No. 12.

(English Abstract from the Japanese Original)

The Standard Atmosphere and the Corrections to be applied to a Reading of an Altimeter.

T. TAMARU, *Rigakuhakusi*,

Member of the Institute.

1. **Assumptions** regarding the Standard Atmosphere are the following :—

i. *Temperature* :—h being the height in meters above sealevel,

$$\text{for} \quad h < 11000 \text{ m.}, \qquad t = 15 - \cdot 0065\,h \quad {}^\circ\text{C.},$$
$$\text{for} \quad h > 11000 \text{ m.}, \qquad t = \text{const.} = -56\cdot 5 \quad {}^\circ\text{C.}$$
$$T = 273 + t, \qquad T_0 = 273 + 15 = 288.$$

ii. g = constant = 980·00. As the merits of taking this value for g, suggested by Prof. Tanakadate, may be mentioned (a) its simplicity and the resulting convenience of calculation ; (b) better adaptedness to the state in the air than a value at the sealevel, 980·00 being the value of g at 2000 m. height at the latitude 45°, and at 3000 m. at Paris ; (c) that it leads to a simple and convenient value of ρ_0 (see below) ; and (d) to a simple and more exact value for the constant involved in the relation for $h > 11000$ (see below).

iii. *Pressure at the sealevel*, $p_0 = 1033\cdot 2$ $(= 76 \times \rho_{Hg})$ g.-weight/cm², where ρ_{Hg}, the density of mercury at 0°C., $= 13\cdot 5955 \times \cdot 999973 = 13\cdot 595$ g/cm³.

iv. *Density of the air*, which is assumed to contain ·04% CO_2 and no water vapour, is taken proportional to p/T. From its value at 0°C., 760 mm of mercury (at 0°C. and $g = 980\cdot 665$) and without CO_2, $= \cdot 0012928$ g/cm³, its value in the same condition and containing ·04% CO_2, is found $= \cdot 0012931$ g/cm³. Hence,

Density at 15°C. and 760 mm. of mercury (at 0°C. and $g = 980\cdot 00$) is—

$$\rho_0 = 0\cdot 0012931 \times \frac{273}{288} \times \frac{980\cdot 00}{980\cdot 665} = \cdot 0012249_2 \text{ g/cm}^3.$$

For most purposes, the abridged value ·001225 will suffice, which gives for ρ_0/g the simple and convenient value $\frac{1}{8}$ *exactly*, in the kg.-m.-s.-system.

2. **Numerical Relations of Height, Pressure and Density.**

I. For $h < 11000$, $T = T_0 - \alpha h$, α being put for 0·0065 °C. per meter, so that

$$dh = -\frac{dp}{g\rho} = -\frac{1}{g\rho_0}\,\frac{p_0 T}{p T_0}\,dp = -\frac{p_0}{gT_0\rho_0}\,(T_0 - \alpha h)\,\frac{dp}{p},$$

whence
$$\frac{p}{p_0} = \left(\frac{T_0 - \alpha h}{T_0}\right)^{\frac{gT_0\rho_0}{\alpha p_0}}, \text{ and } \frac{\rho}{\rho_0} = \left(\frac{T_0 - \alpha h}{T_0}\right)^{\frac{gT_0\rho_0}{\alpha p_0} - 1}.$$

On calculating, I find

$$\frac{gT_0\rho_0}{\alpha p_0}=\frac{980.\ 288.\ \cdot 0012249}{\cdot 000065.\ 1033\cdot 2.\ 980}=5\cdot 253\ (5\cdot 25285).$$

With the abridged value $\cdot 001225$ of ρ_0, the same value $5\cdot 253$ ($5\cdot 25328$) is obtained.

Thus, we have

$$p=760\left(\frac{288-\cdot 0065\,h}{288}\right)^{5\cdot 253}\ \text{mm Hg},\qquad \rho=\cdot 0012249\left(\frac{288-\cdot 0065\,h}{288}\right)^{4\cdot 253}\ \text{g/cm}^3.$$

II. For $h>11000$, $T=\text{constant}=216\cdot 5$, so that

$$dh=-\frac{dp}{g\rho}=-\frac{p_0T}{gT_0\rho_0}\,\frac{dp}{p},$$

whence
$$\log_{10}\frac{p_{11000}}{p}=\log_{10}\frac{\rho_{11000}}{\rho}=\frac{h-11000}{p_0T/(gT_0\rho_0\log_{10}e)}.$$

The denominator is

$$\frac{p_0T}{gT_0\rho_0\log_{10}e}=\frac{1033\cdot 2.\ 980.\ 216\cdot 5}{980.\ 288.\ \cdot 0012249.\ \cdot 4343}=14600\ (14600\cdot 22).$$

Regarding accuracy of numbers in general, we have kept *four* significant figures when the first figure is greater than 1, and *five* when the first figure is 1. The above calculation is carried out on this principle, and the result is true to *five* figures. [With $p_0=1033$ and $\rho_0=\cdot 001225$, we should obtain the same denominator 14600, true to *four* figures.]

The values of p at different heights of the standard atmosphere are given on p 331 (Hyô I.).

3. **Corrections to be applied to a Reading of an Altimeter** graduated according to the standard atmosphere.

Let h' be the actual height, measured from sealevel or the ground as the case may be, of any point, where the indication of the altimeter is h, and let T', g', ρ' be the actual temperature, gravity and density respectively at the same point. Further let T, g, ρ, p correspond to h in the standard atmosphere, p being the same as the actual pressure. If ρ'' be the density of *dry* air at p and T', $\rho''/\rho=T/T'$, and $\Delta\rho=\rho'-\rho''$ is the difference in density due to the water vapour partly replacing the air. Considering that $\Delta\rho=\rho'-\rho''$ and $\Delta g=g'-g$ are small, we put

$$dh'=-\frac{dp}{\rho'g'}=-\frac{dp}{(\rho''+\Delta\rho)(g+\Delta g)}=-\frac{dp}{\rho''g}\left(1-\frac{\Delta\rho}{\rho''}-\frac{\Delta g}{g}\right)$$

$$=-\frac{T'}{T}\frac{dp}{\rho g}+\frac{\Delta\rho}{\rho}\frac{dp}{\rho g}+\frac{\Delta g}{g}\frac{dp}{\rho g}=+\frac{T'}{T}\,dh-\frac{\Delta\rho}{\rho}\,dh-\frac{\Delta g}{g}\,dh,$$

so that
$$d(h'-h)=\frac{T'-T}{T}\,dh-\frac{\Delta\rho}{\rho}\,dh-\frac{\Delta g}{g}\,dh.$$

Hence, putting $h'-h=\Delta h$, $T'-T=\Delta T$, and denoting the value of Δh for h_0 by $(\Delta h)_0$,

$$\Delta h=(\Delta h)_0+(\Delta h)_T+(\Delta h)_v+(\Delta h)_g,$$

where
$$(\Delta h)_T=\int_{h_0}^{h}\frac{\Delta T}{T}\,dh,\qquad (\Delta h)_v=-\int_{h_0}^{h}\frac{\Delta\rho}{\rho}\,dh,\qquad (\Delta h)_g=-\int_{h_0}^{h}\frac{\Delta g}{g}\,dh.$$

The four terms in Δh represent respectively, (a) the correction due to the deviation of zero of h or p, (b) that due to the deviation of temperature distribution, (c) that due to water vapour, and (*d*) that due to the deviation of g from the standard value and to its variation with height.

