

**EXPÉDITION ANTARCTIQUE BELGO-NÉERLANDAISE 1964**  
**BELGISCH-NEDERLANDSE ANTARCTISCHE EXPEDITIE 1964**

ATMOSPHERIC ELECTRICITY

Base Roi Baudouin  
juin 1964 - février 1965

Koning Boudewijn Basis  
juni 1964 - februari 1965

P. M. Buis

**EXANTAR, BRUXELLES, 1968**  
**1, RUE DE LOUVAIN**

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ATMOSPHERIC electricity

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## PREFACE

The 1964 Belgian-Dutch Antarctic Expedition follows on from the three Belgian Antarctic Expeditions 1958 - 1959 - 1960 which continued the tradition established by the famous expedition of the "Belgica" under the command of Baron Adrien de Gerlache de Gomery (1897 - 1899).

The 1964 Belgian-Dutch Antarctic Expedition was organised under the responsibility of the Belgian-Dutch Antarctic Committee presided over by Baron Gaston de Gerlache de Gomery.

The scientific programme was established by the Scientific Committee in accordance with the directives of the SCAR for the IQSY. The Scientific Committee consists of the following members : Prof. Dr. P. Bourgeois (chairman), Prof. Dr. P. Baetslé, Prof. Dr. W. Bleeker, Prof. Dr. A. de Vuyst, Prof. Dr. L. Koenigsfeld, Prof. Dr. E. Picciotto, Prof. Dr. H. Vanderlinden, Prof. Dr. J. Veldkamp, Dr. A. Maenhout, Dr. L. Malet.

The scientific programme included : meteorology, geomagnetism, ionospherics, atmospheric radioactivity, atmospheric electricity, auroras, geodesy, topography, gravimetry, glaciology, biology and physiology.

The atmospheric electric programme was established in collaboration with Prof. Dr. L. Koenigsfeld.

The 1964 Belgian-Dutch Antarctic Expedition consisted of 10 Belgian and 4 Dutch members and was commanded by ing. L. Cebes.

The expedition left Antwerp on the 8th December 1963 on board the m. s. Magga Dan and disembarked in the King Leopold III Bay on the 21st January 1964. A new base was constructed in the neighbourhood of the old base which was evacuated in February 1961. As soon as the base was constructed the Expedition started the scientific programme which was continued till the arrival of the 1965 Expedition in January 1965.

## VOORWOORD

De Belgisch-Nederlandse Antarctische Expeditie 1964 is een voortzetting van de drie Belgische Antarctische Expedities 1958 - 1959 - 1960, die de traditie, gevestigd door de bekende Antarctische Expeditie van de "Belgica" onder leiding van Baron Adrien de Gerlache de Gomery (1897 - 1899), hervatten.

De Belgisch-Nederlandse Antarctische Expeditie 1964 werd georganiseerd onder verantwoording van de Belgisch-Nederlandse Antarctische Commissie onder voorzitterschap van Baron Gaston de Gerlache de Gomery.

Het wetenschappelijk meetprogramma werd overeenkomstig de richtlijnen van het SCAR voor het IQSY opgesteld door het Wetenschappelijk Comité bestaande uit: Prof. Dr. P. Bourgeois, (voorzitter), Prof. Dr. P. Baetslé, Prof. Dr. W. Bleeker, Prof. Dr. A. de Vuyst, Prof. Dr. L. Koenigsfeld, Prof. Dr. E. Picciotto, Prof. Dr. H. Vanderlinden, Prof. Dr. J. Veldkamp, Dr. A. Maenhout, Dr. L. Malet.

Dit programma omvatte waarnemingen op het gebied van: meteorologie, aardmagnetisme, ionosfeer, atmosferische radioactiviteit, atmosferische elektriciteit, poollicht, geodesie, topografie, gravimetrie, glaciologie, biologie en fysiologie.

Het luchtelektrische programma werd in samenwerking met Prof. Dr. L. Koenigsfeld vastgesteld.

De Belgisch-Nederlandse Antarctische Expeditie 1964 stond onder leiding van ing. L. Cabes en werd gevormd door 10 Belgen en 4 Nederlanders. De Expeditie vertrok op 8 december 1963 uit Antwerpen aan boord van het m.s... Magga Dan en arriveerde op 21 januari 1964 in Antarctica waar de ontschepping plaats vond in de Koning Leopold III Baai. Een nieuwe Koning Boudewijn Basis werd gebouwd in de nabijheid van de "oude" basis die in februari 1961 verlaten was. Zodra de basis voltooid was, werd een aanvang gemaakt met het wetenschappelijk programma dat voortgezet werd tot aan de aankomst van de Expeditie 1965 eind januari 1965.

## AVANT - PROPOS

L'Expédition Antarctique Belgo-Néerlandaise 1964 fait suite aux trois Expéditions Antarctique Belges 1958 - 1959 - 1960 qui reprisent la tradition établie par la fameuse Expédition Antarctique de la "Belgica" du Baron Adrien de Gerlache de Gomery (1897 - 1899).

L'Expédition Antarctique Belgo-Néerlandaise 1964 fut organisée sous la responsabilité d'un Comité Antarctique Belgo-Néerlandais présidé par le Baron Gaston de Gerlache de Gomery.

Le programme scientifique a été établi, conformément aux directives du SCAR pour l'IQSY, par une Commission Scientifique composée de Messieurs les Professeurs P. Bourgeois (Président), P. Baetslé, W. Bleeker, A. de Vuyst, L. Koenigsfeld, E. Picciotto, H. Vanderlinden, J. Veldkamp de Messieurs A. Maenhout, L. Malet.

Ce programme comprenait des observations de Météorologie, Géomagnétisme, Ionosphère, Radioactivité atmosphérique, Electricité atmosphérique, Aurores, Géodésie, Topographie, Gravimétrie, Glaciologie, Biologie, Physiologie.

Le programme de Electricité Atmosphérique fut établi en collaboration avec le Professeur L. Koenigsfeld.

L'Expédition Antarctique Belgo-Néerlandaise 1964 fut commandée par l'ing. Luc Cabes. Elle comprenait 14 hommes : 10 belges et 4 hollandais. Partie d'Anvers sur le M/S Magga Dan, le 8 décembre, l'Expédition débarqua dans l'Antarctique, à la Baie Roi Léopold III, le 21 janvier 1964. Elle construisit une nouvelle Base Roi Baudouin à proximité de l'ancienne Base évacuée en février 1961. Dès que la Base fut construite, l'Expédition 1964 exécuta le programme scientifique prévu et le poursuivit jusqu'à l'arrivée de l'Expédition de relève en fin janvier 1965.

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## 1. INTRODUCTION

The ionosphere and the earth can be considered as conducting with respect to the atmospheric layers between them (Israel 1957). These layers are weakly conductive due to the cosmic radiation and the radioactive components of the air and earth. The ionosphere is positively charged with respect to the earth, the potential difference being about 250 kV. This potential difference causes a current to flow from the ionosphere to the earth.

In quasistatic cases without convection of the air the current density will be independent of height and thus the field strength will decrease with increasing height. This can be expressed by the simple equations

$$I = -\lambda(h) \text{ grad } V \qquad V_{\text{ion}} = \int_{\text{earth}}^{\text{ionosphere}} \text{grad } V \, dh$$

with grad V = potential gradient,  $V_{\text{ion}}$  = potential difference between ionosphere and earth  
 I = current density, h = height,  
 $\lambda$  = conductivity of the air

For example, in an undisturbed case 100 metres above the surface of the earth

$$I = 3 \cdot 10^{-12} \text{ A/m}^2$$

$$\text{grad } V = 100 \text{ V/m}$$

$$\lambda = 3 \cdot 10^{-14} \text{ mho} \cdot \text{m}^{-1}$$

The conductivity is due to the positive and negative small ions in the air. Other charged particles give a negligible contribution to the conductivity, because their mobility is too small. As stated above the ions are created by radiation. The conducting ability of the small ions is lost in three ways :

- by recombination of the ions, the principal effect during fair weather in Antarctic;
- by attachment to nuclei, which restricts the mobility of the ions; this is the effect that complicates atmospheric electric measurements on most of the continents. In Antarctica the air is very pure and except during snowdrift we can neglect the influence of the nuclei.
- by the small ions reaching the surface.

The potential difference between the ionosphere and the earth is maintained in regions with thunderstorms.

In Europe as in most of the other continents the interpretation of the atmospheric electric measurements is complicated by changes in the concentration of nuclei and radioactive components of the air. In the Antarctic the ionisation due to radioactivity can be neglected and the only type of nuclei are ice particles. This simplification makes it possible to study various effects. It is a pity that base "Koning Boudewijn" is situated in a zone of katabatic winds. These winds often cause snow drift, which disturbs 70 % of the measurements. It may be expected that more useful observations can be made at the polar plateau.

During 1964 the potential gradient was measured near the surface and as a function of height. Some special effects were investigated, the results of which assisted in the establishing of a new atmospheric electrical programme for 1966.

## 2. TOPOGRAPHY

The base "Koning Boudewijn" ( $24^{\circ} 18' E$ ,  $70^{\circ} 25' S$ , height 39 m) is located on the Princess Ragnhild coast, which forms a part of Queen Maudland. The coast is formed by the ice-shelf, which is 30 m high. The base is situated 10 km inland, where the snow surface is extremely level. The only relief to the flatness of the area is provided by a gentle slope, of a height of 300 m. Between the base and this slope there is a long valley about 5 km west of the base. South of the station at a distance of 150 km are the "Sør Rondane" mountains.

To obtain undisturbed observations it is necessary to keep the apparatus far from masts and other high obstructions (pag. 16 ). A small atmospheric electric observatory was constructed under the snow level at a distance of 150 m south of the base. The prevailing direction of the wind is south, so the air was not polluted by the base. However the influence of the base can be seen in the observations when the wind is North to North-West, because the smoke from the base's engines then drifts in the direction of the observatory.

