

Physics. — *Ultra Radiation (penetrating radiation). III. Annual variation and variation with the geographical latitude.* By J. CLAY. (Communicated by Prof. P. ZEEMAN).

(Communicated at the meeting of September 27, 1930).

§ 1. Since the last communication about the investigation of ultraradiation was made in December 1928, a series of measurements were made at Bandoeng to examine whether variations in the intensity of *ultraradiation* could be observed in the course of the year.

At present the term *ultraradiation* is used instead of *penetrating radiation*, since V. HESS, who contributed very much to the discovery of these rays, proposed to use the name of ultraradiation. By this name the origin of these rays is not mentioned, which at present has not yet been discovered and it is also left unexpressed whether the primary radiation is a β radiation or a γ radiation.

In the months of July, August, September and October only short series of measurements were made. From November 29th till August 23rd 1929 measurements were made regularly every day with only short interruptions of a few days. From November 29th till January 2nd the measurements were made with two instruments both protected on the bottom side and on the side walls by a 12 cm layer of lead, so that chiefly only rays from above could strike the instruments. From January 2nd one instrument was protected on all sides by an enclosing armour of iron of 8 cm to which at the bottom and on the sides 12 cm lead were added, at the upper side 4 cm lead, so that, according to the usual calculation, the upper covering corresponds to 10.6 cm lead or 12.9 cm iron.

By way of control the instruments were interchanged, e.g. from February 25th till March 2nd, July 28th and 29th, August 5th, 6th and 7th.

In the records the values found are given in ions per cm³ per sec.

The instruments were mostly read at 7 p. m. and at 7 a. m. The sensibility of the instruments was such that this was possible without the potential becoming too low, nor was there any danger of getting below the potential of saturation. As a rule the discharge of instrument A was laying between 450 and 180 Volts, of instrument B between 350 and 140 Volts. KOLHÖRSTER ¹⁾ has found, that at these potentials there is no fear of the current being unsaturated. Besides this could also be concluded from the fact that the same space of time was required for the first half of the decrease as for the second half.

¹⁾ W. KOLHÖRSTER, Phys. Zeitschrift, **31**, p. 280, 1930.

During the time that the instruments were above uncovered, the variations in the curve are greater than for the armoured instrument from

Ultra Radiation 12 : 7 : 28 tot 23 : 8 : 29.

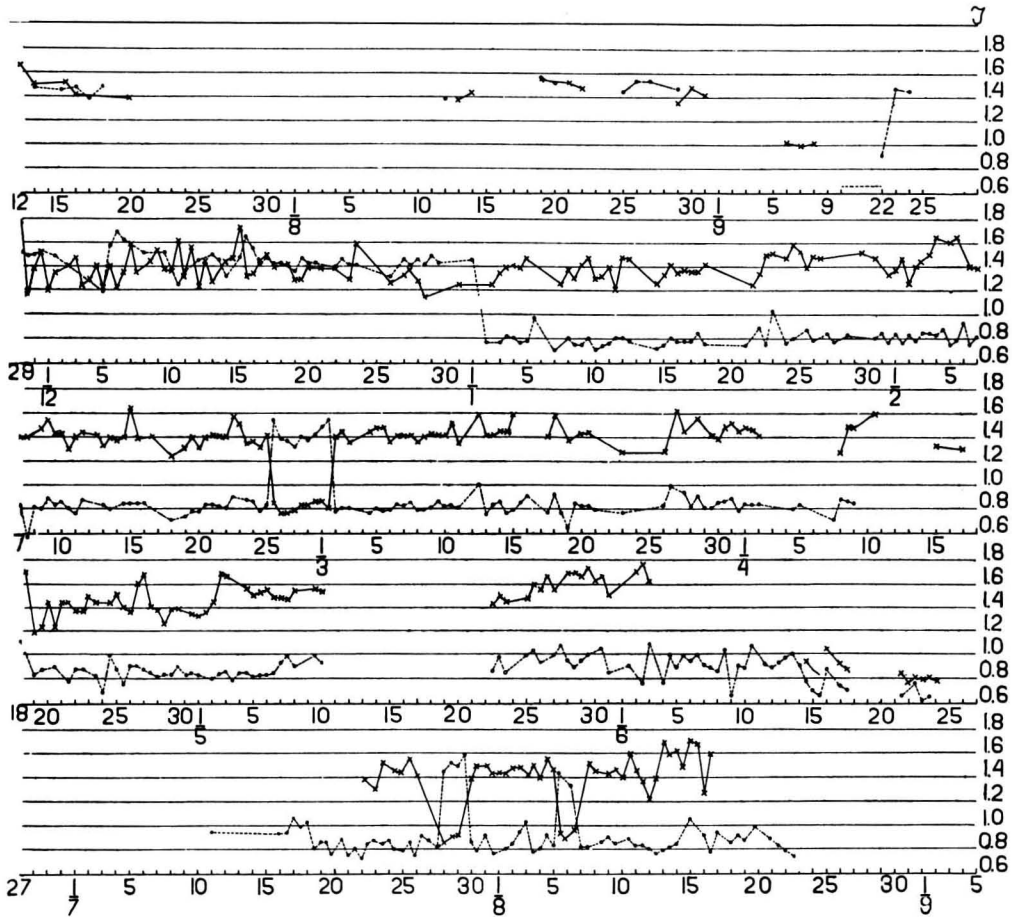


Fig. 1.

