MEASUREMENT OF HIGH ALTITUDE VERTICAL COSMIC RAY INTENSITY, AT NEW DELHI, INDIA, 19° NORTH, GEOMAGNETIC LATITUDE

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Introduction

During the last nine years several experiments have been performed in India between the magnetic latitudes 3° N. to 25° N., to measure the cosmic ray intensity at high altitudes. During 1939–40, Millikan, Neher and Pickering (1942) investigated the total cosmic ray intensity in India using recording electroscopes and G-M counters with a radio-sonde technique. Bhabha and co-workers (1945, 1946) investigated the intensity of the soft and the hard component in aeroplane ascents extending upto 40,000 feet. P. S. Gill (1947), in a similar aeroplane experiment, investigated the production of mesons by non-ionising radiation upto a height of 30,000 feet.

It is very difficult to make a quantitative comparison of data obtained by different workers, using apparatus of different geometry. As Pomerantz (1949) has pointed out, such a comparison is subject to considerable error for several reasons. Principally, the geometrical differences introduce uncertainties in the method of reduction of data on a common scale. In some instances the curves are fitted at high altitudes, in others at sea-level. The change in zenith angle distribution of intensity as a function of altitude may vitiate comparisons based simply upon solid angle corrections, and the results obtained may depend upon the altitude at which the data are normalised.

Bhabha and co-workers, as well as Gill, also found in their aeroplane ascents an anomalous peak and a depression in the normally conceived, smooth intensity-altitude curve for the meson intensity.

A programme was therefore undertaken by the present authors to investigate the latitude effect with a standardised geometry of apparatus. It was also intended to study the significance of the anomalies mentioned above.

Four successful flights were made at New Delhi, magnetic latitude 19° N, on the 15th, 21st, 28th and the 30th of September 1948; the first three without, and the last with 10 cm. of lead absorber. In the last lead flight, data was received only upto 24,000 feet, after which the reception of the cosmic ray data failed, though the flight ascended upto 60,000 feet as indicated by the meteorograph channel. For this reason, the results of this flight will not be discussed in this paper. The flights were made in the afternoon between 1300 and 1400 hours. The flights extended only upto 200 mb. of pressure, owing to the large weight of the apparatus, the restricted amount of hydrogen available at a time, and the small balloons used.

Experimental Procedure

Apparatus.—In each flight, a telescope of four G-M counters in quadruple coincidence was sent up. The geometry of the telescope is given in Fig. 1. The angle subtended by the extreme counters defines a cone making angles of 6° and 25° with the vertical. The counters were made

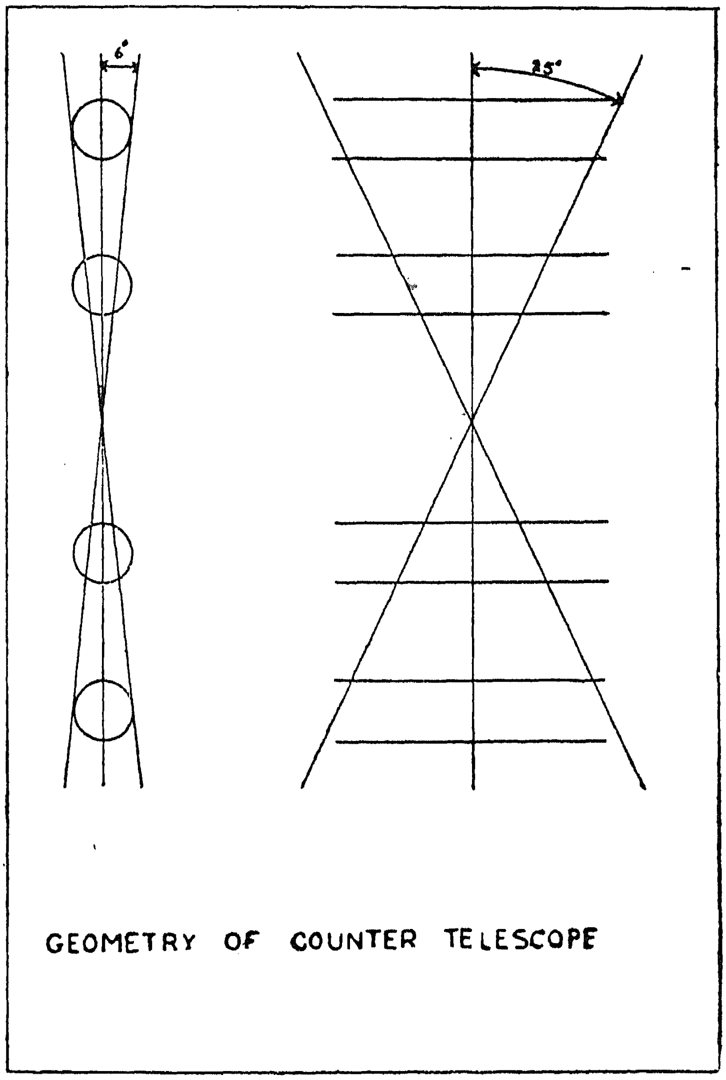


Fig. 1

in the Institute by Mr. H. L. N. Murthy and were of the usual copper-in-glass type filled with a mixture of argon and petroleum ether in a ratio of 4 : 1, to a total pressure of 10 cm. The glass walls were 1·25 mm. thick and the copper cylinders 0·274 mm. thick. Thus, to register a quadruple coincidence, a particle within the above solid angle has to penetrate a total of 3·68 gm./cm.^{2} (1·96 gm./cm.^{2} of glass and 1·72 gm.cm.^{2} of copper).

The quadruple coincidences were transmitted to the ground station over one ultra-high frequency carrier. The pressure and the temperature of the apparatus enclosure were also simultaneously transmitted over another carrier to the ground. Both these data are recorded at the ground station on a continuously moving paper tape, on which a time trace is also recorded throughout the experiment. Details regarding the complete balloon-borne equipment and the ground station equipment are published by R. P. Thatte (1949). Therein, it is shown that the finite resolving times of the various circuits used, introduce very small errors and therefore no corrections have been made in the following data.

The dead-time of our G-M counters was found to be of the order of $3 \cdot 7 \times 10^{-4}$ sec., as measured on a circuit similar to that described by Stevar (1942). This dead-time introduces an appreciable error as the counter is subjected to high counting rates at high altitudes. For a flux of N particles per unit of time and a dead-time τ_0, the efficiency of a counter will be $\epsilon = 1 - N\tau_0$. For a telescope of 'n' fold coincidences, the overall efficiency of the telescope will be ϵ^n. Using Millikan's data for the cosmic ray intensity with a single counter, near the latitude of our experiment, we estimate that the maximum counting rate of a single counter will be about 50 times the rate at sea-level. For our counters, N at ground was 3 counts per second, which at the maximum would be 150 counts per second. The overall efficiency of our quadruple coincidence telescope would therefore be $(1 - 3 \cdot 7 \times 10^{-4} \times 3)^4$ and $(1 - 3 \cdot 7 \times 10^{-4} \times 150)^4$, *i.e.*, 0·9954 and 0·795 at the ground and the maximum counting rate respectively, requiring our observed data for these levels to be multiplied by 1·005 and 1·255. Thus the correction, though very small near the ground, increases with altitude. For lack of data on the intensity given by a single counter with altitude, for the latitude of our experiment, the correction has not been applied to our data. In future experiments it is proposed to obtain the single counter data in preliminary flights to be able to apply these corrections and also to obtain the single counter intensity data at New Delhi at a later date to correct the data published here.

