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16. Abstract

Performance tests were carried out on a solar cosmic radiation detection instrument developed for the Concorde SST. The instrument calibration curve (log dose-rate vs instrument reading) was reasonably linear from 0.004 to 1 rem/hr for both gamma radiation and fast neutrons. Nonlinearity in the calibration curve was observed at dose rates below 0.003 rem/hr. The instrument responded normally after exposure to 30 rem/hr of gamma radiation. The charged particle detectors showed a directional response apparently because of the neutron moderator. The neutron detector did not show a directional response. When accumulated dose -- which is shown on the digital display of the instrument -- was used to compute the dose rate, the dose rate was overestimated by about 169% at 0.0013 rem/hr and 50% at 0.1 rem/hr. Measurements made with the Concorde instrument at 60,000 ft. and high geomagnetic latitudes indicated a galactic cosmic radiation dose rate of 0.7 - 0.9 millirem/hr.

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CALIBRATION OF THE CONCORDE RADIATION DETECTION INSTRUMENT AND MEASUREMENTS AT SST ALTITUDE

I. Introduction.

On rare, unpredictable occasions—perhaps one to five times in each 11-year solar cycle—the radiation at SST cruise altitude during a solar cosmic ray event reaches levels normally considered unacceptable for the general population.[1 2] To protect passengers and crew from unnecessary radiation exposure, airworthiness authorities of Britain and France require that civilian aircraft, which fly above 50,000 ft, have a solar cosmic ray warning device.[3] If the radiation level reaches 100 millirem/hr, the pilot is to descend to a lower altitude.

A radiation warning device, developed at the Atomic Weapons Research Establishment in Aldermaston, Reading, England, for the Concorde SST, was lent to the Office of Aviation Medicine of the Federal Aviation Administration (FAA). In April 1969 we received the instrument (NIS 366/1 detector unit, Ser. No. 3; NIS 366/2 display unit, Ser. No. 102) with instructions to: (1) attach a recorder, (2) calibrate the detectors, (3) measure radiation levels at SST altitudes with the Concorde instrument and (4) compare the Concorde instrument measurements with those made with the High Altitude Radiation Instrument System (HARIS), a research instrument for cosmic radiation measurements currently being flown by the Air Force under contract with the FAA.[4]

II. Description of the Instrument.

The Concorde radiation instrument consists basically of three miniature Geiger-Mueller counters, which measure the dose from charged particles and gamma radiation, and a moderated boron trifluoride proportional counter, which measures the neutron dose (Fig. 1). The pulsed signals from the neutron and charged-particle detectors are amplified, shaped and added. The processed signals from the two detector systems drive a single ratemeter. A four-decade logarithmic continuous indication of dose-rate equivalent is produced and displayed on a dial divided linearly in arbitrary units. A digital display of the total radiation dose, in millirem, is also provided.

The response of the neutron counter is proportional to the dose equivalent of the incident radiation for neutrons with energies from thermal to 10 MeV; the quality factors for neutrons recommended by the International Commission on Radiological Protection (ICRP) are automatically applied. Fast neutrons are slowed down by the moderator (mainly polyethylene) and captured by B^{10}. When B^{10} absorbs a slow neutron it becomes the unstable B^{11} which decays to Li^7 by emitting an alpha particle. The ionization caused by the positively charged alpha particles is measured.

The desired relative response of the two detection systems is accomplished by the use of the three Geiger counters. The response of the Geiger counters is such that a rem/rad ratio of 1.5 for gamma radiation is automatically applied.

A calibration check for the Geiger counters is provided by a Sr^{90} radiation source enclosed in a stainless steel housing inside the instrument near the Geiger tubes. When the button marked "test" on the display unit of the ratemeter is pressed, a shutter in the source housing opens and the Geiger tubes are exposed to Sr^{90} beta radiation.

This brief description of the Concorde instrument is based on information provided by Mr. I. I. McNaughton of the Royal Aircraft Establishment and a report by T. G. Benbow.[5]

III. Preparation of the Instrument for Installation in RB-57F Aircraft.

The detector unit was designed to be hermetically sealed; however, pressure chamber

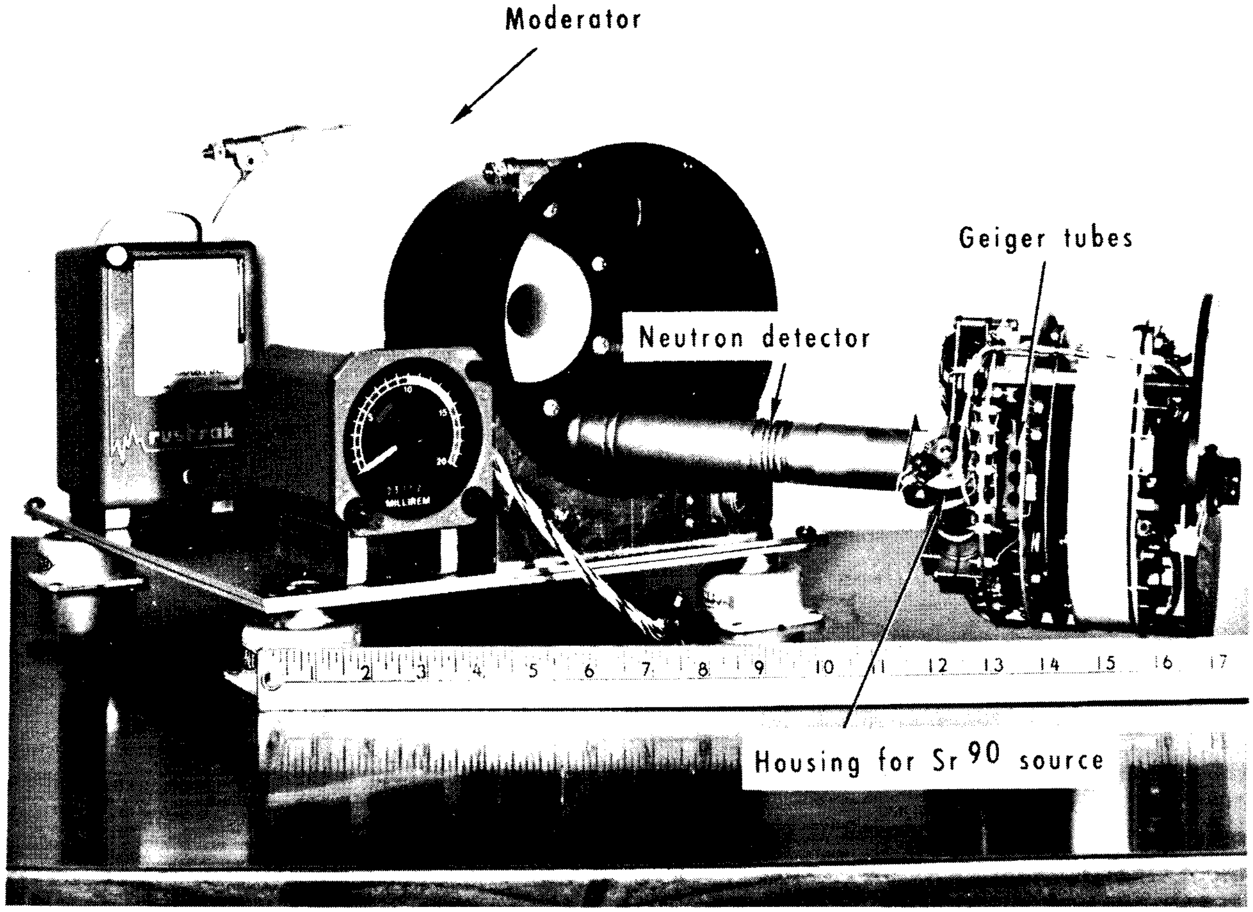


FIGURE 1. Concorde instrument partially disassembled.

tests performed in Aldermaston on production models identical to the unit lent to the FAA indicated that the seals were inadequate at the junction of the polyethylene moderator and the can enclosing the electronic components and also at the bolt heads securing the top plate. Mr. T. G. Benbow of the Atomic Weapons Research Establishment provided us with results of the tests in Aldermaston and a list of production modifications. Accordingly we made the following modifications in the instrument in our charge: (1) a groove was machined in the polyethylene moderator and the flat gasket between the moderator and the can was replaced with a ⅛ inch '0' ring (FSN 5330–551–3963) and (2) the metal lock-washers used with the top-plate bolts were replaced with shakeproof paper-base phenolic washers.

A miniature one-channel Rustrak chart recorder (Model 228, 0–1 ma), which allows continuous data collection for 9 hr, was coupled to the ratemeter. The frequency of the print stroke is 20/min and the gear train moves the chart paper 15 inch/hr. The vertical coordinate of the chart paper is divided linearly.

The Concorde instrument and recorder were attached to a modified Barrymount, type 10020–10 (Fig. 2–4). The mount has 18–40 lb shock absorbers inboard and 10–20 lb shock absorbers outboard. The entire package including the shock-mount rack weighs 39 lb. The power required, about 15 w, is obtained from a 115 v 400 cycle outlet in the aircraft. A mating plug and power cable were provided and the system was fused to meet FAA standards. The instrument package passed the required pull test of nine times its weight.