which ensues that these must have arisen through variations in the radiation. With the armoured instrument the mean deviation from January 2nd to Aug. 23th is 0,04₂ I and with apparatus *A* 0,07₄ I, while it had already been established before that under equal circumstances apparatus *A* in consequence of its smaller residual ionization, presented smaller deviations than apparatus *B*.

It appears from the course of the data, that in May and June a considerable rise in the intensity occurred. Especially the rise found in the ionization chamber inside the armour is, of course, the most reliable. This remarkable increase in May and June deserves the more attention, because it has also been found two years before as was stated in the

first communication in 1927 ¹⁾ That this increase is real, is also corroborated by two data.

TABLE I.
Variation of the intensity of ultraradiation between July 1928 and September 1929.

Data	12 cm lead on bottom and side walls	Mean variation	10.6 cm lead above, 18.6 cm on bottom and side walls	Mean variation
1928:				
July	1.45			
Aug.	1.45			
Sept.				
Oct.	1.44			
Nov.				
Dec.	1.41	0.07 ₇		
1929:				
Jan.	1.40	0.09 ₂	0.76	0.03 ₅
Febr.	1.41	0.11 ₈	0.80	0.05 ₁
March	1.42	0.05 ₄	0.80	0.03 ₄
April	1.42	0.06 ₇	0.83	0.03 ₅
May	1.53	0.06 ₁	0.94	0.05 ₀
June			0.94	0.05 ₃
18—30 July	1.43	0.05 ₉	0.80	0.05 ₃
Aug.	1.43	0.06 ₁	0.85	0.05 ₆

760 Meter up sealevel, barometric pressure 700 mm.

During the same period the number of mobile ions in the atmosphere was recorded and it was found that from August, 26 till April, 27 it did not vary much and amounted to 580 for positive and to 520 for negative ions, the numbers in May being 870 and 750 and in June 1000 and 840 ²⁾).

The number of ions also increased in May 1929, the exact amounts have not yet been published.

It may finally be mentioned, that a publication by STEINKE ³⁾ just appeared about the accurate recording of the radiation during a year

¹⁾ Proc. Royal Akad. of Amsterdam, 30, p. 1118, 1927.

²⁾ Proc. Fourth Pacific Science Congress, Bandoeng 1929, Atm. El. p. 3, 10.

³⁾ E. STEINKE, Ueber Schwankungen der kosmischen Ultrastrahlung, Z. f. Physik, B. 64, p. 51, 1930.

with an instrument with a 12 cm iron armour in which a rise of the radiation in May and June occurs of 3 ‰, HOFFMANN and LINDHOLM ¹⁾ records giving a slight increase between records in January and March. Hence the reality of this increase of radiation is undeniable.

The question now arises, however, what cause can be found for this variation. Here attention must again be called to the conclusion drawn already in 1927. When it appears that in a definite period of the year the radiation considerably increases and this during the whole day, it can hardly be assumed that the cause of this variation lies outside the planetary system; for it is pretty well excluded that suddenly simultaneously in entirely different directions in the cosmos the intensity of radiation should change so much. Hence there must be a terrestrial cause which either gives rise to the emitted intensity, or modifies the absorption in the atmosphere.

§ 2. While the series of observations at Bandoeng had to be broken off because of the voyage back to Europe, this voyage could be utilized for measurements on the variation with the latitude for the third time.

These experiments were made under the same circumstances as those on the voyage to the East-Indies, and now with two instruments, one of them used in the same armour as that used in the measurements at Bandoeng. After my arrival in Europe measurements were made in the physical laboratory at Amsterdam and afterwards in a private house about 14 meters above the ground. These observations confirm again that the intensity varies with the latitude. The difference between Amsterdam and Batavia is about 28 ‰.

It is to be mentioned that as far as the Canal of Suez the barometer was always 76 cm and 77 cm in the Mediterranean, so that here a small correction would have to be applied, which would still increase the value there. At Amsterdam the observations were made at a height of the barometer of 76 cm.

It is very remarkable that on all three voyages a minimum occurs in the Canal of Suez.