(*a*) $(\Delta h)_0 = h_0' - h_0$, h_0' being the height of the ground. In case h' is to be measured from the ground, $h_0' = 0$ and $(\Delta h)_0 = -h_0$.

(*b*) The second correction $(\Delta h)_T$ is the most important of all. Its calculation may be conducted as shown in the schedule (p. 336, Hyô II), where the integral is calculated in sections divided at multiples of 400 m. of h, and where for ΔT and T the means of end values of each section are taken, so that

$$(\Delta h)_T = \sum (t' - t)_m \frac{400}{(273+t)_m} \cdot k,$$

k denoting unity in all intermediate sections and the ratio, (extent of the section)/400, in the end sections.

(*c*) If the maximum vapour tension at t' is p_v, and the relative humidity $f\,\%$,

$$\frac{\Delta \rho}{\rho} = -\frac{\cdot 378\, p_v}{p} \frac{f}{100},$$

so that the third correction (Δh) can be calculated in the same way as in (*b*) from the knowledge of the temperature t' and f (p being known beforehand), as shown in the schedule (p. 340, Hyô III); thus,

$$(\Delta h)_v = \sum \frac{\cdot 378\, p_v}{p} \frac{f}{100} 400.\, k = \sum \frac{\cdot 378 \times 4 \times p_v}{p} f.\ k.$$

The values of $\cdot 378 \times 4 \times p_v$ is tabulated on p. 341 (Hyô IV), where the numbers for $t < -30$ are rough extrapolations.

(*d*) $\Delta g = g' - 980 = (g'_0 - 980) - \beta h$, g'_0 being the value at sealevel and $\beta = 0{\cdot}31$ cm/sec² per kilometer. Hence,

$$(\Delta h)_g = -\int \frac{\Delta g}{g}\, dh = -\frac{g'_0 - 980}{g}(h - h_0) + \frac{\beta}{2g}(h^2 - h_0^2).$$

Writing $-h/g = A$, and $\frac{1}{2}\beta h^2/g = B$, we have,

$$(\Delta h)_g = (\Delta h)_g' + (\Delta h)_g'',$$

where $$(\Delta h)_g' = (g'_0 - 980)(A(h) - A(h_0)), \quad \text{and} \quad (\Delta h)_g'' = B(h) - B(h_0).$$

The values of A and B are tabulated on p. 341 (Hyô V).

4. **Example.** The method of calculation may be seen from an example, which is taken from "Arbeiten des K. Preussischen Aeronautischen Observatoriums be Lindenberg" IX, p. 277.

The first three columns t', p, h_L in the table on p. 343 (Hyô VI) are numbers taken from the original. When continuous records of h, t' and f are available, we can take directly the values of t' and f for $h = 400, 800, \ldots.$ This being not possible in this example, I have found out h (the fourth column of the Table) for each p given by making use of Table I (p. 331), have plotted t' against h so found, have connected successive points by straight lines, and have read the t' for $h = 400, 800, \ldots.$ As to f, it being given only for the ground, I have assumed the same f for all heights. For g'_0 I have assumed the value 981·3.

It is worthy of notice that no correction is required for the circumstance that the unit of p (mm Hg) differs, owing to difference in g, in physical magnitude from that in our standard case.

The further process can be seen from the schedules on pp. 336 and 340 (Hyô II and III). The correction (Δh) for 400, 800, ... being known, I have calculated the Δh for the heights given in the original by interpolation (the fifth column), and compared $h' = h+\Delta h$ with h_L originally given. The greatest difference amounts to 2 m. throughout the whole range of 11230 meters (the number 4601 in the original was in all probabilities a misprint for 4611).

Notice. 1. Schedules like those on p. 336 and 340, with thick type numbers printed beforehand, will be convenient for practical purposes.

2. For most purposes, $(\Delta h)_0+(\Delta h)_T$ (p. 336) will give a sufficient correction, for which records of h and t', but not of f, are required.

Dai 12 Gô

(Taisyô 14 n. (1925) 9 gt.)

Hyôzyun-Taiki,

oyobi

Kôdokei no Yomi no Naosi.

Syoin Rigakuhakusi TAMARU-Takurô.

A. Hyôzyun-taiki.

1. Ondo no Bunpai.

Mukasi kara tukawarete iru Takasa to Kiatu to no Kwankeisiki wa, Ondo wo itiyô to mite dasita Siki de aru. Sikaruni, konogoro Kôkûki ni tukau Kôdokei wo memorisuru Ten kara, Ondo ga Takasa ni yotte tigau koto wo Kandyô ni ireta Kwankeisiki wo motomeru koto ni natta. Zissaino Ondo wa, onazi Takasa demo, Tokoro ni yori Baai ni yotte taihen tigau keredomo, Kôdokei no Memori niwa aru kimatta Ondo-Bunpai wo totte keisansuru koto wa yamu wo enai.

Konoyôna Hyôzyun tosite donna Ondo-bunpai wo torubeki ka wo kimeru Dodai tosite, Yôroppa hen de nasareta Kwansoku no Kekkwa no Aramasi wo ieba :—

(a) Noboru ni sitagatte 10–13 km. hen made Ondo ga sidaini kudaru. Kono Kudari no Wariai wa sitano hô de yaya sukunaku, ueno hô de yaya ôi keredomo, heikinsite 1000 mêtoru ni taisite Sessi no 6·5° de aru.

(b) Sore yorimo ue dewa Ondo ga hotondo kawaranai ; kaette sukosi masu Baai ga ôi yô de aru keredomo, sono Masidaka wa yohodo sukunai.

Kûki no Undô ya Ame-kaze no Eikyô wa (a) no Arisama ni natte iru Bubun ni kagirareru no de, kore wo *Troposphere* to tonae, (b) no Arisama ni natte iru Bubun wo *Stratosphere* to tonaeru.