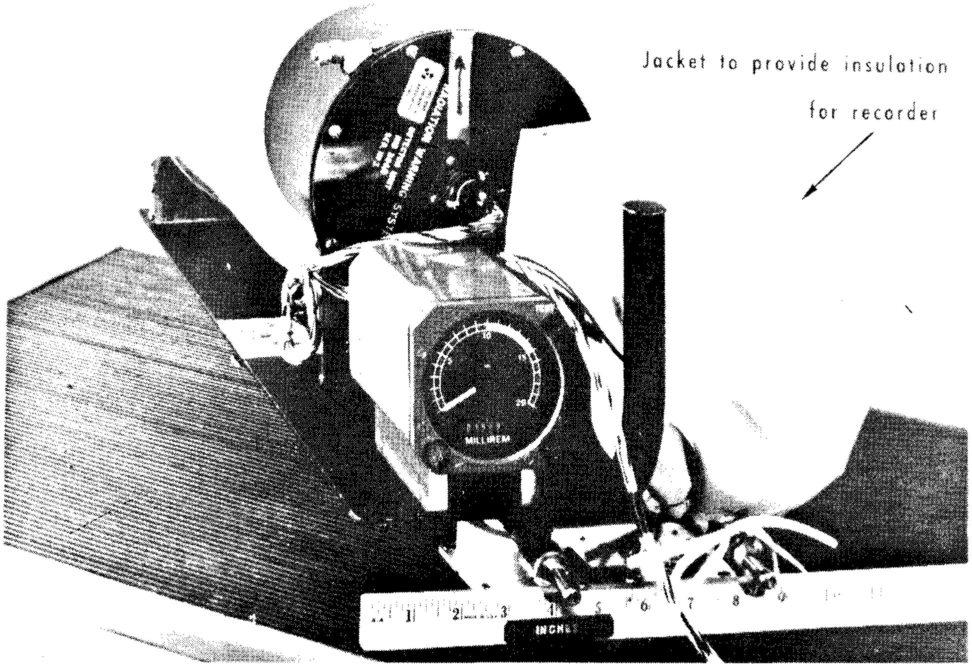


FIGURE 2. Concorde instrument on rackmount ready for installation in RB–57F.

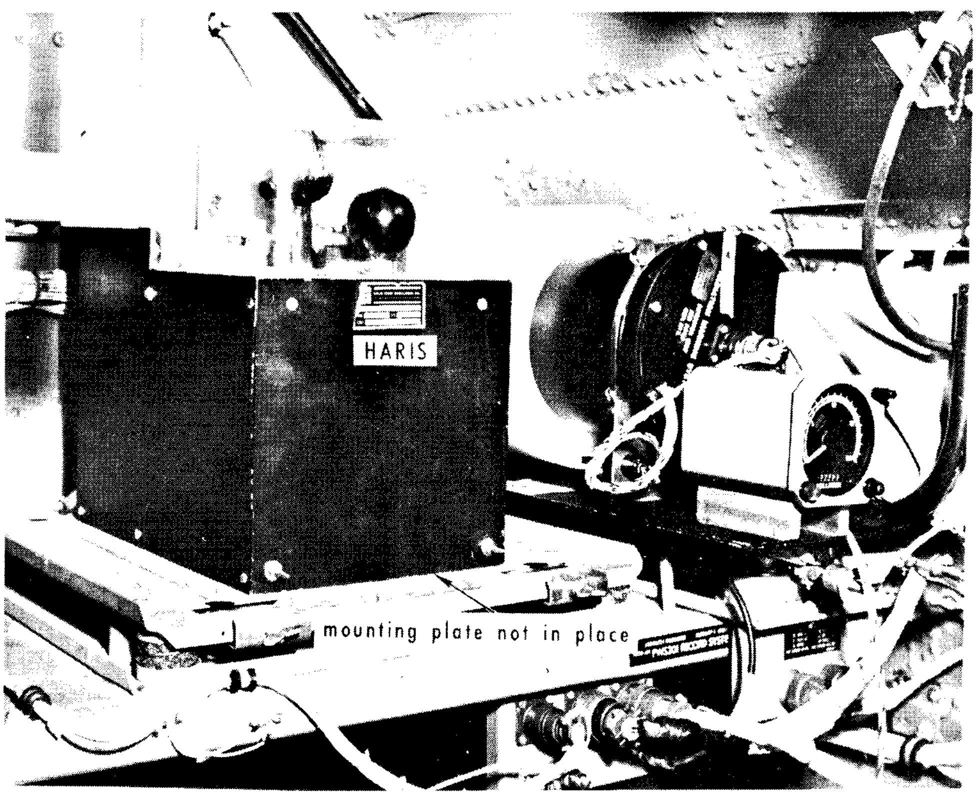


FIGURE 3. HARIS package and Concorde instrument in upper pressurized compartment of RB–57F.

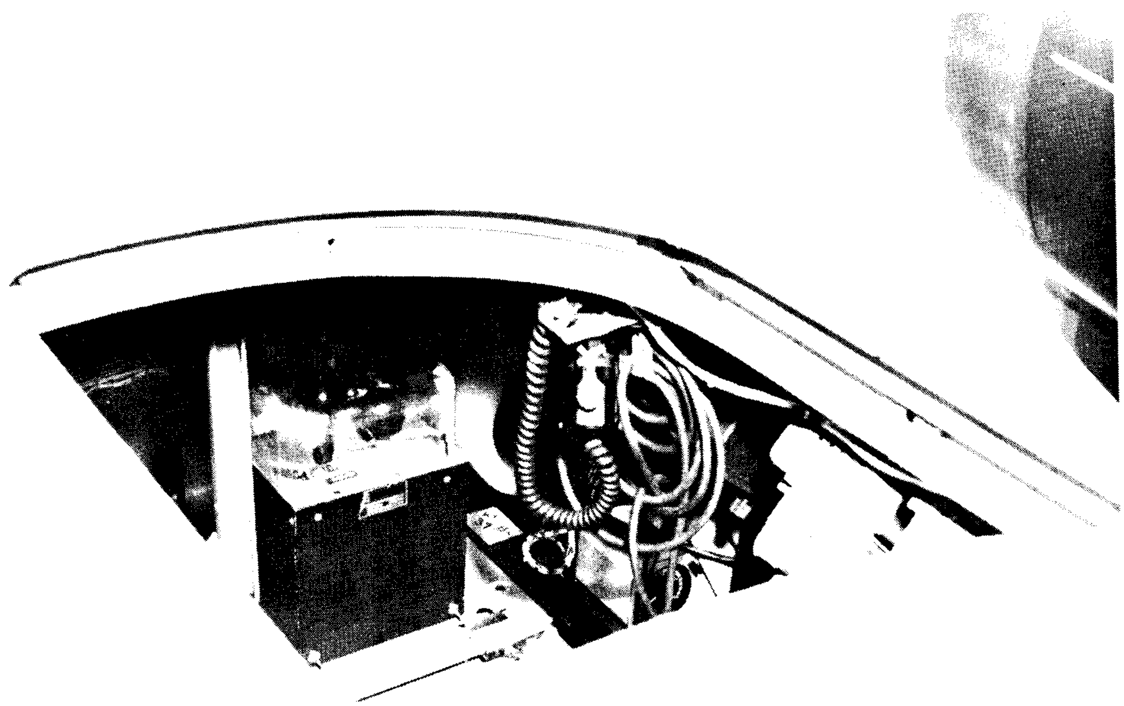


FIGURE 4. HARIS package and Concorde instrument in upper pressurized compartment of RB-57F. View from above the compartment.

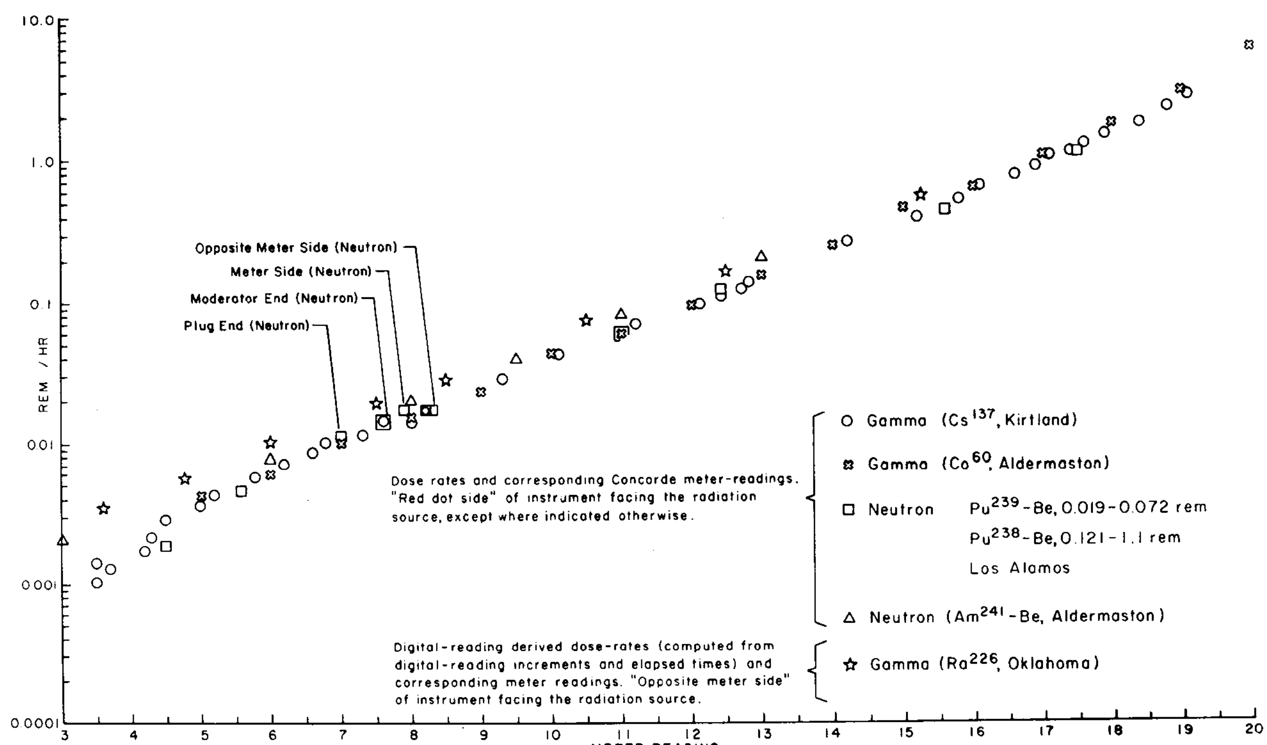


FIGURE 5. Concorde instrument meter-readings with corresponding dose rates for gamma and neutron radiation, and dose rates computed from digital readings with corresponding meter readings.

