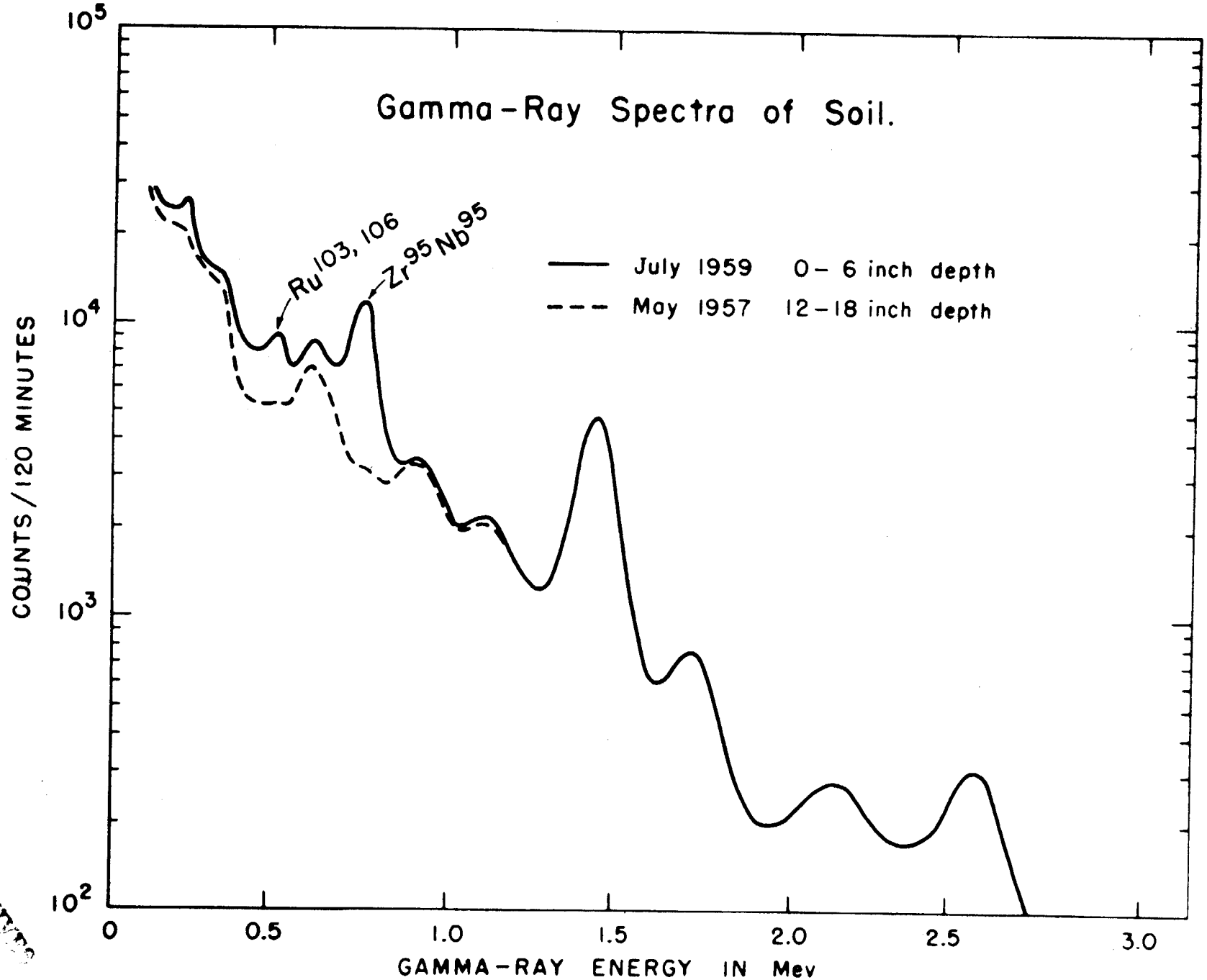

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Fig. 2