Troposphere to *Stratosphere* no Sakai no Takasa to sore kara ueno Basyo no Ondo wa, Tokoro (Ido) to Kisetu ni yotte tigau. Natu wa sore no Ondo ga takakute, Huyu wa hikui ; Sakai no Takasa mo dôyô de aru rasii. Mata, Ido ni taisitewa, Sekidô ni tikai hodo, Takasa ga takaku, Ondo wa kaette hikuku naru rasii. Sekidô de,—Yôroppa hen ni okeru Takasa oyoso 11 km., Ondo oyoso -56°C. ni taisite—Takasa ga 17 km., Ondo ga -91°C. nado to sirusarete aru.

Mata, itinitidyû no Kawarikata tositewa, Dimen ni tikai Tokoro ga, sukosi takai Tokoro yorimo kaette hikui koto ("Inversion") mo aru.

Konoyôni, hitotu-bitotuno Baai niwa Arisama ga taihen matimati de aru keredomo, Hyôzyun to subeki Arisama wo, Yôroppa no Kokusai-iinkwai oyobi Nippon no Kôkû-hyôgikwai no Torikime no tôri, tugino yôni kimeru :—

(A) $h<11000$ m. *dewa*, $t=15-\cdot0065\,h$ °C.,

(B) $h>11000$ m. *dewa*, $t=\text{const.}=-56\cdot5$ °C. ;

tadasi h wa Kaimen kara hakatta Takasa wo Mêtoru de arawasita Kazu. Mata, Kaimen ni okeru Atai wo tugino yôni kaku :—

$$t_0=15°\text{C.},\qquad T_0=273+15=288.$$

Ondo no Bunpai wo kimeta uede, nao kimeru koto wo yôsuru Ryô matawa Kotogara wa,

Dyûryoku no Tuyosa g no Atai,

Kaimen ni okeru Kiatu p_0,

Kûki no Seibun oyobi Mitudo,

korera mittu de aru.

2. Dyûryoku.

Dyûryoku no Tuyosa wa Ido nimo yori, Takasa nimo yotte tigau ga, wareware no Mokuteki ni taisite sore ni kimatta Atai wo ateyô to suru Ten dewa subeteno Hito ga ittisite iru. Yôroppa no Gakusyatati wa motto iroirona Tukaimiti ni kokusaitekino hyôzyunno Atai to sarete iru 980·665 cm./s^2 wo totta ga, Kokusai-iinkwai dewa 980·62 wo toru koto ni kimeta.

Nippon no Kôkû-hyôgikwai wa maeni Nippon de tukau Kazu tosite 980·00 wo toru koto ni sita ga, notini kokusaitekino Tukaimiti nimo, Tanakadate Hakusi no Iken ni sitagatte, onazi Atai 980·00 wo tukau hô ga yoi to kimeta node, koko dewa

(C) *Dyûryoku no Tuyosa wo itiyôni* 980·00 cm./s^2. *ni toru.*

Kono Atai wa Kokusai-iinkwai ni Syûseian tosite dasareru hazu de aru.

Dyûryoku g wo 980·00 to toru koto ni tomonau Rieki wa tugino tôri iroiro aru.

(a) 980·00 wa 1000−2% to iu kantanna Kazu de aru tameni, subeteno Keisan ni benri de aru.

(b) 980·00 wa 980·665 matawa 980·62 yorimo, takai Basyo ni okeru zissaino g no Atai ni tikai. 980·665 matawa 980·62 wa iduremo Ido 45° no Kaimen ni okeru g no Atai de aru ga, 980·00 wa Ido 45° no Tokoro dewa 2000 m., Paris dewa hobo 3000 m., London dewa hobo 4000 m. no Takasa ni okeru g ni ataru no de aru. Tôkyô ni taisitewa, 980·00 yorimo nao tiisai Atai de nakereba Kûtyû no g ni naranai keredomo, kono Koto wa, kokusaitekino Mondai to iu Ten to 980·00 ga ataeru hokano Rieki to kara yamu wo enai to suru.

(c) Hyôzyun to subeki Kûki no Mitudo (Hyôzyun-taiki no Kaimen ni okeru Atai) wo arawasu Kazu ρ_0 ga kantan de katu benrina Kazu ni naru [sita (§ 5) wo miraretai].

(d) 11 km. izyô no Takasa ni okeru Aturyoku oyobi Mitudo no Siki ni hairu Zyôsû ga kantan de kâtu seimituna Kazu ni naru [sita (§ 7) wo miraretai].

3. Kaimen ni okeru Kiatu.

Kaimen ni okeru Kiatu p_0 wo,

(D) 0°C. *ni okeru Suigin no Hasira no Takasa* 760 mm. *no Aturyoku to hitosiku toru koto*

niwa dare mo Izon ga nai. Tada, sore ni hataraku Dyûryoku no Tuyosa wo, ueno § ni sitagatte, 980 cm./s^2. to toru koto ni tyûisubeki de aru.

Suigin (0°C.) no Mitudo ga $\rho_{Hg} = 13{\cdot}5955 \times 0{\cdot}999973 = 13{\cdot}595$ g./cm^3. de aru kara,

$$p_0 = 1033{\cdot}2 \quad \text{g.-Omosa}/\text{cm}^2.$$
$$= 1033{\cdot}2 \times 980 \ \text{dyne}/\text{cm}^2.$$

4. Kûki no Seibun.

Kûki no Seibun ni tuitewa, Tansan-gasu to Suizyôki to no Bunryô ga Mondai ni naru. Suizyôki no Bunryô wa Baai ni yotteno Kawarikata ga amari ôkii node, sore no heikinno Atai wo tukatta tokorode, taisite Tugô ga yokumo naku, mata Takasa ni taisite Seibun ga kawaru to iu Wadurawasisa ga aru. Sorede, koko dewa,

(E) *Suizyôki no nai no wo hyôzyunno Zyôtai to site, Hituyô ga areba Naosi wo kuwaeru koto*

ni suru. Kono Ten dewa, Yôroppa no Iinkwai mo Nippon no Hyôgikwai mo onazi Iken de aru.

Tansan-gasu no Bunryô wa taitei kimatte iru node,

(F) 0·04% *no Tansan-gasu ga aru koto*

to suru. Kôkû-hyôgikwai dewa, motowa kore wo irenaide keisansite ita ga, notini Yôroppa no Kokusai-iinkwai no Iken ni sitagatte koredakeno Tansan-gasu wo ireru koto ni sita.

5. Kaimen ni okeru Mitudo.

Ueno yôna Seibun wo motu Kûki ga Kaimen ni okeru Hyôzyunzyôtai T_0 oyobi p_0 de motu Mitudo ρ_0 wo keisansuru. Sore niwa Kûki no Mitudo ga ippanni p/T sunawati $p/(273+t)$ ni hireisuru mono to suru.