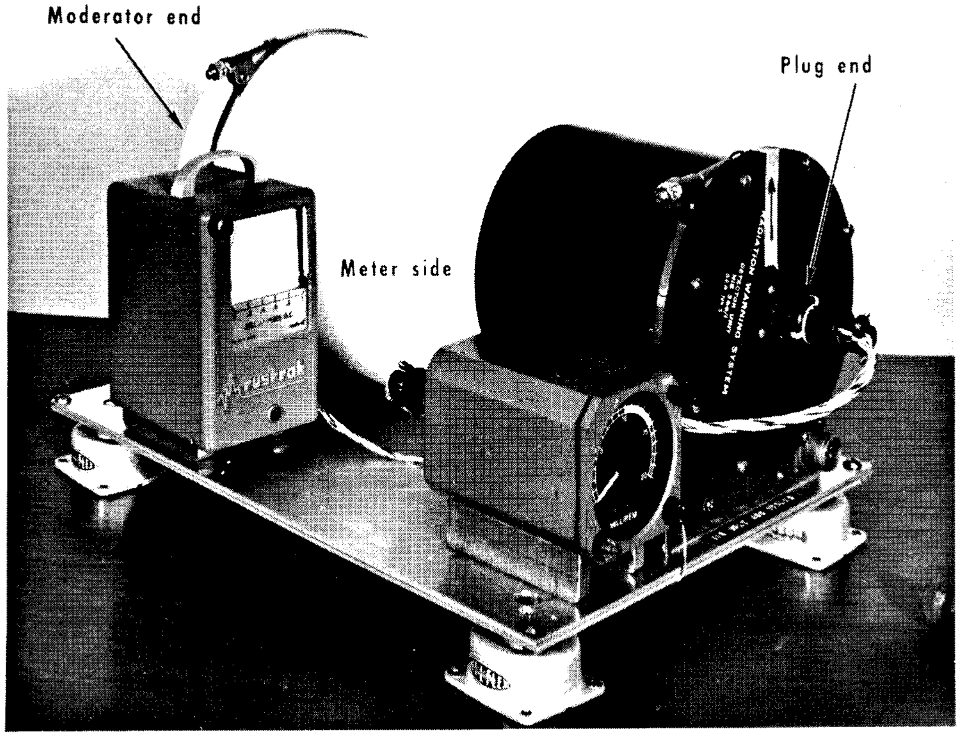


FIGURE 6. Configuration of Concorde instrument for calibrations.

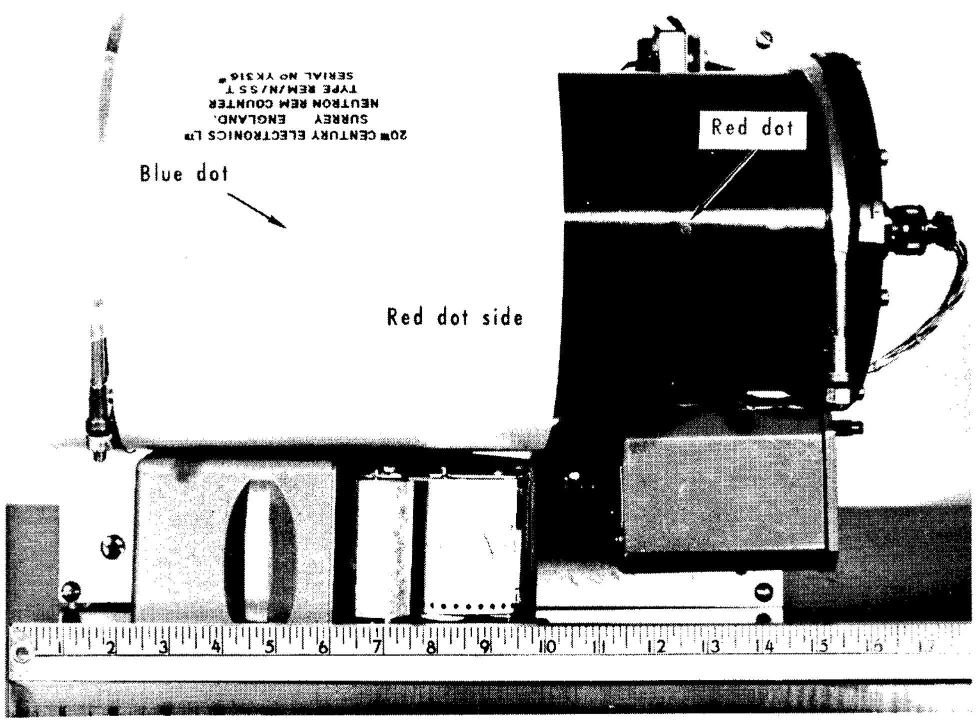


FIGURE 7. Configuration of Concorde instrument for calibrations. Red dot side of instrument facing source. Reference scale in inches.

The upper pressure-compartment in the RB–57F, where the Concorde instrument was to be located, is extremely cold at SST altitudes; therefore, to ensure proper operation of the Rustrak recorder, a 3000 ohm resistor was installed to supply extra heat and a jacket was provided for insulation (Fig. 2).

IV. Calibration of the Instrument With Cs.[137]

Concorde instrument meter-readings and corresponding dose rates for gamma and neutron radiation are shown in Fig. 5. The data designated "Aldermaston" were replotted from calibration curves that came with the instrument. These calibrations were performed on or about 30 December 1968 at the Atomic Weapons Research Establishment in Aldermaston, Reading, England. "Kirtland" denotes measurements made at the Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, on 9–10 June 1969 and "Los Alamos" indicates measurements made 11 June 1969 at the Los Alamos Scientific Laboratory, New Mexico.

Figure 6 shows the configuration of the Concorde instrument used for the measurements at Kirtland and Los Alamos. In order for the "red dot side" (Fig. 7) to face the radiation source, the instrument was placed on its side with the meter and Rustrak recorder down. For the Kirtland data in Fig. 5 see Table 1 measurements 1–33 and 76B–91. The calculations are described in Fig. 8–10. The Los Alamos data used in Fig. 5 are given in Table 2 and the calculations are described in Fig. 11–14.

TABLE 1.—Concorde Instrument Meter- and Chart-Readings and Corresponding Gamma Radiation Dose Rates*

Measurement No.	d_1 (cm)†	R/hr at d_1†	Rem/hr at Detector‡	Meter Reading	Chart Reading	Average "Background"§
			Red Dot**, Source-Off Plug-Out††			
1	222.6	0.1000	0.13740	12.8	12.8	1.7
2	157.4	0.2000	0.26934	14.2	14.2	1.5
3	128.5	0.3000	0.39777	15.2	15.0	1.9
4	111.3	0.4000	0.52338	15.8	15.6	1.9
5	99.5	0.5000	0.64656	16.1	16.0	2.0
6	90.9	0.6000	0.76759	16.6	16.2	2.3
7	84.1	0.7000	0.88669	16.9	16.6	2.3
8	78.7	0.8000	1.00400	17.1	16.9	2.3
9	74.2	0.9000	1.11966	17.4	17.1	2.3
10	70.4	1.0000	1.23376	17.6	17.4	2.5
11	64.2	1.2000	1.45766	17.9	17.7	2.6
12	57.5	1.5000	1.78385	18.4	18.1	2.9
13	49.7	2.0000	2.30493	18.8	18.4	3.2
14	44.5	2.5000	2.80202	19.1	18.8	3.3
15#(10)	70.4	1.0000	1.23376	17.6	17.2	2.5
16#(6)	90.9	0.6000	0.76759	16.7	16.3	2.1
17#(2)	157.4	0.2000	0.26934	14.3	14.1	1.9
18#(1)	222.6	0.1000	0.13740	12.8	12.7	1.7
19	234.7	0.0900	0.12396	12.7	12.5	1.7
20	248.9	0.0800	0.11047	12.4	12.3	1.9
21	266.1	0.0700	0.09693	12.1	11.9	1.7
22	314.9	0.0500	0.06966	11.2	11.2	1.7
23	406.5	0.0300	0.04211	10.1	9.9	1.7
24	497.9	0.0200	0.02820	9.3	9.0	1.7
25	642.8	0.0120	0.01700	8.2	8.1	1.6
26	704.2	0.0100	0.01419	8.0	7.6	1.5
27#(26)	704.2	0.0100	0.01419	8.0	7.8	1.5
28#(25)	642.8	0.0120	0.01700	8.1	7.9	1.5
29#(24)	497.9	0.0200	0.02820	9.4	9.1	1.6
30#(23)	406.5	0.0300	0.04211	10.2	9.9	1.7

See footnotes at end of Table 1.