Free Balloon Flights

In collecting the data by the radio-sonde technique, the rate of ascent has to be decided on from the beginning not only to meet a desired statistical accuracy in a chosen interval of height and time, but also to reach the maximum possible height in a time interval in which the battery voltages remain within their useful operating ranges and the temperature of the apparatus does not fall below the tolerable limit. These two requirements are usually contradictory to each other and a compromise has to be made. Our G-M high tension battery, which had to be assembled just before the ascent, had a working range of only one and a half to two hours, and consequently we had to reach the maximum possible height in this time.

The weights of our complete balloon-borne equipment using telescopes, with and without 10 cm. lead absorber, were 22 k. gm. and 30 k. gm. respectively. Indian made latex balloons, type NR-220 made by the Nagpur Rubber Industries, were used. The performance of these balloons is equivalent to that of American, Darex J-800 balloons.

With the amount of hydrogen available to us for one ascent from a set of eighteen army portable hydrogen generators (utilising the ferro-silicon-caustic soda reaction), the maximum number of balloons that could be used at a time was limited. With the abovementioned weights of our equipment, with free lifts of 2500 to 3000 gm. per balloon, and the maximum possible number of these that could be used per ascent, our apparatus could only reach altitudes upto 40,000 feet.

Temperature Control

It is well known that G-M counters filled with organic quenching vapours have an appreciable temperature coefficient at low temperatures. The battery voltages also fall appreciably when the temperature is near 0° C. To study the anomalous hump and the depression in the 500 mb. region, reported by Bhabha and Gill, we wanted a good temperature control of our apparatus, since the air temperature at these pressures is near 0° C.

The temperature control was obtained by the "green house" effect possible in a daytime flight. In a few preliminary flights the proper method of securing the radiation balance was found. For the size of the bamboo cage required by our cosmic ray apparatus, the ratio of the transparent to reflecting area of the covering cellophane was varied. It was found that even with no reflectors the temperature inside the enclosure fell below 0° C. during an ascent. Finally a double jacket, of violet cellophane inside, and clear cellophane outside, was found to give an adequate temperature control.

Fig. 2 shows the performance of the different enclosures in some preliminary ascents made at Poona in the month of June 1948. The double cellophane enclosure flight shows a temperature + 32° C., even at a pressure of 150 mb.

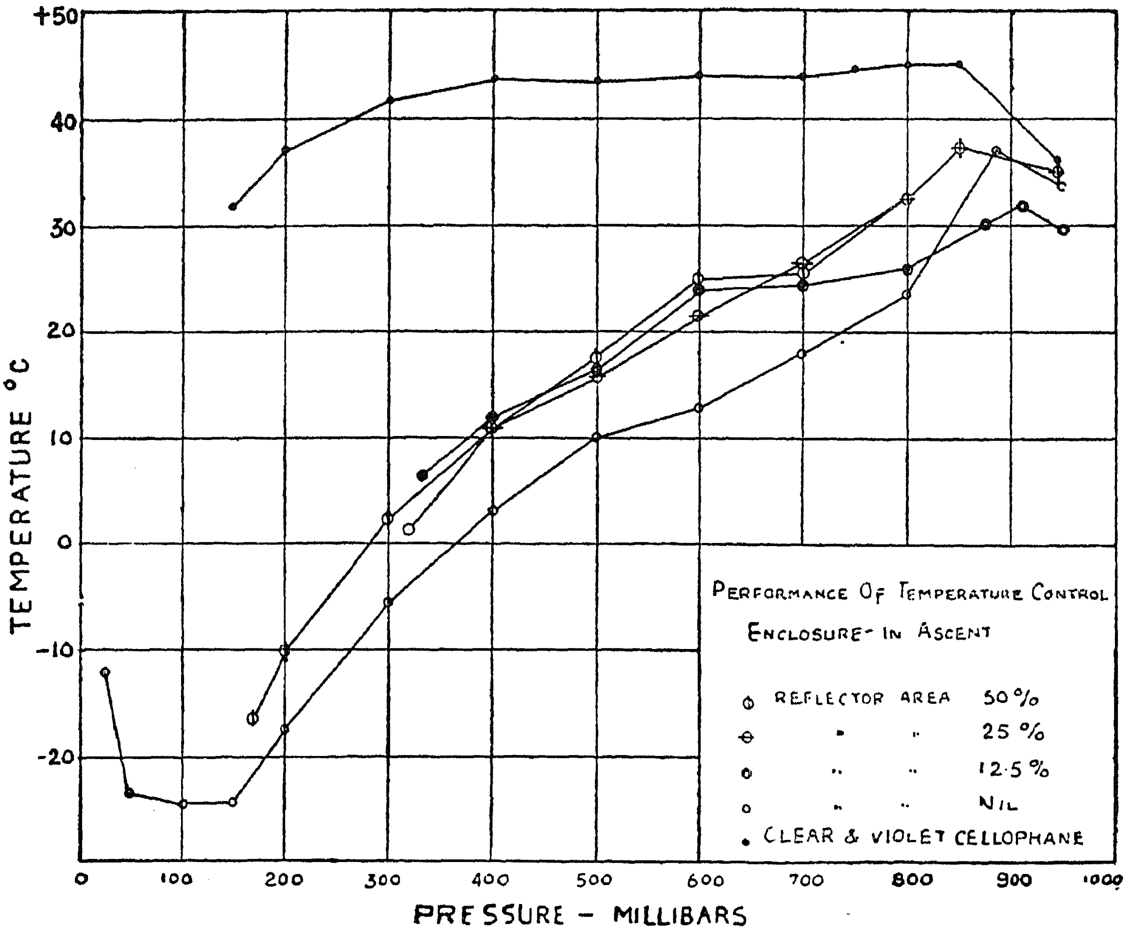


FIG. 2

THE EXPERIMENTAL DATA

The cosmic ray counts are recorded continuously on a tape while the apparatus continues to ascend. The usual method of tabulating the data is to count the total number of counts obtained between two pressures, divide this number by the corresponding time to obtain the mean counting rate in the interval, and then ascribe this mean rate to the mean pressure value in the interval. There is a certain latitude in the choice of an interval during which the counts are lumped together. If the intervals are large there is greater error in determining the mean pressure in the interval, if they are small the statistical fluctuation of the counts in the interval is larger. The statistical fluctuations which are usually large in the lower levels, make it difficult to fit a smooth curve to the points by eye. In applying some of the rigorous statistical methods of analysis for finding out if the deviation of a point from the smooth curve is due to fluctuation or is significant, it is also necessary to assume some relation between the intensity and pressure, based on either some theoretical hypothesis or on previous experimental data.

The general trend of the total vertical cosmic ray intensity as a function of pressure is known fairly accurately from the results already published. The data of Biehl, Montgomery and others (1948), may be taken as a good representation, since the experimental errors are less than 1%. Taking the curve for the data at Rapid City (Fig. 3 in the paper just mentioned), we decided to find the equation which would best represent it. We tried the following equations:

$$Y = A + Bx + Cx^2 + Dx^3 \tag{1}$$

$$Y = A + B(\log x) + C(\log x)^2 + D(\log x)^3 \tag{2}$$

$$\log Y = A + B(\log x) + C(\log x)^2 + D(\log x)^3, \tag{3}$$

where Y is the intensity (counting rate) and x is the pressure in millibars.