0°C., 760 mm Hg ni okeru, Tansan-gasu ya Suizyôki wo hukumanai Kûki no Mitudo wa, Suigin ni hataraku Dyûryoku ga $g=980{\cdot}665$ cm./s². no tokini, 0·0012928 g./cm³. de aru kara, onazi g no Tokoro de 0·04% no Tansan-gasu wo hukumu Kûki no 0°C., 760 mm Hg ni okeru Mitudo wa 0·0012931 g./cm³. de aru. Kono Kazu wo tukatte, $g=980{\cdot}00$ cm./s²., $T_0=288$ no tokino Mitudo ρ_0 wo daseba,

$$\rho_0 = 0{\cdot}0012931 \times \frac{980{\cdot}00}{980{\cdot}665} \times \frac{273}{288}$$
$$= 0{\cdot}0012249_2 \ \text{g.}/\text{cm}^3.$$

Hutûno Mokuteki niwa, 4-keta dake totte,

$$\rho_0 = 0{\cdot}001225 \text{ g./cm}^3. = 1{\cdot}225 \text{ kg./m}^3.$$

to totte yoi. Kono Atai wa, ρ_0/g ni taisite m.-kg.-s.-Tan'i-kumiai de *tyôdo* 1/8 to iu kantanna Kazu wo ataeru. Kore wa, Hikôki ni kwansuru iroirona Kwankeisiki no Keisan ni taihen benrina Koto de aru(1).

6. 11 km. ika ni okeru Kwankeisiki.

Maeni nobeta yôni, Takasa ni taisite Ondo no kudaru Wariai ga itiyô de aru to mite, sore wo $\alpha = 0{\cdot}0065$ °C/m. to sureba, kattena Takasa h ni okeru Ondo wa

$$T = T_0 - \alpha h$$

de arawasareru. Mata,

$$dh = -\frac{dp}{g\rho} = -\frac{p_0}{gT_0\rho_0}(T_0 - \alpha h)\frac{dp}{p}.$$

Yueni,

$$\log\left(\frac{T_0 - \alpha h}{T_0}\right) = \frac{\alpha p_0}{gT_0\rho_0}\log\frac{p}{p_0};$$

tadasi, T_0, p_0, ρ_0 wa $h=0$ ni okeru sorezoreno Ryô de, § 1, 3, 5 ni dasita Atai wo motu.

Sitagatte,

$$\frac{p}{p_0} = \left(\frac{T_0 - \alpha h}{T_0}\right)^{\frac{gT_0\rho_0}{\alpha p_0}};$$

mata,

$$\frac{\rho}{\rho_0} = \frac{p}{p_0}\cdot\frac{T_0}{T} = \left(\frac{T_0 - \alpha h}{T_0}\right)^{\frac{gT_0\rho_0}{\alpha p_0} - 1}.$$

Korerano Siki no Sisû ni aru Ryô $\frac{gT_0\rho_0}{\alpha p_0}$ no Atai wo, maeni dasita p_0, ρ_0 nado kara keisansuruto,

$$\frac{gT_0\rho_0}{\alpha p_0} = \frac{980.\ 288.\ {\cdot}0012249}{{\cdot}000065.\ 1033{\cdot}2.\ 980} = 5{\cdot}253\ (5{\cdot}25285)$$

ni naru. ρ_0 ni ·001225 wo tukattemo onazi Atai 5·253 (5·25328) ga

(1) Hyôzyun-taiki ni tuite kimeta Kotogara wo, Kôdokei no Memori ni kagirazu, hiroku Kôkûki ni kwankeisita subeteno Keisan ni tukau yôni suru koto wa Kokusai-iinkwai demo Kôkû-hyôgikwai demo kibôsite iru Koto de aru.

erareru. Sorede, Kekkwa wa tumari tugino yôni naru[1]:—

$$
\text{(G)}\quad \begin{cases} p=760\left(\dfrac{288-0{\cdot}0065\,h}{288}\right)^{5\cdot253}\ \text{mm Hg}, \\[2ex] \rho=1{\cdot}2249\left(\dfrac{228-0{\cdot}0065\,h}{288}\right)^{4\cdot253}\ \text{kg./m.}^3 \end{cases}
$$

7. 11 km. izyô ni okeru Kwankeisiki.

11 km. yorimo ue dewa, Ondo ga itiyô de aru kara,

$$
dh=-\frac{dp}{g\rho}=-\frac{p_0 T}{g T_0 \rho_0}\,\frac{dp}{p}
$$

ni oite, $T=\text{const.}=216{\cdot}5$; sitagatte,

$$
\log_{10}\frac{p_{11000}}{p}=\log_{10}\frac{\rho_{11000}}{\rho}=\frac{h-11000}{\dfrac{p_0 T}{g T_0 \rho_0 \log_{10} e}}
$$

Owarino Bunsû no Bunbo wa, Mêtoru wo Tan'i ni site,

$$
\frac{1033{\cdot}2.\ 980.\ 216{\cdot}5}{980.\ 288.\ {\cdot}0012249.\ {\cdot}4343.\ 100}=14600\quad(14600{\cdot}22)
$$

de, kore wa 5-keta made tadasii. Sitagatte,

$$
\text{(H)}\qquad \log_{10}\frac{p_{11000}}{p}=\log_{10}\frac{\rho_{11000}}{\rho}=\frac{h-11000}{14600}\,.
$$

Kono Siki ni hukumareru Zyôsû ni taisitewa, Kokusai-iinkwai demo 14600 wo tukatte iru ga, Kokusai-iinkwai no g ya ρ_0 kara kandyôsuruto, zituwa sore wa 14590 de aru. Soreyueni, wareware no Torikime no hô ga Kazu ga kantan de katu seimitu de aru.

8. Takasa (h) ni taisuru Aturyoku (p) no Hyô.

Ueni eta Siki ni hukumareru iroirona Zyôsû wo keisansuru niwa,

(1) Kokusai-iinkwai dewa $g=980{\cdot}62$ to totta tameni, korerano Siki ni okeru Kazu 5·253 no kawarini 5·256, 4·253 no kawarini 4·256 wo tukatte iru. Mottomo, Kôdokei no Memori ni tuitewa, p no Siki no Sisû ni okeru ·003 no Tigai wa 11000 m. ni oite tada 5 m. gurai no Tigai wo syôzuru ni suginai.

Hyô I. Hyôzyun-taiki no Aturyoku (mm Hg de).

[Pressure of the Standard Atomosphere in mm Hg.]