TABLE 1.—Continued

Measurement No.	d_1 (cm)†	R/hr at d_1†	Rem/hr at Detector‡	Meter Reading	Chart Reading	Average "Background"§
31#(22)	314.9	0.0500	0.06966	11.3	11.1	1.8
32#(21)	266.1	0.0700	0.09693	12.1	12.0	1.7
33#(19)	234.7	0.0900	0.12396	12.7	12.5	1.7
		Opposite Meter Side**, Source-Off Plug-Out††				
34	222.6	0.1000	0.13081	12.6	12.5	1.7
35	157.4	0.2000	0.25147	14.1	13.9	1.9
36	90.9	0.6000	0.68385	16.2	16.1	2.3
37	70.4	1.0000	1.06619	17.2	17.0	2.5
38	49.7	2.0000	1.89071	18.3	18.1	2.6
39#(35)	157.4	0.2000	0.25147	14.1	14.0	2.3
40#(34)	222.6	0.1000	0.13081	12.7	12.5	2.1
41	266.1	0.0700	0.09301	12.0	11.8	2.0
42	314.9	0.0500	0.06727	11.2	10.9	1.9
43	406.5	0.0300	0.04098	10.0	9.6	1.7
44	497.9	0.0200	0.027588	9.3	8.9	1.7
45	642.8	0.0120	0.016714	8.0	7.7	1.8
46	704.2	0.0100	0.01396	7.6	7.3	1.9
		Meter Side**, Source-Off Plug-Out††				
47	704.2	0.0100	0.01396	7.7	7.5	1.7
48	497.9	0.0200	0.02758	9.1	9.2	2.0
49	406.5	0.0300	0.04098	10.0	10.0	1.9
50	314.9	0.0500	0.06727	11.2	11.1	1.9
51	266.1	0.0700	0.09301	11.9	11.9	1.9
52	222.6	0.1000	0.13081	12.8	12.8	1.9
53	157.4	0.2000	0.25147	14.1	14.1	2.3
54	90.9	0.6000	0.68385	16.3	16.2	2.3
55	49.7	2.0000	1.89071	18.5	18.2	2.9
		Meter Side**, Source-On Plug-Out††				
56	185.0	10.00	Off scale			
57A	106.8	30.00	Off scale			
57B	49.7	2.0000	2.0533	18.2	18.0	3.0
58	70.4	1.0000	1.12915	17.0	16.8	2.5
59	90.9	0.6000	0.71445	16.0	15.9	2.3
60	157.4	0.2000	0.25770	13.9	13.8	1.9
61	222.6	0.1000	0.13306	12.4	12.3	1.8
62	266.1	0.0700	0.09434	11.8	11.6	1.7
63	314.9	0.0500	0.06807	10.8	10.8	1.7
64	406.5	0.0300	0.04136	9.7	9.5	1.8
65	497.9	0.0200	0.02779	9.0	8.7	1.8
66	704.2	0.0100	0.01404	7.5	7.2	1.8
		Moderator End**, Source-Off Plug-Out††				
67	704.2	0.0100	0.01323	4.0	3.8	1.7
68	497.9	0.0200	0.02557	4.7		
69	406.5	0.0300	0.03739	5.3	5.0	1.9
70	314.9	0.0500	0.05986	6.2	5.7	1.6
71	266.1	0.0700	0.08116	7.0	6.5	1.9
72	222.6	0.1000	0.11142	7.6	7.1	1.9
73	157.4	0.2000	0.20214	9.2	8.5	1.6
74	90.9	0.6000	0.48415	11.2	10.6	2.0
75	70.4	1.0000	0.70028	11.9	11.5	2.0
76A	49.7	2.0000	1.10470	12.9	12.6	2.0

See footnotes at end of Table 1.

TABLE 1.—Continued

Measurement No.	d_1 (cm)†	R/hr at d_1†	Rem/hr at Detector‡	Meter Reading	Chart Reading	Average "Background"§
			Red Dot**, Source-On Plug-In††			
76B	458.7	0.0010	0.00142	3.5	4.2	1.7
77	324.4	0.0020	0.00284	4.5		
78	264.8	0.0030	0.00424	5.2	4.9	1.7
79	205.1	0.0050	0.00704	6.2	5.9	1.7
80	173.4	0.0070	0.00982	6.8	6.6	1.7
81	162.2	0.0080	0.01121	7.3	6.7	1.8
82	145.0	0.0100	0.01397	7.6	7.3	1.8
83	187.3	0.0060	0.00844	6.6	6.3	1.8
84	229.4	0.0040	0.00565	5.8	5.4	1.7
85	290.1	0.0025	0.00354	5.0	4.5	1.5
86	374.6	0.0015	0.00213	4.3	4.0	1.5
87	418.8	0.0012	0.00170	4.2	3.8	1.5
88	483.6	0.0009	0.00128	3.7	3.5	1.6
89	548.3	0.0007	0.00099	3.5	3.4	1.7
90	102.5	0.0200	0.02760	9.3	8.9	1.7
91	32.4	0.2000	0.25257	14.2	13.9	1.9

*The number of digits does not reflect experimental precision.

† Distance (d_1) from center of Cs^{137} source to Concorde instrument and corresponding dose rate (R/hr) on 9 June 1969.

‡ No correction was made for "background".

§ Concorde chart-reading with source shutter closed.

**The side of the Concorde instrument that faced the Cs^{137} source.

†† Configuration of the Cs^{137} source. "Source-on plug-in" is the low dose-rate configuration and means that the Cs^{137} source capsule, which is in a lead-filled steel container, was positioned in front of the container aperture with the aperture plug in place to attenuate the radiation. "Source-off plug-out" is the high dose-rate configuration and means that the Cs^{137} capsule was positioned away from the aperture and the plug was out.

#Repetition of measurement indicated in parenthesis. The repeat measurement was not unbiased (the observer knew the previous reading), and was not included in the graph.

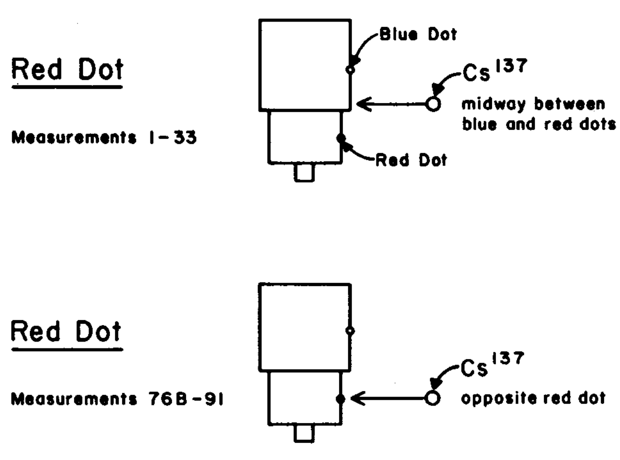
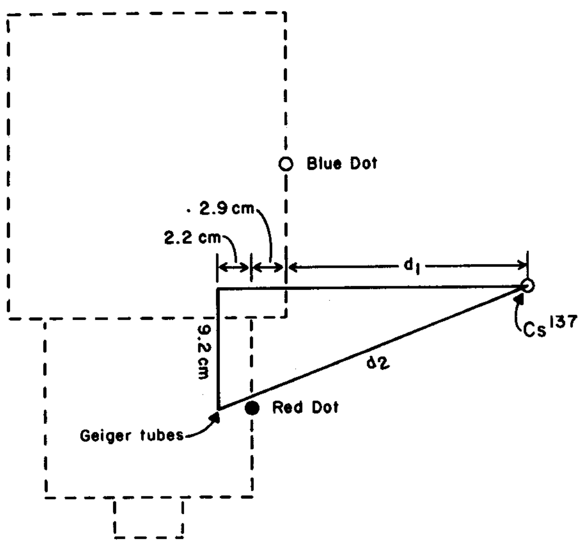


FIGURE 8. Position of gamma source relative to Concorde instrument for measurements 1–33 and 76B–91.

Calculations: gamma source, measurements 1 - 33

Red Dot



$(d_2)^2 = (d_1+2.2+2.9)^2 + (9.2)^2$ [i]

$A_1/A_2 = (d_2)^2/(d_1)^2$ [ii]
where A_1=R/hr at d_1
and A_2=R/hr at d_2

$A_2 = (A_1)(d_1)^2/(d_2)^2$ [iii]

rem/hr at $d_2 = (0.96)^* \ (1.5)^\dagger \ (A_2) = 1.44 \ A_2$ [iv]

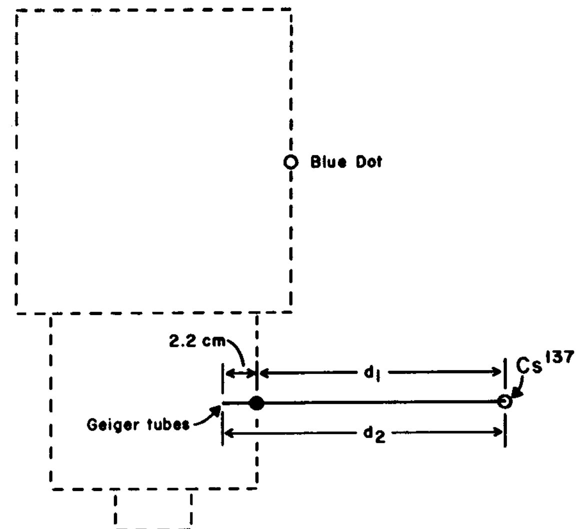
* rads/R ratio for Cs^{137} for muscle.

† rem/rad ratio used by Aldermaston group for gamma radiation.

FIGURE 9. Diagram of radiation geometry (not to scale) and calculation of dose rates (rem/hr) at Geiger tubes for measurements 1–33. A_1 is the dose rate in R/hr at distance d_1 (cm) from the Cs^{137} gamma source according to calibration information obtained at Kirtland. d_1 is the distance from the source to the surface of the moderator. d_2 is the distance from the source to the Geiger tubes.

Calculations: gamma source, measurements 76B-91

Red Dot



$d_2 = d_1 + 2.2$ [i]

$A_1/A_2 = (d_2)^2/(d_1)^2$ [ii]
where A_1=R/hr at d_1
and A_2=R/hr at d_2

$A_2 = (A_1)(d_1)^2/(d_2)^2$ [iii]

rem/hr at $d_2 = 1.44^* \ A_2$ [iv]

* See Fig. 9.

FIGURE 10. Diagram of radiation geometry (not to scale) and calculation of dose rates (rem/hr) at Geiger tubes for measurements 76B–91. A_1 is the dose rate in R/hr at distance d_1 (cm) from the Cs^{137} gamma source according to calibration information obtained at Kirtland. d_1 is the distance from the source to the can. d_2 is the distance from the source to the Geiger tubes.

