SUPPLEMENT No. 3
to the *Treatises* on the *Atmospheres*
of the *Sun* and the *Earth*

# The Vacuum-Pyrheliometer and the Solar-Radiation

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# ADVERTISEMENT

ATMOSPHERIC Physics consists in the application of the Boyle-Gay Lussac Law in its most general form with all of its terms variables.

$$P.V = K.T$$

$$g\,\rho_m B \cdot \frac{m}{\rho} = NkT = mRT = \frac{2}{3} \cdot \frac{1}{2} m_H \bar{u}^2 . N$$

The corresponding equation of motion is

$$g(z_1 - z_0) = -\frac{P_1 - P_0}{\rho_{10}} - P_{10}(v_1 - v_0) - (U_1 - U_0) - \frac{1}{2}(q_1^2 - q_0^2)$$

$$g(z_1 - z_0) = (\varkappa - 1)\,kT\,N(v_1 - v_0) - (U_1 - U_0) - \frac{1}{2}(q_1^2 - q_0^2)$$

International practical meteorology uses only $B$ the barometric pressure, $C$ or $F$ degrees, and $q$, and these are in detached, unrelated units. Practical meteorology is therefore unscientific and chaotic, and it does not possess the principles of rational growth. The neglect of density $\rho$, volume $v$, Kinetic Energy $k$ is fatal to the solution of a long list of problems.

My research consists in restoring to the fundamental formulas all the terms in their full force, and the result has been the development of three new meteorologies, consistent with each other and in conformity with the three groups of fundamental physical laws. These are:

1. The Non-adiabatic Terrestrial Meteorology.
2. The Non-adiabatic Solar Physics.
3. The Electron-Dynamics of the Magnetic and the Electric Fields.

In the Earth's atmosphere there are two different temperature systems. The first being the total solar radiation as it is measured by the Vacuum Pyrheliometer. The second is the partial air temperature as measured by common thermometers. These Theses will be discussed in Supplements No. 3 and No. 4 of this series.

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PILAR, ARGENTINA,
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# TABLE OF CONTENTS

# TABLES



# FIGURES

# THE STATUS OF ATMOSPHERIC PHYSICS

## *Introduction*

The Science of Atmospheric Physics consists in the development of two fundamental terms, $k$ the mean molecular kinetic energy, and $h$ the mean electron-atomic radiation of the constituents of matter in its several forms. The laws, which connect these together are not very numerous, being chiefly thermodynamic, but their ramification into all the branches of gaseous phenomena becomes very complex. Practically these have been studied under seven well known aspects:

1. Terrestrial Thermodynamics or Meteorology.
2. Solar Thermodynamics or Solar Physics.
3. Solar Radiation or Bolometry of the thermal spectra.
4. Solar Elements or Spectroscopy of the visual spectra.
5. Terrestrial Radiation or Pyrheliometry.
6. Atmospheric Terrestrial Magnetism.
7. Atmospheric Electricity and Ionization.

These branches have grown up as science has progressed quite independently of one another, in obedience to some important discovery or to satisfy some practical demand. The general consequence is that they are not sufficiently harmonious to work together. This isolated segregation has resulted in much confusion and even in chaotic antagonism. There has been a lack of an Analytic Theory which is sufficiently comprehensive and strong to weld them together into a real Unity. It has, therefore, been the purpose of this research, to develop some of the basic Theorems that appear to have practical application when tested by the results of exact observations. The ultimate problem is the connection between the kinetic energy $k$ and the radiation $h$ and this we have found to be expressed in the Two-orbit Theory of Radiation, as has been explained. The essential characteristic of this Theory is that $k$ and $h$ have been changed from constants into differential variables, which will conform to the primary laws of Physics.

## *The Status of Meteorology*

Meteorology is confronted by three practical dilemmas.

*First Dilemma:* It is impossible to satisfy the requirements of science with the systems of units in public use. Science is restricted to the absolute units (C. G. S. A.) which for meteorology may be transformed into (M. K. S. A.), because all the physical sciences are developed on this basis. Public units are relative and incoherent, entirely unfit for analytic computations. Pressure in inches of mercury, millimeters of mercury, millibars must give place to kinetic energy per volume; temperature in degrees Fahrenheit and degrees Centigrade must be replaced by degrees absolute; the density, the volume, the kinetic energy are not utilized by the public in any way. The test of concrete values is that these four quantities simultaneously satisfy the Boyle-Gay Lussac Law and the kinetic theory at every point in a free atmosphere.

$$1)\ PV = P\,m\,v = KT = m\,RT = N\,k\,T = \frac{2}{3}\cdot\frac{1}{2}\,m_{II}\,\bar{n}^2 N = \frac{2}{3}\,W_{II}\,N.$$

In other words meteorology must be put upon a strictly Kinetic Energy Basis. This applies to Climatology, Synchronous Weather Maps, and Thermodynamics. The present systems of forecasting have made no progress in fifty years because they are inconsistent with the fundamental laws of Atmospheric Physics.

*Second Dilemma:* Adiabatic Thermodynamics and the observational data, pressure and temperature, of a thousand kite and balloon ascensions are inconsistent with each other, so that a strictly non-adiabatic system of thermodynamics must be used in the free air. The adiabatic gravity balance equation

$$2) \quad g(z_1 - z_0) = -\frac{P_n - P_0}{\rho_{a0}} - \frac{1}{2}(q_1^2 - q_0^2)$$

must be changed to the non-adiabatic equation

$$3) \quad g(z_1 - z_0) =$$

$$= -\frac{P_1 - P_0}{\rho_{10}} - \frac{1}{2}(q_1^2 - q_0^2) - (W_1 - W_0) - (U_1 - U_0);$$

$$4) \quad g(z_1 - z_0) = (\varkappa - 1) P_{10} (v_1 - v_0) - \frac{1}{2}(q_1^2 - q_0^2) - (U_1 - U_0);$$

$$5) \quad g(z_1 - z_0) = -\frac{kT}{m}(N_1 - N_0) - \frac{1}{2}(q_1^2 - q_0^2) - (U_1 - U_0),$$

compare the Solar Treatise, pages 222, 223.

Free atmospheres are not constructed on the adiabatic model, but in every unit volume there are to be found free heat, circulation and radiation. Hence, the kinetic energy is variable, so that *K*, *R*, *k* are variables and not constants. We have from 1)

$kT = C_1$ constant in all atmospheres;

$k_1 N_1 = C_2$ another constant in the Sun's adiabatic strata.

We have, also,

$$P = NkT, \quad Pv = RT = N\frac{kT}{m}.$$

These theories lead to many valuable practical results.

*Third Dilemma:* Meteorology cannot take its proper place alongside the other six branches of Atmospheric Physics unless it conforms to the laws that they employ. At present Meteorology is in direct conflict with the Boyle-Gay Lussac Law, the Kinetic Theory of Gases, the non-adiabatic Gravity Balance, the first Law of Thermodynamics, Poynting Theorem, Stefan's Law, Maxwell's Electrodynamic Equations, the Einstein Equations, the Planck-, Bohr- and Bigelow Theories of Radiation.

### *The Status of Solar Physics*

Applying the equations of terrestrial non-adiabatic thermodynamics using the method of trials, it has been possible to construct the solar thermodynamics for the monatomic elements. The work on the more complex elements has not been undertaken on account of the difficulty of assigning a value of $\varkappa = c_p/c_v$. The isothermal layer has a temperature 7655° to 7710°; above it there is a non-adiabatic region, and below it there is an adiabatic region, where $dQ = 0$. It turns out, that $N_1$ and $k_1$ are both variables, while $N_1 k_1 = C_2$ is constant so that there is circulation. All of the thermodynamic terms are computed at short intervals, and any of the fundamental formulas can be effectively tested. In every one both $k$ and $h$ are variables, and all the formulas based upon constant kinetic energy and constant atomic radiation are invalid.

### *The Status of Solar Radiation and Bolometry*

The evidence is that all the complex elements are broken up into hydrogen atoms at high temperatures as 12000°. The electrons seem to accumulate in the isothermal layer as surface charges. It would seem that there is a thin radiating layer put between the adiabatic and the isothermal strata where the solar radiation is chiefly generated, by the two-orbit atom-electron model which has been explained. The temperature of radiation is 7655° equivalent to 5.85 gr cal/cm².min at the distance of the earth. By the bolometer coefficients of transmission this black radiation, $a = -15{\cdot}86500$, $\alpha = 4{\cdot}00$, leaves the sun at 6950° and arrives at the earth as 475° or 3·98 calories. It reaches the surface at 365° or 2·75 calories having changed the "a" to —14·16600. The change in the coefficient is due to the absorption by the diatomic elements.

## *The Status of Solar Spectroscopy*

The thermal lines of the spectrum extend from 3700 Å. to about 2500 Å., the shorter being absent and the others being subject to line and band depletions. The visual line spectra originate at all possible levels in the solar atmospheres according to the thermal conditions. Strenuous efforts have been made to determine the solar thermodynamics from the visual spectra, but the success is very limited. It would seem to be a more promising mode of attack to proceed from the thermodynamics to the spectra. Planck's formula holds fairly well in the sun's adiabatic strata, where $k$ and $h$ are more nearly constants, but it fails above that region. Bohr's orbital formulas are correct for the hydrogen line 911·50 Å. Their extension to other lines is restricted to a very few empirical series.

## *The Status of Pyrheliometry*

The results of researches on the intensity of the solar radiation by pyrheliometers fall into two groups,

1. the majority falling between 2·70 and 4·00 calories,
2. the minority falling between 1·90 and 2·10 calories.

The maximum $\Delta T_m$ and the maximum $T_m$ in the zenith may be found by the Bouguer Law. It is not possible to proceed by $dQ = C\,d\,T_m$ or $d\,W = C\,d\,T_m$ to find this value. For $d\,U = C\,d\,T$ as developed by the Poynting Theorem we obtain 2·75 calories at the surface, and 3·98 calories at the top of the atmosphere. The vacuum pyrheliometer gives directly the $T$ of the Stefan Law and this again produces 2·75 calories on the sea level. Common pyrheliometers are defective because they are in free contact with the surrounding atmosphere, and do not fulfil the adiabatic conditions required by the differential theory.

## *The Status of Atmospheric Magnetism*

Terrestrial Magnetism and Atmospheric Magnetism are two aspects of the same laws of physics. Singularly little progress has been made in a hundred years in resolving the cause of this phenomenon, which is common to the atmospheres of the sun and the earth. The synchronism has been established between solar spots and prominences, radiation, magnetic field, atmospheric temperature and pressure in the 11-year, annual, 26·68-day periods, and this is being successfully extended to diurnal and hourly variations. The usual kinetic theory of gases for uncharged molecules with simple free path trajectories must be radically modified for charged atoms and electrons. In the latter case all the trajectories become solenoidal spirals, and the kinetic energy $k$ is supplemented by orbital motions which culminate in the radiation $h$. Hence the equations

6) $W_0 = \frac{1}{2} m v^2 = h\nu = Ve = \frac{e}{a} \cdot e$ have equivalent value

as will be fully explained.