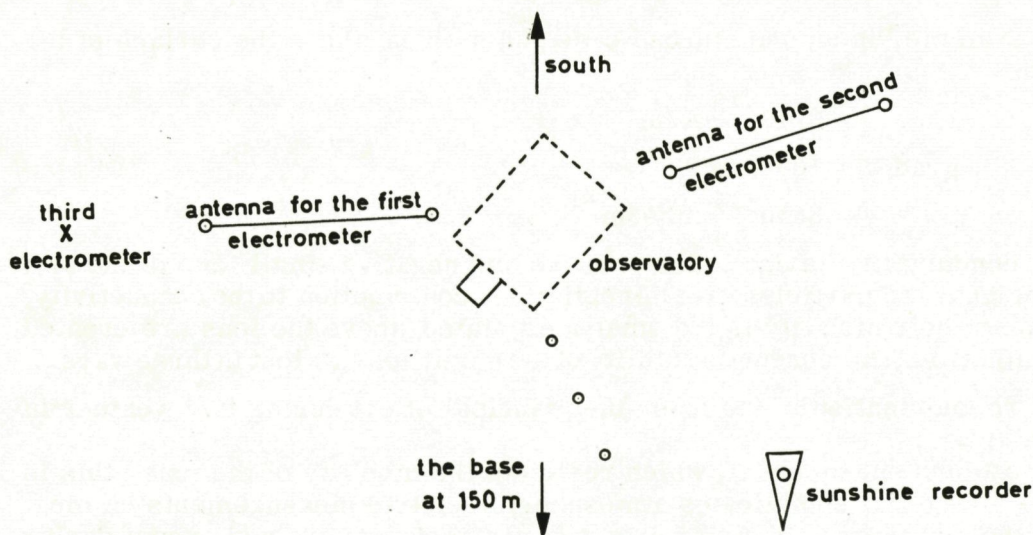


Fig. 2.1. Surroundings of the electric observatory.

## 3. POTENTIAL GRADIENT AT THE SURFACE

### 3.1 The apparatus

Measurements of the potential gradient during 1959 at base "Koning Boudewijn" were performed with an inverted triode electrometer (Koenigsfeld 1963). To obtain comparable results during 1964 the same type of electrometer was used. This electrometer worked reliably from June 1964 to January 1965. In order to remove any doubts concerning the apparatus a completely different type of measuring device was designed: the cathode follower electrometer. This electrometer was used from 20 October 1964 to 20 February 1965. A third type of electrometer was used during part of January 1965; a direct amplifier electrometer. This electrometer was borrowed from the laboratory of Prof. Dr. H. Israel, Germany.

The results obtained with these three different electrometers agree within 10 %.

### 3.1.1 The inverted triode electrometer

This system was introduced by L. Koenigsfeld and Ph. Piraux (Koenigsfeld 1950). The anode of a triode is kept negative and the grid positive with respect to the cathode (fig. 3.1). The current in the grid-cathode circuit depends in an approximately linear way on the anode potential. Thus the anode voltage can be determined from the grid current when the triode is calibrated. The currents between anode and cathode are very small; a leak resistance between anode and cathode of  $10^{13} - 10^{14}$  ohm can be obtained.

Two antennae are stretched horizontally and insulated from the masts by perspex isolators, leak resistance  $10^{13}$  ohm and higher (fig. 3.2). Two radioactive sheets (Ra D, 10 microC each) are connected to the two antennae and so each antenna can adapt itself to the potential of the surrounding atmosphere. The contact resistance between the air and each antenna is about  $10^{10}$  ohm. The potentials of the antennae are brought into the observatory by teflon-isolated lines, length 13 metres. The lower antenna is connected to the anode of the triode, the upper antenna to the cathode.

A suitable electrometer tube, for example 1LH4, could not be obtained in time, so we had to use tube 958 A. This tube is smaller and cannot withstand high tensions. It is necessary to keep the supply batteries, the recorder and the electrometer high-ohmic insulated from the earth, because the cathode is connected to a high-ohmic antenna.

The leak resistance is checked every fortnight. Several times it was necessary to replace the electrometer tube, and once the connecting lines were replaced because the insulation broke down.

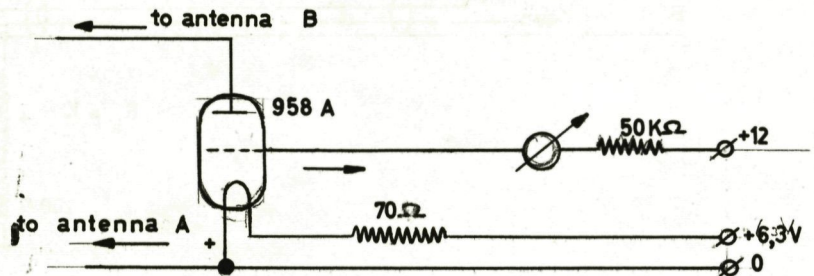


Fig. 3.1. Inverted triode electrometer.

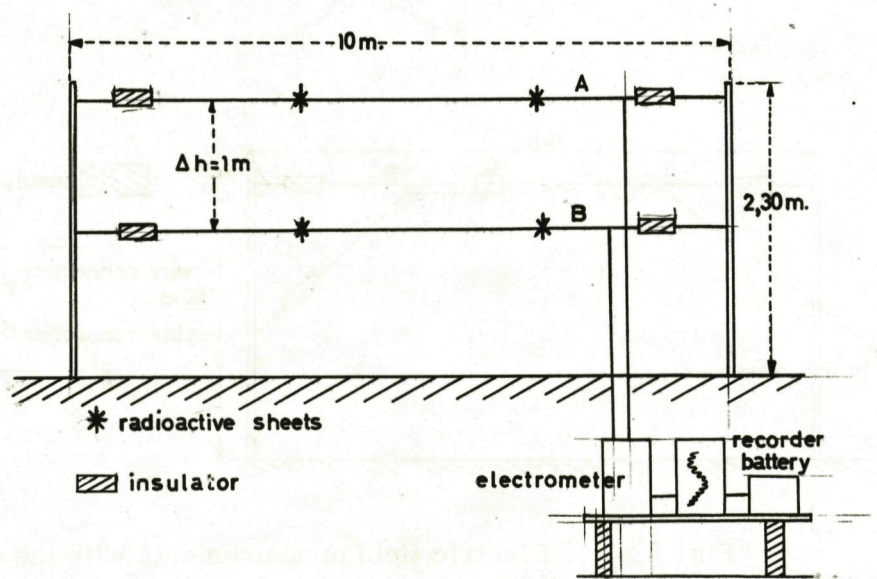


Fig. 3.2. Electric field measurements with the inverted triode.

### 3.1.2 Cathode follower electrometer

The unknown positive voltage from antenna A is connected to the grid of a special electrometer tube, Philips 4066. The circuit acts as a simple cathode follower (fig. 3.3): the current through the cathode resistance  $R_k$  is directly proportional to the grid potential. Because the voltage amplification of such an electrometer tube is about 0.8 and because the anode-cathode voltage may not exceed 10 volts, it is necessary to use a protecting pentode in the anode circuit. The grid of the pentode is connected to the cathode of the electrometer tube by way of a battery. In this way the anode-cathode voltage is practically independent of the anode current. As we were res-

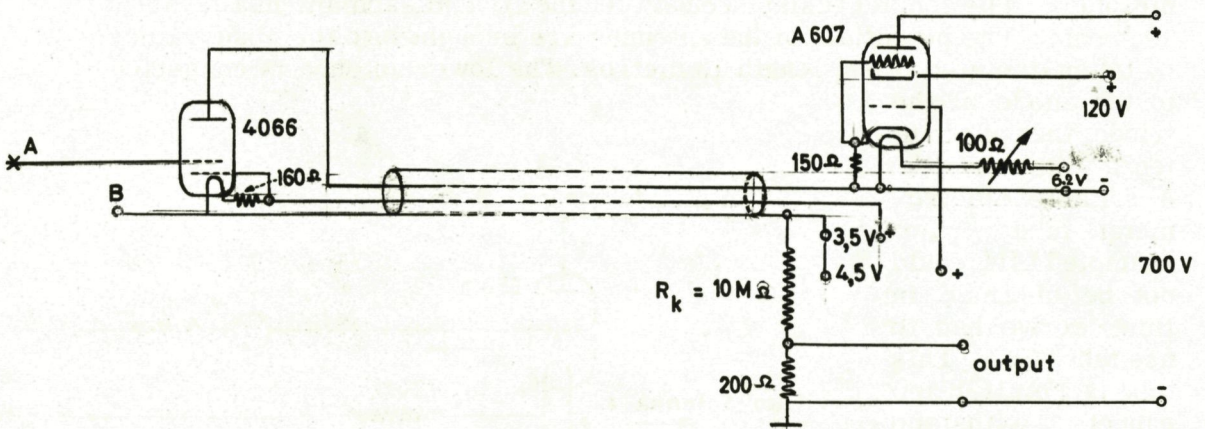


Fig. 3.3. The cathode follower electrometer.

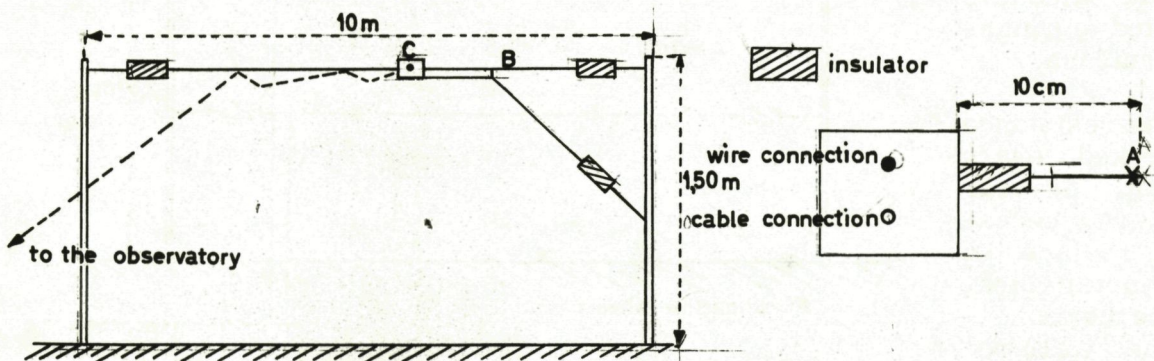


Fig. 3.4. Electric field measurements with the cathode follower electrometer.

tricted in our choice of the pentode, an A 607 was used with a lowered filament current to adapt it to the low current of the electrometer tube. The second grid in the electrometer tube is kept at 3.5 volts. This grid current does not flow through the cathode resistance.