TABLE 2.—Concorde Instrument Meter- and Chart-Readings and Corresponding Neutron Radiation Dose Rates*

Measurement No.	d_1 (cm)†	Rem/hr at d_1†	Rem/hr at Detector‡	Meter Reading	Chart Reading	Average "Background"§
			Blue Dot**, Pu^{239}-Be††			
1	300	0.002	0.00193	4.5	4.3	2.0
2	200	0.005	0.00475	5.6	5.4	2.3
3	100	0.019	0.01723	8.2	8.0	2.1
4	50	0.072	0.05950	11.0	10.8	1.9
			Blue Dot**, Pu^{238}-Be††			
5	100	0.133	0.12069	12.4	12.2	2.3
6	50	0.532	0.4396	15.6	15.3	2.6
7	30	1.500	1.1019	17.5	17.1	1.8
			Blue Dot**, Pu^{239}-Be††			
8#(3)	100	0.019	0.01723	8.2	8.0	1.9
			Moderator End**, Pu^{239}-Be††			
9	100	0.019	0.01387	7.6	7.3	1.9
			Plug End**, Pu^{239}-Be††			
10	100	0.019	0.01085	7.0	6.7	2.1
			Opposite Meter Side**, Pu^{239}-Be††			
11	100	0.019	0.01723	8.3	8.0	2.1
			Meter Side**, Pu^{239}-Be††			
12	100	0.019	0.01723	7.9	7.6	2.1

* The number of digits does not reflect experimental precision.

† Distance (d_1) from Pu-Be neutron source housing to center of neutron detector and corresponding dose-rate (rem/hr) on 11 June 1969.

‡ No correction was made for "background".

§ Chart reading with source out of room.

** The side of the Concorde instrument that faced the neutron source.

†† The neutron source.

Repetition of measurement indicated in parenthesis. The repeat measurement was not unbiased (the observer knew the previous reading), and was not included in the graph.

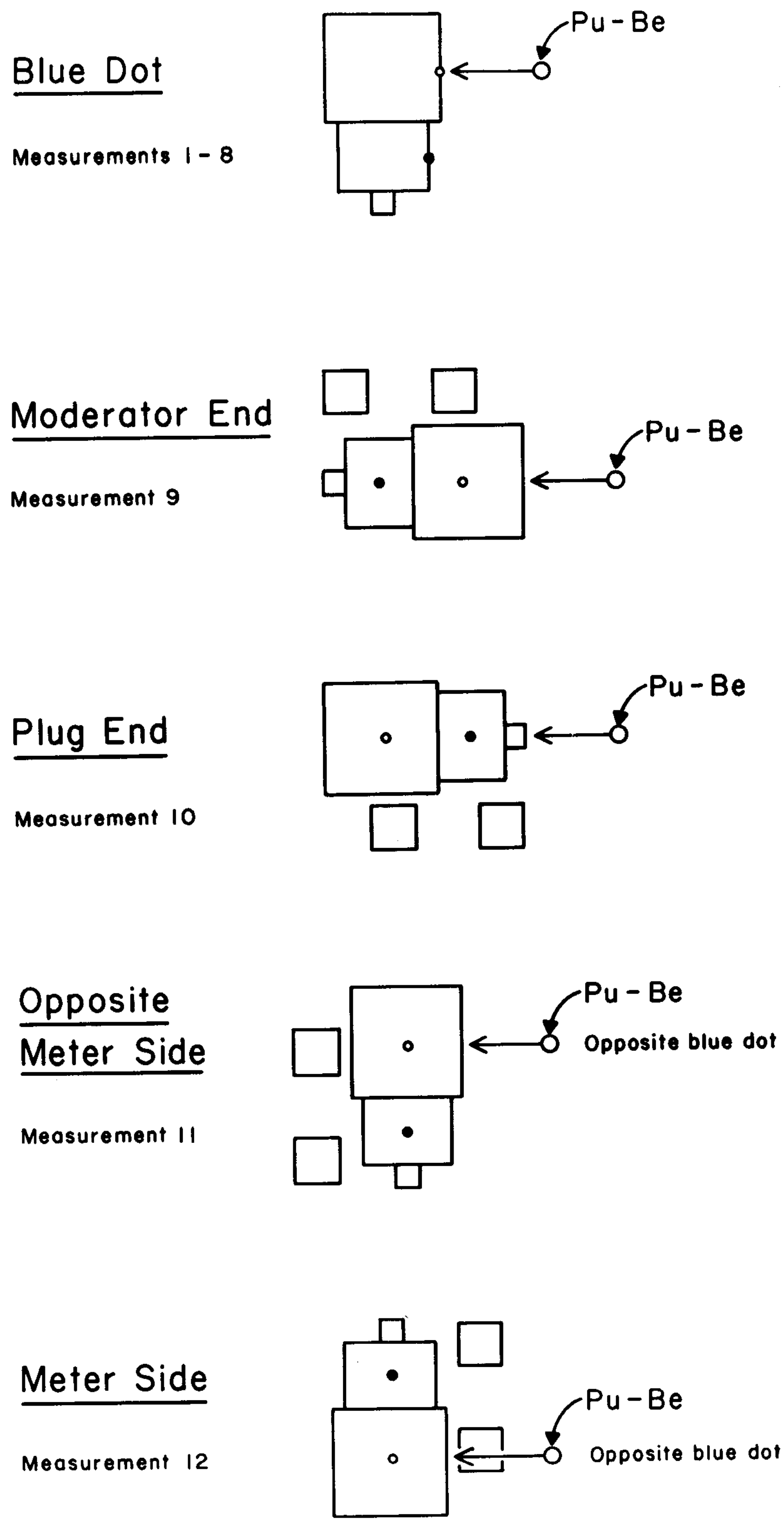
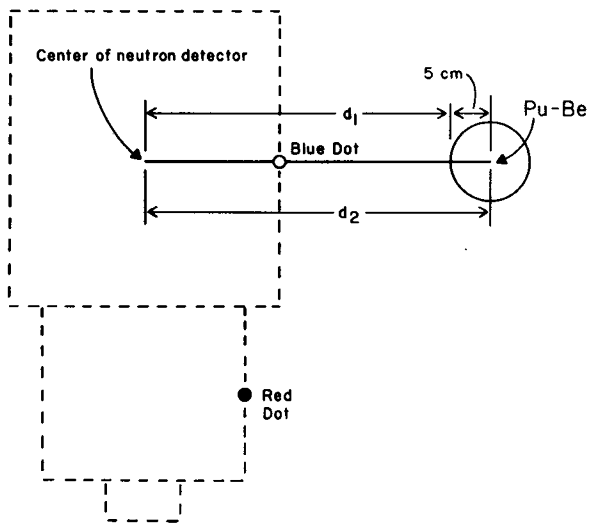


FIGURE 11. Position of neutron source relative to Concorde instrument for measurements 1–12.

Calculations: neutron source, measurements 1-8, 11, 12

Blue Dot, Opposite Meter Side, Meter Side



$d_2 = d_1 + 5$ [i]

$A_1/A_2 = (d_2)^2/(d_1)^2$ [ii]

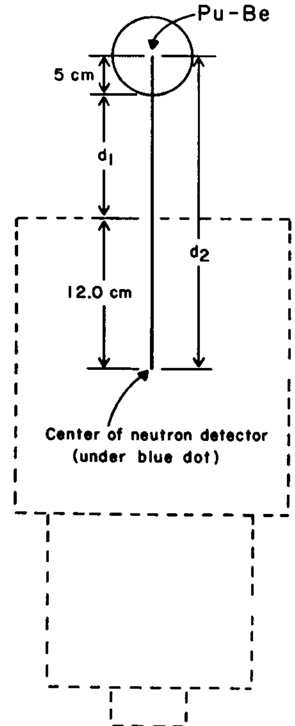
where A_1 = rem/hr at d_1
and A_2 = rem/hr at d_2

rem/hr at $d_2 = (A_1)(d_1)^2/(d_2)^2$ [iii]

FIGURE 12. Diagram of radiation geometry (not to scale) and calculation of dose rates (rem/hr) at neutron detector for measurements 1–8, 11, 12. A_1 is the dose rate in rem/hr at a distance d_1 (cm) from the Pu-Be neutron source according to calibration information obtained at Los Alamos. d_1 is the distance from the source holder to the center of the neutron detector. d_2 is the distance from the source (point source assumed) to the center of the detector.