The methods of polynomial fitting are very much simplified if the independent variable is chosen at equal intervals. In calculating polynomial values for equations (1), (2) and (3) we chose x and $\log x$ respectively, at equal intervals and found out from the above curve the intensities at the pressure corresponding to the interval chosen.

The calculation of a polynomial is further simplified if it suffices to know the values of the polynomial at the points selected. Fisher (1946) in section 28 of his book deals with these simplified arithmetical methods of curve fitting, which we have used.

It was found out that a polynomial of type (3) satisfied the above data of the chosen curve very well. It was further varified, that the same polynomial still gave the best fit if only a portion of the curve was taken. For example, observations upto 1·6 metres of water equivalent of pressure were taken from the curve and still a good fit obtained. This we did with a view to satisfying ourselves that such a polynomial would be satisfactory for our data, which reached a pressure just near the maximum of the intensity-pressure curve. Fig. 3 shows the Rapid City data in solid curve. The solid points represent the values of the polynomial calculated to give the best fit to the whole set of observations, while the open circles are the calculated values of the polynomial fitting the data below the maximum. As a further check, this polynomial (a cubic in log of intensity versus log of pressure) was calculated for a few other observations, and particularly for the observations of Neher and Pickering (1942) at 17° N., in India. It was found that this particular polynomial represented all the observations very well.

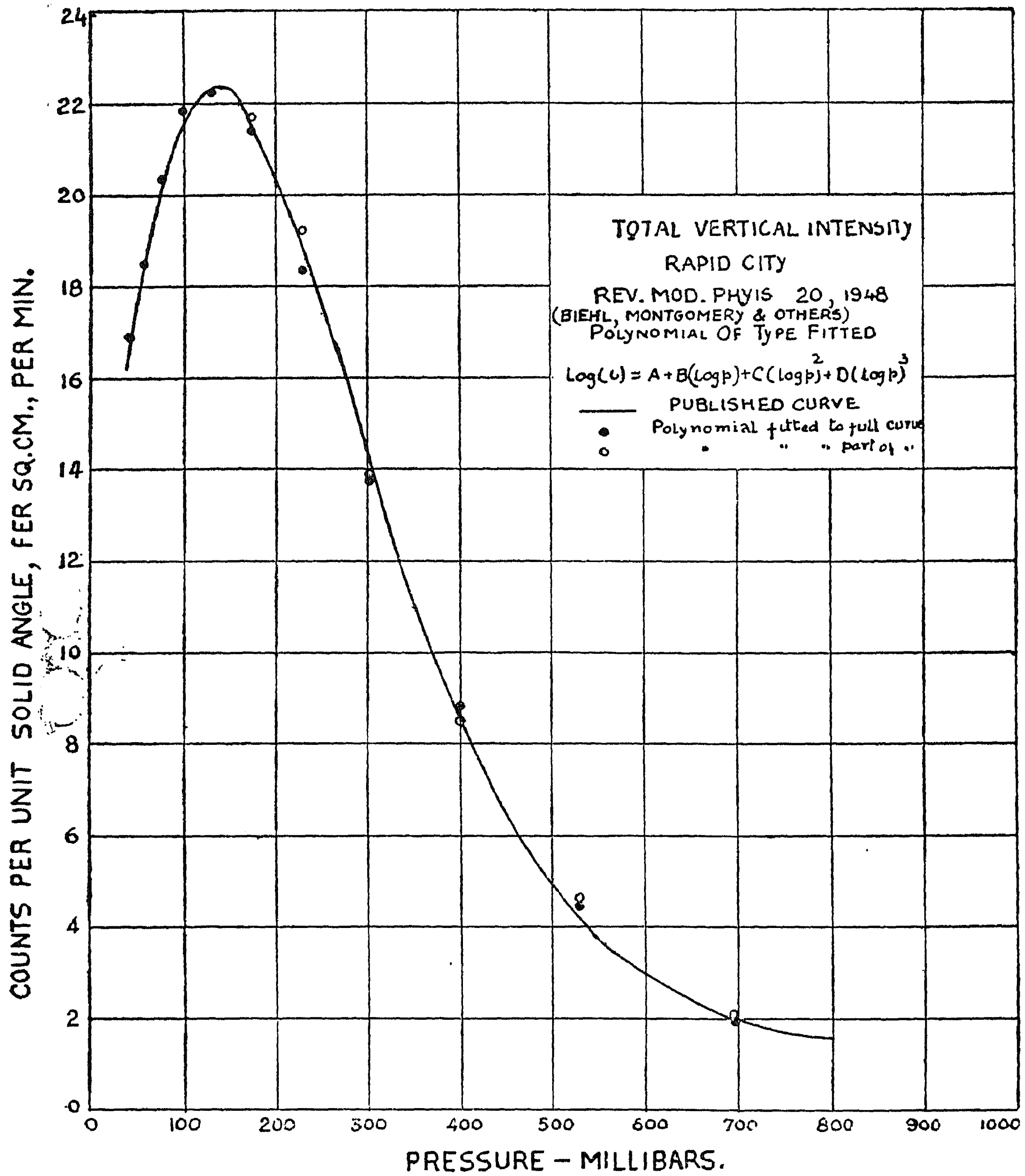


FIG. 3

We therefore fitted the above polynomial of type (3) to the data of our successful flights for the total cosmic ray intensity. We had first to choose equal log pressure intervals. This interval was made as small as possible without reducing the number of counts in each interval so much as to increase the statistical fluctuations; also, a choice of a large interval would obscure the significance of any observed deviations.

Since, in our tape recording, the pressure readings were recorded once during each cycle of the meteorograph, to find out the pressures corresponding to a required log p interval, time *versus* pressure interpolation curves were drawn on semi-log paper, from the recorded pressures and the time marking on the tape. The scale of the time axis was chosen to read accurately to 0·01 minute. From these curves the required pressure points were marked on the tape and the number of counts and the time duration was measured to calculate the rate. Since the relation of the log pressure against height in the atmosphere is a straight line, the average counting rate is taken to represent the rate at the average height in the interval (not the average pressure in the interval). The mean of the log p values for an interval was therefore shown against the average rate calculated.