The electrometer tube is mounted in a small metal box C ( $4 \times 4 \times 5 \text{ cm}^3$ ), hanging on a horizontal wire B (fig. 3.4). This wire B is insulated from the masts by two ceramic insulators. The wire B and the box C are connected to the cathode of the electrometer. A second wire serves to keep the box in a fixed position. The antenna A projects southwards 10 cm from the box. A radioactive sheet (Ra D,  $10 \text{ microC}$ ,  $0.5 \text{ cm}^2$ ) is soldered to the end of the antenna to adapt the antenna to the potential of the surrounding atmosphere. The pentode and the supply batteries were kept in the observatory. The potential gradient is recorded by a Brown servorecorder.

The important advantage of this circuit is, that the output is not high-ohmic insulated from the earth and can easily be recorded. The calibration is very stable because it depends only on the cathode resistance. The deformation of the atmospheric electric field due to the box and the wires causes a potential increase at the radioactive point that is less than 2 volts. One disadvantage of the method is that the snow surface is used as reference level. Because the surface is not completely level, there remains an uncertainty of 5 % in the effective height of the antenna.

### 3. 1. 3 Direct amplifier electrometer

The principal circuit of this electrometer is given in figure 3.5. A radioactive sheet at the end of a vertical antenna brings the antenna at the potential of the air at that height. This potential is connected to the measuring apparatus by an isolated line. A divider of high-ohmic resistance reduces the potential threehundred times. The reduced potential is applied to the grid of an electrometer tube. The measured potential in the air can be determined from the anode current.

The input resistance is  $10^{12}$  ohm.

One advantage of this device is its simplicity. A disadvantage is the changing calibration, even if the supply tensions are stabilised.

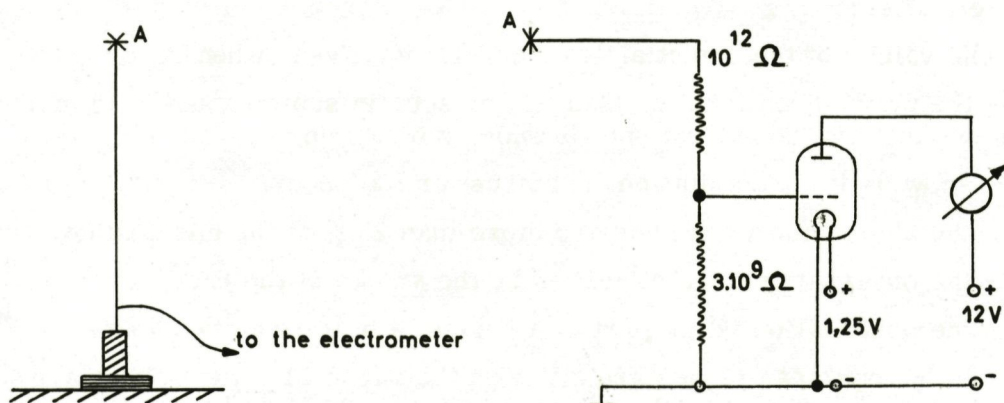


Fig. 3. 5 : Simplified circuit and set-up of the direct amplifier electrometer

### 3.2 Results

The potential gradient close to the surface is influenced by several factors. It is useless to give the results without a certain selection. First we define two types of variations.

#### Short-term variations :

The signal changes at random between every two successive recordings (30 sec. interval). The resulting registration is not a single line but a band of points around a mean value. The width of the band is defined by the band round the mean value that includes 95 % of the registration points. The width can range from unobservable (less than 2 %) to 200 % of the mean value.

Short-time variations are probably caused by changes in the lowest atmospheric layers. Meteorological factors as snow drift and precipitation are the main sources of short time variations.

#### Long-term variations :

Long-term variations are variations in the potential gradient that last 5 minutes or longer. For example : when the ionosphere-earth potential difference suddenly changes, it is about 10 minutes before a new equilibrium in the atmosphere is established and the change has completely penetrated to the surface. On the other hand, changes in the potential gradient are unlikely to originate in the upper atmosphere, when these changes last less than a few minutes (Israel 1961).

Long-time changes can be due to :

- changes in the ionosphere-earth potential difference;
- changes in the meteorological conditions at the surface;
- changes in the meteorological conditions in higher atmospheric layers;
- changes in the ionisation of the atmosphere as function of height.

In general short and long time variations can easily be distinguished in the registrations.

#### Selection :

The values of the potential gradient are not given, when :

- the wind speed is more than 5-7 m/sec. in summer and 7-10 m/sec. in winter. At these wind speeds snow is blown up;
- snow drift, precipitation, hoarfrost or fog occurs;
- the short time variations are more than 25 % of the mean value;
- the observations are disturbed by the smoke of the base;
- the observation is not part of a series of more than two hours.

The hourly mean values are given on the pages 21 - 28. . They are sometimes accompanied by three signs :

E : At the marked hours the conditions were favourable for an a-normal electrode effect (page 14). The electrode effect is a surface effect that causes a potential gradient at the surface that is about twice the potential gradient in free space. This effect is quite constant when the air turbu-

lence is sufficiently great. However during weak winds (less than 1 m/sec) and a temperature inversion close to the surface the air turbulence is reduced and the electrode effect can become more pronounced. In such cases an increase of 0 - 20 % of the normal value of the potential gradient can occur. At the moment the theory is not sufficiently developed to give a correction for this effect. These hourly values are used in the computation of the mean values.

P : Sometimes there is pronounced long-time variations in the potential gradient that completely disappears after 15-45 minutes. Such perturbations are excluded from the hourly mean values. The mean hourly values are obtained by interpolation of the normal course of the registration during the hours that the registration is perturbed. During such a perturbation the short-time variation stayed the same, as distinct from perturbations caused by smoke of the base. The disturbance by the base resulted in an increase in the short-time variation to 50-100%. It is probable that the cause of these "P's" will be found in the atmospheric layers higher than 1 km.

S : During the hours marked by S precipitation of snow occurred.

#### Accuracy :

The inaccuracy in the height of the cathode follower electrometer is about 5 %, the inaccuracy in the distance between the antennae of the inverted triode electrometer is 2 %. Both electrometers have a response-time of a few seconds and so the short time variations that are registered by each, are roughly the same. The input resistance of both electrometers is more than  $10^{12}$  ohm, so the influence of the electrometer on the atmospheric electric field can normally be neglected. The mean values of the inverted triode electrometer and the cathode follower electrometer correspond normally within 10 %. The total inaccuracy caused by these measuring methods can be supposed to be less than 10 %. With some special precautions a useful accuracy of 5 % can be obtained on the Antarctic continent.

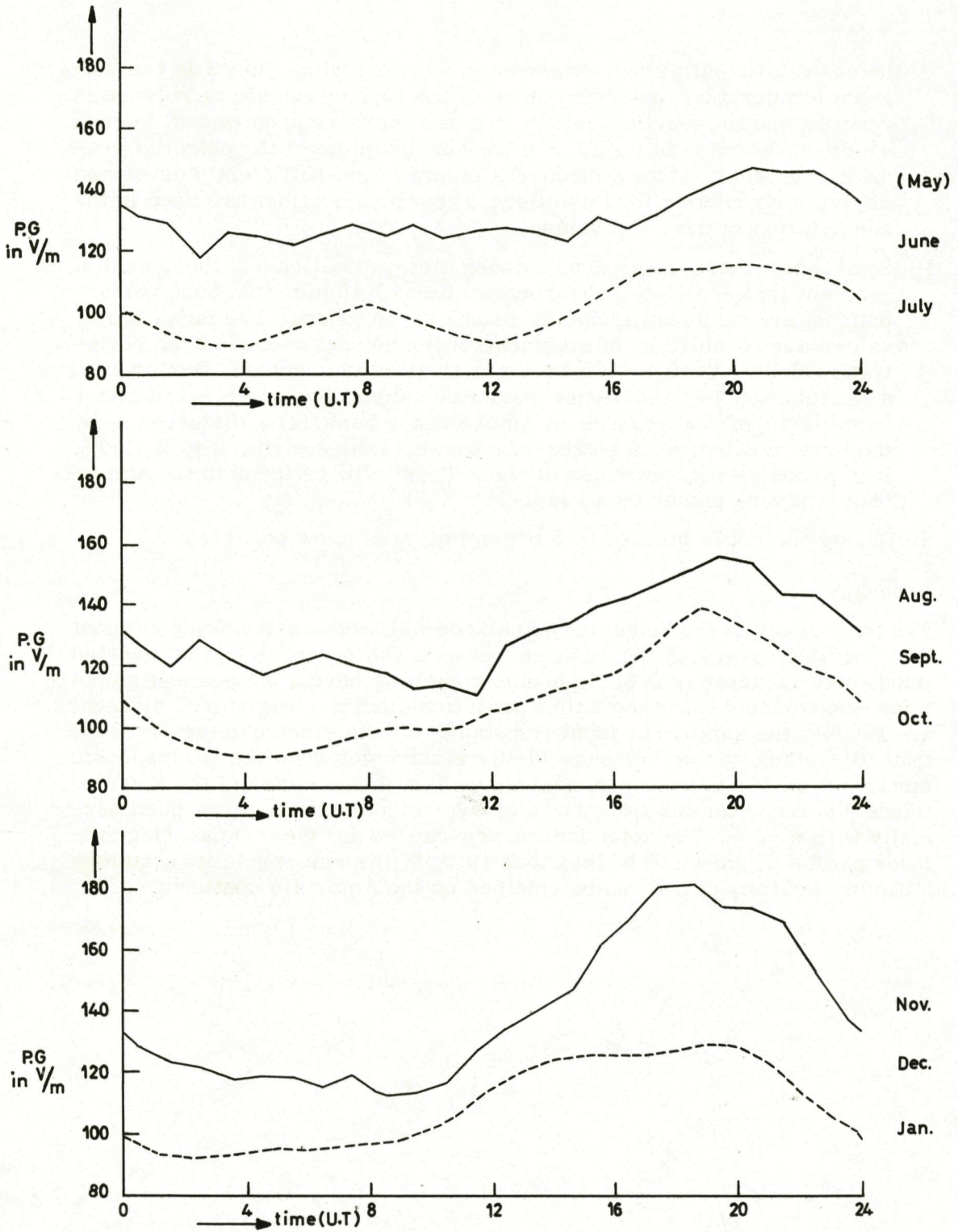


Fig. 3.6 : Mean diurnal variations of the potential-gradient for three-month periods.