## *The Status of Atmospheric Electricity*

The hypotheses regarding the origin of the atmospheric electricity and ionization are very numerous, but they have been only partially valid, representing certain features of the phenomena. We have been able to prove that the diurnal values are closely associated with the kinetic energy $R = \frac{K}{m} = \frac{Nk}{m}$, which agree together in summer and winter with the observations. Since $k$ and $h$ and $e$ are closely interwoven, we may expect to develop this branch of the subject much more fully as our experience penetrates into the details of the complex system of forces involved.

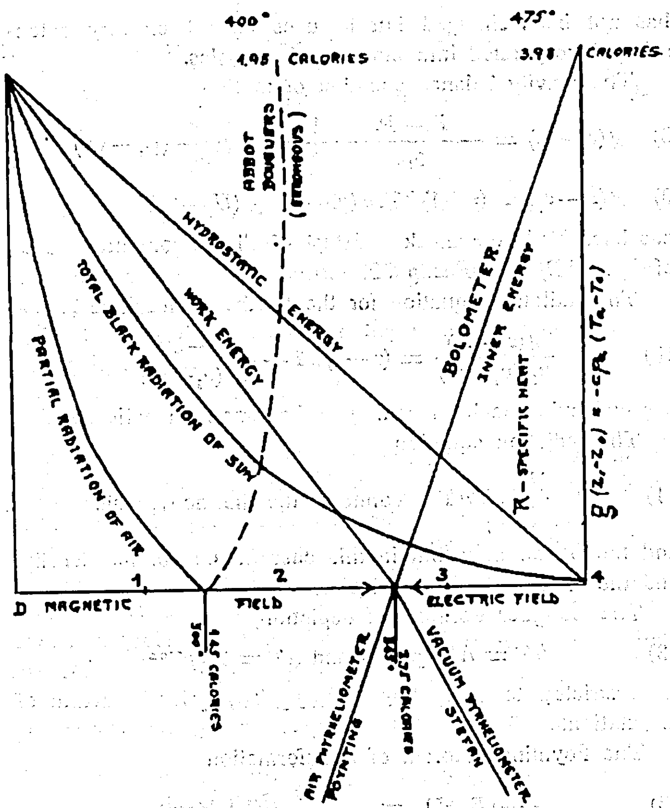



FIG. 1. The Unity of Atmospheric Physics.

(1) Thermodynamics, (2) Bolometer, (3) Vacuum Pyrheliometer, (4) Air-Pyrheliometer, (5) Magnetic Field, (6) Electric Field, all converge on 2·75 calories at the surface and 3·98 calories at the top of the atmosphere. The Bouguer formula, as extended from 1·45 calories to 1·95 calories is erroneous. It measures the radiation of the air, not of the sun.

*The First Law of Thermodynamics in Strata*

7) $$(Q_1 - Q_0) = (W_1 - W_0) + (U_1 - U_0)$$

has not been changed but its uses have been very extensively incorporated into atmospheric physics.

The gravity balance equation of motion,

8) $$g(z_1 - z_0) = -\frac{P_1 - P_0}{\rho_{10}} - \frac{1}{2}(q_1^2 - q_0^2) - (Q_1 - Q_0),$$

9) $$g(z_1 - z_0) = (\varkappa - 1)\, kT . n\, (v_1 - v_0) - (U_1 - U_0)$$

has been made the check and test of all the computed values of $P$, $v$, $\rho$, $R$, $T$ in $P = \rho RT$.

The radiation equation for the Earth's atmosphere

10) $$\frac{g(z_1 - z_0)}{n_{10}(v_1 - v_0)} = (\varkappa - 1)\, kT - \frac{U_1 - U_0}{n_{10}(v_1 - v_0)}$$

per molecule has been computed from non-adiabatic data.

The radiation equation

11) $$\frac{U_1 - U_0}{v_1 - v_0} = a T^{\alpha}$$ connects the thermodynamics

and the Stefan Law, but in this case $a$, the volume density, and the exponent $\alpha$ are variables.

The Bouguer Formula of depletion,

12) $$\Delta T = \Delta T_m p_1^{\sec z} \quad \text{and} \quad T = T_m p_2^{\sec z}$$

are restricted to computing $\Delta T_m, p_1, T_m, p_2$ in the zenith of the station.

The Poynting theorem of transformation

13) $$\frac{1}{4\pi}[E . H]_n = \frac{1}{8\pi}\frac{\partial}{\partial z}(E^2 + H^2 v^2)$$

in unit conditions has been developed for computing the radiation $h$ for the solar envelope as well as the earth's atmosphere. These form *two distinct sources of radiant energy*, and they must not be confused.

The Stefan Law of Radiation in atmospheres

14) $$u = a T^{\alpha} = a_1 T^{4.00}$$

results in four different fundamental values of the coefficient $a$, namely $a_1, a_2, a_3, a_4$.

The Einstein equations of equivalents

15) $$W = \frac{1}{2} m v^2 = h\nu = Ve = \frac{e}{a} \cdot e$$

have been developed for $m$ and $h$ variables hence are applicable to all radiating atoms.

The Bohr's orbital equations;

16) for $a_0, v_0, \nu_0, \omega_0, V_0, W_0, f_0, E_0, H_0$

applicable to only the head hydrogen atom of $K$-series have been extended to all spectrum and thermal radiations by making $m, h, k$ variables.

In the Planck equation for the distribution of radiant energy, in the term

$e^{-\frac{h\nu}{kT}}$, we find $kT =$ constant and $h, \nu$ to be both variables. Planck's equation was limited to strictly adiabatic volumes and it is nearly applicable in the Sun's Atmosphere below the isothermal layer. It is not available in the higher strata of the sun's atmosphere nor in the earth's atmosphere.

Bigelow's Two-orbit Theory of Radiation gives an account of the atom-electron mechanism as a radiator, and it seems to avoid many of the difficulties of the Planck and the Bohr models of radiation.

The Maxwell electro-magnetic Equations on the propagation of energy are accepted without modification.

## *Various Types of Pyrheliometers*

The intensity of the solar radiation can be determined in at least halt a dozen ways, and there are six types of pyrheliometers. There are two fundamental theorems, Stefan's Law and Poynting's Theorem, but these must be adapted to non-adiabatic thermodynamics. There are two parameters, $T$ the absolute temperature and $\Delta T$ the rate of change. The Stefan Law depends upon $T$ and the Poynting Theorem is founded upon $\Delta T$. If radiation energy of the intensity $u$ is enclosed in a perfectly adiabatic vessel with mirror walls, a small mass of matter which is enclosed within will assume a temperature $T$. This is the case of a perfect transformation from $h$ to $k$. If the volume is non-adiabatic, as when one or more sides are open, the flux of radiation will change the volume density and the temperature by $\Delta T$. Numerous mixed cases occur. If the vessel contains gaseous media and is open to the atmosphere through which the radiation streams, we are dealing with three distinct temperatures:

$T_s$ the possible solar radiation temperature (vacuum).

$T_p$ the observed temperature of a pyrheliometer (mixed case).

$T_a$ the actual temperature of the surrounding atmosphere.

Example.

$$T_s = 365^\circ > T_{p,1} = 325^\circ > T_{p,2} = 315^\circ > T_a = 305^\circ.$$

Pyrheliometers of all types except the new vacuum type take up temperatures which are nearer the air temperature than the zenith solar temperature. This is the primary fault with pyrheliometers, and it accounts for the discrepancy between groups I and II. If an imperfect pyrheliometer observes $\Delta T$ per minute this value is controlled by the atmosphere and the layer of air which is in contact with the thermometer, and it is therefore more a thermodynamic phenomenon than a radiation value. Finally, the entire atmosphere is the ultimate solar pyrheliometer, and the solution is in non-adiabatic thermodynamics.

## *Theory of the Several Pyrheliometers*

1) *The Vacuum Pyrheliometer* gives values of $T$ at the zenith-distances $\sec z$ which correspond perfectly to the graph ($\log T$, $\sec z$) in the Bouguer Formula

$$T = T_m p^{\sec z}.$$

The maximum $T_m = 273^\circ + 92^\circ = 365^\circ$. The value of $p$ for the forenoon is about 95 % and for the afternoon it is 97 %. If the method of extrapolating from $\sec z = 1$ to sec $z = 0$ were applied, the temperature on the outside of the earth's atmosphere would be 385° instead of 475°, which it is. The formula of computation is

$$S_v = \frac{c}{4} \frac{60}{A} \cdot 2\,[-15{\cdot}86400]\,T_m^{4\cdot00} \ldots \text{Stefan Law.}$$

The radiation coefficient is twice the standard Kurlbaum value $= 2\,a$, as has been proved by computations, see Bulletin of the Argentine Meteorological Office. The factor *two* always stands between radiation and temperature, because radiation is an effect of the single atom-electron system, while the temperature is an effect of the hydrogen-molecule which contains two atoms in action. This factor occurs throughout atmospheric physics, and it is fundamental in pyrheliometry. For example, the thermodynamics of the earth's atmosphere gives the value $a = [-14{\cdot}2686]$. The vacuum pyrheliometer gives the value $a = [-14{\cdot}16503]$ which is twice the Kurlbaum value. The value of $S_v$ for the inner energy at a constant volume is 2·75 gr.cal/cm².min, and it is for the point 3 indicated on Fig. 1

$$S_p = S_v + a + R = 3{\cdot}98 \text{ calories.}$$

Pyrheliometry must always admit the specific heat $R$.

2) *The Bigelow No. 2, Non-circulating Pyrheliometer* reaches a maximum of 273° + 52° = 325°, this is exactly the same value as was obtained by the graph method of extrapolation described in Supplement No. 1. The same formulas of computation apply

$$S = \frac{c}{4} \cdot \frac{60}{A}\, a \left(\frac{\Delta T_m}{p} + Z\right) P + (T_m + Y)^2$$

$$S = \frac{c}{4} \cdot \frac{60}{A}\, a \cdot \frac{I_1}{p} (P_m + Y)^a$$

$$S = \frac{c}{4} \cdot \frac{60}{A}\, a\,(T + X)^{4\cdot00}.$$

These are quasi-Stefan formulas and they all give the same result 3·98 calories, as has been proved by several years of experience. The criticism contained in Supplement No. 1 are fully confirmed.

3) *The Abbot or Bigelow Open and Circulating pyrheliometer* measures correctly a certain $\Delta T$ and $T$ at each observation. Only the $\Delta T$ is used in computing. This is the rate of change in the temperature of the layer of atmosphere surrounding the thermometer and it can be computed only by the Poynting Theorems as interpreted by the non-adiabatic thermodynamics; compare the Treatises on Meteorology and Solar Physics.

$$S = (H+J) + k(H+J) + U_c + a + R + (C.B.D).$$

The kinetic energy $H$ is $C.\Delta T_m$ in the zenith of the station, $C$ being a specific heat coefficient in the pyrheliometer. This has been commonly misinterpreted in practice. If $C.\Delta T_m = (Q_1 - Q_0)$ the free heat, then there is no radiation at the surface but full radiation on the upper strata (Planck). If $C.\Delta T_m = (W_1 - W_0)$ the work of expansion, then there is large radiation at the surface and none on the outer layer.