Calculations: neutron source, measurement 9

Moderator End



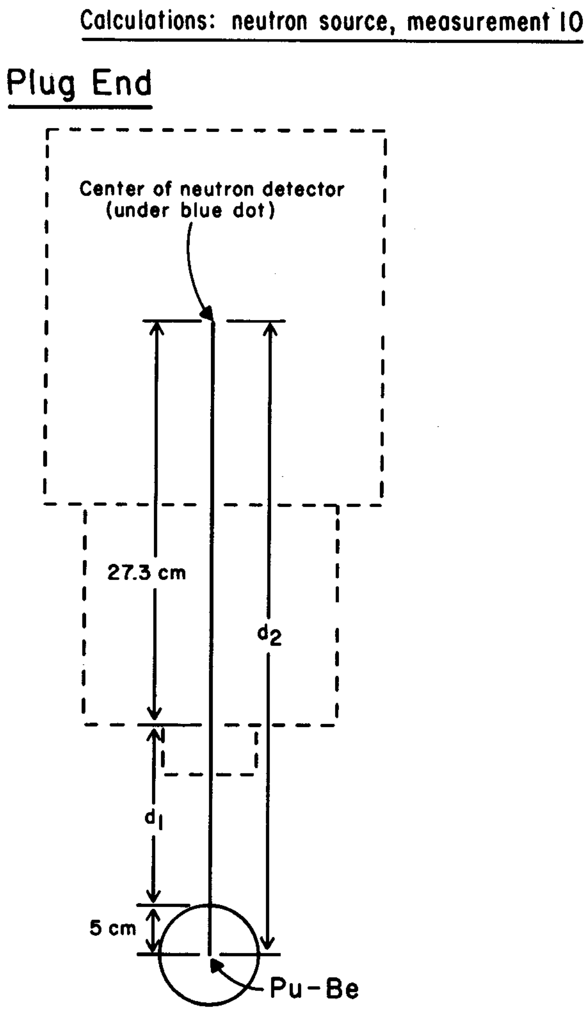
$d_2 = d_1 + 12.0 + 5$ [i]

$A_1/A_2 = (d_2)^2/(d_1)^2$ [ii]

where A_1 = rem/hr at d_1
and A_2 = rem/hr at d_2

rem/hr at $d_2 = (A_1)(d_1)^2/(d_2)^2$ [iii]

FIGURE 13. Diagram of radiation geometry (not to scale) and calculation of dose rate (rem/hr) at neutron detector for measurement 9. A_1 is the dose rate in rem/hr at a distance d_1 (cm) from the Pu-Be neutron source according to calibration information obtained at Los Alamos. d_1 is the distance from the source holder to the center of the neutron detector. d_2 is the distance from the source (point source assumed) to the center of the detector.



$$d_2 = d_1 + 27.3 + 5 \quad [i]$$

$$A_1/A_2 = (d_2)^2/(d_1)^2 \quad [ii]$$

where A_1=rem/hr at d_1
and A_2=rem/hr at d_2

$$\text{rem/hr at } d_2 = (A_1)(d_1)^2/(d_2)^2 \quad [iii]$$

FIGURE 14. Diagram of radiation geometry (not to scale) and calculation of dose rate (rem/hr) at neutron detector for measurement 10. A_1 is the dose rate in rem/hr at a distance d_1 (cm) from the Pu-Be neutron source according to calibration information obtained at Los Alamos. d_1 is the distance from the source holder to the center of the neutron detector. d_2 is the distance from the source (point source assumed) to the center of the detector.

At dose rates between about 0.004 and 1.0 rem/hr (Fig. 5), the Concorde instrument responded essentially the same to Co^{60} gamma (Aldermaston), Cs^{137} gamma (Kirtland) and Pu-Be neutrons (Los Alamos). Although the difference was small, results of the calibration using Am^{241}-Be neutrons (Aldermaston) were not consistent with the others; for example, in the range 0.004 to 0.2 rem/hr estimates of dose rate from meter readings by use of the Aldermaston neutron curve were higher than the others by about 25%.

The Kirtland gamma and Los Alamos neutron curves (Fig. 5) show nonlinearity in the log dose-rate vs meter-reading plot at dose rates below 0.003 rem/hr; whereas the Aldermaston neutron curve suggests linearity down to 0.002 rem/hr. It should be noted, however, that at rates below 0.004 rem/hr only one neutron measurement each was made in Aldermaston and Los Alamos. No gamma measurements were made in Aldermaston below 0.004 rem/hr. Measurements at the lower dose-rates will be considered in more detail below.

Measurements in Fig. 5, labeled "opposite meter side", "meter side", "moderator end" and "plug end", indicate that the Concorde instrument responds equally well to neutrons regardless of the side of the instrument facing the radiation source.

To test the digital readout, which shows total dose in millirem, the Concorde instrument was placed at various distances from an uncalibrated radium needle and rate-meter readings, digital-reading increments and elapsed times were recorded (Table 3). Figure 5 shows a curve relating the meter readings and dose rates computed from digital-reading increments and elapsed times. Digital-reading derived dose-rates were higher than indicated by the Cs^{137} dose-rate vs meter-reading curve. For example, with the Concorde instrument at a distance from the radium needle such that the meter reading was 3.6, the Cs^{137} curve showed a dose rate of 0.0013 rem/hr; however, according to digital-reading increments and elapsed times, the dose rate was 0.0035 rem/hr. Thus, the dose rate based on digital readings was 169% higher than indicated by the Cs^{137} curve. When the meter reading was 12.5, the Cs^{137} curve showed a dose rate of 0.11 rem/hr; based on digital readings, the dose rate was 55% higher (0.164 rem/hr).

Possible reasons for the nonlinearity of the dose-rate vs instrument response curve at low dose-rates are considered. Results in Fig. 15

TABLE 3.—Rate-Meter Readings and Corresponding Digital Readings When Concorde Instrument Placed at Various Distances From An Uncalibrated Radium Needle

Measurement No.	Rate-Meter Reading	Elapsed Time (min)	Digital Increment (Units)*	Digital Units per Hour (millirem/hr)†
1	5.97	99.	17	10.3
2	3.6	104.	6	3.46
3‡	15.3	6.	54	540.
4	12.5	31.5	86	164.
5	10.5	94.	119	76.
6	8.5	59.5	28	28.2
7	4.75	83.	8	5.8
8	7.5	124.	40	19.4
9	6.0	147.	25	10.2
"Background"	1.5			

*A unit is one millirem.
†No correction was made for "background".
‡Detectors exposed to a Sr^{90} test source located inside the Concorde instrument.

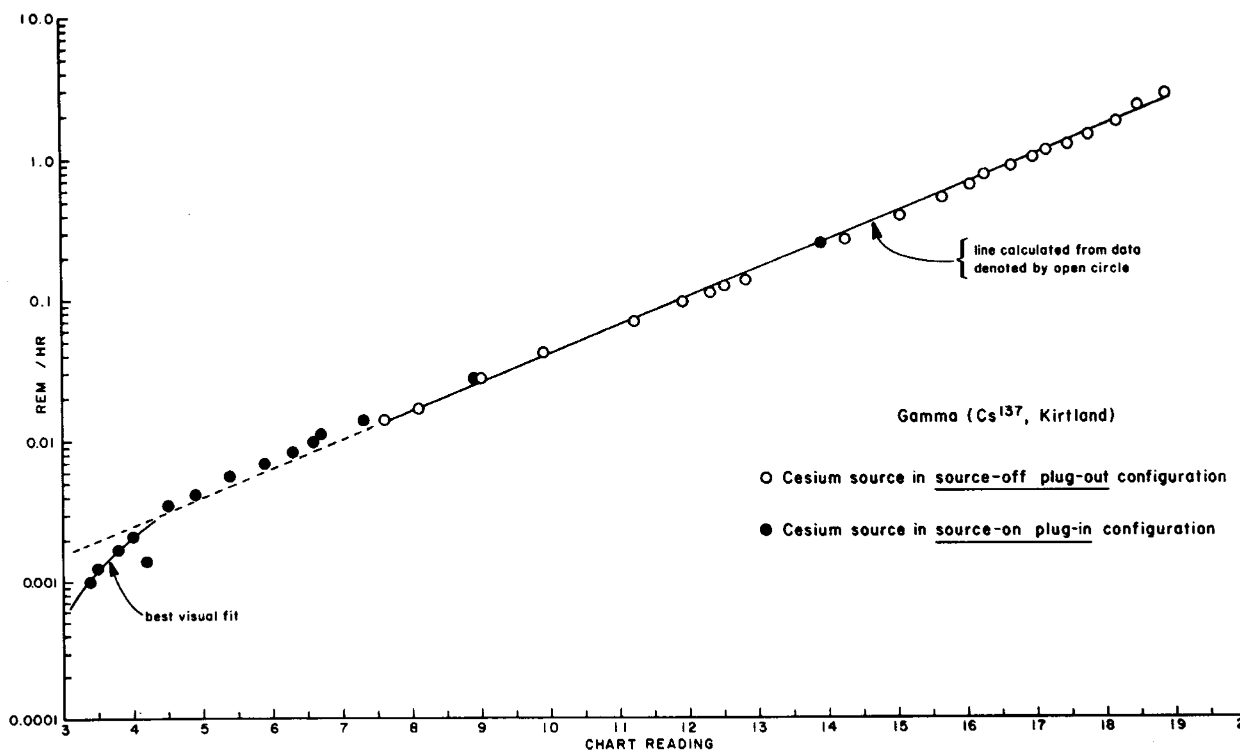


FIGURE 15. Concorde instrument chart-readings with corresponding dose rates for gamma radiation: calibration curve.

show gamma radiation dose-rates and corresponding Concorde instrument chart-readings (data from Table 1 measurements 1–33 and 76B–91, calculations in Fig. 8–10). Between 0.014 and 2.8 rem/hr with the Cs^{137} source in its high dose-rate configuration (source-off plug-out, see Table 1 footnote ††), the chart readings increased linearly with logarithmic increase in dose rate. A straight line, fitted to the data points by the least squares method, was extended to lower dose rates so that the high dose-rate data could be compared with low dose-rate measurements made