----- Carnegie 1915 - 1921, sea observations.

———— Base "Koning Boudewijn", 1964.

Observations :

The hourly mean values are given on the pages 21 - 28. Fig. 3.6 shows the mean diurnal variations of the potential gradient for three month periods, together with the results obtained on board the Carnegie during 1915/1921 (Torreson 1946).

Fig. 3.7 shows the relative yearly variations of the monthly mean for the potential gradient during the same cruises of the Carnegie (Israel 1961), together with the relative yearly variation at base "Koning Boudewijn". The results from base "Koning Boudewijn" are adapted to the results of the Carnegie by assuming November, December and January to be the same in both cases. During March, April and May no registrations were obtained. If we fill up the gap as given in figure 3.7 we can compute a yearly mean value : 141 V/m. The yearly mean value obtained on board of the Carnegie is 116 V/m. The difference in the results can partially be explained from distribution of cosmic radiation that reaches the earth. Because the distribution is determined by the earth's magnetic field, this effect will depend on latitude. This distribution causes a difference in ionisation height functions that results in a potential gradient at the surface that depends on the latitude. Fig. 3.8 shows the observations on board the Carnegie as a function of the latitude (Israel 1961). The same figure shows the yearly mean value obtained at base "Koning Boudewijn".

We can compare the results obtained at base "Koning Boudewijn" during 1959 and 1964.

P. G. in V/m	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Febr.
1959	43	36	42	34	41	41	57	73	65	-
1964	-	136	126	125	133	147	147	152	149	153

It is possible that the mean values during 1959 are lower, because the atmospheric antennae were placed in the vicinity of the base. Another possibility is that the input resistance of the whole system was not sufficiently checked.

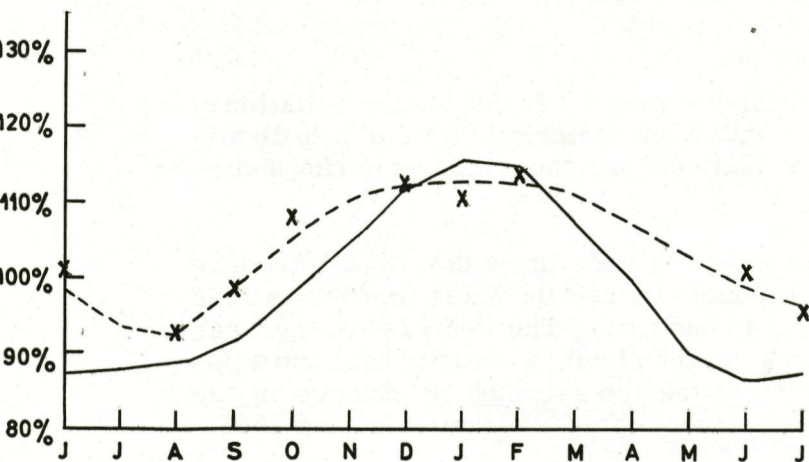


Fig. 3.7 : — Carnegie 1915 -1921  
x Base Boudewijn 1964/65

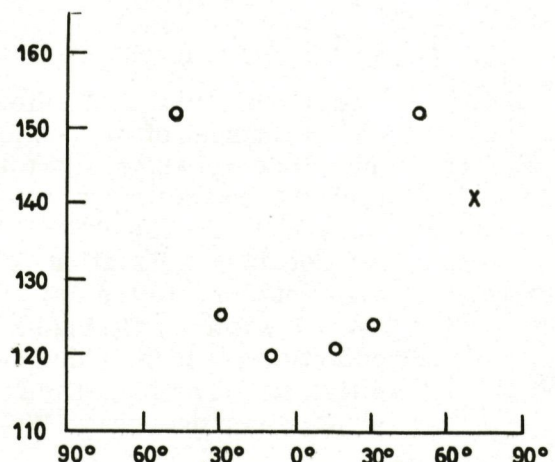


Fig. 3.8 : o Carnegie 1928 - 1929  
x Base Boudewijn 1964/65

### 3.3 Meteorological influences

#### Wind :

Although the wind speed and direction do not influence the potential gradient, important secondary effects can be observed :

- When the wind speed is more than 5-7 m/sec. in summer and more than 7-10 m/sec in winter snow crystals are blown up and disturb the measurements (snowdrift).
- When the wind speed is less than 0.5 m/sec and a temperature inversion develops close to the surface, an increase of the potential gradient is observed. This is due to the electrode effect (page 14).
- When the wind direction is between North and North-West the measurements are disturbed by the smoke of the base.

#### Snowdrift :

Snowdrift causes an increase of the potential gradient and its variations. This effect is mainly due to the decrease of the conductivity of the air, because the ions are partially caught by the snow crystals. The space charge due to the snow crystals can also cause a change in the potential gradient.

That this increase is not caused by the discharging of snow crystals that touch the antennae can be seen by comparison of the observations of the inverted triode electrometer and the cathode-follower electrometer. The sensitive surface of the cathode-follower electrometer that can be touched by snow crystals is about 100 times smaller. However, the increase of the potential gradient is the same for the two electrometers. This implies that a real increase is measured and not a charging effect (Koenigsfeld 1963). Thus it is no use to construct a complicated shielding to protect the antennae from ice crystals. It is possible that the influence of the snow crystals touching the antennae becomes important at higher wind speeds.

#### Snow storm :

Although more pronounced, the effects are the same as during snowdrift: increasing potential gradient and stronger variations. Sometimes the potential gradient is negative during certain hours.

#### Snow precipitation :

The mean potential gradient decreases in general during the precipitation of snow. Changes of 100 % and more with a characteristic time of 5 to 10 minutes occur, while short time variations are the same as during undisturbed circumstances.

A probable explanation for this effect is : the snow does not introduce many nuclei into the air so the conductivity and the short time variations are the same as during undisturbed conditions. The decrease of the mean potential gradient is due to charges in the cloud, a negative base and a positive top. The long-time changes can then be ascribed to changes in the cloud cover overhead. We will try to check this explanation during 1966.

Hoar-frost :

Hoar-frost causes a break down of insulation that is not specially protected. Our recordings during hoar-frost are completely useless. Probably it is no use protecting the insulation, because during hoar-frost ice crystals are observed in the air. These crystals can disturb the potential gradient in the same way as drifting snow.

Fog :

Fog occurs so seldom that it is impossible to give a general description after one year. The potential gradient was the same or slightly less than normal in the observed cases.

4. Measurements of the atmospheric electric potential gradient as a function of height.

4.1 The sonde

The potential gradient is measured by means of radioactive points at the end of two antennae. One radioactive collector, B, is at the side of the sonde at a distance of about 25 cm, the other one, A, is hanging below the sonde. The vertical distance between the two collectors is 150 cm. (see fig. 4.1)

The potential difference between the two antennae is measured with an electrometer based on the principle of Koenigsfeld-Piroux (Koenigsfeld 1963), the so-called inverted triode electrometer.

The electrometer is adapted to fit the American meteorological sonde AN/AMT4 (see fig. 4.2) by using the humidity contacts for the temperature measurement and connecting the temperature contacts to the electrometer circuit.

The result is that the atmospheric potential gradient is measured till the balloon bursts and that the temperature is measured up to about 12 km. If needed, we can derive the temperature from the normal meteorological sounding that is made a few hours afterwards. The accuracy obtained by this method is sufficient for atmospheric electric purposes.

In order to check the zeropoint during the flight the "high reference contact" on the signal bench of the sonde is cut loose. This contact is connected to the lower antenna. When the earthed contact arm passes over the 30th, 45th

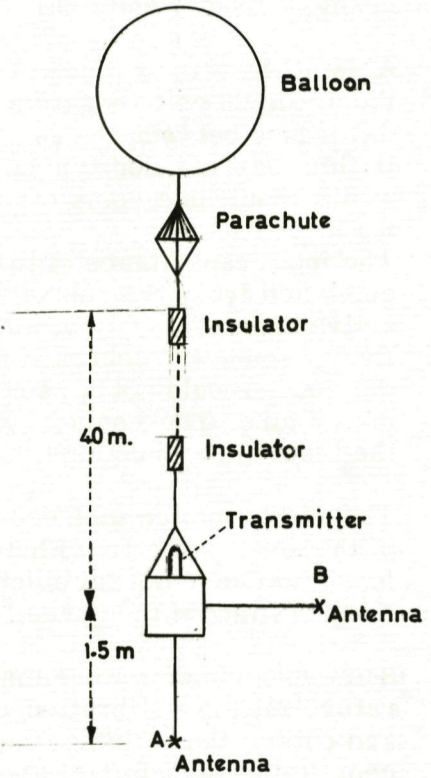


Fig. 4.1. The atmospheric electric sonde.