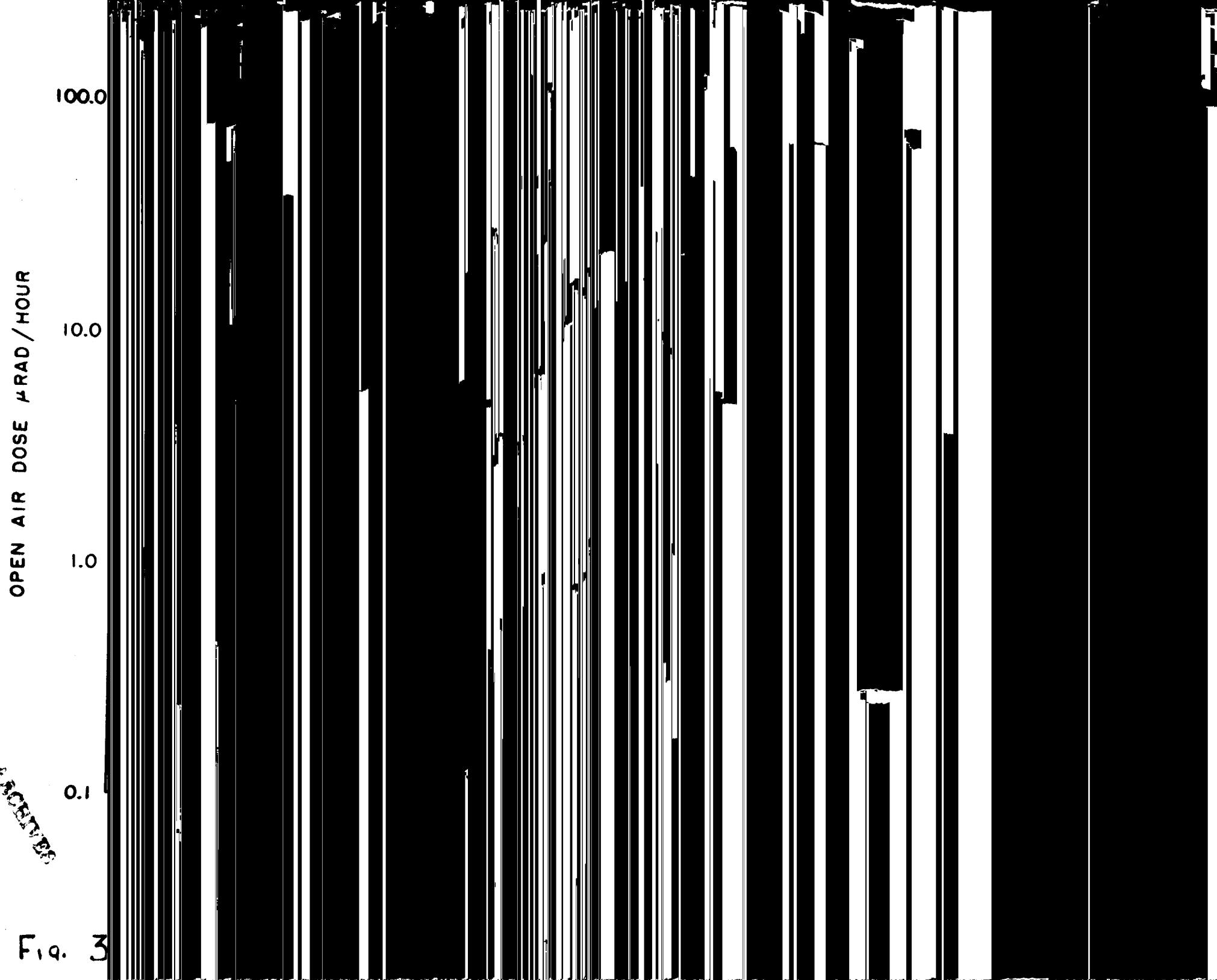

Fig. 3

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