In Tables I, II and III the data for our three flights are shown with equal selected intervals of log (p). It will be seen that starting with the

TABLE I

Pressure mb. of selected points p	Log p	Diff. log p	Mean of log p of interval	Diff. mean log p	Pressure mb. at mean of log p	Counts in interval	Time of interval minutes	Counting rate at the average of int. counts per min.
Surface 970·0	2·9868		2·9868		970·00	85	120·00	0·7083
		0·0214						
923·4	2·9654			0·0429				
		0·0429	2·94395		879·0	6	4·66	1·2876
836·6	2·9225			0·0429				
		0·0429	2·90105		796·4	10	6·57	1·5221
757·8	2·8796			do				
		do	2·85815		721·4	6	5·52	1·0870
686·6	2·8367			do				
		do	2·81525		653·6	4	5·15	0·7767
622·0	2·7938			do				
		do	2·77235		592·1	18	5·92	3·0405
563·5	2·7509			do				
		do	2·72945		536·4	12	3·57	3·3613
510·5	2·7080			do				
		do	2·68655		486·0	16	5·22	3·0651
462·5	2·6651			do				
		do	2·64365		440·2	23	5·39	4·2672
419·0	2·6222			do				
		do	2·60075		398·8	21	4·56	4·6053
379·6	2·5793			do				
		do	2·55785		361·3	25	4·52	5·5310
343·9	2·5364			do				
		do	2·51495		327·3	29	4·25	6·8235
311·6	2·4935			do				
		do	2·47205		296·6	28	3·67	7·6294
282·2	2·4506			do				
		do	2·42915		268·6	51	5·02	10·1594
255·7	2·4077			do				
		do	2·38625		243·4	60	5·82	10·3093
231·6	2·3648			do				
		do	2·34335		220·5	50	5·26	9·5057
209·8	2·3219			do				
		do	2·30045		199·7	125	12·1	10·3306
191·1	2·2790							

Observations for total vertical intensity measurement ascent at New Delhi. 19° N. (Magn.), India. Time of release 1·50 P.M. Preassure-time interpolation has been done to obtain the counting rates at equal intervals of log (p) to facilitate the computation of polynomial.

TABLE II

Pressure mb. of selected point p	Log p	Diff. log p	Mean of log p of interval	Diff. of mean log p	Pressure mb. at mean of log p	Counts in interval	Time of interval minutes	Counting rate at the average of int. counts per min.
Surface 983·0	2·9926		2·9926		983·00	106	150	0·7067
		0·02135		0·0427				
936·1	2·97125							
		0·0427	2·9499		891·0	1	2·1	0·4762
848·4	2·92855			0·0427				
		do	2·9072		807·4	3	2·92	1·0274
769·0	2·88585			do				
		do	2·8645		731·9	4	2·80	1·4285
696·9	2·84315			do				
		do	2·8218		663·4	10	4·05	2·4691
631·7	2·80045			do				
		do	2·7791		601·3	6	3·74	1·6043
572·5	2·75775			do				
		do	2·7364		545·0	9	3·63	2·4793
518·9	2·71505			do				
		do	2·6937		494·0	16	3·95	4·0506
470·3	2·67235			do				
		do	2·6510		447·0	12	4·47	2·6846
426·3	2·62965			do				
		do	2·6083		405·8	22	3·43	6·4140
386·4	2·58695			do				
		do	2·5656		367·8	29	3·34	8·6826
350·1	2·54425			do				
		do	2·5229		333·4	32	4·12	7·6699
317·4	2·50155			do				
		do	2·4802		302·1	35	3·49	10·0287
287·7	2·45885			do				
			2·4375		273·8	44	4·34	10·1382
260·7	2·41615							

Observations for ascent on 21st September at New Delhi. 19° N. (Magn.), India. The rates are found at pressures with equal log (p) difference to facilitate polynomial calculations.

surface pressure the first point is taken at half the value of the following intervals. Therefore the mean log p for the interval at which the rates are indicated then fall at equal intervals from the surface point, which then can be included in the calculation of the polynomial values.

From these observations, the values of the counting rate are calculated at the observed points for the polynomial of type (3) discussed above. As a matter of additional curiosity values were also calculated to fit an exponential of the type

$$Y = Ae^{-Bx}, \tag{4}$$

where Y is the counting rate and x the corresponding pressure A and B being constants.

TABLE III

Pressure mb. of selected points p	Log p	Diff. log p	Mean of log p of interval	Diff. mean log p	Pressure mb. at mean of log p	Counts in interval	Time of interval Minutes	Counting rate at the average of int. counts per min.
Surface 982·0	2·9921		2·9921		982·0	102	120·0	0·8500
		0·02125						
935·3	2·97085			0·0425				
		0·04250	2·9496		890·4	3	3·95	0·7594
848·0	2·92835			0·0425				
		0·0425	2·9071		807·4	8	5·89	1·3582
769·0	2·88585			do				
		do	2·8646		732·1	3	4·70	0·6382
697·2	2·84335			do				
		do	2·8221		663·9	8	6·16	1·2987
632·3	2·80085			do				
		do	2·7796		602·0	8*	6·04	1·3245*
573·3	2·75835			do				
		do	2·7371		545·9	15*	5·57	2·6929*
519·9	2·71585			do				
		do	2·6946		495·0	26	4·82	5·39241
471·4	2·67335			do				
		do	2·6521		448·8	32	4·86	6·5843
427·5	2·63085			do				
		do	2·6096		407·0	39	4·81	8·1081
387·7	2·58835			do				
		do	2·5671		369·1	39	4·41	8·8435
351·5	2·54585			do				
		do	2·5246		334·8	53	4·69	11·3006
318·7	2·50335			do				
		do	2·4821		303·5	57	4·76	11·9747
289·0	2·46085			do				
		do	2·4396		275·2	45	4·22	10·6635
262·0	2·41835			do				
		do	2·3971		249·6	91	7·40	12·2972
237·6	2·37585			do				
		do	2·3546		226·2	177	13·77	12·8540
215·4	2·33335							

Observations for ascent on 28th September at New Delhi, India. 19° N. (Magn.). Rates are found at pressures with equal differences of log (p).

* Some counts were lost in 602·0 and 545·9 mb. interval due to reception failure; the true rate would then be higher than indicated above.

Tables IV, V and VI give the values from the polynomial and the exponential at the observed points calculated for the three flights. In Figs. 4, 5 and 6 are drawn the observed points and the calculated polynomial and exponential curves. In these figures, at the top are indicated the temperatures inside the apparatus enclosure at corresponding pressure points during the ascent. It will be seen from these curves that the observed points in the regions of 800–400 mb. lie well off the smooth calculated curves for the polynomial and the exponential. To find out whether these deviations are

TABLE IV

Pressure mb.	Observed counts in interval	Time for int. min.	Observed rate counts/m.	Calculated rate counts/min.		Calculated total counts in interval		χ^2	
				Polyn.	Expon.	Polyn.	Expon.	Polyn.	Expon.
Surface 970·0	85	120·00	0·7083	0·8549	0·656	102·588	78·72	3·0153	0·5009
879	6	4·66	1·2876	0·9683	0·904	4·5123	4·2126	0·4904	0·7583
796·4	10	6·57	1·5221	1·1310	1·210	7·4306	7·9497	0·8884	0·5287
721·4	6	5·52	1·0870	1·3540	1·576	7·4740	8·6995	0·2906	0·8376
653·6	4	5·15	0·7767	1·6520	2·001	8·5078	10·3052	2·3834	3·8578
592·1	18	5·92	3·0405	2·0430	2·486	12·0945	14·7171	2·8835	0·7323
536·4	12	3·57	3·3613	2·5470	2·907	9·0927	10·3780	0·9295	0·2535
486·0	16	5·22	3·0651	3·1810	3·612	16·6048	18·8546	0·0220	0·4321
440·2	23	5·39	4·2672	3·9590	4·240	21·3390	22·8536	0·1292	0·0009
398·8	21	4·56	4·6053	4·8790	4·912	22·2482	22·3987	0·0700	0·0873
363·3	25	4·52	5·5310	5·9270	5·533	26·7900	25·0092	0·1196	0·0
327·3	29	4·25	6·8235	7·0490	6·320	29·9583	26·8600	0·0306	0·1704
296·6	28	3·67	7·6294	8·1660	7·042	29·9692	25·8441	0·1293	0·1798
268·6	51	5·02	10·1594	9·1600	7·771	45·9832	39·0104	0·5473	3·6849
243·4	60	5·82	10·3093	9·8950	8·493	57·5889	49·4293	0·1009	2·2605
220·5	50	5·26	9·5057	10·2300	9·206	53·8098	48·4236	0·2697	0·0513
199·7	125	12·1	10·3306	10·0700	9·907	121·8470	119·8747	0·0815	0·2190
				Total χ^2 for all points ..				12·3812	14·5554
				Total χ^2 omitting surface point ..				9·3659	14·0545