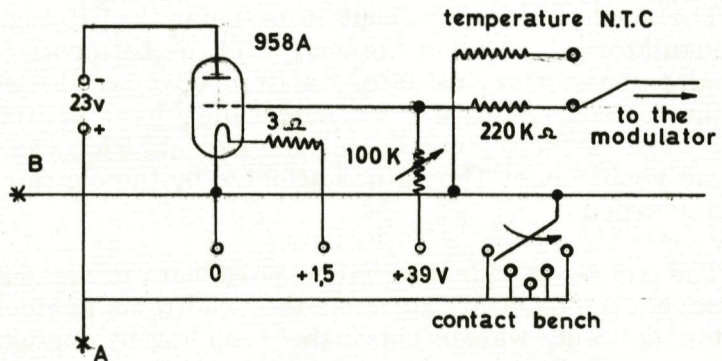


Fig. 4.2. The electrometer of the sonde.

etc. contact the lower antenna is connected to the mass of the sonde and the zero of the electrometer is indicated on the recorder. The zeropoint changes about 4 volts during the flight.

A small battery is placed between the anode and the lower antenna to keep the anode 23 volts negative with respect to the cathode, when the potential difference between the two antennae approaches zero.

If this was not done, a small potential difference between the antennae would result in a complete breakdown of the input resistance.

The input capacitance of the sonde is about 30 pF. The input resistance is computed from the relaxation time of the discharge curve without radioactive antennae. Only sondes with an input resistance of  $10^{13}$  ohm are used. Every sonde is rechecked half an hour before launching. Fifty percent of the sondes could not be used, mainly because of leakage inside the electrometer tube. The contact bench has to be of high ohmic material to keep the input impedance high.

The electrometer tube proved to be extremely sensitive to the ultraviolet of the solar radiation. Photoionisation causes a complete breakdown of the input resistance of the electrometer tube. During daytime-soundings careful darkening of the sonde is necessary.

Some experiments were made to determine the influence of the air temperature on the calibration of the sonde. The sonde was calibrated inside and outside the building, the temperature difference being about  $50^{\circ}$  C. Except for a zershift of about 3 volts no change in the calibration could be measured. The zershift is probably due to a change of the battery at the anode and the electrometer is not affected by a change in temperature.

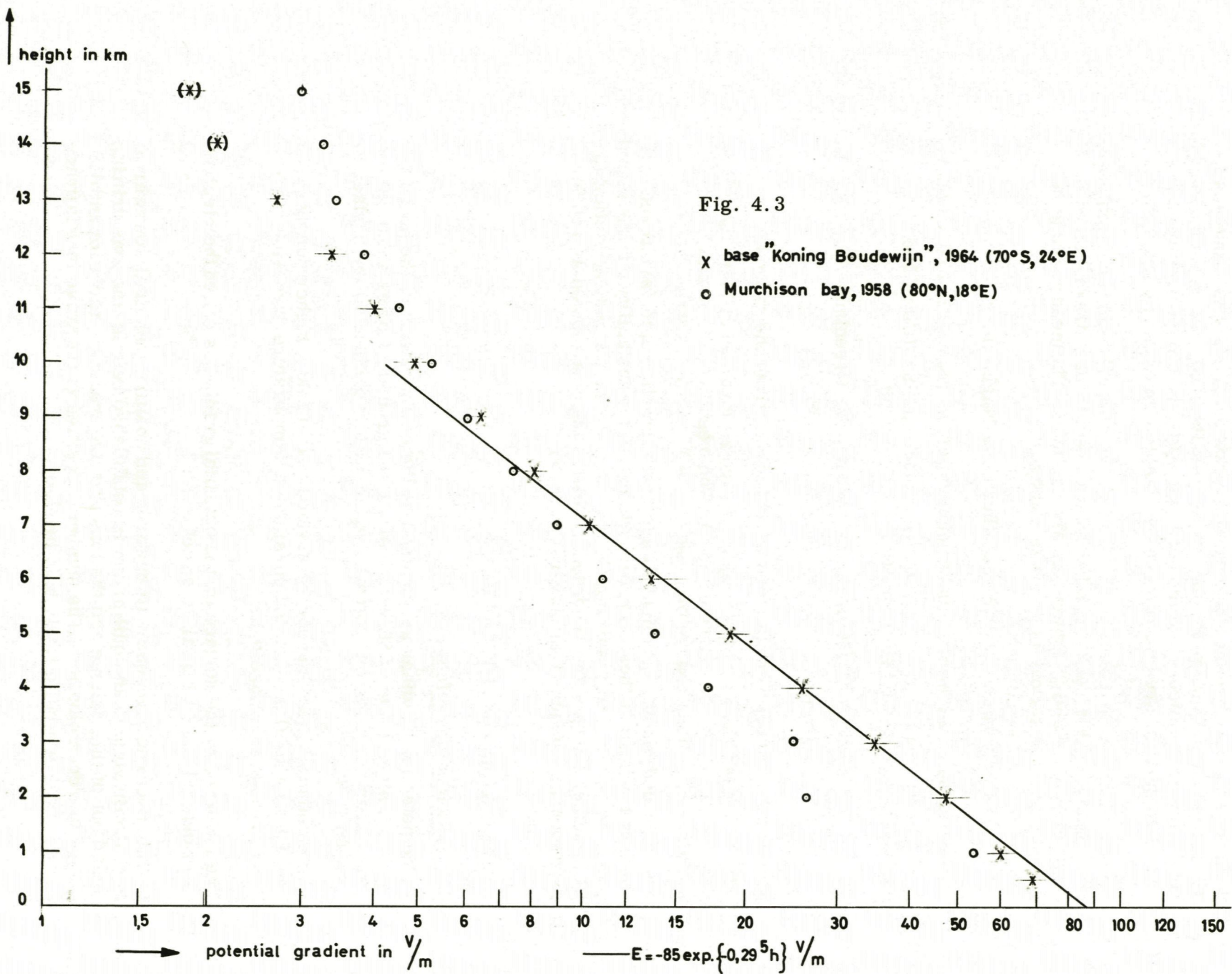
#### 4. 2 Launching

The sonde is hanging about 40 m under the balloon. We used two high ohmic insulators to prevent the charge of the balloon from influencing the measurements. One insulator is attached near the sonde, the other close to the balloon. However, we sometimes have difficulties from the electric charge of the balloon during the ascent. This can easily be recognized in the recordings. The values affected by the charge of the balloon have been discarded.

The sonde is launched with a parachute to measure the potential gradient during the descent. Because the conditions are completely changed during the descent, we can check the sounding by comparing the ascent and descent values.

The battery of the American sonde can be used for about three hours after activation. The ascent lasts at least two hours, so the calibration and the measurement of the input resistance and other preparations have to be done in less than half an hour. Often the battery is exhausted before reaching the surface.

Because of the large distance between the balloon and the sonde and because of the delicate electric antennae it is not possible to launch a sonde when the wind is 10 m/sec or more.



### 4.3 Results

The results of 11 successful soundings are given on the pages 29 - 39. Soundings were only performed when the sky overhead was cloudless, so as to simplify the interpretation of the results. Only the sounding on 23 September was noticeably influenced by clouds. 17 sondes have been launched, 4 of the 6 failures were due to incomplete darkening of the sonde.

The decrease of the potential gradient as function of height is approximately exponential. Fig. 4.3 gives the mean of 9 soundings, the disturbed soundings of 13 June and 23 September are excluded. The mean gradient height function below 8 km can be represented by

$$E = -80 \exp(-0.295 h) \text{ V/m, where } h \text{ is height in km.}$$

The coefficient of the individual soundings ranges from  $0.27$  to  $0.33 \text{ km}^{-1}$ . Airborne atmospheric electric measurements in 1955 (Clark 1958) give as undisturbed gradient-height function

$$E = E_0 \exp(-0.250 h) \text{ Søndre Strømfjord, Greenland;}$$

$$E = E_0 \exp(-0.285 h) \text{ Chesapeake Bay, U.S.A..}$$

The measurements were performed up to 6 km from the ground.

Fig. 4.3 gives the gradient-height function as obtained at Murchison Bay, Spitzbergen 1957-1958 (Lugeon 1960). The results were not selected for influence of balloon charge or clouds.

The recorded potential gradient always shows small, rapid variations. The width of the band of these variations is called the instability of the signal and is given with the results of the soundings. Sometimes long-lasting (3-10 minutes) changes are recorded. These changes are possibly related to phenomena in the upper air layers (page 6).

## 5. SPECIAL INVESTIGATIONS

### 5.1 The electrode effect :

- The potential gradient as obtained by the extrapolation of the soundings gives a mean value of 80 V/m close to the ground. This is about 50 % of the mean value of the potential gradient found close to the surface at 00.00 U. T. .
- The potential gradient near the surface is up to 20 % higher during hours of weak winds (less than 0.5 m/s) and a temperature inversion close to the ground. (see page 6).

The influence of the surface on the potential gradient is called the electrode effect and can be explained as follows :

In free space negative ions drift upwards and positive ions drift downwards. In a certain volume an equilibrium is established between the ions drifting in and out of this volume and the ions that are created by radiation and destroyed by recombination. The number of positive and negative ions is practically equal at a sufficiently high level.

The surface-air boundary cannot be crossed by negative ions, so the conduction current is completely due to the positive ions. We can prove that the number of positive ions close to the surface and in free space is practically the same when the air is sufficiently turbulent. As the current density at the surface is twice the current density in free space due to positive ions, the potential gradient at the surface has to be twice the potential gradient in free space. If the mixing by air turbulence is not sufficient during weak winds and a temperature inversion, the number of positive ions decrease close to the ground. Now the potential gradient will increase even more because the current density is independent of height and independent of this surface effect.

The electrode effect has been known in theory from the beginning of this century (Von Schweidler 1908, Swann 1913, Chalmers 1966). Calculations not including the air turbulence predict an increase of 170 % close to the ground. Up to a few years ago the electrode effect had never been observed due to several disturbing factors: nuclei, additional ionisation due to the radio-activity of the earth etc.. This situation is not encountered above the sea and above the snow fields of the Arctic and the Antarctic continent. The first satisfactory observations of the electrode effect were given by Mühleisen (1961) and Ruhnke (1962). Mühleisen found an increase of the potential gradient close to the sea surface ranging from 40 to 80 % of the free space value. Ruhnke found large effects, especially during weak winds. The potential gradient at base "Koning Boudewijn" was found to be greater during weak winds with a temperature inversion close to the ground.