The first series of observations, (July 1927) which for the rest has very little value because the mistake was made to place the apparatus on deck so that it was exposed to great variations of temperature, which most probably was the cause that the apparatus got to leak, also showed the minimum in the Canal of Suez very clearly. ²⁾

The values in the third column of table II had to be revised as far as the absolute values are concerned, in consequence of the fact that the capacity assumed in the preceding communication appeared to be too small. The determination of the capacity as it appeared later to give the just value, will be given in the next paragraph.

¹⁾ G. HOFFMANN und F. LINDHOLM, *Gerlands Beiträge zur Geophysik*, 20, p. 12, 1928.

²⁾ *Proc. Royal Acad. of Amsterdam*, 30, p. 1116, 1927.

TABLE II.
Variations of the intensity of ultraradiation with the geographical latitude.

	Latitude	Voyage from Genoa to Batavia June 1—23 1928, in 8 cm iron	Voyage from Batavia to Genoa, Sept. 11—Oct. 3 1929, in 8 cm iron	Without armour more
Amsterdam	52°		1.24	
Genoa—Messina	40°		1.10	
Messina—Creta	35°	1.41	1.12	
Creta—Port-Said	33°	1.43	1.00	
Suez-Canal	30°	1.18	0.95	0.36
Red Sea (Northern Part)	25°	1.33	1.01	
Red Sea (Southern Part)	15°	1.33	0.98	0.31
Gulf of Aden	12°	1.27	1.00	0.26
Indian Ocean	10°	1.27	0.95	
Sabang	5°	1.26	1.04	
Sabang—Singapore	2°	1.23	0.93	
Singapore—Batavia	—3°	1.18	0.94	
Batavia	—6°	1.27	0.96	
Bandoeng (750 M. above sea-level)	—7°	1.43	1.31	

As the residual ionization was measured under 84 M. rock, it is possible that under a still thicker layer it would be found to be about 0.5 I less, according to the results of REGENER¹⁾ in the Lake of Constanx. If so, to all the values of *I* in Table I and II 0.5 must be added.

It may be pointed out here that owing to the circumstance, that the observations in 1928, made on the voyage to the East-Indies happened to be made from June 1st to June 23rd, the values were probably greater than normal in consequence to the fact that the above mentioned increase of intensity observed in 1927 and 1929, took place in the same period in 1928. This will probably also have caused the variation with the latitude to be greater than normal.

Finally attention may be drawn to the observation of CORLIN, who found a decrease of 2.78 to 1.75 between 55° and 68° N. Lat.²⁾ We have to wait for the measurements of BOTHE and KOLHÖRSTER last summer, made between Hamburg and Spitzbergen, which seem, however, not to confirm this variation, as they told me.

From this, together with the observations by KOLHÖRSTER³⁾ in Wanikoi

¹⁾ E. REGENER, *Naturwissenschaften*, 17, p. 183, 1929.

²⁾ AXEL CORLIN, *Arkiv. f. Mat. Astr. ad Phys.*, B. 22, p. 1, 1930.

³⁾ W. KOLHÖRSTER, *Zeitschr. f. Phys.*, B. 11, p. 379, 1922.

(Asia Minor) which were found very low, 1.05 I, it might be derived that the ultraradiation would have a zone of maximum intensity in Europe. That the intensity in Asia Minor is observed to be very low, coincides remarkably well with the minimum value in the Suez Canal found by me three times.

Hence, as STEINKE justly remarked at the congress at Königsberg in Sept. 1930, there is every reason to collect results with equal instruments which are compared with each other, under equal circumstances at different places of the earth (which work is going on now) in order to know more about the distribution of intensity. This could, e. g. very well be combined with magnetic measurements, which are made at present at different places, and which will more particularly be performed in the magnetic year 1932.

§ 3. It was already mentioned before, that with the electrometers of the type of KOLHÖRSTER there was a difficulty to measure accurately the very small capacity of the system, insulated in the ionization chamber. In the preceding communication it was explained how the capacity was found by means of an interference method with two circuits of vibration in which the electrometer was placed. A second determination was made in the Reichsanstalt in Berlin with high frequency vibrations in the MAXWELL bridge. Now a simple electrostatic method was applied, which still exceeds the two other methods in sensibility.

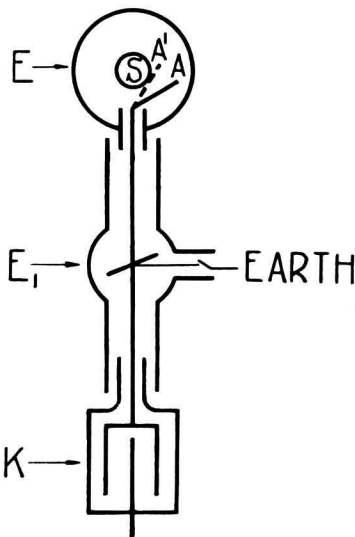


Fig. 2.