Calculated values of the polynomial and the exponential for data of the ascent on 15th September given in Table I. The χ^2 values for the polynomial and the exponential are given.

significant the χ^2 test used in statistics is applied to these points as well as to all other points. In our case, χ^2 is the square of the difference between the observed and the calculated (from the polynomial and the exponential) number of counts divided by the calculated number of counts in the same interval. The last columns of Tables IV, V and VI give the values of χ^2 for the different intervals.

TABLE V

Pressure mb.	Observed counts in interval	Time for int. min.	Observed rate counts/m.	Calculated rate counts/min.		Calculated total counts in interval		χ^2	
				Expon.	Polyn.	Expon.	Polyn.	Expon.	Polyn.
Surface 983	106	150	0·7067	0·428	0·5830	64·2	87·45	27·215	3·9348
891·0	1	2·1	0·4762	0·631	0·7452	1·3251	1·5649	0·0790	0·2039
807·4	3	2·92	1·0274	0·931	0·9610	2·7185	2·8061	0·0291	0·0133
731·9	4	2·80	1·4285	1·296	1·2460	3·6288	3·4888	0·0379	0·0749
663·4	10	4·05	2·4691	1·744	1·618	7·0632	6·5529	1·2210	1·8133
601·3	6	3·74	1·6043	2·295	2·099	8·5833	7·8503	0·7774	0·4361
545·0	9	3·63	2·4793	2·936	2·7110	10·6577	9·8409	0·2578	0·0718
494·0	16	3·95	4·0506	3·671	3·474	14·5005	13·7223	0·1550	0·3780
447·0	12	4·47	2·6846	4·512	4·403	20·1686	19·6814	3·3084	2·9979
405·8	22	3·43	6·4140	5·404	5·501	18·5357	18·8684	0·6474	0·5197
367·8	29	3·34	8·6826	6·384	6·754	21·3226	22·5584	2·7643	1·8394
333·4	32	4·12	7·6699	7·421	8·121	30·5745	33·4585	0·0664	0·0635
302·1	35	3·49	10·0287	8·512	9·528	29·7069	33·2527	0·9431	0·0918
273·8	44	4·34	10·1382	9·635	10·870	41·8159	47·1758	0·1140	0·2137
				Total χ^2 for all points ..				37·6185	12·6521
				Total χ^2 excluding surface ..				10·4035	8·7175

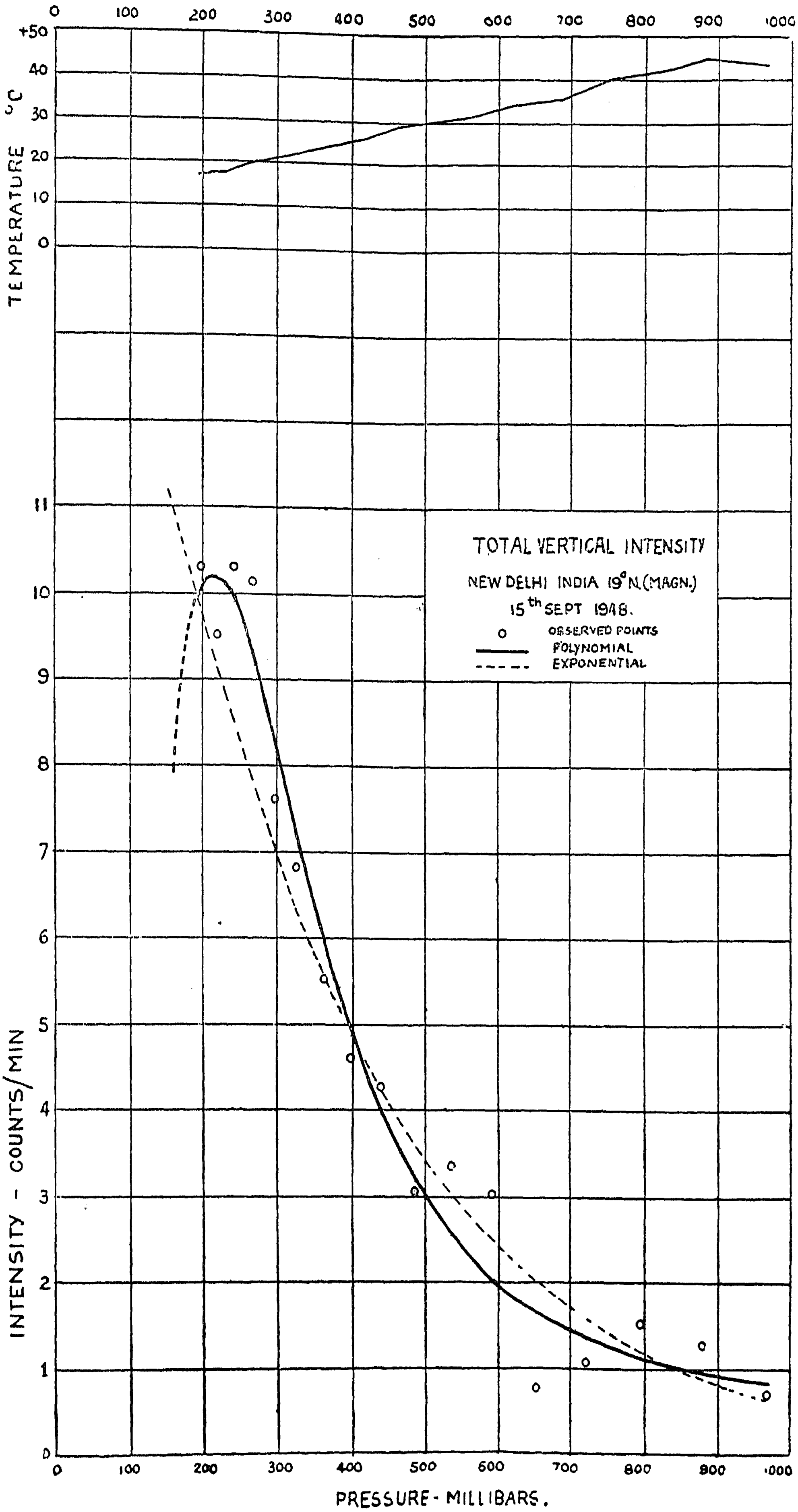
Calculated polynomial and exponential values for counting rate of the ascent data in Table II, with respective values of χ^2.

Reference to Fisher and Yates' probability tables for χ^2 for various degrees of freedom, gives us then the significance of any observation. The total of χ^2 for all observations gives the goodness of fit.