$g=980{\cdot}00$. Suizyôki nasi. $\cdot 04\%$ CO_2. $t=\begin{cases}(15-{\cdot}0065h)^\circ\mathrm{C}. & (h<11000)\\ -56{\cdot}5^\circ\mathrm{C} & (h>11000)\end{cases}$

h(m)	0		1000		2000		3000		4000	
0	760.00_0		674.11_6		596.26_5		525.85_9		462.34_0	
100	751.03_3	8.96_7	665.97_9	8.13_7	588.89_9	7.36_6	519.20_6	6.65_3	456.34_6	5.99_4
200	742.15_1	8.88_2	657.92_2	8.05_7	581.60_6	7.29_3	512.62_1	6.58_5	450.41_6	5.93_0
300	733.35_5	8.79_6	649.94_5	7.97_7	574.38_7	7.21_9	506.10_4	6.51_7	444.54_7	5.86_9
400	724.64_4	8.71_1	642.04_5	7.90_0	567.24_1	7.14_6	499.65_5	6.44_9	438.74_2	5.80_5
500	716.01_6	8.62_8	634.22_4	7.82_1	560.16_7	7.07_4	493.27_2	6.38_3	432.99_7	5.74_5
600	707.47_2	8.54_4	626.48_0	7.74_4	553.16_4	7.00_3	486.95_5	6.31_7	427.31_4	5.68_3
700	699.01_0	8.46_2	618.81_2	7.66_8	546.23_3	6.93_1	480.70_4	6.25_1	421.69_1	5.62_3
800	690.63_1	8.37_9	611.22_1	7.59_1	539.37_2	6.86_1	474.51_8	6.18_6	416.12_8	5.56_3
900	682.33_3	8.29_8	603.70_6	7.51_5	532.58_1	6.79_1	468.39_7	6.12_1	410.62_5	5.50_3
1000	674.11_6	8.21_7	596.26_5	7.44_1	525.85_9	6.72_2	462.34_0	6.05_7	405.18_1	5.44_4

h(m)	5000		6000		7000		8000		9000	
0	405.18_1		353.88_4		307.97_5		267.01_2		230.57_7	
100	399.79_6	5.38_5	349.05_8	4.82_6	303.66_3	4.31_2	263.17_2	3.84_0	227.16_7	3.41_0
200	394.46_8	5.32_8	344.28_6	4.77_2	299.40_0	4.26_3	259.37_6	3.79_6	223.79_8	3.36_9
300	389.19_8	5.27_0	339.56_6	4.72_0	295.18_6	4.21_4	255.62_5	3.75_1	220.47_0	3.32_8
400	383.98_6	5.21_2	334.89_9	4.66_7	291.02_0	4.16_6	251.91_8	3.70_7	217.18_1	3.28_9
500	378.83_0	5.15_6	330.28_4	4.61_5	286.90_2	4.11_8	248.25_4	3.66_4	213.93_3	3.24_8
600	373.73_0	5.10_0	325.72_1	4.56_3	282.83_1	4.07_1	244.63_4	3.62_0	210.72_4	3.20_9
700	368.68_6	5.04_4	321.20_8	4.51_3	278.80_7	4.02_4	241.05_6	3.57_8	207.55_4	3.17_0
800	363.69_8	4.98_8	316.74_7	4.46_1	274.82_9	3.97_8	237.52_1	3.53_5	204.42_3	3.13_1
900	358.76_4	4.93_4	312.33_6	4.41_1	$270\ 89_8$	3.93_1	234.02_8	3.49_3	201.33_1	3.09_2
1000	353.88_4	4.88_0	307.97_5	4.36_1	267.01_2	3.88_6	230.57_7	3.45_1	198.27_6	3.05_5

h(m)	10000		11000		12000		13000		14000	
0	198.27_6		169.74_0		144.97_4		123.82_2		105.75_6	
100	195.25_9	3.01_7	167.08_4	2.65_6	142.70_5	2.26_9	121.88_4	1.93_8	104.10_1	1.65_5
200	192.27_9	2.98_0	164.46_9	2.61_5	140.47_2	2.23_3	119.97_7	1.90_7	102.47_2	1.62_9
300	189.33_6	2.94_3	161.89_6	2.57_3	138.27_4	2.19_8	118.10_0	1.87_7	100.86_9	1.60_3
400	186.43_0	2.90_6	159.36_2	2.53_4	136.11_1	2.16_3	116.25_2	1.84_8	99.29_0	1.57_9
500	183.56_0	2.87_0	156.86_9	2.49_3	133.98_1	2.13_0	114.43_3	1.81_9	97.73_7	1.55_3
600	180.72_6	2.83_4	154.41_4	2.45_5	131.88_5	2.09_6	112.64_2	1.79_1	96.20_7	1.53_0
700	177.92_7	2.79_9	151.99_8	2.41_6	129.82_1	2.06_4	110.88_0	1.76_2	94.70_2	1.50_5
800	175.16_3	2.76_4	149.62_0	2.37_8	127.79_0	2.03_1	109.14_5	1.73_5	93.22_0	1.48_2
900	172.43_4	2.72_9	147.27_8	2.34_2	125.79_0	2.00_0	107.43_7	1.70_8	91.76_1	1.45_9
1000	169.74_0	2.69_4	144.97_4	2.30_4	123.82_2	1.96_8	105.75_6	1.68_1	90.32_6	1.43_5

saisyono Yûkôsûzi ga 1 de aru Kazu wa go-keta, sore ga 2 izyô de aru Kazu wa yo-keta toru to iu Hôsin de keisansite aru. Sikasi, Kôdokei wo memorisuru tameniwa, h to p ni *seimituni* tadasii hitotuno Kwankei-siki wo *kimete* oku koto ga hituyô de aru. Kono Imi ni oite, ueno (G) oyobi (H) de simesareru p to h no Kwankei wa *seimituni* tadasii to site, motto ôkuno Ketakazu wo keisansuru koto wa sasitukaenai.(1)

Hyô I wa h no 100-m.-okino Atai ni taisuru p wo (G) oyobi (H) ni yotte keisansita Atai wo simesu. Mata, Hyô I′ wa 500-m.-okino h ni taisite keisansita t oyobi ρ no Atai wo simesu.

Hyô I′.