Actually $C.\Delta T_m = (U_1 - U_0)$ the inner energy and the radiation is 2·75 calories on the surface rising to 3·98 calories on the outer atmosphere, compare Fig. 1. The bolometer develops along the $(U_1 - U_0)$ line and not along the $(Q_1 - Q_0)$ line nor the $(W_1 - W_0)$ line. The Bouguer formula gives $\Delta T_m$ and $p$, and nothing more.

$$\Delta T = (\Delta T_m) p^{\sec z}.$$

The Abbot method of extrapolating from $\sec z = 1$ to $\sec z = 0$ is unscientific and misleading.

4) *Terrestrial and Solar Non-adiabatic Thermodynamics.* The ultimate pyrheliometer is the free atmosphere with its pressure, density, kinetic energy and temperature as derived from the radiation. The values when computed in strata and summed from the sea level to the vanishing plane agree upon 3·98 calories by ten processes. This is in complete harmony with the solar thermodynamics developed in a similar manner. In free atmospheres through which radiation is streaming there

are circulation and free heat. The conditions are strictly non-adiabatic because there can be no radiation in adiabatic volumes, only inner energy and work of expansion. $0=(W_1-W_0)+(U_1-U_0)$. Meteorologists who do not accept this fundamental fact are automatically prohibited from all problems in radiation and circulation. In fact the current weather map meteorology is on a completely erroneous basis and consists of merely detached, relative statistics which have no scientific coherence or power of development.

*The Vacuum Pyrheliometer* consists of the usual solar thermometer (black bulb thermometer) enclosed in a glass case from which the gaseous media have been exhausted which is placed in a small box $10\times10\times43$ cms; all the sides being lined with white asbestos except one long side. This is covered by thin glass, and the solar radiation streams through it. The box is mounted on a polar axis, having an hour circle, so that it can be exposed by clock work automatically. If the black bulb is wound with the wire of a thermal circuit, the apparatus can be made a thermal register of great precision for continuous record. The incoming radiation of short wave lengths is transformed into long wave lengths and so it is imprisoned in the layer of heated air in the box. This same radiation enters the vacuum chamber, raises the temperature to $T_s=273°+92°=365°$. This high temperature is due to the fact that the enclosing air chamber is also so highly heated that the tendency to radiate outwards from the vacuum is greatly diminished. The fault with all other types of pyrheliometers is that they radiate rapidly to the surrounding air which has a low temperature. In effect they more closely register air temperature than they record solar radiation temperature. This defect is fatal to pyrheliometry, and it has been the source of the confusion that dominates this branch of science.

1. The Pouillet pyrheliometer radiates on all sides into air.
2. The Ångström or Marvin electric balances radiate freely to the surrounding atmosphere, they do not distinguish $\Delta T$ or $T$ except remotely by secondary coefficients.

3. Abbot's silverdisk in a copper lined chamber has one side open to the atmosphere, but it is full of air in constant circulation and reaches only a low maximum $T_p = 273° + 42° = 315°$. This pyrheliometer gives $\Delta T$ and $T$ but they must be interpreted by the Poynting Theorem.

4. Bigelow No. 1 is like the Abbot type except that the copper disk is in an asbestos lined chamber, one side being open to air circulation. It is more sensitive by about twenty percent.

5. Bigelow No. 2 places a thin glass plate over the open side, which stops circulation and it raises the temperature to $273° + 52° = 325°$.

6. Bigelow No. 3 places a vacuum thermometer within the non-circulating layer of air and the temperature is raised to $273° + 92° = 365°$. This type approaches the conditions of the true Stefan Law very closely.

Fig. 2 contains an example of the relative diurnal values of the air temperature, the Marvin electric balance, the Abbot, Bigelow No. 1, No. 2 and vacuum pyrheliometers. The great change in the values of the solar temperature $T_s$ as compared with the air temperature, $365° - 305° = 60°$ explains a large number of outstanding problems in atmospheric physics. There are 50° to 60° of temperature which meteorologists have never taken into account in the weather map work, power enough to account for the worldwide sudden changes in the surface circulation. The problem of evaporation upon which precipitation depends is controlled by this great energy. The dotted lines in Fig. 2 contain the ordinates of the total observed variation in the magnetic field which have been insoluble when compared with the common air temperatures. The magnetic field is as full of radiation as an egg is of meat. Here are vast physical forces of solar origin in our atmosphere which are wholly unexploited.

## *Radiation*

Radiation presents two distinct problems, (1) the intensity $u$ which is due to the solar temperature $T_s = 7655°$

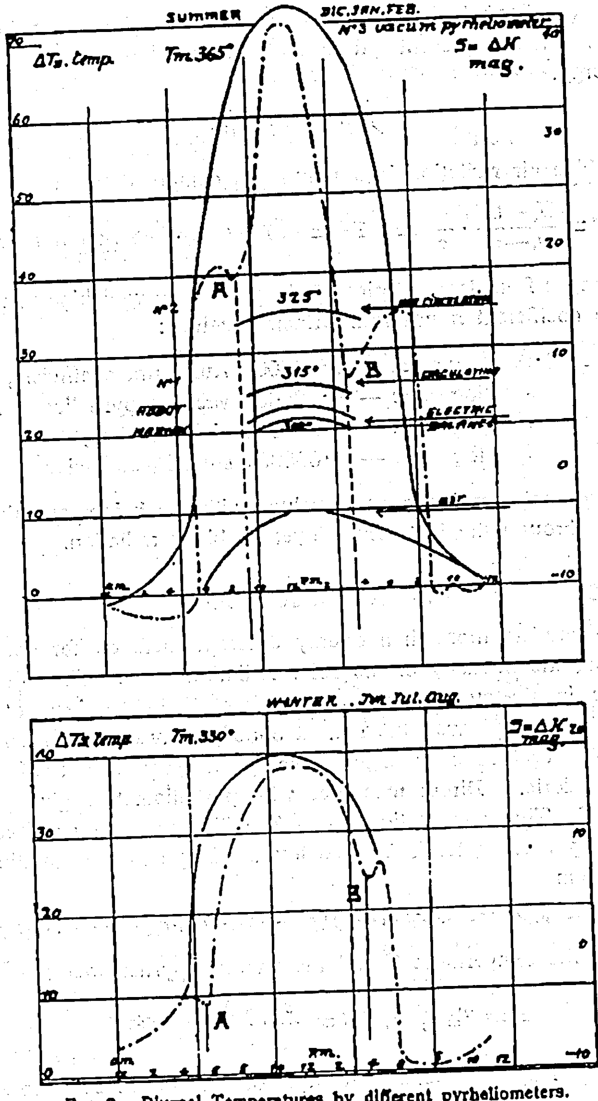



FIG. 2. Diurnal Temperatures by different pyrheliometers.

and (2) that which is due to the air temperature $T_a = 292°$. The latter represents that part absorbed trom the solar energy.

## *Air Radiation*

The air radiation in a volume is computed from:

$$u = \frac{U_1 - U_0}{v_1 - v_0} \cdot \frac{4}{c} = a T^{\alpha} = a_1 T^{4 \cdot 00} \quad \text{by the Stefan Law.}$$

$u$ ranges from 1·45 calories at the surface to vanishing values. The coefficient $\alpha$ has four principal values:

| | | |
|---|---|---|
| $\alpha = 4 \cdot 00$ | $\log a_1 = -15 \cdot 88400$ | Kurlbaum coefficient, |
| » » | $\log a_2 = -14 \cdot 16500$ | vacuum pyrheliometer, |
| » » | $\log a_3 = -14 \cdot 26860$ | air coefficient, |
| » » | $\log a_4 = -14 \cdot 69800$ | solar-$T_s$ coefficient. |

These coefficients change in values with the height and they pass through the isothermal layer as black radiation.

## *The Solar Radiation*

There are more than twenty different methods for determining the intensity of the solar radiation itself. This originates in the sun's isothermal layer at 7655° equivalent to 5·85 calories, leaves the sun at 6950°, arrives at the earth at 475° or 3·98 calories and reaches the ground at 365° or 2·75 calories. Direct measures with pyrheliometers give $\Delta T$ and $T$. The computation for $\Delta T$ with the open or circulating pyrheliometer is by the Bouguer Law and the Poynting Theorem:

$$\Delta T = \Delta T_m p^{\sec z}, \quad S = (1 + k)(H + J) + U_c + a + R + (B.C.D).$$

Using the temperature $T$ and the vacuum pyrheliometer

$$T = T_m p_1^{\sec z}, \quad S = \frac{c}{4} \cdot \frac{60}{A} \cdot a_2 . T_m^{4 \cdot 00}.$$

The open pyrheliometer gives a $T_p$ of equilibrium between $T_s$ and $T_a$ such as $T_s = 365° > T_p = 315° > T_a = 300°$.

The solar radiation has a temperature energy of 50° to 60° greater than the air temperature, and of this meteorologists have not taken account in forecasting methods.

## *The Intensity of the Solar Radiation*

The researches for determining the intensity of the Sun's radiation falling on the outside of the earth's atmosphere, may be collected into three groups.

*I. Pyrheliometers and Actinometers.*

| | | | *S* | *T* |
|---|---|---|---|---|
| Pouillet ....... | 1837 | pyrheliometer | 1·76 | 5610 |
| Langley ...... | 1881—82 | » | 2·20 | 6020 |
| Corva ........ | 1888 | » | 3·00 | 6480 |
| Pernter ....... | 1889 | » | 3·20 | 6570 |
| Saveliew ...... | 1890 | » | 3·47 | 6730 |
| Ångström ..... | 1890 | » | 4·00 | 6980 |
| Corva ........ | 1896 | » | 2·90 | 6430 |
| Hansky ....... | 1900 | » | 3·30 | 6625 |
| Langley ...... | 1902 | bolometer | 2·54 | 6220 |
| Abbot ........ | 1903 | » | 2·23 | 6040 |
| Abbot ........ | 1917 | » | 1·95 | 5820 |
| Kimball ....... | 1917 | electric | 2·20 | 6020 |
| Bigelow ...... | 1905 | pyrheliometer | 1·98 | 5840 |

The computations have all been made by the Bouguer formula alone.