TABLE VI

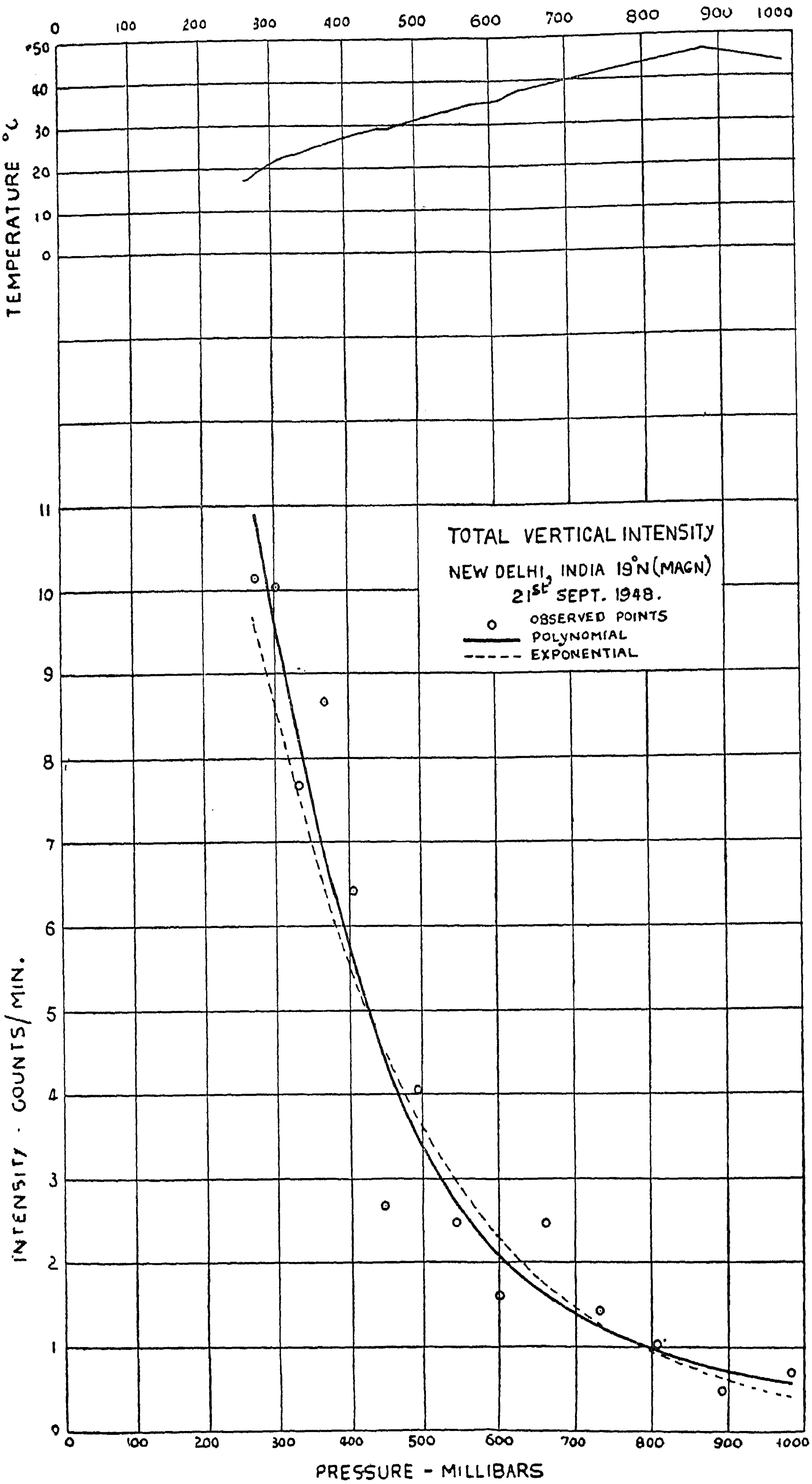
Pressure mb.	Observed counts in interval	Time of interval	Observed rate counts/m.	Calculated rate counts/min.		Calculated total counts in terval		χ^2	
				Polyn.	Expon.	Polyn.	Expon.	Polyn.	Expon.
Surface 982	102	120·0	0·8500	0·8130	0·462	97·56	55·44	0·2020	74·9475
890·4	3	3·95	0·7594	0·8015	0·700	3·1659	2·7650	0·0086	0·1999
807·4	8	5·89	1·3582	0·8804	1·020	5·1856	6·0078	1·5274	0·6606
732·1	3	4·70	0·6382	1·057	1·437	4·9679	6·7539	0·7795	2·0864
663·9	8	6·16	1·2987	1·362	1·957	8·3899	12·0551	0·0181	1·3640
602·0	8	6·04	1·3245	1·848	2·591	11·1619	15·6439	0·8956	8·6211
545·9	15	5·57	2·6929	2·589	3·344	14·4207	18·6261	0·0232	0·7059
495·0	26	4·82	5·3941	3·678	4·213	17·7280	20·3067	3·8597	1·5962
448·8	32	4·86	6·5843	5·198	5·197	25·2623	25·2574	1·7970	1·7999
407·0	39	4·81	8·1081	7·168	6·284	34·4781	30·2260	0·5930	2·5469
369·1	39	4·41	8·8435	9·471	7·464	41·7671	32·9162	0·1833	1·1244
334·8	53	4·69	11·3006	11·75	9·071	55·1075	42·5430	0·0805	2·5703
303·5	57	4·76	11·9747	13·47	10·05	64·1172	47·8380	0·7900	1·7547
275·2	45	4·22	10·6635	13·96	11·43	58·9112	48·2346	3·2849	0·2169
249·6	91	7·40	12·2972	12·85	12·83	95·0900	94·9420	0·1759	0·1636
226·2	177	13·77	12·8540	10·31	14·28	41·9687	196·6356	8·6441	1·9607
				Total χ^2 all points			..	22·8628	102·3190
				Total χ^2 omiting surface point			..	22·6608	27·3115

Calculated polynomial and exponential values for counting rate of the ascent data in Table III, with respective values of χ^2.



TEMPERATURE °C
+50
40
30
20
10
0
0
100
200
300
400
500
600
700
800
900
1000
TOTAL VERTICAL INTENSITY
NEW DELHI INDIA 19°N.(MAGN.)
15th SEPT 1948.
OBSERVED POINTS
POLYNOMIAL
EXPONENTIAL
INTENSITY - COUNTS/MIN
11
10
9
8
7
6
5
4
3
2
1
0
PRESSURE - MILLIBARS.