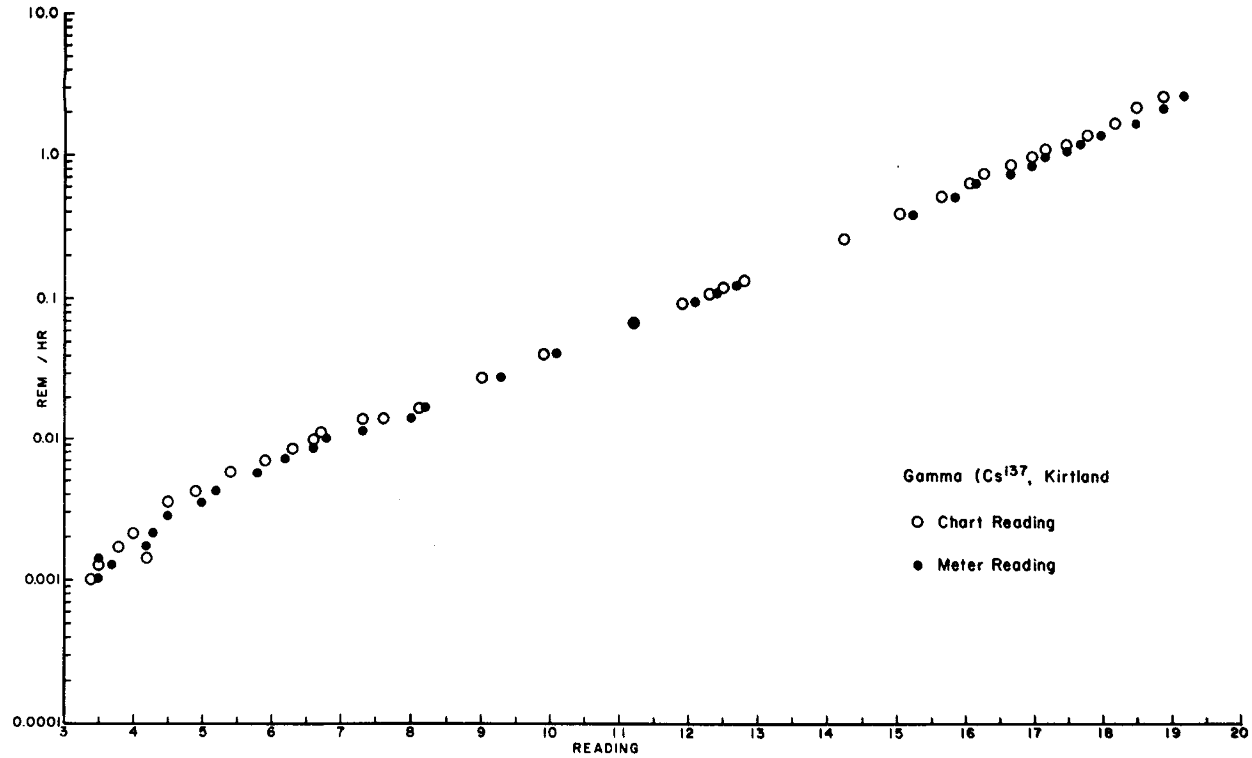


FIGURE 16. Concorde instrument chart- and meter-readings with corresponding dose rates for gamma radiation. Red dot side of instrument facing source.

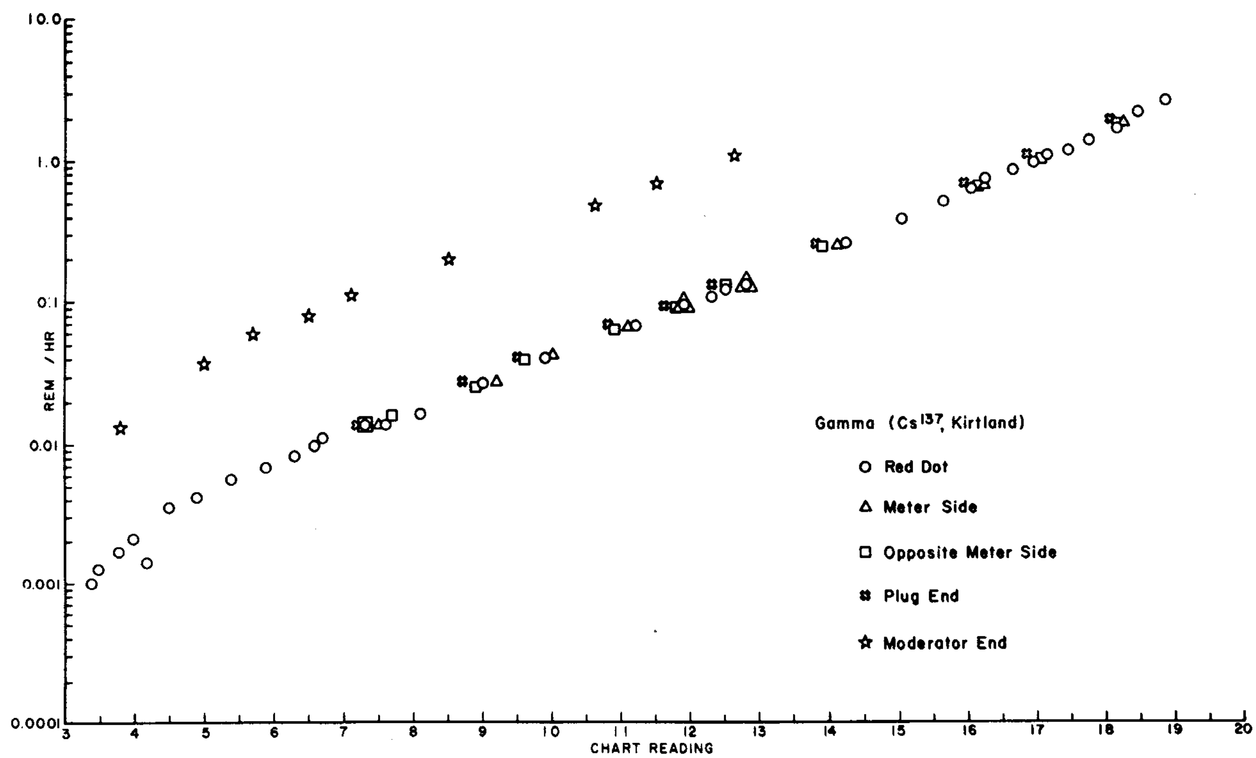


FIGURE 17. Concorde instrument chart-readings with corresponding dose rates for gamma radiation: different sides of instrument facing radiation source.

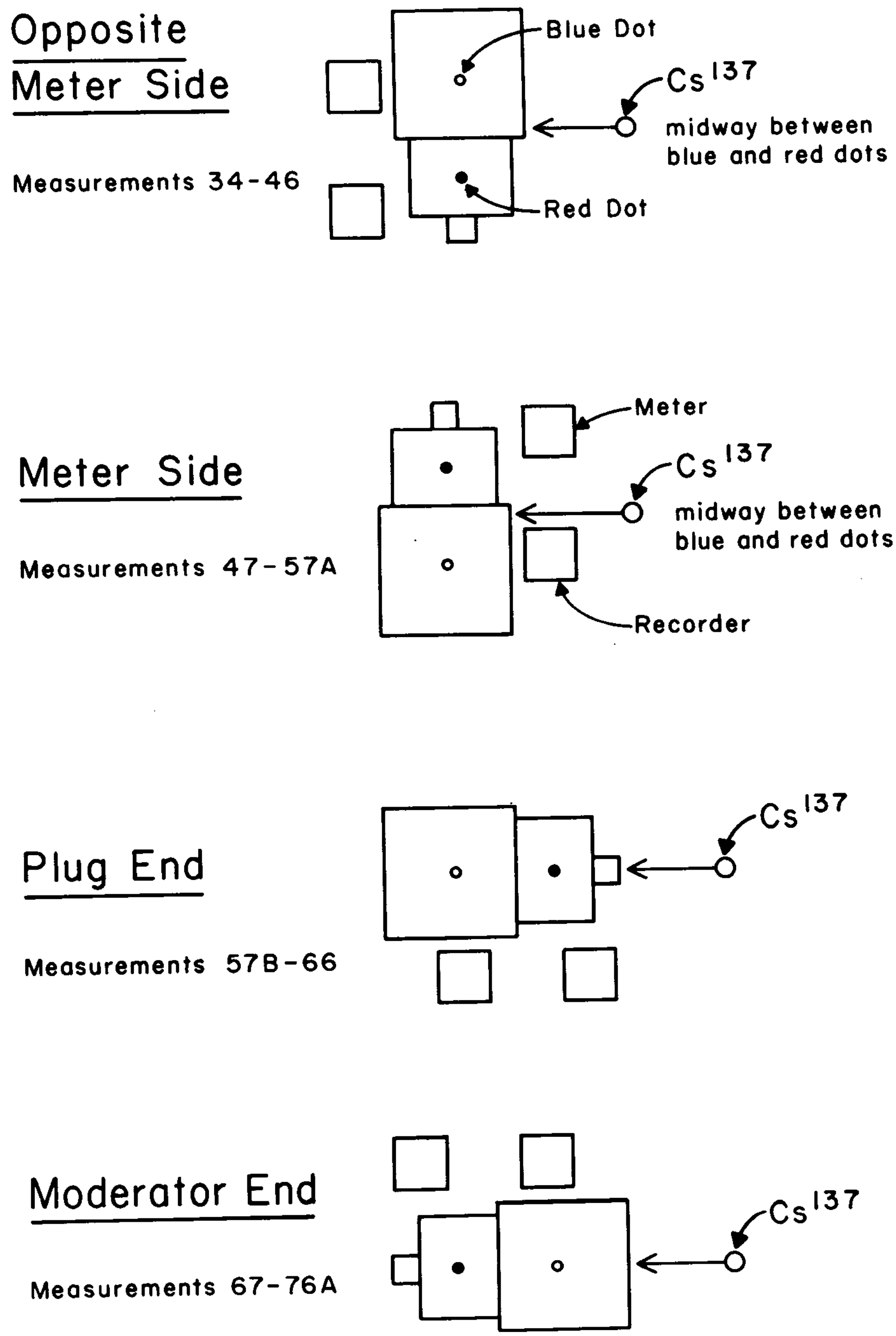


FIGURE 18. Position of gamma source relative to Concorde instrument for measurements 34–76A.

with the Cs^{137} source in its low dose-rate configuration (source-on plug-in). With the Cs^{137} source in its source-on plug-in (low dose-rate) configuration, the two measurements (0.0276 and 0.253 rem/hr) made within the range of dose rates used to calculate the straight line fell on or very close to the line. The eight measurements made between 0.0035 and 0.0139 rem/hr, below the range of the high dose-rate measurements from which the line was calculated, fell a little above but parallel to the line. The five measurements made at dose rates between 0.0010 (the lowest dose-rate measured) and 0.0021 rem/hr were below and not parallel to the line and the chart readings were higher than expected from either the high dose-rate data or the other low dose-rate data. The deviation from linearity was not associated with the position of the Concorde instrument in the Cs^{137} calibration-range room (nearness to a wall, etc.). The distance between the Concorde instrument and the Cs^{137} source, for all measurements made with the source in its source-on plug-in (low dose-rate) configuration, was within the range of distances for measurements made with the Cs^{137} source in its source-off plug-out (high dose-rate) configuration (Table 1, measurements 1–33 and 76B–91). Assuming that dose rates on the Kirtland Cs^{137} range are accurate and include background radiation (as designed), then nonlinearity in the Concorde instrument calibration curve (Fig. 15) at low dose-rates can be attributed to a characteristic of the instrument.