One of the purposes of the atmospheric electric programme during 1966 is a better understanding of the observations and theory of the electrode effect from observations. For this purpose the potential gradient is measured at heights at 1, 2, 4 and 6 m. The connection of the effect with wind and temperature as a function of height will be studied. The effect as a function of height will be measured when the conditions are suitable.

## 5.2 Influence of auroras

The potential gradient is in general quite stable when the wind speed is below 5 m/s. However, sometimes there are changes in the potential gradient that cannot be attributed to changes in the meteorological circumstances (page 10). Sometimes these changes seem to be due to the auroral activity.

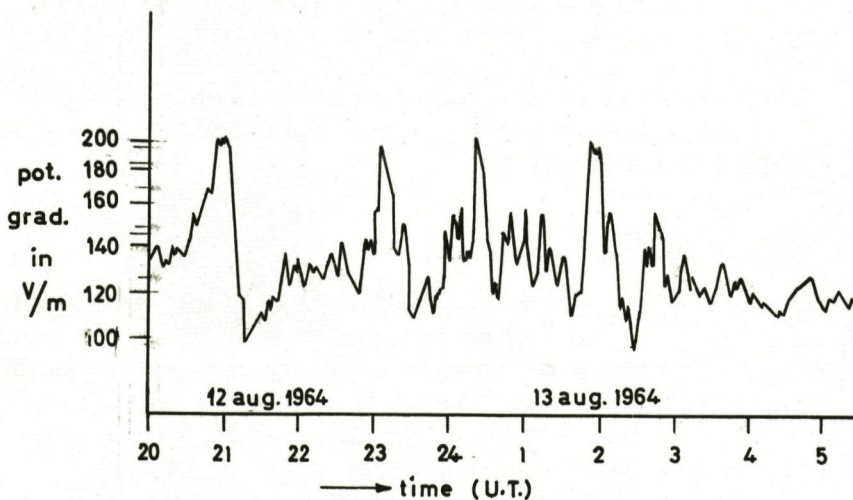


Fig. 5.1. The electric field during an auroral display.

Examples are the recordings of the potential gradient during the night of 12 to 13 August 1964. At 21.00, 00.30 and 02.00 U. T. the aurora changed from a quiet homogeneous arc brightness 1-2 to draperies, brightness 2-4. At 23.00 U. T. no auroral observations were made. The wind speed was always less than 5 m/sec. At 24.00 U. T. ice needles were observed. Sometimes sudden changes are observed in the potential gradient at a sounding during an auroral display. (page 29).

Much contradiction is found in literature about the influence of auroras on the potential gradient. Scholz (1935) gives results that show the same changes in the potential gradient as mentioned above. Others (Wait 1923, Israel 1961) do not find a clear correlation. It is possible that this contradiction can be solved if the type of aurora is taken into account (Chamberlain 1961, Swift 1965).

During 1966 more accurate observations will be made.

### 5.3 Influence of buildings and other constructions

Nearly all the materials used for construction have a specific resistance that is small compared to the specific resistance of the air. For atmospheric electric purposes they can be regarded as conductors. Thus in the neighbourhood of buildings the equipotential layers are not horizontal and no reliable observations can be made.

An electric analogon was built to get an impression of the influence of a building on the atmospheric electric field. A sheet of copper was folded to make a simple model of a building. This was placed in water and connected to the negative pole of a battery. The positive pole of the battery was connected to another sheet of copper placed at a relatively large distance. The equipotential layers could now be measured in the solution. The results showed that the disturbance of a building is negligible at a distance of more than twice the height of the building. This conclusion made it necessary to build a special cottage under the snow at 150 m south of the base.

A so-called "reduction factor" is often used in literature to compute, from observations made close to a building, the values of the potential gradient in undisturbed circumstances (Israel 1961). This is a doubtful method because space charge develops near the building as a result of the change in the potential gradient and as a result of the electrode effect. This space charge moves with the air and so the reduction factor is dependent on the air turbulence and wind speed. Atmospheric electric observatories should be built under a large and flat surface.

### 5.4 The conductivity of the snow

In general the earth is considered to be a perfect conductor compared to the air. If this is true, the earth will be an equipotential surface in undisturbed circumstances. Doubt as to the validity of this important assumption was expressed in the report of the expedition of 1959 (Koenigsfeld 1963). The resistance of the snow near the base was measured in order to check if this assumption was also valid for the snowfields of the Antarctic.

**Measuring principle :**

A sample of snow is placed between two copper grids (fig. 5.2). When a tension is applied to the grids, a current,  $i$ , flows and is measured by a sensitive ammeter A. The potential difference  $V$  between two points in the sample is measured with a high ohmic voltmeter B. Now we can compute the specific resistance,

$$\rho = \frac{V \cdot 0}{L \cdot i}$$

with  $0$  = the cross sectional area of the sample ( $44 \text{ cm}^2$ )

$L$  = the vertical distance between the two contact points (5-10 cm).

The snow sample and the voltmeter, B, are both high ohmic isolated from the ground. This method was used to exclude the influence of the contact of the snow sample and the grid.

**Results :**

Snow samples were taken with a drill down to 10 m. The mean length of the samples was about 20 cm. The temperature during the resistance measurements was between  $-13.0^\circ\text{C}$  and  $-11.5^\circ\text{C}$ . Although the results of measurements on one sample are reproducible within 20 %, there is a difference of a factor of 10 between the observations on different samples. Taking the mean of 60 measurements we get :

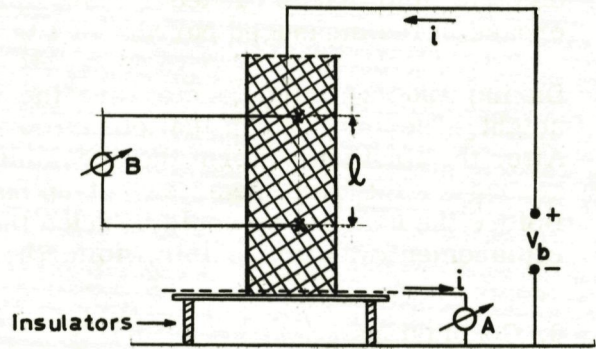


Fig. 5.2 Measurement of ice resistance.

Depth in metres	0-2	2-4	4-6	6-8	9-10
Spec. resistance in Megaohm. metres	0.52	1.12	0.58	0.53	0.35

The mean specific resistance of the snow on the Greenland icecap is 0.5 Megaohm. metres (Israel, personal communication). The samples with the finest crystal structure have the highest specific resistance.

**Conclusion :**

The specific resistance of the snow is low compared to the specific resistance of the air near the ground ( $5 \cdot 10^7$  Megaohm.m), thus the snow surface can be considered as an equipotential layer during undisturbed circumstances. This does not imply that there are no potential differences in the snow surface during snowstorms. They are caused by mechanical charge transport by drifting snow. While the equipotential layers are horizontal during fair weather, strong deviations may occur during snowstorms due to the charges on the surface and in the drifting snow.

## 5.5 Problems with current measurements.

A reliable current density measurement is difficult to perform. A current density that is obtained by multiplying conductivity and the potential gradient (indirect method) is wrong, because the contribution of the convection current is neglected. Direct measurements of the current density are performed by spreading an insulated net close to the surface. The received current density is assumed to be the current density between earth and ionosphere. Although this is one of the best methods, the system is difficult to use in Antarctica, because during snow drift the net is quickly buried. As the snow is rather hard in Antarctica, it costs much time to dig it out undamaged. At our station snow drift occurred almost every day. Spreading the net at a height of 2 metres has two disadvantages : Firstly: because of the field deformation the current density is more than normal. Secondly: the space charge caused by the electrode effect drifts between the net and surface because of air turbulence. The ions will partly drift to the net because of the electric field that is caused by this space charge. This can cause an increase in the measured current of 10-20 %.

During 1964 we tried to measure the current density with a net at 10 cm height. The snow storm that occurred soon after caused an accumulation. After the first snow storm the accumulation caused by the net became dangerous for the base, so a new set-up had to be made far from the buildings. Before the new set-up could be tried the current meter broke down and, as replacement was impossible, no further attempts were made.

## 6. Conclusions :

### 6.1 Measurements

The estimated yearly mean value of the potential gradient is 141 V/m during 1964. A daily variation was observed: the difference between maximum and minimum being about 15 % of the mean value during the Antarctic winter and 30 % during the Antarctic summer. A yearly variation was observed: during the Antarctic winter the mean value was 130 V/m, during the summer 150 V/m. These results are in reasonable agreement with the observations during the cruises of the Carnegie. (page 8 ).

The potential gradient height relation can be expressed by

$$P. G. = 80. \exp (-0.295 h) V/m.$$

The electrode effect (page 14) is clearly seen by comparison of the surface measurements and the soundings. Approaching the surface the potential gradient increases by 80 %.

Possibly the potential gradient is affected by active auroras (page 15). The potential gradient increases shortly before or during the increase of auroral activity. The original, unperturbed value of the potential gradient is observed when the auroral activity disappears.

The stable signal that is often registered during clear days with weak winds is sometimes perturbed by an increase that can be more than 100 %. After 15-45 minutes the normal value is registered again. During the change the stability of the signal is not affected.

## 6.2 Apparatus

In Antarctica the insulation problem is simple : an unprotected clean piece of perspex is the best insulator. More complicated insulators are not suitable because snow adheres behind every unevenness.

The cathode-follower electrometer (page 4) is suitable for potential gradient measurements at the surface, because the insulation problem is reduced and the calibration remains constant.

The inverted triode electrometer is suited for potential gradient measurements in the upper atmosphere. The calibration is stable during the hours of the sounding and the circuit is very reliable, if precautions are taken (page 12).

The snow can be considered as a conductor for atmospheric electric measurements during hours without snow drift. The measurements have to be performed far from masts and buildings.

## 7. ACKNOWLEDGEMENTS

I want to thank Prof. Dr. H. Israel and Prof. Dr. L. Koenigsfeld for their valuable advice and Prof. Dr. W. Bleeker for the support of the atmospheric electric programme for 1966. I am grateful of the members of the meteorological group of the expedition for the help given during the soundings and the construction of the observatory during the Antarctic winter.