FIG. 4



0 100 200 300 400 500 600 700 800 900 1000
TEMPERATURE °C
50
40
30
20
10
0
TOTAL VERTICAL INTENSITY
NEW DELHI, INDIA 19°N (MAGN)
21st SEPT. 1948.
OBSERVED POINTS
POLYNOMIAL
EXPONENTIAL
INTENSITY - COUNTS/MIN.
11
10
9
8
7
6
5
4
3
2
1
0
0 100 200 300 400 500 600 700 800 900 1000
PRESSURE - MILLIBARS

FIG. 5

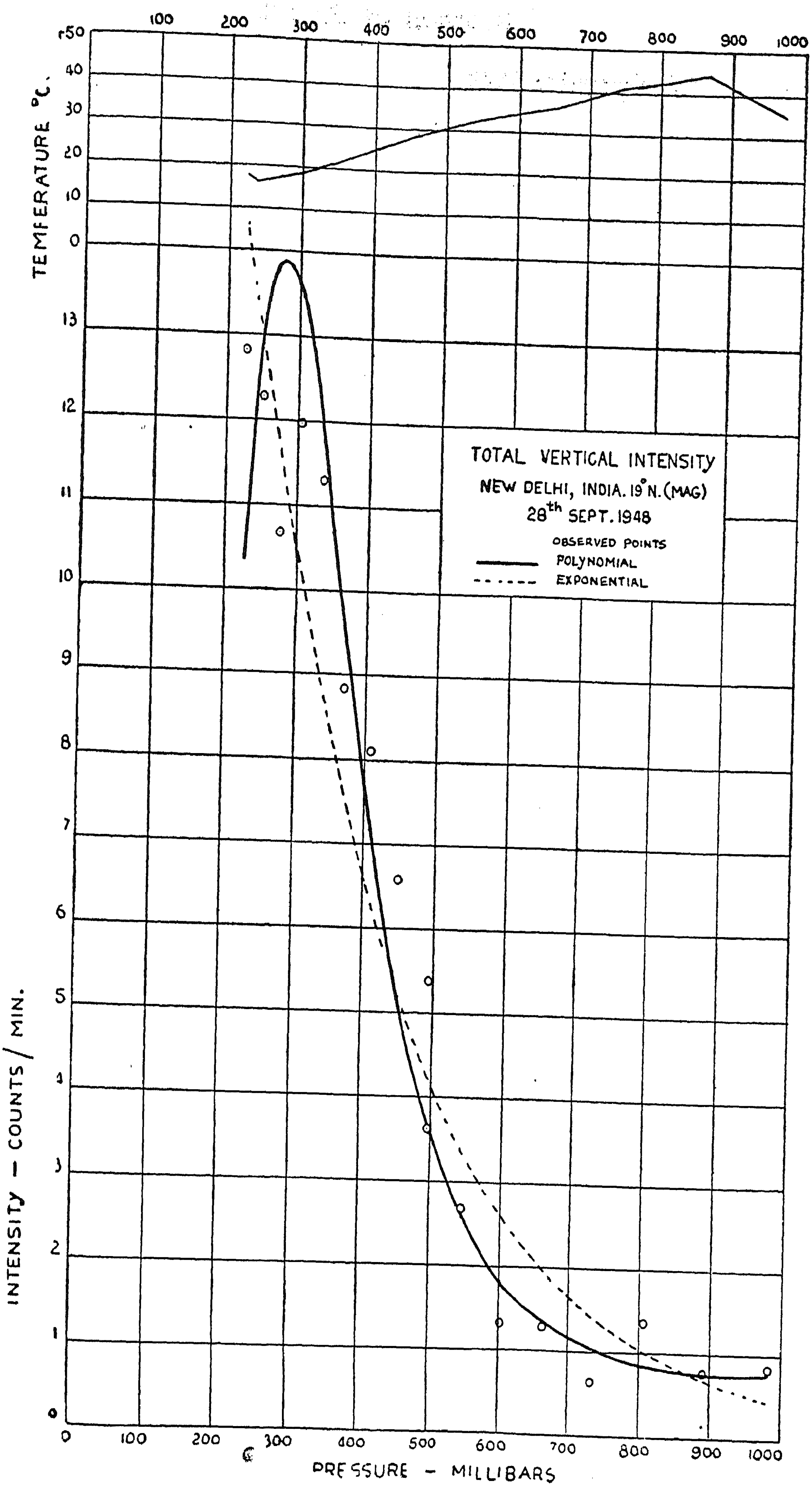

100 200 300 400 500 600 700 800 900 1000
50 40 30 20 10 0
TEMPERATURE °C.
13 12 11 10 9 8 7 6 5 4 3 2 1 0
TOTAL VERTICAL INTENSITY
NEW DELHI, INDIA. 19°N. (MAG)
28th SEPT. 1948
OBSERVED POINTS
POLYNOMIAL
EXPONENTIAL
INTENSITY – COUNTS / MIN.
0 100 200 300 400 500 600 700 800 900 1000
PRESSURE – MILLIBARS

FIG. 6

Discussion of Results

Ascent on 15th September 1948

From Tables IV and Fig. 4 the goodness of fit of the polynomial and the exponential to the seventeen observed points can be judged. From Table IV the fit of the curve can be better judged by examining the sum of the values of χ^2 for the whole curve. Thus, for the polynomial, the four coefficients of the cubic have been chosen to give the best possible fit and the number of "degrees of freedom" left is $17 - 4 = 13$. For the exponential, the constants to be calculated are two, giving $17 - 2 = 15$ degrees of freedom. The sum of χ^2 for the polynomial and the exponential are 12·3812 and 14·5554 respectively. Reference to the Fisher and Yates' tables for the probability of χ^2 for various degrees of freedom, shows that for both the polynomial and the exponential the probability is 50%, and the overall fit is good. However upon examining the individual values of χ^2 we see that the surface point where the rate was determined from two hours observation, gives the value of χ^2 as 3·0153 for the polynomial, which from tables show a probability of slightly more than 5% showing that at this value the polynomial does not fit the surface observation. If we omit the surface point we find from the sum of the residual χ^2 values and for the new degrees of freedom ($16 - 4 = 12$ for the polynomial and $16 - 2 = 14$ for the exponential) the probability of total χ^2 is 70% for the polynomial. There is no improvement in the value for the exponential which still shows 50% probability. Therefore if we omit the surface point, the polynomial fits the observed points better than exponential. For the individual values of χ^2 for the exponential, the points at 296·6 and 243·4 show large values of χ^2 giving about 5% probability. This is self-explanatory, since if the curve were to have a hump as is known, an exponential would give high values of χ^2 for points on the two sides of the saddle points. Comparison of the χ^2 values for the other two ascents in Tables V and VI also indicate the same conclusion.

If we then assume that the polynomial is a better fit for the observed points we find that points corresponding 653·6 and 592·1 mb. also show a high value of χ^2; these do not, however, show the points, as statistically significant. However, these points are very nearly in the same pressure regions where Bhabha and co-workers (1947) found significant aberration in their aeroplane ascent, where they suspect a hump at 511 mb. and depression between 650 and 700 mb. The points in our Fig. 4 also have a tendency to show a hump and a depression in these regions.

Ascent on 21st September

A similar examination of the data for the ascent on 21st shows, from Table V and Fig. 5, that for the total fit the polynomial is the better of the two. Individual χ^2 value show that both these curves fit the surface points poorly. Omitting the surface point gives equal probability for both. This is clear since in this ascent, data were not obtained beyond the saddle point. Here the individual χ^2 values in the regions between 500 and 700 mb. do not show high values of χ^2 as in previous flight, It may be, that, because of the higher rate of ascent used in this flight the statistical weights of the points was low compared to the previous flight. An eye examination of the observed points however does give an indication of a hump and depression in those regions.

Ascent on 28th September

For the data of the flight on the 28th from Tables III, VI and Fig. 6, we can see that for the overall fit the polynomial is the better of the two. However, during this flight some data were lost due to reception failure in both the 602·0 and 545·9 pressure intervals. If recorded, they would have given larger counting rates at both these points and would again have indicated a hump and a depression at about the same regions discussed under the flight on 15th (Tables IV and Fig. 4).