Curves (Fig. 16) derived from Concorde-instrument chart and meter readings and corresponding Cs^{137} gamma dose-rates were almost identical (data from Table 1, measurements 1–33 and 76B–91; calculations in Fig. 8–10).

Figure 17 shows calibration curves from measurements made with different sides of the Concorde instrument facing the Cs^{137} gamma source. When the moderator end of the instrument was facing the Cs^{137} source, approximately nine times the dose rate was required to give the same chart reading obtained with any other side of the instrument facing the source (data from Table 1, calculations in Fig. 8–10 and 18–21). Thus, the Geiger counters show a directional response apparently because of the moderator.

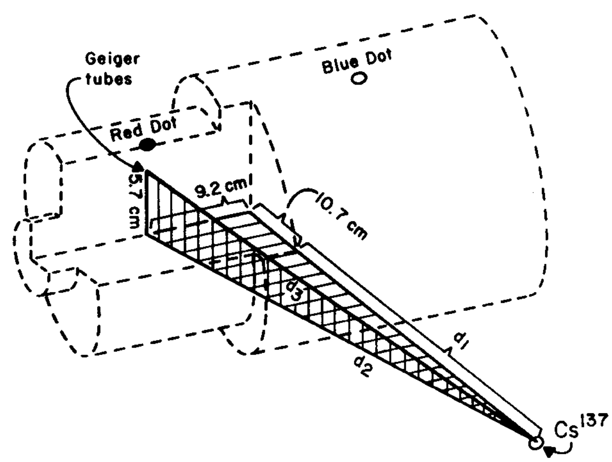
The Concorde instrument responded normally after exposure to 10 and 30 rem/hr of gamma radiation (Table 1 measurements 56 and 57A). Measurements made before and after these off-scale exposures fell on the same curve (Fig. 15).

V. Radiation Measurements Made At 60,000 Ft With the Concorde Instrument.

Table 4 shows measurements made on RB–57F flights in October and November from Eielson Air Force Base, Alaska. The maximum in-flight dose rate was estimated from the maximum chart-reading by use of the extrapolated portion of the calibration curve in Fig. 15. The data

Calculations: gamma source, measurements 34–57A

Opposite Meter Side and Meter Side



$$(d_2)^2 = (d_1 + 10.7)^2 + (9.2)^2 \quad [i]$$

$$(d_3)^2 = (d_2)^2 + (5.7)^2 \quad [ii]$$

$$A_1/A_3 = (d_3)^2/(d_1)^2 \quad [iii]$$

where A_1 = R/hr at d_1
and A_3 = R/hr at d_3

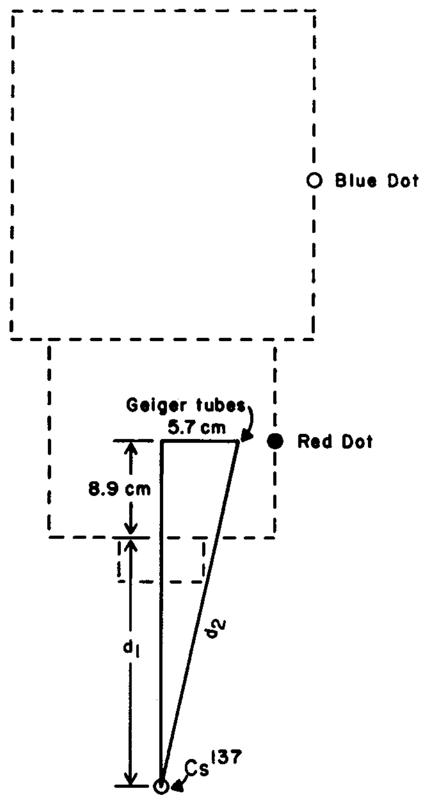
$$\text{rem/hr at } d_3 = 1.44^* A_3 \quad [iv]$$

* See Fig. 9.

FIGURE 19. Diagram of radiation geometry (not to scale) and calculation of dose rates (rem/hr) at the Geiger tubes for measurements 34-57A. A_1 is the dose rate in R/hr at distance d_1 (cm) from the Cs^{137} gamma source according to calibration information obtained at Kirtland. d_1 is the distance from the source to the surface of the moderator. d_3 is the distance from the source to the Geiger tubes.

Calculations: gamma source, measurements 57B-66

Plug End



$$(d_2)^2 = (d_1 + 8.9)^2 + (5.7)^2 \qquad [i]$$

$$A_1/A_2 = (d_2)^2/(d_1)^2 \qquad [ii]$$

where $A_1 = R/hr$ at d_1
and $A_2 = R/hr$ at d_2

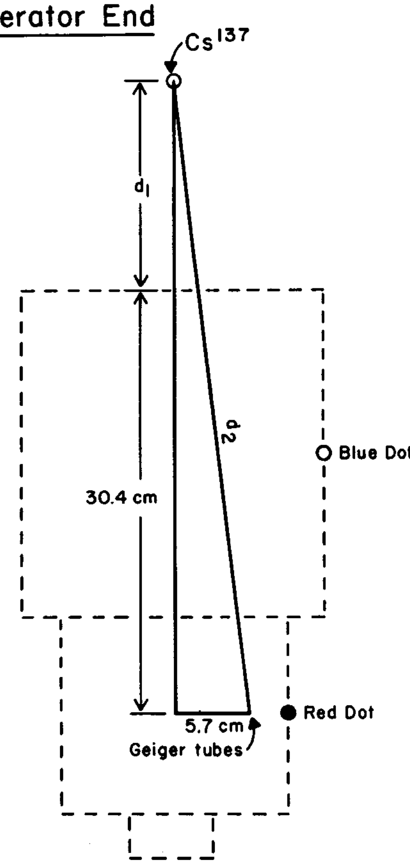
rem/hr at $d_2 = 1.44^* A_2$ [iii]

* See Fig. 9.

FIGURE 20. Diagram of radiation geometry (not to scale) and calculation of dose rates (rem/hr) at the Geiger tubes for measurements 57B–66. A_1 is the dose rate in R/hr at distance d_1 (cm) from the Cs^{137} gamma source according to calibration information obtained at Kirtland. d_1 is the distance from the source to the can. d_2 is the distance from the source to the Geiger tubes.

Calculations: gamma source, measurements 67-76A

Moderator End



$$(d_2)^2 = (d_1 + 30.4)^2 + (5.7)^2 \qquad [i]$$

$$A_1/A_2 = (d_2)^2/(d_1)^2 \qquad [ii]$$

where $A_1 = R/hr$ at d_1
and $A_2 = R/hr$ at d_2

rem/hr at $d_2 = 1.44^* A_2$ [iii]

* See Fig. 9.

FIGURE 21. Diagram of radiation geometry (not to scale) and calculation of dose rates (rem/hr) at the Geiger tubes for measurements 67–76A. A_1 is the dose rate in R/hr at distance d_1 (cm) from the Cs^{137} gamma source according to calibration information obtained at Kirtland. d_1 is the distance from the source to the surface of the moderator. d_2 is the distance from the source to the Geiger tubes.

TABLE 4.—Radiation Measurements Made with the Concorde Instrument on Flights from Eielson Air Force Base in Alaska

Date	10/22/69	10/29/69	11/3/69	11/17/69	11/18/69	11/19/69	11/21/69	11/21/69	11/21/69
Maximum In-Flight Chart Reading	3.2	3.4	3.3	3.2	3.2	3.1	3.2	3.2	3.2
Dose Rate, Millirem/hr*	0.7–0.9	1.0	0.9	0.7–0.9	0.7–0.9	0.5–0.7	0.7–0.9	0.7–0.9	0.7–0.9
Altitude, Kilofeet	60	60	60	60	60	60	60	60	60
Latitude, °N	65	70		67	71	70	70	70	68
"Background" Chart reading†	1.7	1.6	1.6	1.5	1.5	1.5	1.5	1.7	1.6
Internal Source chart reading‡	15.2	15.3	15.2	15.0	15.2	15.1	15.3	15.2	15.3

*Estimated from the maximum in-flight chart reading by use of the extrapolated portion of the calibration curve in Fig. 15.

†In the aircraft on the ground. This data was collected as an additional instrument check but not used to correct the readings at altitude.

‡Constancy check with Sr^{90}.

indicate a galactic radiation dose-rate of 0.7–0.9 millirem/hr at 60,000 ft and 65°–71°N geomagnetic latitude. This compares reasonably well with 1.1 millirem/hr±40%, the reported value from recent earlier measurements made with the HARIS package at 60,000 ft and high geomagnetic latitude.[6] It should be realized that the Concorde instrument was designed to measure solar cosmic radiation at levels much higher than obtained from galactic radiation.

VI. Conclusions.

Results of the calibrations performed at Los Alamos Scientific Laboratory and at Kirtland Air Force Base compare favorably with those carried out by the British. Galactic radiation measurements made with the Concorde instrument at SST altitude and northern latitudes are reasonably consistent with those obtained with the HARIS package.

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