*II. Bolometer spectra and other special researches.*

| | *S* | *T* |
|---|---|---|
| Abbot, bolometer, Sun and A. J. ... | 4·11 | 7000 |
| Very, Meteorology ............... | 3·0—4·0 | 6480—6960 |
| Very, 1912 ..................... | 3·6 | 6780 |
| Defant, 1912 ................... | 2·97 | 6400 |
| Bigelow, Thermodynamic 1917 | | |
| Free heat ............. | 4·08 | 6990 |
| Hydrostatic pressure ..... | 4·08 | 6990 |

| | S | T |
|---|---|---|
| Inner energy and external work | 4·08 | 6990 |
| Black radiation | 3·94 | 6930 |
| Free heat in stratum | 3·92 | 6920 |
| Hydrostatic pressure in stratum | 4·00 | 6970 |
| Inner energy in stratum | 3·92 | 6920 |
| Work and efficiency in stratum | 4·02 | 6980 |
| Kinetic potential absolute radiation | 3·90 | 6910 |
| Total radiation | 3·98 | 6950 |
| Pyrheliometric stations | 3·98 | 6950 |
| Terrestrial thermodynamics | 3·90 | 6930 |
| | 3·98 | 6950 |

*III. Solar photosphere temperature.*

| | | |
|---|---|---|
| Shook, 1913, filters | 5·65 | 7580 |
| Biscoe, 1916, filters | 6·01 | 7700 |
| Bigelow, 1917, Thermodynamics | 5·85 | 7655 |
| The solar depletion in its atmosphere | 1·87 | |
| Outside the earth's atmosphere | 3·98 | 7655 |

1) In computing the intensity of the solar radiation as observed by pyrheliometers there are three principal equations employed:

Bouguer Formula $\Delta T = \Delta T_m p^{\sec z}$

Poynting Equation $S = f(T + \Delta T)$

Stefan Law $\frac{\Delta u}{u} = a \frac{\Delta T}{T}$.

It has been demonstrated in Supplement No. 1, that computations by the Bouguer Formula *alone* are insufficient, but that the Poynting and the Stefan Laws are to be employed, the Bouguer formula being contributory to them. The entire group under I must be raised in value, according to details, and then I, II, III will be in agreement.

2) There are other principal thermodynamic equations which must be satisfied by the transformed products of the solar radiation in the earth's atmosphere.

Boyle-Gay Lussac Law $P = \rho R T$

Gravity balance . . . . . . . $g\,dz = -\frac{dP}{\rho} - q\,dq - dQ$

First Law of Thermodynamics $dQ = dW + dU$.

It has been proved that group I is not in harmony with any of these three laws.

3) There are radiation equations to be satisfied

Stefan $S = \sigma T^a$

Wien-Planck $J_m = \dfrac{8\pi c h_0 \left(\frac{R}{D}\right)^2}{\lambda^5 \left(10^{\frac{ch.M}{kT\lambda}} - 1\right)}$.

It has been proved that neither of these are to be applied with a system of constants in either the Sun's or the Earth's atmospheres.

## *A List of Twenty-five Different Methods of Evaluating the Intensity of the Solar Radiation*

These converge upon 2·75 calories with $T = 365°$ at the bottom and 3·98 calories or $T = 475°$ at the top of the earth's atmosphere. The low value 1·95 calories is out of harmony with all of the thermodynamic elements in the earth's atmosphere, the bolometric spectra, the magnetic and the electric fields. It is necessary for the development of atmospheric science that the value 3·98 calories shall be adopted; compare Fig. 1, Supplement No. 3.

1) Solar Thermodynamics, Tables 28 and 73 . . . . . 3·90
Sun 7655°, 5·85 cal; 6950° . . . 475° . . . . . . . . . . . 3·98
365° . . . 2·75 cal

2) Free Heat $-(Q_1 - Q_0)$ Table 75 . . . . . . . . . . . . . 3·98

3) Hydrostatic Pressure $\frac{P_1-P_0}{\rho_{10}}$ Table 75 ...... 4·08

4) Inner Energy and External Work

$-(U_1-U_0)-(W_1-W_0)$ Table 73 ...... 4·08

5) Back Radiation $\Sigma J_0$ Table 75 ............... 3·94

6) Free Heat in the Stratum $-(Q_1-Q_0)m$ Table 77 3·92

7) Hydrostatic Pressure in the Stratum Table 77

$-m\frac{P_1-P_0}{\rho_{10}}$ ............... 4·00

8) Inner Energy in the Stratum

$-m(U_1-U_0)$ Table 77........... 3·92

9) External Work and Gas Efficiency in the Stratum

$-(W_1-W_0)m+R_{10}(T_a-T_0)$ Table 77 .... 4·02

10) Kinetic Energy + Potential Energy + Absorbed Radiation $H+J+\Sigma\Delta J_0$ .................... 3·90

11) Total Radiation by Table 79

I + II + III + IV + V + VI ........... 3·98

$S_1=(H+J)+k(H+J)+U_e+(a+R)+(C.B.D)$.... 3·98

12) Solar Radiation to Earth 5·85 calories.

$S=\frac{c}{4}\cdot\frac{60}{A}\cdot\left(\frac{R}{D}\right)^2 a_1 T^{4\cdot00}$ $a_1=-15\cdot86400$ Isothermal layer.

$T$ (sun) = 6950° $T$ (earth) = 475° 3·98 calories.

The Kurlbaum value of $a_1$ is used down to the earth's isothermal stratum.

13) Vacuum Pyrheliometer

$S=\frac{c}{4}\cdot\frac{60}{A}\cdot 2a_1T^{4\cdot00}$ $2a_1=-14\cdot16500=a_2$

At surface $T=365°$ $S=2\cdot75$ calories.

14) Air conditions

$$S = \frac{c}{4} \cdot \frac{60}{A} a_3 T^{4 \cdot 00} \qquad a_3 = -14 \cdot 26860.$$

$$T = 300° \qquad S = 1 \cdot 45 \text{ calories}; \quad S = P \frac{60}{A} \cdot$$

15) Air Radiation and Solar Radiation

$$S = \frac{c}{4} \cdot \frac{60}{A} \cdot a_4 T^{3 \cdot 82} \text{ air radiation} \qquad a_4 = -14 \cdot 69800.$$

This is the same as the preceding.

$$S = \frac{c}{4} \cdot \frac{60}{A} \cdot a_4 T^{4 \cdot 00} = 3 \cdot 98 \text{ calories} \qquad a_4 = -14 \cdot 69800.$$

This is the way to pass from air to solar radiation; the factor of transformation is 2·75.

16) Semi-Stefan Methods, Supplement No. 1.

$$S = \frac{c}{4} \cdot \frac{60}{A} \cdot a \left( \frac{\Delta T_m}{p} + Z \right) P (T_m + Y)^{\alpha}$$

$$\alpha = 3 \cdot 82; \quad a_4 = -14 \cdot 70620$$

17)
$$S = \frac{c}{4} \cdot \frac{60}{A} \cdot a \cdot \frac{I_1}{p} (T_m + Y)^{\alpha}$$

$$\alpha = 3 \cdot 82; \quad a_4 = -14 \cdot 70620$$

18)
$$S = \frac{c}{4} \cdot \frac{60}{A} \cdot a (T + X)^{4 \cdot 00}$$

$$\alpha = 4 \cdot 00; \quad a = -14 \cdot 26860.$$

There are three points of special importance:

| | | |
|---|---|---|
| Atmosphere as given by Pressure $P$ | 6·00571 | 1·45 cal |
| Atmosphere as given by Inner Energy | | 2·75 cal |
| Solar Radiation by Thermodynamics | | 3·98 cal |

19) Meteorological Pressure.

$$\frac{3}{2} PV = \frac{1}{2} m_H \bar{u}^2 N \qquad PV = Pmv = \frac{Pm}{\rho}$$

$$\frac{3}{2} Pv = \frac{1}{2} m_H \bar{u}^2 N = \frac{1}{2} m_H \bar{q}^2 \quad \text{for} \quad \bar{u}^2 N = \bar{q}^2$$

$$3P = \rho m_H \bar{u}^2 N.$$

The ratio $\frac{2}{3}$ is really $\frac{1\cdot 85}{2\cdot 75}$ as given by observations.

$1\cdot 45 \times 1\cdot 85 = 2\cdot 68$, ... the inner energy,
$1\cdot 45 \times 2\cdot 75 = 3\cdot 98$, ... the solar radiation.

20) The Bolometer falls on the $(U_1 - U_0)$ line to $2\cdot 75$ calories at surface and $3\cdot 98$ at the vanishing plane.

21) The magnetic diurnal field is computed from the temperature of the vacuum pyrheliometer 365°.

22) The Electric potential is computed from the kinetic energy $V = \frac{Rm}{n} . 300 \times 100 \times \frac{3}{8}$.

| | | | | | | |
|---|---|---|---|---|---|---|
| 23) Sun | 7655° | 5·85 Bigelow | | ..... Abbot | |
| | 6950° | | | 5810° | |
| Earth | 475° | 3·98 cal | | 396° | 1·94 cal |
| Surface | 365° | 2·75 » | | 305° | 1·45 » |

Abbot is in error because we observe $T = 365°$, while his computed $T$ is 305°.

24) $$P = \int \sin\theta \cos^2\theta \, d\theta \int_{u_1}^{u_n} \frac{u_n}{n} u^2 \, du \int s \, d\sigma \, n . m =$$

$$= \frac{1}{3} m n \bar{u}^2 = \frac{1}{3} m n \frac{\bar{q}^2}{N} = \frac{1}{3} \rho \bar{q}^2 = n k T.$$

$$f(u_0, u_1, u_2) \, dx \, dy \, dz = \left( \frac{1}{2\pi \frac{P}{m}} \right)^{\frac{3}{2}} \cdot e^{-\frac{3 P_n}{P}} dx \, dy \, dz =$$

$$= \frac{1}{\pi} \left( \frac{1}{2 \frac{P}{m}} \right)^{\frac{3}{2}} u^2 . e^{-\frac{3 P_n}{2 P}} du$$

$$H = \frac{1}{2} m \left( \frac{1}{2\pi \cdot \frac{P}{m}} \right)^{\frac{3}{2}} \iint u^2 . e^{-\frac{3 P_u}{2 P}} d u =$$

$$= \frac{1}{2} m n \bar{u}^2 = \frac{3}{2} n k T = \frac{3}{2} P$$

$$P = \frac{2}{3} H = \frac{1}{3} m n \bar{u}^2 = n k T; \quad k T = \frac{1}{3} n \bar{u}^2;$$

$$n = \frac{3 P}{\bar{u}^2} = \frac{P}{k T}.$$

25) Kinetic and potential energies $H$ and $J$. By the first Law of Thermodynamics we have in the diatomic non-adiabatic free atmospheres

$$H + J = -W = U - Q.$$

$H, J, U, Q$ are positive, while $W$ is negative. We have:

Kinetic Energy $\quad H = \frac{3}{2} P_v = \frac{3}{2} R \rho T$

Potential Energy $\quad J = P = R \rho T$

Work Energy $\quad -W = -\frac{5}{2} P = -\frac{5}{2} R \rho T$

Inner Energy $\quad V = \frac{5}{2} P - Q = \frac{5}{2} R \rho T - Q$

Free Heat $\quad Q = (c_{p_a} - c_{p_w}) . \rho (T_a - T_0)$

$$Q = \left( \frac{7}{2} R_a - \frac{7}{2} R \right) \cdot \rho (T_a - T_0).$$

For adiabatic strata $R_a = R$ and $Q = 0$.
The specific heat $= (c_{p_a} - c_{p_w}) = R$.
Inner Energy at constant pressure becomes

$$U_p = (c_{p_a}) \rho T = \frac{7}{2} R \rho T.$$

Summarizing in order, the result is

$$\text{Potential } P = R\rho T + \text{Kinetic } \frac{3}{2}P = \frac{3}{2}R\rho T +$$

$$+ \text{Specific heat } P = R\rho T = \left(\frac{2}{2}+\frac{3}{2}+\frac{2}{2}\right)P = \frac{7}{2}R\rho T.$$

The total thermodynamic energy $= \frac{7}{2}P = 3^1/_2$ pressure.