Hyôzyun-taiki no Ondo to Mitudo.

h(m)	t(°C.)	ρ(kg./m.³)	h(m)	t(°C.)	ρ(kg./m.³)	h(m)	t(°C.)	ρ(kg./m.³)
0	15·0	1·2249	5500	−20·75	0·6971	11000	−56·5	0·3639
500	11·75	1·1672	6000	−24·0	0·6597	11500	−56·5	0·3363
1000	8·5	1·1116	6500	−27·25	0·6238	12000	−56·5	0·3108
1500	5·25	1·0580	7000	−30·5	0·5895	12500	−56·5	0·2873
2000	2·0	1·0064	7500	−33·75	0·5565	13000	−56·5	0·2655
2500	−1·25	0·9568	8000	−37·0	0·5252	13500	−56·5	0·2453
3000	−4·5	0·9091	8500	−40·25	0·4951	14000	−56·5	0·2267
3500	−7·75	0·8632	9000	−43·5	0·4664	14500	−56·5	0·2096
4000	−11·0	0·8191	9500	−46·75	0·4389	15000	−56.5	0·1937
4500	−14·25	0·7763	10000	−50·0	0·4127	15500	−56·5	0·1790
5000	−17·5	0·7361	10500	−53·25	0·3877	16000	−56·5	0·1654

(1) Kwankeisiki (H) ni aru Zyôsû 14600 no rirontekino Siki ni sakanobotte, $\frac{p_0 T}{g T_0 \rho_0 \log_{10} e}$ ga *genmituni* 14600 ni hitosii to site, sore to $T = 216{\cdot}5$, $\alpha = {\cdot}0065$ wo tukatte, (G) ni aru Sisû no rirontekino Atai $\frac{g T_0 \rho_0}{\alpha p_0}$ wo keisansuruto, 5·253000 ni natte, 7-keta mademo 5·253 ni ittisuru no wa gûzen nagara omosiroi Itti de aru ga, sikasi kono Koto wa kore izyôno Imi wo motanai.

B. Kôdokei no Yomi no Naosi.

9. Yottuno Naosi.

Kôdokei no Domori h wa Aturyoku p ni taisite maeno Siki (G) (H) no tôrino Kwankei wo nasite, sore no Yomi niwa Ondo no Eikyô ya kwakono Toriatukai ni motoduku Tigai nado wa nai mono to suru.

Sore wo noseta Kôkûki no Tobidasi-basyo ni okeru sore no Yomi wo h_0 m., Kûtyû no aru Basyo ni okeru Yomi wo h m. to suru. Sono Basyo no zissaino Takasa ga Kaimen kara matawa Tobidasi-basyo kara h' m. da to suru tokini, hutatu no Tigai $h'-h=\Delta h$ wa yottuno Gen'in kara okoru.

(a) $h'=0$ no Basyo de Aturyoku ga 760 mm. de nai koto. Kore wa Kaimen no Kiatu ga Toki ni yotte kawaru koto, oyobi, h' wo Dimen kara hakaru Baai niwa, sore no Reiten ga Kaimen de nai koto kara okoru.

(b) Ondo no Bunpai ga Hyôzyun-taiki ni okeru to tigau koto. Kore wa Natu matawa Huyu niwa kanari ôkina Eikyô wo syôzuru mono de, Naosi no nakano itiban daizina mono de aru.

(c) Kûki ni Suizyôki ga aru koto. Hyôzyun-taiki wa Suizyôki wo hukumanai to mite aru kara, zissaino Baai ni sore ga hukumarete iru koto no Eikyô ga aru no wa iu mademo nai.

(d) Dyûryoku no Tuyosa ga Hyôzyun-taiki de kimeta Atai 980·00 to tigau koto. Dyûryoku wa Basyo ni yori, Takasa ni yotte tigau kara, sono Tigai ga Δh ni kiite kuru.

10. Naosi no rirontekino Keisan.

Aturyoku p no Tokoro no zissaino Takasa ga h', Ondo ga T', Mitudo ga ρ', Dyûryoku ga g'; sono Aturyoku ni sôtôsuru Hyôzyun-taiki no Takasa ga h, Ondo ga T, Mitudo ga ρ, Dyûryoku ga g de aru to suru. Sôsureba, h, h', p no aidani tugino Kwankei ga aru:—

$$dh' = -\frac{dp}{g'\rho'}, \qquad dh = -\frac{dp}{g\rho}.$$

Ima Suizyôki wo hukumanai Kûki ga T', p ni oite motubeki Mitudo wo ρ'' to sureba,

$$\rho''/\rho = T/T'$$

no Kwankei ga aru ; mata, $\rho' - \rho''$ wa, hitotuno kimatta Ondo T' de Aturyoku p wo okonau Kûki no utino itibubun—Suizyôki no Tyôryoku ni ataru dake—wo Suizyôki ni torikaeta tameni okoru Mitudo no Masidaka de aru kara, T' ni okeru Suizyôki no Saidai-tyôryoku wo p_v, sono Basyo ni okeru Situdo wo $f\%$ to sureba,

$$\frac{\rho' - \rho''}{\rho''} = -\frac{\cdot 378\, p_v}{p}\,\frac{f}{100}$$

no Kwankei ga aru.

$\rho' - \rho'' = \Delta\rho$, $g' - g = \Delta g$ to kaite, korerano Ryô ga iduremo ρ ya g ni kurabete taihen tiisai koto wo mitomeruto, maeni mita dh' no Siki wo tugino yôni kaku koto ga dekiru :—

$$\begin{aligned} dh' &= -\frac{dp}{g'\rho'} = -\frac{dp}{(g+\Delta g)(\rho''+\Delta\rho)} = -\frac{dp}{g\rho''}\left(1 - \frac{\Delta\rho}{\rho''} - \frac{\Delta g}{g}\right) \\ &= -\frac{T'}{T}\,\frac{dp}{g\rho} + \frac{\Delta\rho}{\rho}\,\frac{dp}{g\rho} + \frac{\Delta g}{g}\,\frac{dp}{g\rho} \\ &= \frac{T'}{T}\,dh - \frac{\Delta\rho}{\rho}\,dh - \frac{\Delta g}{g}\,dh. \end{aligned}$$

Sitagatte, $T' - T = \Delta T$ to kaite,

$$d(h' - h) = \frac{\Delta T}{T}\,dh - \frac{\Delta\rho}{\rho}\,dh - \frac{\Delta g}{g}\,dh.$$

Kore wo h_0 kara h made sekibunsi, $h' - h$ wo Δh, h_0 ni taisuru Δh wo $(\Delta h)_0$ to kakuto,

$$\Delta h = (\Delta h)_0 + \int_{h_0}^{h} \frac{\Delta T}{T}\,dh - \int_{h_0}^{h} \frac{\Delta\rho}{\rho}\,dh - \int_{h_0}^{h} \frac{\Delta g}{g}\,dh$$

ni naru. Korerano yottuno Husi ga ueni nobeta yottuno Naosi wo arawasu koto ga yôini mitomerareru. Kono Imi ni oite,

$$\Delta h=(\Delta h)_0+(\Delta h)_T+(\Delta h)_v+(\Delta h)_g$$

to kakuto,

$$(\Delta h)_T=\int_{h_0}^{h}\frac{\Delta T}{T}\,dh,\quad (\Delta h)_v=-\int_{h_0}^{h}\frac{\Delta \rho}{\rho}\,dh,\quad (\Delta h)_g=-\int_{h_0}^{h}\frac{\Delta g}{g}\,dh$$

to naru.