Lastly, we normalised the observations of the 21st and 28th September flights, to the flight on 15th September at ground values, where the counting rates were observed for over 2 hours. In Fig. 7 are shown these normalised values for these three flights. Polynomial values of type (3) used before have been calculated for these fresh normalised observations and are drawn for these three flights. The points at the maxima agree fairly well although the maxima for the polynomial do not agree for the 15th and 28th flight either in magnitude or the pressure of the maxima. However, as Janossy (1948) has shown, in order to get the counting rate at the top of the order of 10 per minute to agree within 0·1 per minute (*i.e.*, 0·01% of the individual rate) 36,00,00 counts must be recorded at ground level to find the normalising factor which would make the observations agree within 0·01% at the top. We have in these flights only about 200 counts recorded at the ground giving a significance of 30% to the normalization factor and thus giving an agreement of the maximum within these limits for these three normalised values. The deviations of the pressures, where maxima are indicated, can be attributed to the limited pressure accuracy of our meteorograph at these altitudes.

We have also shown in this figure Neher and Pickering's data (1942) (given in Fig. 8, p. 412 in above reference) for a quadruple coincidence flight made at Agra, India, 17° N. (magnetic) during 1939–40. The values have been normalised at the top at 200 mb. This curve agrees quite well

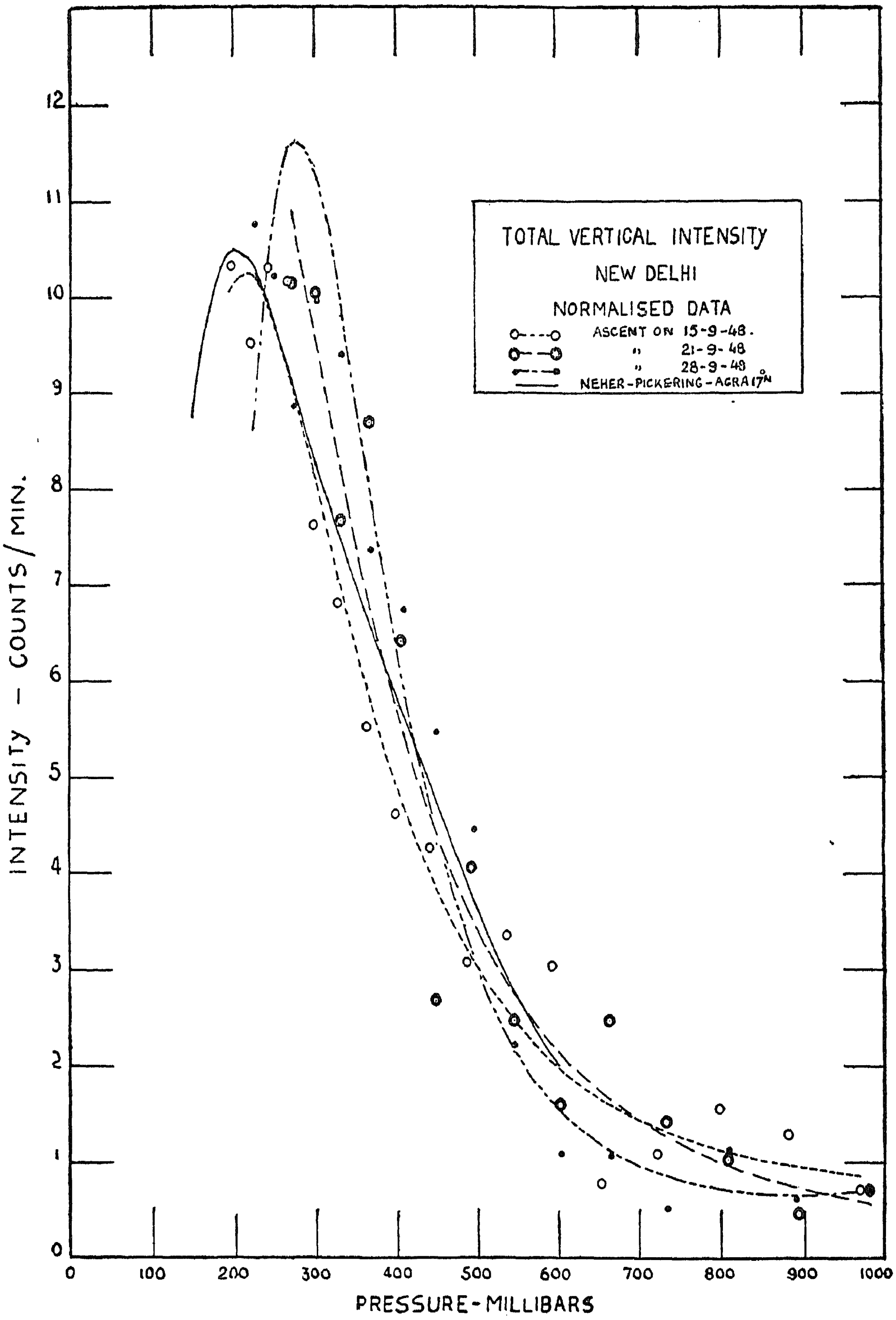


FIG. 7

with data of our three ascents. The pressure at which the maxima occurs agrees very well with the data in the flight of the 15th, showing that our flights just reached the point of maximum cosmic ray intensity. This was at first doubtful as usually in all other data on altitudes *vs.* pressure, the maxima occurs near about the 50–100 mb. regions. It is for this reason that we first tried to fit an exponential to our set of data, feeling that for the portion of the curve well below the maxima the exponential may give a reasonable fit. However, from the data of Neher and Pickering for the total intensity, the maximum for the intensity for a single counter is reached near about 100 mb., for a double coincidence 180 mb. and for triple and quadruple coincidence flight at 200 mb. in Indian latitudes. Apparently the geometry of the telescope plays a very important part in comparison of the various data as emphasized in our introductory remarks, when stressing the need of a standardised geometry in a latitude-effect study.

The temperature curves for these flights as given in Figs. 4, 5, 6 definitely show that wherever there was an indication of aberrations from the normally conceived intensity-pressure curve, the temperature of the apparatus was quite within the limits where the counting rate was not likely to have been affected. This definitely suggests that the anomalies observed by workers in India are real and are not due to instrumental uncertainties. It is proposed to investigate these regions with better statistical accuracy, by using a telescope with larger counting rate with an increased sensitive area and slower rates of ascent, in special flights intended to reach only upto 400 mb. level in the maximum possible time.

SUMMARY

Using the radio-sonde technique, three high altitude balloon flights were made at New Delhi 19° N. (Mag.) to measure the total vertical intensity to heights upto 40,000 feet (200 mb.). It has been found that the intensity *vs.* pressure curve for the total intensity as reported by other workers is well represented by a third degree polynomial of the log (intensity) against log (pressure). There is good agreement between our three flights when normalised to the same reading at ground level, and our results are well represented by the same polynomial. There is a renewed indication of a hump and a depression in the regions previously reported by Bhabha and co-workers and Gill in their aeroplane ascents, and this cannot be attributed to temperature effect here since the temperature was very well controlled inside the gondola by the 'green house' effect.

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