## *Note*

The atmospheric pressure $P$ is due to the transmitted kinetic energy, about 89 % on the average at sea level. Hence the reduction of $P$ in (C. G. S.) to calories is per minute

$$\frac{P \times 60}{A \times 0{\cdot}89} = \frac{1013235 \times 60}{4{\cdot}1851 \times 10^7 \times 0{\cdot}89} = 1{\cdot}65 \text{ calories}$$

for the kinetic energy $H$.

## *Examples of Evaluation*

There are two methods of evaluating the kinetic energy $H$ and the potential energy $J$, the first through the radiation and the second through the pressure.

1) *Radiation.* The observed radiation and the coefficient of transmission range generally between the values $\frac{1{\cdot}45}{0{\cdot}85} = 1{\cdot}65$ calories and $\frac{1{\cdot}50}{0{\cdot}90} = 1{\cdot}65$ calories, the kinetic energy $H$. Thence $J = \frac{2}{3}H = 1{\cdot}10$ calories, the potential energy.

2) *Pressure.* It is not the simple pressure $P_0$, but the product $Pv = RT$, which gives the potential energy.

$$J = \frac{Pv \times 60}{A} = \frac{1013235 \times 773 \cdot 38 \times 60}{4 \cdot 1851 \times 10^{10}} = 1 \cdot 10 \text{ calories}$$

$$\frac{c_{p_a} . T \times 60}{A} = \frac{935 \cdot 787 \times 273 \times 60}{4 \cdot 1851 \times 10^{10}} = 3 \cdot 98 \frac{\text{gr.cal}}{\text{cm}^2.\text{min}}.$$

We have $Pv = RT = \frac{N}{m} \cdot kT = \frac{2}{3} \cdot \frac{1}{2} m_H \bar{u}^2 \frac{N}{m}$. Hence the kinetic energy $H = \frac{1}{2} m_H \bar{u}^2 \frac{N}{m} = \frac{3}{2} Pv = \frac{3}{2} J = 1 \cdot 65$ calories. We reach the same values of $J = 1 \cdot 10$ and $H = 1 \cdot 65$ by the radiation and the thermodynamic methods. Hence

$$(H+J) = -W = U = 1 \cdot 65 + 1 \cdot 10 = 2 \cdot 75 \text{ calories.}$$

This confirms the preceding results and methods. Finally for the additional specific heat

$$(c_{p_a} - c_v)(T_a - T_0) = R(T_a - T_0) = 1 \cdot 10 \text{ calories} = J.$$

Summarizing we obtain

$$J = 1 \cdot 10 + H = \frac{3}{2} J = 1 \cdot 65 + J = 1 \cdot 10 = 3 \cdot 85 \text{ calories.}$$

This method is precise when exact observations are employed as at Pilar and La Quiaca, 1912 to 1920 with the pyrheliometers by the Poynting Theorem.

## *The Ratio of the Specific Heat $\varkappa = c_p/c_v$.*

The value of $\varkappa$ can be computed for molecules of different complexities.

| molecules | kinetic + potential + specific heat | $\frac{\varkappa}{\varkappa-1}$ | $\varkappa = c_p/c_v$ |
|---|---|---|---|
| monatomic | $\frac{3}{2}J + 0 + J = \frac{5}{2}J$ | $\frac{5}{2}$ | $\frac{5}{3} = 1 \cdot 66$ |
| diatomic | $\frac{3}{2}J + J + J = \frac{7}{2}J$ | $\frac{7}{2}$ | $\frac{7}{5} = 1 \cdot 40$ |
| triatomic | $\frac{3}{2}J + 2J + J = \frac{9}{2}J$ | $\frac{9}{2}$ | $\frac{9}{7} = 1 \cdot 20$ |
| 4-atomic | $\frac{3}{2}J + 3J + J = \frac{11}{2}J$ | $\frac{11}{2}$ | $\frac{11}{9} = 1 \cdot 22$ |

In this manner the value of $\varkappa$ for all solar elements is found. The preceding examples are for $(Q_1 - Q_0) = 0$ adiabatic. In the non-adiabatic case for $(Q_1 - Q_0) =$ finite values

$$\frac{3}{2} J + J = -(W_1 - W_0) = (U_1 - U_0) - (Q_1 - Q_0).$$

The corresponding values of $(Q_1 - Q_0) = (c_{p_a} - c_{p_m})(T_a - T_0)$.

$$(Q_1 - Q_0) = \frac{\varkappa}{\varkappa - 1} (R_a - R_{10})(T_a - T_0) = \frac{7}{2}(J_a - J_1)$$

are formal. They range from $J_{10} = J_a$ at the surface to $J_{10} = 0$ at the top of the atmosphere.

This direct connection between the observed radiation and the resulting thermodynamic values will form the basis of many valuable researches and their practical applications.

## *The Effect of Local Conditions upon the Solar Radiation*

Fig. 3 exhibits the local effects of meteorological conditions upon the incoming solar radiation in the course of a year.

*La Quiaca*, 3465 meters above sea level, vapor pressure $e = 0{\cdot}8$ *mm* in July and $e = 6{\cdot}5$ *mm* in January. Generally the curve has a single maximum in winter, the minor depression in September and October being due to dust. The range is from 3·94 to 4·10 gr.cal/cm².min, 4 % to 5 % annually, the maximum occurring in winter, when the sun is at the extreme north. The radiation follows the course of the vapor pressure and this is a little modified by wind and dust in the autumn.

*Calama*, 2250 meters above sea level, vapor pressure $e = 0{\cdot}8$ in July and $e = 4{\cdot}5$ in January. The data are for 1918 and the original values are multiplied by the factor 2 in order to reduce them to the true solar standard. The annual curve ranges from 3·94 to 4·04 calories, about 2·5 %. The Abbot pyrheliometer, reinforced by bolometer data, is incompetent to eliminate the local effects of vapor, dust and other depletions. Calama, located in a rainless district, has the advantage of continuity. However, with the vacuum pyrheliometer at Pilar, we obtain from 25 to 28 daily values.

*Pilar*, 380 meters, $e = 6{\cdot}5\ mm$ in July and $e = 17{\cdot}5\ mm$ in January. In this case there are two maxima, Mareh-April

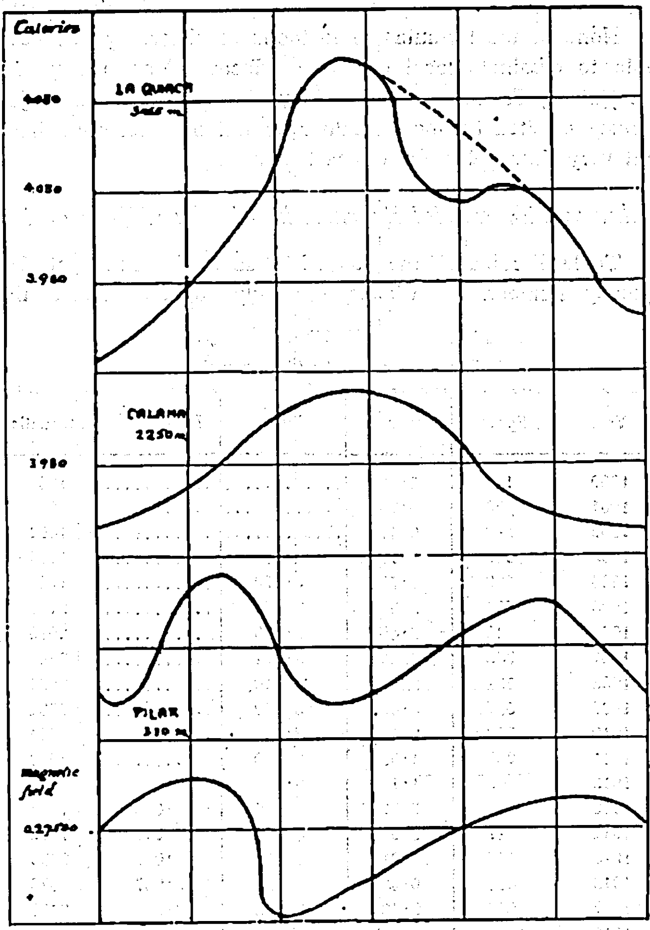



FIG. 3. The observed Annual Radiation at La Quiaca, Calama, Pilar.

and October-November. The great depression in winter is due to the dry fine dust which is blown up by the wind and fills the lower atmosphere. The magnetic force *H* has been determined at Pilar from ten years of data, and it follows the observed pyrheliometer curve perfectly. The depletion of solar radiation and magnetic field synchronize in all respects.

None of the formulas or methods of observing has been able to eliminate local depleting effects. Consequently the La Quiaca, Calama and Pilar daily data are so much injuriously affected by local weather conditions, that they have but very little value for forecast control.

## *Solar and Terrestrial Synchronism in the 11-year Period*

Table 1 contains the following data: the sun spot frequency numbers by Wolfer, the daily mean number of the

TABLE 1.

Synchronism in the 11-year Period.

| Year | Spots | Promin. | Pilar | La Quiaca | Magnetic |
|---|---|---|---|---|---|
| 1900 | 114 | 3·33 | ........... | ........... | 1589 |
| 1901 | 33 | 0·73 | ........... | ........... | 1374 |
| 1902 | 60 | 0·41 | ........... | ........... | 1464 |
| 1903 | 293 | 1·13 | 3·980 | ........... | 1026 |
| 1904 | 503 | 2·73 | 3·970 | ........... | 1787 |
| 1905 | 752 | 2·93 | 3·955 | ........... | 2104 |
| 1906 | 646 | 2·45 | 3·975 | ........... | 2016 |
| 1907 | 745 | 4·35 | 3·971 | ........... | 2299 |
| 1908 | 588 | 3·47 | 3·940 | ........... | 2584 |
| 1909 | 527 | 3·60 | 3·960 | ........... | 2334 |
| 1910 | 203 | 2·54 | 3·952 | ........... | 2354 |
| 1911 | 223 | 1·53 | 3·960 | ........... | 1923 |
| 1912 | 68 | 1·14 | 3·997 | 3·960 | 1520 |
| 1913 | 43 | 0·97 | 4·015 | 4·014 | 1504 |
| 1914 | 17 | 3·51 | 4·004 | 4·019 | 1672 |
| 1915 | 115 | 7·31 | 4·004 | 4·027 | 2635 |
| 1916 | 569 | 0·93 | 3·936 | 3·967 | 2676 |
| 1917 | 685 | 9·20 | 3·956 | 3·953 | 3480 |
| 1918 | 1186 | .......... | 3·972 | 3·974 | 3322 |
| 1919 | 907 | .......... | 3·970 | 3·989 | 3607 |
| 1920 | 707 | .......... | 3·940 | 3·935 | 3452 |