11. Reiten no Naosi $(\Delta h)_0$.

Tobidasi-basyo no Takasa ga h'_0 de areba,

$$(\Delta h)_0=h'_0-h_0.$$

Mosi Takasa h' wo Tobidasi-basyo kara hakaru naraba, $h'_0=0$ to oite, $(\Delta h)_0=-h_0$ ni naru.

12. Ondo ni taisuru Naosi $(\Delta h)_T$.

Kono Naosi

$$(\Delta h)_T=\int_{h_0}^{h}\frac{\Delta T}{T}\,dh$$

ni oite, T wa $288-{\cdot}0065\,h$ de ari, ΔT wa, Kôdokei ga h wo simesita to onazi Toki ni Kandankei ga t' wo simesita to sureba, $\Delta T=T'-T=t'-t=t'-(15-{\cdot}0065\,h)$ de aru.

Onazi Zikoku ni okeru h to t' to wa Kiroku-sôti ni yotte renzokutekini, matawa tugini iu yôna tekigina Aima wo oite tyokusetuni yomitotte aru mono to suru.

Ueno Sekibun wo keisansuru no ni, h_0 kara h madeno aida wo 400, 800, 1200,....no Tokoro de kugiri, ΔT oyobi T ni onônono Kuiki no Ryôhazi ni okeru Atai no Heikinsû $(\Delta T)_m$ oyobi T_m wo totte,

$$\int\frac{\Delta T}{T}\,dh=\sum(\Delta T)_m\frac{400}{T_m}\,.\,k$$

wo keisansuru. Koko de k wa ippanniwa $=1$ de aru ga, tada itiban sitano Kuiki to itiban ueno Kuiki ga 400 m. to tigau Baai ni, Kuiki/400 wo arawasu Bunsû de aru.

Ueno Keisan niwa tugino Hyô II no yôna kakikomi-yôno Surimono

Hyô II. $(\Delta h_0+(\Delta h)_T$ no Keisan no Hinagata.

[Schedule for calculating $(\Delta h)_0+(\Delta h)_T$].

h	t'	t	$t'-t$	$(t'-t)_m$	$\frac{400}{(273+t)_m}$	$\delta(\Delta h)_T$	$(\Delta h)_0+(\Delta h)_T$	$(\Delta h)_T+(\Delta h)_g$	Δh
96	2.8	14.4	−11.6				$(\Delta h)_0=20$	0	+ 20
				− 9.7 ×	$1.40\times\frac{304}{400}$	= −10.3			
400	4.6	12.4	− 7.8				+ 9.7	+ .4	+ 10.1
				− 7.7 ×	1.41	= −10.9			
800	2.2	9.8	− 7.6				− 1.2	1.0	− 0.2
				− 8.15 ×	1.42	= −11.6			
1200	− 1.5	7.2	− 8.7				− 12.8	1.5	− 11.3
				− 9.4 ×	1.43	= −13.4			
1600	− 5.5	4.6	−10.1				− 26.2	1.8	− 24.4
				− 6.35 ×	1.45	= − 9.2			
2000	− 0.6	2.0	− 2.6				− 3.54	2.3	− 33.1
				− 2.7 ×	1.46	= − 3.9			
2400	− 3.4	− 0.6	− 2.8				− 39.3	3.0	− 36.3
				− 2.45 ×	1.48	= − 3.6			
2800	− 5.3	− 3.2	− 2.1				− 42.9	3.5	− 39.4
				− 1.8 ×	1.49	= − 2.7			
3200	− 7.3	− 5.8	− 1.5				− 45.6	4.1	− 41.5
				− 1.9 ×	1.51	= − 2.9			
3600	−10.7	− 8.4	− 2.3				− 48.5	4.6	− 43.9
				− 1.55 ×	1.52	= − 2.4			
4000	−11.8	−11.0	− 0.8				− 50.9	5.0	− 45.9
				− .65 ×	1.54	= − 1.0			
4400	−14.1	−13.6	− 0.5				− 51.9	5.6	− 46.3
				− .65 ×	1.55	= − 1.0			
4800	−17.0	−16.2	− 0.8				− 52.9	6.0	− 46.9
				− 1.3 ×	1.57	= − 2.0			
5200	−20.6	−18.8	− 1.8				− 54.9	6.4	− 48.5
				− 2.2 ×	1.58	= − 3.5			
5600	−24.0	−21.4	− 2.6				− 58.4	6.9	− 51.5
				− 3.2 ×	1.60	= − 5.1			
6000	−27.8	−24.0	− 3.8				− 63.5	2.3	− 56.2
				− 4.7 ×	1.62	= − 7.6			
6400	−32.2	−26.6	− 5.6				− 71.1	7.8	− 63.3
				− 5.9 ×	1.63	= − 9.6			
6800	−35.4	−29.2	− 6.2				− 80.7	8.1	− 72.6
				− 6.55 ×	1.65	= −10.8			
7200	−38.7	−31.8	− 6.9				− 91.5	8.6	− 82.9
				− 7.4 ×	1.67	= −12.4			
7600	−42.3	−34.4	− 7.9				−103.9	9.2	− 94.7
				− 8.45 ×	1.69	= −14.3			
8000	−46.0	−37.0	− 9.0				−118.2	9.5	−108.7
				− 9.6 ×	1.71	= −16.4			
8400	−49.8	−39.6	−10.2				−134.6	10.0	−124.6
				−10.95 ×	1.73	= −18.9			
8800	−53.9	−42.2	−11.7				−153.5	10.6	−142.9
				−11.85 ×	1.75	= −20.7			
9200	−56.8	−44.8	−12.0				−174.2	11.2	−163.0
				−11.75 ×	1.77	= −20.8			
9600	−58.9	−47.4	−11.5				−195.0	11.9	−183.1
				−11.45 ×	1.79	= −20.5			
10000	−61.4	−50.0	−11.4				−215.5	12.9	−202.9
				−11.55 ×	1.81	= −20.9			
10400	−64.3	−52.6	−11.7				−236.4	13.3	−223.2
				−10.3 ×	1.83	= −18.8			
10800	−64.1	−55.2	− 8.9				−255.2	14.1	−241.1
				− 8.55 ×	1.84	= −15.7			
11200	−64.7	−56.5	− 8.2				−270.9	15.1	−255.8
				— ×	1.85	=			
11600	—	−56.5	—				—	—	—
				— ×	1.85	= —			
12000	—	−56.5	—				—	—	—
				—	—	—			
—	—	—	—				—	—	—
11495	−62.0	−56.5	− 5.5	− 6.85 ×	$1.85\times\frac{295}{400}$	= − 9.3	−280.2	15.7	−234.5

wo yôisite okeba benri de aru. Kono Hyô ni aru hutoi Sûzi no Kazu wa Hazime kara Surimono ni insatusite oku Sûzi, nanamena Sûzi wa Baaibaai ni kakikomu Sûzi de aru (koko ni dasita nanamena Sûzi wa notini noberu Rei ni tuite keisansita mono de aru).