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**SURFACE OBSERVATIONS**

JUNE 1964

	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	
20				145	140	130	140	145	150	145	135	150	150	155											
22		145	125	140	130	130	130	140	155	150	135	135	145	160	145	155	140	140	155	155	160	170	170		
24						125	140	125	150S										160	160	170				P: 8-9
26		125	110	110	120	135	130	125	125	120	120														
30	140	120	110	105	110S	125	120S	110	90	100	110	120S	115	110	120	120	130	130	145	140	140	135	135	135	P: 4-5;6-7 and 11-12
Average	140	130	115	125	120	129	132	129	136	129	125	135	136	142	138	142	135	135	153	151	156	152	152	135	

JULY 1964

	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24
1	120	120	120	125	125	130	130	135	135	140	135	135	130	130	130	130	130	135	145	160	165	165	160	145
2	125	130	120		125	105	115	120	120	130	120	115	135	115	110	135	130	120	125	140				
23										105	110	110	95	95	95 S	100	105		105	107	114	120	124	
Average	122	125	120	125	125	117	122	127	127	125	123	120	120	113	112	122	122	127	125	136	140	142	142	145

AUGUST 1964

	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	
8													115	115	115	110	115	115	120	150					
9			145	120	110	120																			
10							90	90	95	110	120														
12														130	130	125	130	145	155	155	135	140	135		P : 20-24 E : 22-24
13	145 S	145 S	130	120	135	140	150	155	150																P : 0-2 E : 0-4
20													130	135	130	120	135	140	150	160	150	145	140	140	
21	135	115	120	110	120	100	105	105	115	105	95	100													P : 4-5
22													95	95	97										
Average	140	130	132	116	124	120	115	117	120	107	107	100	112	115	118	122	123	128	137	145	152	140	140	137	

SEPTEMBER 1964

	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	
2													130	140	135	130	135	145	140	155	145	130	145	135	
3	120	140	150	150	150	140	150	155	160	160	155	150	140 S	140	145	155	100	135							P : 12-13 in de morgen
23													140	145	135	135	135 S	130							P : 16-17 luchtspiegdingen
24	120	120	120	125																					
25								105	110	110	110	115	120	120	115	135	170	170	165	150	145	145	140	120	
26	110	110	115	125	115	120	120	125	120	115	110 S	110													P : 10-11
Average	116	123	128	133	122	120	135	128	130	128	125	125	137	139	133	139	135	145	152	153	145	138	143	127	

OKTOBER 1964

	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24			
14																			110	110	115	120			S : 22-24		
15						140	135	130	115	115	115	120	120	115												S : 0-24 occasionally	
20														170	155	165											
23																163	171	176	180	180	190	176	163	159		P : 20-21	
24	131	119	135	123	123	131	132x	132	119	119	130	123				170	195	195	192	192	180	172	153	152		E : 12-18 and 16-21	
25	143	139																									
28																	176	176	185	198	185	198	170			P : 22-23	
29											176		176	176	176	180	185	171	194	198							P : 18-19
30																	185	198	219	219	222						
Average	131	119	135	123	123	135	133	131	117	117	122	121	148	154	165	170	182	183	180	183	178	166	162	155			

NOVEMBER 1964

	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24		
1																	159	174	198	210	159					
2												126	134	151	167	176	176	189	194	202	206					P : 17-18
3													143	159	155	167	163	180	194	176	214	143	143	122		P : 16-17
4	122	122	126	130	126	122	126	130	122	118	122	126	134	139	176	198	202	206	210	198						
5															166	180	189	189	196	176	163	167	159	130		P : 16-17
6	118	122	114	105	65	90									151	151	159	155	194	219	198	194	143			P : 16-17
7														143	155	194	176	171	185	189	180c	194	171			P : 18-19
17										135	140	148	190	182	182	177	190	199	204	186	161					P : 13-14
19							92	100	100	118	114	131	135	148	148	161	182	199	169	169	169	161				
20																	190	190	182	214	190	182	165	148		
21										120	122	135	144	140	144	157	182	190	182	177	169	157	157	135		P : 14-15
22														122	140	144	165	177	173	165	161	148	114			
23							84	96	92	88	100	109	100	118	114	118	118	131	122	118	122	114	105	100		
24	92	83	83																							
25															152	144	165	204	214	204	190	186	173	165		
27															157	165	177	206	209	214	214	190	186	190		E : 20-24
28	186	214	194	194	209	177	173	165	157	157	157	165	152	152	177	173	177	204	209	218	209	199	209	190		E : 0-24
29															165	161	182	182	182	194	186	173	148	135		
30															165	177	169	173	173							
Average	129	135	129	130	133	133	119	123	118	123	126	134	141	145	156	165	172	184	188	190	181	170	156	146		

DECEMBER 1964

	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24		
9													183	183	192	210	229	253	224	224	234	206	183		P : 16-18	
10													155	160	165	169	169	177								
15													132	142	155	175	188	197								P : 14-18
16							164	132	143		143	165				197	185	190	18180							P : 16-17
21																148	170	166	170		168	172	139	125		P : 18-21
22	121	125	130																							
24	134	123	130	121	121	107	108	120	124	130	130	139	143	150	148											
25													132	150	180	158	210	213	200	195	202	175	148	135		P : 14-15 E : 15-21
26	130	125	125																							
27												152	168	182	195	205	207	223	225	217	220	203	188	198		
28	185	151	160	160	177	179	166	153	129	135	153	142	140	140	138	154	156	165	190	200	176	160	155	148		
29															175	195	197	206	175	163	200					
31				155	140		144	153	135	143	149	161	154	170	168	175	180	180	185	206	200	180	172	164		
Average	143	131	138	140	151	142	139	147	130	138	144	152	151	160	168	179	189	197	194	201	200	183	164	154		

JANUARY 1965

	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24		
4																			207	193	168					
5																					240	220	195	153	S : 15-18 P : 20-21	
6	128	128	133													177	197	193	207	190	180	153x	133			
7					123	123		117	130							163	192	202	240	260	240	220	183	197	153	S : 12 P : 17-20
8																136	163	187	190	188				180	165	
9	173																									
10	132	121	132	123	112	114		117	117																	E : 18-19
11												125														
12													150	150	160	190	190	183	188	218	254	224	203			
14													138	138	138	155	162	160	151	156						S : 21-24
15	158	158	134	113	107	107	124	127	124	113	117	134	138	154	148	144	163	183	203	204						
16																238	254	260	244	254	224					Strong mirage
19															120	143	115	143	143	149						S : 0-6 and 21-24
20									110	110	110	105														S : 3-6 and 21-24
24																175	180	180	190	187	185	178				
25															165	180	180	200	195	210	215	195	190			
26																					186	173	164	134	116	S : 3-6
Average	148	136	133	118	114	115	119	121	117	112	111	130	142	147	147	176	183	192	197	197	204	188	176	144		

FEBRUARY 1965

	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24		
4										160	157	170	16168	170	180	195	191	203	242	242	260					P : 20-21 E : 18-24
5			132	122	146	127	118	118	130	113	132	148	150	144	148	164	180	175	180	190	183	175				P : 19-20
6																175	175	180	200	203	203	184				E : 18-24
7										136	136	132	146	175	175	170	163	180	180	165	185	180	215	200		E : 18-24
8														175	200	200	200	203	190	185	175	160	165			P : 17-18 and 22-23
10																	190	190	200	193	200	192	197	190		P : 21-22
11														185	190	202	193	190	190	195	184					P : 16-17 and 20-21
Average			132	122	146	127	118	118	130	125	134	140	148	170	178	182	184	186	190	188	188	178	192	195		

UPPER-AIR OBSERVATIONS

BASE "KONING BOUDEWIJN"

11 April 1964 00.00 U. T.

HEIGHT in km	PRESSURE in mb	TEMPERATURE in °C	POTENTIAL GRADIENT in V/m	
			ascent	descent
0.5	930	-10.8	-	-
1.0	872	11.5	+65	-
2.0	765	13.5	59	-
3.0	670	17.8	45	-
4.0	585	22.4	29.5	-
5.0	510	28.0	20.5	-
6.0	442	35.6	15.5	-
7.0	382	42.0	11.5	-
8.0	329	49	9.4	-
9.0	282	54	7.4	-
10.0	243	57	5.8	-
11.0	207	51	4.5	-
12.0	177	51	3.3	-
13.0	152	-51	2.6	-
14.0	131	-	2.1	-
15.0	111	-	+ 2.0	-

Remarks

The stability of the signal during the ascent is :  
0 - 5 km 2 V/m  
5 - 10 km 1 V/m  
10 - 15 km 0.5 V/m

Clear sky.

Because the sonde was launched without parachute, no results were obtained after the balloon burst.

BASE "KONING BOUDEWIJN"

13 June 1964 00.00 U. T.

HEIGHT in km	PRESSURE in mb	TEMPERATURE in °C	POTENTIAL GRADIENT in V/m	
			ascent	descent
0.5	930	-21.6	+ 32.7	-
1.0	869	21.7	30.8	-
2.0	757	23.7	23.0	-
3.0	658	30.2	22.5	-
4.0	572	36.8	19.3	+ 23.4
5.0	494	43.6	16.0	19.8
6.0	425	49.5	11.6	15.9
7.0	363	56	9.5	12.7
8.0	310	61	7.5	9.5
9.0	264	64	5.8	7.3
10.0	224	66	5.0	6.0
11.0	190	66	4.7	5.0
12.0	161	67	4.4	4.0
13.0	136	-68	3.9	3.2
14.0	114	-	2.8	3.0
15.0	94	-	+ 2.5	+ 2.5

Remarks

Clear sky. No drifting snow.