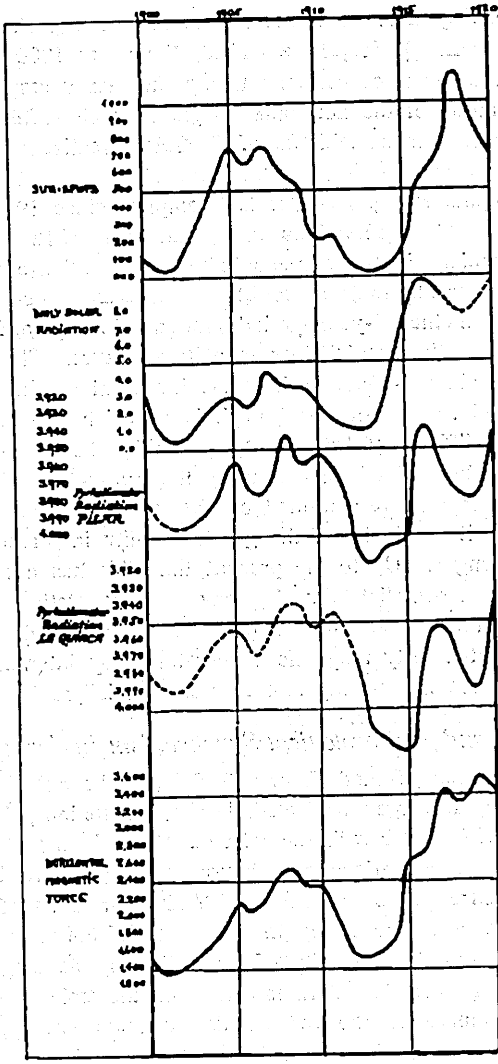


FIG. 4. The Annual Synchronism between Solar Variations and Terrestrial Radiation and Magnetic Field.

prominences by Riccó, the intensity of the solar radiation at Pilar and at La Quiaca, 1912—1920, the years 1900—1911 being from several sources, and finally the yearly amplitudes of the variation of the horizontal magnetic force. This table has the same data as table 85 of the Solar Treatise extended to 1920.

The radiation data for Pilar are complete since 1912 and they average 110 observations each year. From 1912 to 1920 the synchronism is so complete between the solar and the terrestrial elements that no doubt can exist as to its reality. The range in the 11-year period amounts to 2 % and this corresponds with about 2 degrees of temperature. The local variation is about 5 %, and it is the incessant admixture of the true solar and the local depletions which render this problem so difficult of bringing to a working basis. If any method can be devised for measuring the true solar radiation, as if an observer were stationed on the outside of the earth's atmosphere, it would be of the greatest utility in forecasting weather changes. Up to the present time this has not been possible to accomplish day by day at any station. The proof that the magnetic field synchronizes leads to the conclusion that the forty magnetic observatories by international cooperation are most competent to resolve this problem.

## *The Solar and Meteorological Synchronism in Argentina*

Tables 2, 3, 4, 5 and Figures 5, 6, 7, 8 show the result of comparing the Argentine Meteorology at ten stations, during the years 1900—1920 with the solar variations in the 11-year period. The precipitation, temperature, vapor pressure, barometric pressure, all synchronize with the variations of the solar energy, as registered by the frequency of the sun spots, the prominences, the intensity of the radiation, the magnetic field and all other transformed parts of the solar output. The upper curve is the mean solar variable energy, the second curve is for the annual means at the ten stations, and in the succeeding curves these stations are individually exhibited. A glance shows that the Meteorology of Argentina responds continuously to the intensity of the solar energy in the 11-year period, and in the successive minor maxima and minima. Entirely similar results are published by me for the United States 1890—1910.

In Argentina we make the following remarks:

*Precipitation.* This varies up to 40 % and enough to distinguish good agricultural years from poor years. Generally *when the sunspot numbers are rising the rainfall in Argentina shows deficiency and vice versa.*

*Temperature.* This curve is inverted and is the least secure, because the *air-temperature* is 50° to 60° lower than the *true solar temperature,* and it is distorted by clouds.

*Vapor pressure.* This element depends largely upon the circulation, and this upon many general conditions.

*Barometric pressure.* The changed pressure is sustained by years and it becomes more pronounced towards the South.

The art of forecasting is dependent upon these primary facts.

## *The Selection of Sites for Observatories designed for Solar Radiation Phenomena*

In solar radiation observations it is necessary to be able to follow the variations of the intensity accurately to less than one percent. The irregular local absorptions by aqueous vapor and dust make this a very difficult programme to realize. Unfortunately the Bouguer, Poynting and Stefan formulas, taken separately or in combination, are imcompetent to eliminate the small variations with sufficient precision, in order to measure the existing intensity in its purity. This would be done if observations were possible in the high strata, where vapor and dust do not prevail. Special devises appropriate to the locality enable us to make monthly and annual corrections so that the mean values of several observations are really reliable, but it is at present impossible to do this for *daily* values. There is no station in the world known to be exempt from this practical difficulty. Nevertheless it is

TABLE 2. Precipitation.

| | Tucuman | Andalgalá | Goya | Concordia | Cordoba | Pilar | Buenos Aires | Victorica | Bahia Blanca | Patagones | Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | m. m. | | | | | | | | | | |
| 1900 | 921 | 230 | 1092 | 1037 | 712 | 829 | 2025 | 493 | 917 | 270 | 8320 |
| 01 | 843 | 222 | 687 | 1037 | 551 | 829 | 890 | 493 | 317 | 216 | 5765 |
| 02 | 1178 | 329 | 1187 | 1112 | 669 | 629 | 717 | 493 | 404 | 358 | 7070 |
| 03 | 836 | 316 | 1067 | 1321 | 968 | 820 | 1044 | 493 | 628 | 304 | 7608 |
| 04 | 1239 | 406 | 1624 | 1444 | 1017 | 829 | 791 | 493 | 876 | 339 | 8858 |
| 1005 | 986 | 142 | 1200 | 1077 | 586 | 511 | 1061 | 451 | 576 | 382 | 6978 |
| 06 | 1144 | 360 | 851 | 568 | 623 | 613 | 771 | 542 | 380 | 271 | 6134 |
| 07 | 834 | 271 | 1204 | 802 | 654 | 537 | 084 | 537 | 048 | 201 | 0372 |
| 08 | 867 | 338 | 1222 | 956 | 593 | 503 | 759 | 224 | 374 | 180 | 6036 |
| 09 | 609 | 318 | 1013 | 791 | 057 | 590 | 798 | 395 | 393 | 117 | 5681 |
| 1010 | 1372 | 293 | 1058 | 029 | 566 | 446 | 665 | 365 | 311 | 304 | 6300 |
| 11 | 1104 | 321 | 1132 | 740 | 845 | 687 | 1232 | 389 | 547 | 445 | 7442 |
| 12 | 844 | 159 | 1417 | 1320 | 742 | 759 | 1504 | 631 | 527 | 151 | 8060 |
| 13 | 702 | 231 | 1067 | 1000 | 650 | 648 | 1140 | 625 | 405 | 208 | 6981 |
| 14 | 1006 | 209 | 1526 | 1271 | 885 | 949 | 1741 | 672 | 754 | 288 | 9301 |
| 1915 | 906 | 276 | 1405 | 1179 | 582 | 671 | 028 | 504 | 613 | 408 | 7622 |
| 16 | 648 | 113 | 815 | 989 | 450 | 393 | 604 | 227 | 481 | 340 | 4880 |
| 17 | 508 | 167 | 505 | 717 | 588 | 427 | 855 | 544 | 394 | 275 | 4980 |
| 18 | 1009 | 415 | 1682 | 1271 | 841 | 056 | 760 | 756 | 801 | 594 | 9085 |
| 19 | 831 | 265 | 1392 | 1319 | 1006 | 852 | 1390 | 850 | 1185 | 012 | 9500 |
| 1020 | 726 | 294 | 1271 | 930 | 766 | 550 | 939 | 629 | 743 | 257 | 7009 |

TABLE 3. Temperature.

| | Tucuman | Andalgalá | Goya | Concordia | Cordoba | Pilar | Buenos Aires | Victorica | Bahia Blanca | Patagones | Means |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1000 | 19.68 | 19.70 | 21.22 | 18.01 | 17.97 | 16.32 | 17.70 | 16.48 | 16.23 | 14.61 | 17.66 |
| 01 | 19.89 | 19.67 | 20.59 | 18.61 | 18.10 | 16.32 | 17.33 | 15.48 | 15.94 | 15.18 | 17.71 |
| 02 | 19.27 | 18.82 | 20.60 | 18.85 | 17.69 | 16.32 | 17.67 | 15.48 | 15.81 | 14.76 | 17.55 |
| 03 | 18.87 | 18.65 | 20.24 | 18.64 | 16.71 | 16.32 | 18.15 | 16.48 | 15.54 | 15.11 | 17.37 |
| 04 | 18.41 | 18.42 | 20.01 | 18.51 | 16.43 | 16.32 | 17.64 | 16.48 | 14.83 | 14.79 | 17.08 |
| 1005 | 18.08 | 17.39 | 19.91 | 18.03 | 16.37 | 16.06 | 17.12 | 14.81 | 14.09 | 14.15 | 16.69 |
| 06 | 18.97 | 19·19 | 20.75 | 19.14 | 17.21 | 17.07 | 16.55 | 16.58 | 16.53 | 15.06 | 17.51 |
| 07 | 18.36 | 18.15 | 20.10 | 18.66 | 16.22 | 15.94 | 16·76 | 14.87 | 15.04 | 14.51 | 17.74 |
| 08 | 18.41 | 17.87 | 19.06 | 18.19 | 16.05 | 16.23 | 16.73 | 15.86 | 16.03 | 15.01 | 17.02 |
| 09 | 18.81 | 17.90 | 19.98 | 18.30 | 16.44 | 16.13 | 16.64 | 15.77 | 16.10 | 14.78 | 16.99 |
| 1010 | 17.94 | 18.58 | 20.24 | 17.54 | 16.56 | 16.29 | 15.91 | 15.39 | 15.74 | 14.76 | 16.90 |
| 11 | 17.71 | 17.80 | 19.21 | 17.56 | 16.29 | 15.97 | 15.26 | 14.96 | 14.69 | 14.13 | 16.30 |
| 12 | 18.51 | 19.12 | 10.91 | 18.52 | 16.93 | 16.27 | 16.22 | 15.76 | 16.66 | 15.99 | 17.39 |
| 13 | 19.00 | 10.82 | 21.03 | 20.40 | 17.94 | 17.26 | 17.03 | 16.63 | 16.83 | 15.97 | 18.20 |
| 14 | 18.45 | 18.38 | 20.76 | 19.16 | 16.63 | 16.24 | 16.54 | 15.43 | 15.37 | 14.58 | 17.17 |
| 1916 | 18.61 | 18.66 | 20.58 | 18.92 | 17.10 | 16.09 | 16.09 | 16.45 | 16.46 | 15.01 | 17.20 |
| 16 | 20.28 | 18.61 | 20.18 | 21.00 | 17.37 | 16.06 | 16.19 | 16.00 | 15.30 | 14.58 | 17.65 |
| 17 | 20.19 | 18.27 | 21.14 | 18.95 | 17.11 | 16.85 | 15.97 | 15.63 | 16.82 | 16.38 | 17.03 |
| 18 | 19.31 | 17.85 | 20.37 | 18.56 | 16.94 | 16.77 | 16.12 | 15.52 | 15.48 | 14.92 | 17.18 |
| 19 | 19.70 | 18.73 | 21.15 | 19.52 | 17.03 | 16.67 | 16.60 | 15.15 | 16.08 | 14.60 | 17.43 |
| 1020 | 20.05 | 18.56 | 20.48 | 18.51 | 17.30 | 16.60 | 10.50 | 15.65 | 16.58 | 15.06 | 17.43 |