Let S be the system, insulated in the ionizationvessel E and A a small rod, passing insulated through the wall of the vessel, which can charge the system by contact with S in the position A' , then the following method will be used to determine the capacity of the system C_s .

The rod A is connected with a sensitive electrometer E_1 (e.g. LINDEMANN electrometer) which is further connected with a condenser (e.g. a measuring condenser of WULF).

When in this arrangement the outside of E and of K are charged to a potential V , the needle of E_1 being earthed, a variation of capacity which is caused by movement of A and eventually contact of A with S , after the connection with the earth has been broken, can be compensated by a variation of the capacity of K . It now appears that this method becomes exceedingly sensitive, when the outside of E and of K is charged to a sufficiently high potential. For, if the capacity of the whole, namely the rod A , the electrometer E and the condenser

K , is C , an increase of the capacity dC will give a change of the potential of the needle dV_1 , so that $C dV_1 = -V dC$, hence

$$dC = -C \frac{dV_1}{V}.$$

If $dV_1 = 0,001$ Volt (value of one scalar division), $C = 15$ cm and $V = 100$ Volt, then $dC = 15 \cdot 10^{-5}$ cm. The sensibility can even be increased by taking the potential of the outside of E n times as high as that of K . The variation in capacity which then must be given to K to compensate a small variation of the capacity in E , is n times as great as this last one. Accordingly the method is amply sufficient to measure a variation of 0,001 cm of the system, if the value of K is sufficiently accurately known. It has, besides, the advantage to be completed in a few seconds.

In this measurement it now appeared that one thing had been overlooked in the earlier calculation. For, when S is first uncharged and A is brought into a position in which no inductive influence between A and S exists as yet, the electrometer is brought to zero. If now A is turned towards S , an induction arises which increases the capacity of A , till the moment that A gets in contact with S . At that moment the capacity is increased by an amount C_s , but at the same moment the capacity of S is diminished by an amount C_i , which is corresponding to the part of the field occupied by A_1 . The capacity of A_1 is further diminished by an amount C_i' , which is caused by the presence of S . As C_i and C_i' are small we may put according to MAXWELL ¹⁾ $C_i = C_i'$.

Now C_i can be found by three methods. In the first place C_i may be found by turning A back to the position where the influence practically ceases. Likewise C_i may be found from the variation which was measured at the first movement, when A was turned towards S to the point that contact just took place. (This method, however, always gives somewhat too small values.) A very accurate value is, however, found when in charging the electrometer E as for the ordinary measurements, the potential V_1 is read when the charging rod still makes contact, and again the potential V_2 is read after the charging rod is turned off. Now $(C_s - C_i) V_1 = C_s V_2$.

What before was overlooked in the same measurement is, that to the capacity measured in the way indicated above, the amount C_i must be added twice. For at the moment of contact not only C_s is diminished by the amount C_i , but also the capacity of the rod A in the position A_1 is diminished by the amount C_i' .

Consequently, as HESS ²⁾ already suspected, the absolute value in Communication II was calculated too small; but the difference is not so great as he expected.

¹⁾ J. C. MAXWELL, Electricity and Magnetism, § 88.

²⁾ V. F. HESS, Phys. Zeitschr., **31**, p. 284, 1930.

For $C_s - 2 C_i$ had been found before with the method of interference of electric oscillations : 0.288 ± 0.001
 with MAXWELL's bridge : 0.297 ± 0.005
 according to the last measurement : 0.272 ± 0.001 .

The difference between the last value and the first can perhaps be explained by the fact that the standard condenser of WULF was calibrated (P. T. R.) within two percent, and that the value measured by vibration gives systematic difference with the static method. Also it is possible that the capacity really has got a small difference since 1928.

We took the value of 0,272 cm. as the most probable on the moment.

C_i was measured by the third method given above and a number of values were obtained for which $a = \frac{V_1}{V_2}$ varied between 1,22 and 1,23 and from which $a = 1,226$ was calculated.

From these data we got $C_i = 0,070$ and $C_s = 0,412$ for instrument A. In the same way 0,441 was found for instrument B, hence the ratio of their capacities is, 1,07. In a control experiment in which 2,49 mG radium was placed at 1,5 meter distance from the two apparatus, this ratio was found to be 1,15 when the same ionization may be assumed in the two apparatus.

Owing to the great value of the capacity of the rod, which was 8,0 cm, the method of the divisions of charge, applied by KOLHÖRSTER ¹⁾, could not be used. Nor did the method of HESS and REITZ ²⁾ yield reliable results in consequence of the insufficient insulation of the quartz on the outside of the instrument.

¹⁾ W. KOLHÖRSTER, Phys. Zeitschr., 31, p. 280, 1930.

²⁾ V. F. HESS and F. A. REITZ, Phys. Zeitschr., 31, p. 284, 1930.

Amsterdam, Sept. '30.