Stability of the signal : 0 - 2 km 1 V/m  
 2 - 6 km 2 V/m  
 6 - 15 km 0.5 V/m

During the first 15 minutes of the ascent an aurora was seen overhead : a fast moving drapery with brightness III to IV. When the balloon was at 1.2 km there was a sudden lowering of the potential gradient (7 V/m). The gradient recovered over the following 10 minutes. The change in the potential gradient was completed in 20 sec. During the change the stability of the signal of 1 V/m was preserved. The gradient recovered over the following 10 minutes. No special change in temperature was recorded at this height.

BASE "KONING BOUDEWIJN"

24 June 1964 00.00 U. T.

HEIGHT in km	PRESSURE in mb	TEMPERATURE in °C	POTENTIAL GRADIENT in V/m	
			ascent	descent
0.5	955	-13.7	+64	-
1.0	895	13.9	55	-
2.0	782	13.8	41	-
3.0	687	20.2	34	-
4.0	598	27.0	26.0	-
5.0	519	34.1	19.7	-
6.0	441	42.6	14.5	-
7.0	387	50	10.4	-
8.0	331	57	8.4	-
9.0	283	63	6.7	-
10.0	239	67	5.0	-
11.0	202	70	3.5	-
12.0	170	71	2.4	-
13.0	143	-71	1.7	-
14.0	118	-	1.4	+ 1.0
15.0	99	-	+ 1.0	+ 0.9

Remarks

Clear sky.

During the flight a faint aurora was seen : diffuse surfaces, brightness II.

There were no special effects on the potential gradient.

The stability of the signal during ascent is :

0 - 5 km	2 V/m
5 - 10 km	1 V/m
10 - 15 km	0.3 V/m

BASE "KONING BOUDEWIJN"

22 July 1964 00.00 U. T.

HEIGHT in km	PRESSURE in mb	TEMPERATURE in °C	POTENTIAL GRADIENT in V/m	
			ascent	descent
0.5	930	-15.9	+50	-
1.0	869	18.2	44	-
2.0	760	23.0	34	-
3.0	662	26.8	24	-
4.0	574	35.0	17.0	-
5.0	496	43.5	13.2	-
6.0	426	49.4	10.7	-
7.0	366	57	9.1	-
8.0	311	62	8.0	-
9.0	266	65	6.7	+6.7
10.0	225	69	5.5	5.3
11.0	189	70.0	4.6	4.3
12.0	160	-73.0	3.8	3.5
13.0	133	-	3.2	2.8
14.0	110	-	2.5	2.1
15.0	91	-	+ 2.0	+1.5

Remarks

Clear sky

The stability of the signal during the ascent is : 0 - 5 km 2 V/m  
 5 - 12 km 1 V/m  
 12 - 15 km 0.5 V/m

BASE "KONING BOUDEWIJN"

23 July 1964 00.00 U. T.

HEIGHT in km	PRESSURE in mb	TEMPERATURE in °C	POTENTIAL GRADIENT in V/m	
			ascent	descent
0.5	930	-17.1	-	+65
1.0	871	18.1	-	58
2.0	760	22.5	-	44
3.0	662	27.3	-	33
4.0	576	33.7	-	23.7
5.0	497	39.2	-	16.7
6.0	428	46.8	-	11.0
7.0	368	54	-	8.6
8.0	313	62	-	7.2
9.0	267	67	-	6.0
10.0	226	70	+ 4.3	4.5
11.0	190	72	3.9	3.9
12.0	160	-73	3.4	3.3
13.0	134	-	2.8	2.8
14.0	112	-	2.4	2.4
15.0	92	-	+ 1.9	+ 1.8

Remarks

Clear sky.

The stability of the signal during the descent is :

0 - 3 km	5 V/m
3 - 10 km	2 V/m
10 - 15 km	1 V/m

BASE "KONING BOUDEWIJN"

24 July 1964 00.00 U. T.

HEIGHT in km	PRESSURE in mb	TEMPERATURE in °C	POTENTIAL GRADIENT in V/m	
			ascent	descent
0.5	936	-17.2	-	+66
1.0	875	16.3	-	57
2.0	766	19.8	-	42
3.0	668	24.4	-	32
4.0	581	32.1	-	23.8
5.0	504	38.6	-	18.2
6.0	434	45.5	-	13.2
7.0	373	53	-	11.1
8.0	318	60	-	9.0
9.0	270	67	-	7.7
10.0	228	70	-	6.3
11.0	193	72	-	5.3
12.0	163	-72	-	4.4
13.0	137	-	+ 3.7	3.6
14.0	114	-	3.3	3.0
15.0	97	-	+ 3.1	+ 2.7

Remarks

Clear sky.

The stability of the signal during the descent is :  
 0 - 5 km 6 V/m  
 5 - 15 km 1 V/m

BASE "KONING BOUDEWIJN"

9 August 1964 15.00 U. T.

HEIGHT in km	PRESSURE in mb	TEMPERATURE in °C	POTENTIAL GRADIENT in V/m	
			ascent	descent
0.5	921	-25.0	+63	+75
1.0	862	21.7	56	58
2.0	753	25.0	50	48
3.0	654	32.3	40	35
4.0	566	40.0	31.6	25.0
5.0	488	46.5	24.0	17.8
6.0	418	53.5	16.0	11.5
7.0	360	58	13.0	9.5
8.0	304	61	8.0	6.9
9.0	258	64	5.3	+ 5.2
10.0	220	66	3.6	-
11.0	184	-68	+ 2.8	-

Remarks

Clear sky..

During the flight an aurora was seen 25° above the horizon : quiet homogeneous arc, brightness II. No special effect on the potential gradient.

The stability of the signal during the ascent is :  
 0 - 4 km 2 V/m  
 4 - 8 km 1 V/m  
 8 - 12 km 0,5 V/m

The stability of the signal during the descent is : 0 - 10 km 1 V/m

The recording during the ascent between 600 mb and 400 mb is not complete, because the receiver sometimes broke down. The given values are found by interpolation of the recording during the short times the receiver worked well.

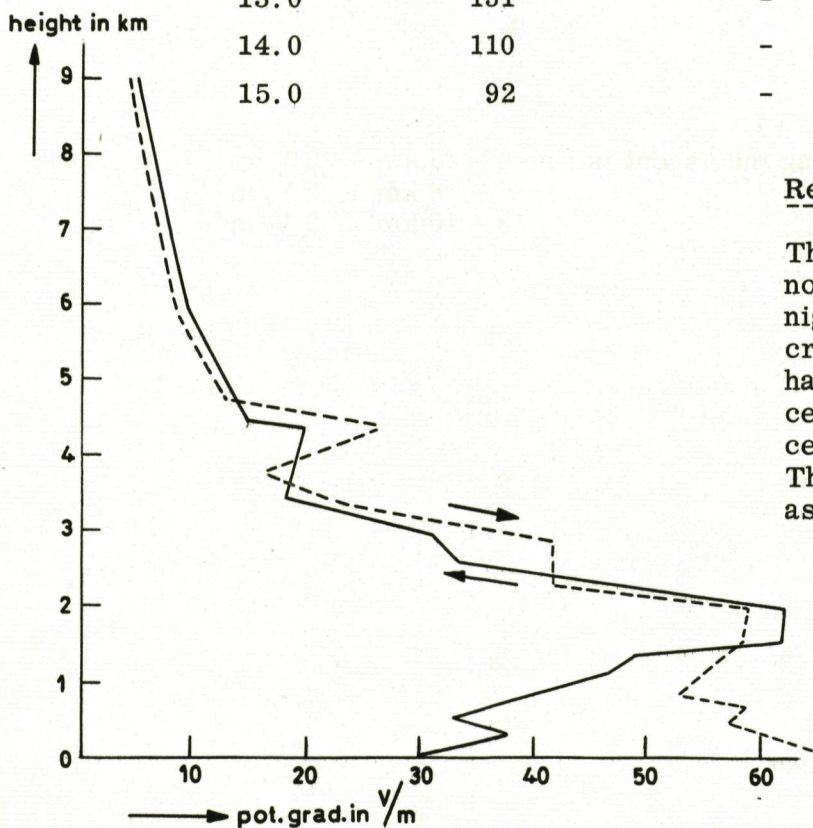




BASE "KONING BOUDEWIJN"

23 September 1964 00.00 U. T.

HEIGHT in km	PRESSURE in mb	TEMPERATURE in °C	POTENTIAL GRADIENT in V/m	
			ascent	descent
0.5	915	-21.3	+35	+58
1.0	856	23.5	44	53
2.0	746	29.0	57	58
3.0	647	37.2	27	30
4.0	559	42.0	19	16
5.0	481	46.1	13.2	12.0
6.0	414	51.4	9.8	8.3
7.0	353	56	8.0	7.2
8.0	300	60	6.4	5.7
9.0	258	66	5.0	4.6
10.0	218	69	4.4	3.8
11.0	184	69	3.6	3.1
12.0	155	-70	3.0	+ 2.5
13.0	131	-	2.7	-
14.0	110	-	2.3	-
15.0	92	-	+ 2.0	-



Remarks

The detected thin cloud layers were not clearly visible during the polar night. However the presence of ice crystals could be detected from a faint halo around the moon. During the ascent the measurements were influenced by the charge of the balloon. The stability of the signal during the ascent is :  
 0 - 4 km 8 V/m  
 4 - 15 km 2 V/m

BASE "KONING BOUDEWIJN"

30 December 1964 15.00 U. T.

HEIGHT in km	PRESSURE in mb	TEMPERATURE in °C	POTENTIAL GRADIENT in V/m	
			ascent	descent
0.5	938	- 1.7	-	-
1.0	878	4.5	-	-
2.0	773	12.7	-	-
3.0	678	19.0	-	-
4.0	591	22.3	+23.0	-
5.0	564	29.5	16.7	-
6.0	446	36.6	14.2	-
7.0	388	44	11.3	-
8.0	332	52	7.5	-
9.0	284	54	5.9	-
10.0	243	52	5.2	-
11.0	208	50	4.5	-
12.0	179	-47	+ 3.3	-

Remarks

Clear sky.

The stability of the signal during the ascent is :

0 - 6 km	2 V/m
6 - 8 km	5 V/m
8 - 10 km	2 V/m