TABLE 4. Vapor Pressure.

| | Tucuman | Andalgalá | Goya | Concordia | Cordoba | Pilar | Buenos Aires | Victorica | Bahia Blanca | Patagones | Means |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1900 | 12.72 | 8.24 | 14.05 | 11.81 | 10.50 | 9.10 | 12.26 | 7.60 | 9.01 | 7.58 | 10.36 |
| 01 | 11.94 | 7.58 | 13.10 | 11.81 | 9.30 | 9.10 | 11.40 | 7.06 | 8.38 | 7.58 | 9.70 |
| 02 | 12.52 | 8.17 | 14.35 | 12.14 | 9.98 | 9.10 | 11.80 | 7.00 | 8.08 | 7.44 | 10.22 |
| 03 | 12.64 | 8.15 | 14.09 | 12.33 | 10.30 | 9.10 | 11.90 | 7.08 | 9.38 | 8.23 | 10.38 |
| 04 | 12.45 | 7.81 | 13.66 | 12.14 | 9.78 | 9.10 | 11.48 | 7.60 | 9.07 | 8.01 | 10.18 |
| 1905 | 12.28 | 8.19 | 13.96 | 11.60 | 9.28 | 8.70 | 11.22 | 8.57 | 9.35 | 7.58 | 10.07 |
| 06 | 12.38 | 8.59 | 13.38 | 12.06 | 9.12 | 7.97 | 11.70 | 7.84 | 7.88 | 7.67 | 9.80 |
| 07 | 12.11 | 8.17 | 13.32 | 11.70 | 9.24 | 8.20 | 10.55 | 8.17 | 8.14 | 7.20 | 9.80 |
| 08 | 12.09 | 8.24 | 12.98 | 11.39 | 9.03 | 9.03 | 9.88 | 7.30 | 7.67 | 7.37 | 9.50 |
| 09 | 11.96 | 7.68 | 12.42 | 10.90 | 8.41 | 8.70 | 9.84 | 7.04 | 7.41 | 8.33 | 9.27 |
| 1910 | 12.30 | 8.51 | 12.28 | 10.89 | 8.00 | 8.40 | 9.72 | 6.78 | 7.02 | 7.05 | 9.22 |
| 11 | 11.96 | 8.66 | 12.10 | 10.88 | 8.72 | 8.55 | 9.82 | 6.71 | 7.28 | 7.19 | 9.19 |
| 12 | 12.41 | 9.80 | 13.57 | 12.19 | 9.53 | 9.73 | 10.00 | 7.54 | 7.83 | 7.02 | 10.05 |
| 13 | 13.18 | 9.90 | 14.06 | 12.78 | 10.04 | 10.04 | 11.12 | 8.23 | 8.00 | 7.48 | 10.48 |
| 14 | 13.10 | 10.48 | 14.30 | 12.00 | 10.20 | 10.17 | 11.42 | 8.30 | 8.02 | 7.62 | 10.72 |
| 1915 | 12.17 | 10.08 | 14.11 | 11.32 | 9.10 | 9.54 | 10.08 | 7.08 | 7.83 | 7.26 | 10.01 |
| 16 | 11.57 | 7.85 | 11.66 | 12.22 | 7.81 | 7.61 | 9.26 | 6.18 | 7.34 | 7.10 | 8.87 |
| 17 | 11.23 | 8.73 | 10.44 | 9.70 | 8.20 | 8.43 | 10.02 | 7.36 | 7.55 | 6.53 | 8.83 |
| 18 | 12.92 | 9.26 | 13.32 | 11.60 | 9.41 | 9.56 | 10.72 | 7.45 | 8.35 | 6.83 | 9.04 |
| 19 | 12.86 | 9.76 | 14.41 | 12.51 | 10.24 | 10.53 | 11.00 | 8.11 | 9.08 | 7.87 | 10.06 |
| 1920 | 13.06 | 9.70 | 13.87 | 12.00 | 10.21 | 9.47 | 11.09 | 7.58 | 8.13 | 7.07 | 10.28 |

TABLE 5. Barometric Pressure.

| | Tucuman | Andalgalá | Goya | Concordia | Cordoba | Pilar | Buenos Aires | Victorica | Bahia Blanca | Patagones | Means |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1900 | 721.30 | 668.85 | 756.58 | 759.05 | 723.51 | 732.61 | 760.17 | 733.05 | 759.02 | 757.81 | 737.01 |
| 01 | 22.06 | 69.48 | 56.97 | 59.05 | 23.04 | 32.01 | 60.07 | 33.93 | 59.66 | 58.23 | 37.75 |
| 02 | 21.45 | 69.01 | 56.42 | 58.76 | 23.57 | 32.61 | 59.70 | 33.95 | 58.39 | 56.10 | 37.00 |
| 03 | 22.18 | 69.73 | 57.74 | 59.68 | 24.33 | 32.01 | 59.91 | 33.05 | 59.00 | 56.49 | 37.56 |
| 04 | 21.00 | 69.02 | 57.32 | 59.66 | 23.96 | 32.61 | 60.14 | 33.05 | 58.34 | 56.61 | 37.47 |
| 1905 | 22.03 | 69.49 | 57.42 | 60.19 | 24.19 | 32.34 | 59.86 | 733.43 | 59.24 | 57.30 | 37.55 |
| 06 | 22.08 | 69.75 | 57.75 | 59.27 | 24.36 | 32.53 | 59.72 | 33.07 | 59.93 | 57.40 | 37.65 |
| 07 | 22.22 | 60.47 | 57.86 | 58.74 | 24.52 | 32.85 | 60.18 | 34.14 | 60.77 | 57.78 | 37.85 |
| 08 | 23.11 | 69.80 | 58.45 | 59.84 | 25.10 | 33.18 | 60.60 | 34.04 | 60.06 | 57.95 | 38.20 |
| 09 | 23.07 | 69.98 | 58.51 | 59.54 | 25.14 | 33.07 | 60.57 | 34.03 | 60.27 | 58.02 | 38.22 |
| 1910 | 22.85 | 69.37 | 58.08 | 59.68 | 24.82 | 32.80 | 60.39 | 33.80 | 59.74 | 57.60 | 37.91 |
| 11 | 22.60 | 69.87 | 57.91 | 60.15 | 24.58 | 32.70 | 60.33 | 34.43 | 60.52 | 57.40 | 38.05 |
| 12 | 22.56 | 69.81 | 58.23 | 60.49 | 24.65 | 32.64 | 60.32 | 34.29 | 59.86 | 57.24 | 38.01 |
| 13 | 22.16 | 69.46 | 58.15 | 60.39 | 24.14 | 32.36 | 60.00 | 33.94 | 59.60 | 56.90 | 37.74 |
| 14 | 21.87 | 69.04 | 57.41 | 59.28 | 24.08 | 32.08 | 59.35 | 33.81 | 58.32 | 55.73 | 37.10 |
| 1915 | 21.98 | 69.10 | 58.18 | 59.50 | 24.07 | 32.19 | 59.67 | 33.82 | 58.64 | 56.28 | 37.34 |
| 16 | 22.30 | 70.44 | 58.69 | 59.72 | 24.46 | 32.40 | 59.97 | 34.06 | 58.53 | 57.28 | 37.30 |
| 17 | 22.91 | 70.83 | 59.20 | 60.68 | 25.19 | 33.04 | 60.95 | 34.77 | 59.81 | 58.24 | 38.56 |
| 18 | 21.79 | 69.65 | 58.22 | 59.62 | 23.85 | 31.79 | 59.64 | 33.60 | 58.20 | 57.13 | 37.34 |
| 19 | 21.88 | 69.97 | 57.08 | 59.11 | 24.06 | 31.84 | 59.71 | 33.70 | 58.75 | 57.08 | 37.41 |
| 1920 | 722.10 | 669.46 | 758.43 | 758.09 | 724.30 | 732.31 | 760.08 | 733.75 | 758.17 | 756.82 | 737.44 |

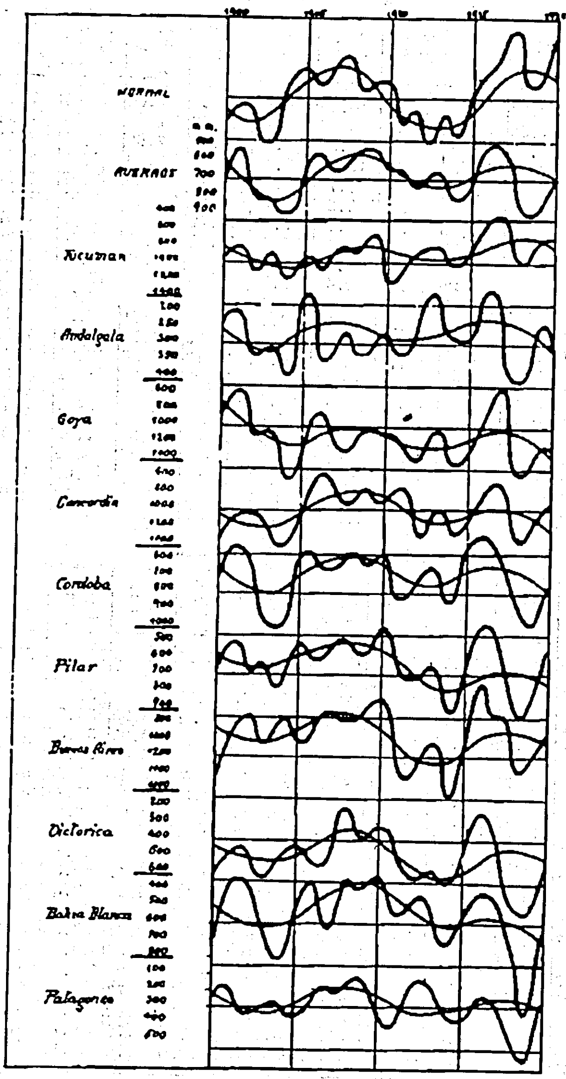



Fig. 5. Argentine Precipitation.

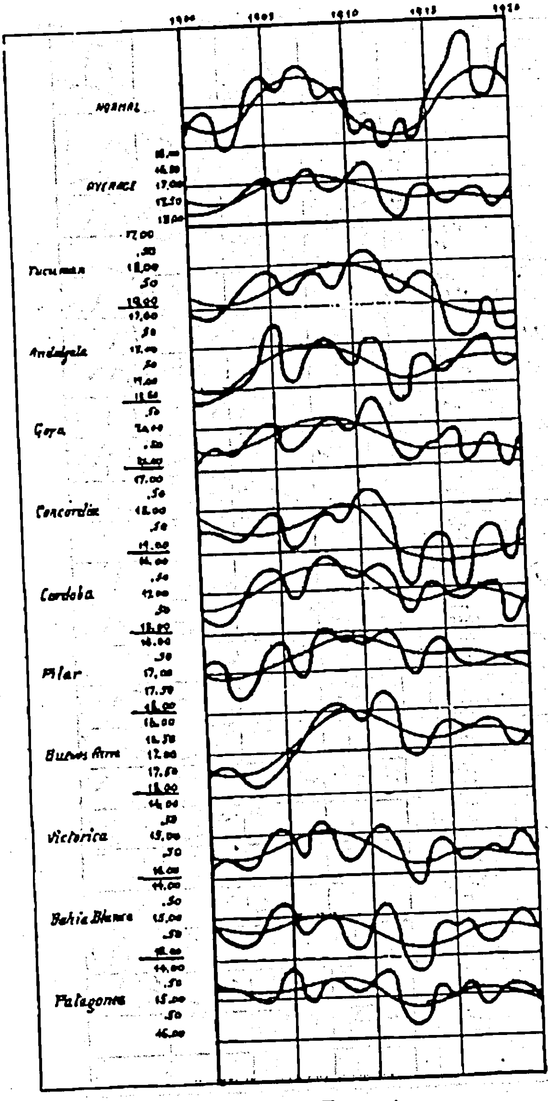



FIG. 6. Argentine Temperature.

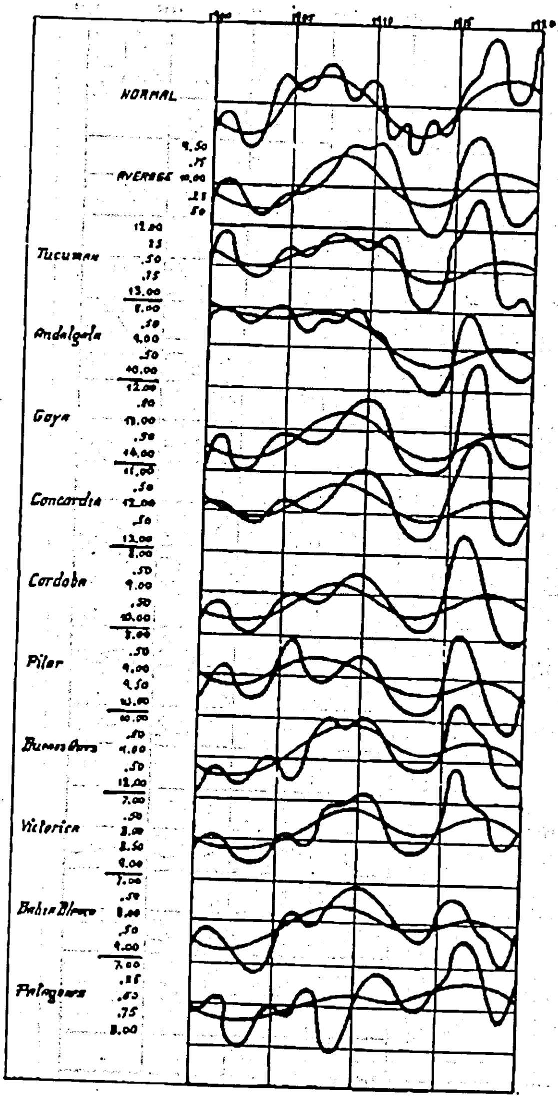



Fig. 7. Argentine Vapor Pressure.

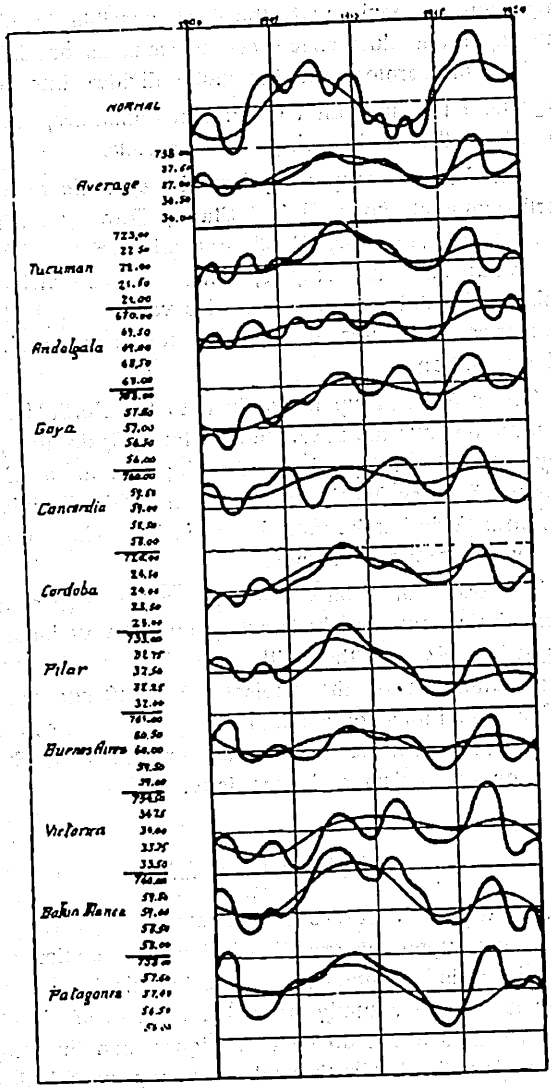



Fig. 8. Argentine Barometric Pressure.

important to begin with the best possible localities where the vapor and dust effects are as small as possible.

The meteorology of the globe divides into two groups.
1) where the horizontal circulation dominates, and
2) where the vertical circulation prevails.

The former group comprises the cyclonic regions of the north temperate zone, United States, Europe, North Asia; the south temperate zone, South Argentina, South Africa, South Australia; and the Tropics, where the tradewinds prevail. This horizontal movement carries vapor and dust about in a manner that ruins the sky for successful observations of solar radiation.

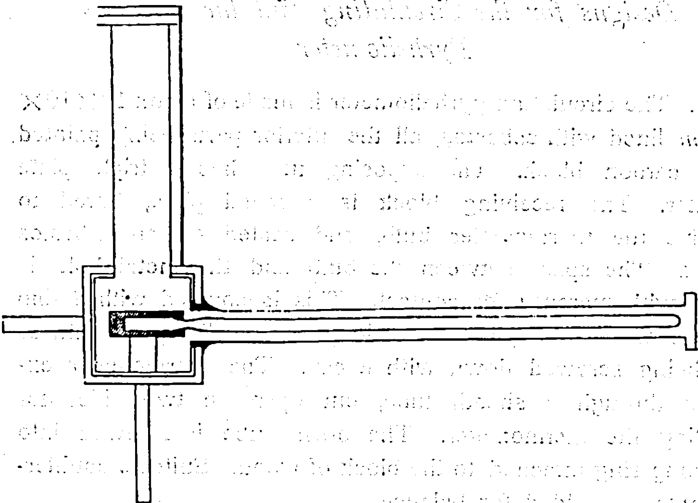
The second group is confined to the North High Pressure Belt, as the Extreme S. W. United States, Spain, Italy, N. Africa, Egypt, Arabia and portions of India; also to the South High Pressure Belt, as North Argentina and Chili, Bolivia, portions of South Africa and Australia. It is here alone that efficient observatories can be located.

The study of local absorption will be dependent chiefly upon the vacuum pyrheliometer, and the variations of the magnetic field, together with extensions of thermodynamics to all branches of the subject. A brief summary of the general conditions for a zenith-sun, may be seen in Figure No. 1 which will be more fully explained in Supplement No. 4 on Magnetism and Electricity.

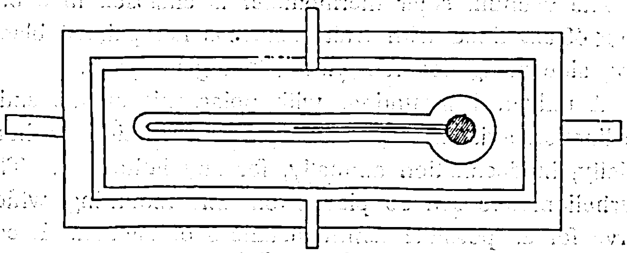
## *Note on Climatology*

Climatology discusses the effects of local rain and air-temperature upon the growth of plants, vegetation and trees. But this basis is erroneous because botanical and agricultural products depend actually upon the *solar-radiation-temperature,* which is about 60 degrees higher than the temperature of the air. The latter thermal efficiency would destroy all sorts of development of this kind.

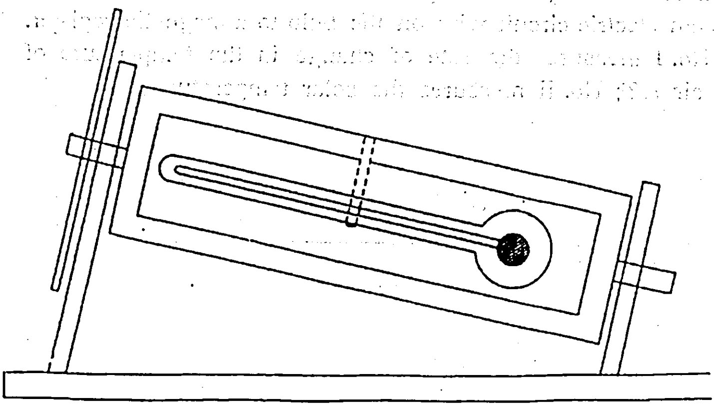
FIG. 9. Circulating and Vacuum Pyrheliometer.



a) The circulating pyrheliometer for the Poynting Equation.



b) The vacuum pyrheliometer for the Stefan Equation.



c) The mounting for latitude φ and declination δ.

## *Designs for the Circulating and the Vacuum Pyrheliometers*

I. The circulating pyrheliometer is made of a box $10 \times 10 \times 10\,cm$ lined with asbestos, all the interior parts being painted with carbon black. The exposing tube has a triple plate shutter. The receiving block is a metal plate, bored to receive the thermometer bulb, and seated on an asbestos block. The space between the bulb and the metal hole is filled with mercury for contact. This is covered with a thin roll of wollen thread for elasticity and shellac for tightness all being screwed down with a cap. The thermometer extends through a sheath tube, cut open on two sides for lighting the thermometer. The brass tube is screwed into a strong ring attached to the block of wood. Suitable counterweights are added for balance.

II. The vacuum solar thermometer is enclosed in a box $10 \times 10 \times 43\,cm$ lined with white asbestos not painted black, one long side being covered with a thin glass plate.

III. A universal mounting, with polar axis on the ends, and declination axis at the centre, provides motion in hour angle daily, in declination annually, for any latitude $\varphi$. The two pyrheliometers can be placed on this mounting which will serve for all possible zenith distances of the sun. It can be made self registering by a clock work on the hour circle, and an electric circuit wire on the bulb to a magnetic register.

No. I measures the rate of change in the temperature of the air $\Delta T$; No. II measures the solar temperature $T_s$.