Konoyôna Surimono ni kakikomubeki Sûzi wa—

Daiitino Kudari (I) dewa, itiban ueni Dimen ni okeru Kôdokei no Yomi h_0 wo kakikomu; itiban sitano Gyô ni itiban takai Basyo ni taisuru h (h_1) wo kakikomu (sore ga tyôdo 400 no Baisû ni natte inai Baai).

Dainino Kudari (II) niwa, Kôdokei no Yomi ga I no Kazu ni ataru tokino Kandankei no Yomi wo kakikomu.

Daisanno Kudari (III) niwa, itiban ueno Gyô ni, h_0 ni taisuru Hyôzyun-taiki no Ondo $15-\cdot 65\, h/100$ wo kaku; itiban sitano Gyô nimo dôyôni h_1 ni taisuru Hyôzyun-taiki no Ondo wo kaku.

Daisino Kudari (IV) niwa II kara III wo hiita Kazu wo kaku.

Daigono Kudari (V) niwa IV no Kudari de diki ue to sita to ni aru Kazu no Heikinsû wo kaku.

Dairokuno Kudari (VI) dewa, itiban sitano Gyô ni sono Takasa ni taisuru (onazi Kudari no ueno hô ni sutte aru) Kazu (kono Rei de 1·85) wo utusi-toru.

Daisitino Kudari (VII) niwa, soko ni simesareta Keisan wo site eta Kazu wo kaku. Koko de itiban ueno Gyô to itiban sitano Gyô ni yobunni kakeru Bunsû (ueno Siki no k) no Bunsi wa sono Kuiki no Hirosa no Mêtoru-sû de aru.

Daihatino Kudari (VIII) niwa, itiban ueno Gyô ni $(\Delta h)_0 = h'_0 - h_0$ wo kaki-komi, Nigyôme karawa sore ni VII no Kazu wo tugitugini kuwaeta Kazu wo kakikomu. Kore ga sunawati sorezoreno h ni taisuru $(\Delta h)_0 + (\Delta h)_T$ no Atai de aru.

Sonotugino Kudari wa Hyô III de keisansite eru $(\Delta h)_v + (\Delta h)_g$ (§13, 14) wo utusi-totta mono de, owarino Kudari wa, korerano hutatuno Kudari wo kuwaete eru zentaino Δh no Atai de aru.

Tyûi 1. Kono Rei wo mitemo sireru yôni, omona Naosi wa

$(\Delta h)_0+(\Delta h)_T$ de ataerareru kara, aramasino Mokuteki niwa Hyô II no Keisan dake de zyûbun de aru.

Tyûi 2. Aramasino Mokuteki niwa, $(\Delta h)_T$ wo keisansuru no ni T_m wo ôyosono Atai ni totte,

$$\Delta h = h'_0 - h_0 + \frac{1}{T_m}\int \Delta T dh$$

to totte yoi. Tatoeba, $\Delta T = -10°C$. (doko demo) no Baai ni, $T_m = 280$ to tori, h' wo Dimen kara hakaru to sureba,

$$\Delta h = -h_0 - \frac{10}{280}(h - h_0).$$

sitagatte, $$h' = h + \Delta h = h - h_0 - \frac{1}{28}(h - h_0).$$

$h - h_0 = 2800$ m. ni taisite, Naosi ga 100 m. ni naru.

Tyûi 3. Kôdokei no Hari (matawa Domoriita) wo mawasite, Dimen de 0 ni awaseru koto wa, Memori ga itiyô de aru Baai ni $(\Delta h)_0$ no Naosi wo okonau koto niwa naru keredomo, sore wo sureba Ondo ni taisuru Naosi no Keisan ga dekinaku naru kara, sinai hô ga yoi.

13. Suizyôki no tameno Naosi $(\Delta h)_v$.

Kono Naosi wa

$$(\Delta h)_v = -\int_{h_0}^{h} \frac{\Delta\rho}{\rho} dh$$

de ataerareru ga, $\Delta\rho/\rho$ wa $\Delta\rho/\rho''$ to onazini totte aru kara, maeno Siki (§ 10) ni yotte,

$$(\Delta h)_v = +\int_{h_0}^{h} \frac{\cdot 378\, p_v}{p} \frac{f}{100} dh.$$

Koko de p_v wa Ondo t' ni taisite kimatta Atai wo motte oru si, p wa Hyôzyun-taiki de h ni taisuru Aturyoku de, onônono h ni taisite sirete iru. Soreyue, onônono h ni sôtôsuru t' to f to ga kirokusarete areba, ueno Sekibun ga keisan dekiru.

Zissaino Keisan niwa, maeno Setu no $(\Delta h)_T$ to dôyôni, $h_0 - h_1$ wo 400, 800, ...no Tokoro de kugitte, $p_v f/p$ ni onônono Kuiki no Ryôhazi ni okeru Atai no Heikinsû wo tukatte yoi. Sunawati,

$$(\Delta h)_v=\sum \cdot 378\left(\frac{p_v f}{p}\right)_m \frac{400}{100} k=\sum\left(\frac{\cdot 378\times 4\times p_v}{p} f\right)_m k,$$

tadasi k wa maeni atta to onazi Kazu (1 matawa Bunsû) de aru.

Kono Keisan wo kantanni suru tameni, Hyô IV (p. 341) ni Ondo t' ni taisuru $\cdot 378\times 4\times p_v$ wo dasite aru[1]. Sore wo tukaeba, $(\Delta h)_v$ no Keisan wa tugino Pêzi no Hyô III ni dasita Rei no yôni site kantanni dekiru. [Koko ni dasita Kazu wa notini noberu zissaino Kwansoku ni taisuru monó de aru ga, sono Kwansoku dewa, Situdo ga tada Dimen ni okeru mono dake ataete aru kara, f ga doko demo onazi da to kateisite, kandyôsite aru.]

Tyûi 1. $(\Delta h)_v$ wa itumo *seino* Kazu de aru.

Tyûi 2. $(\Delta h)_v$ wa kono Rei de miru yôni sô ôkikuwa nai keredomo, Natu ni t' no ôkii Baai niwa, kono Rei ni kurabete 8-bai ya 9-bai niwa naru koto ga aru.

14. Dyûryoku ni taisuru Naosi $(\Delta h)_g$.

Kono Naosi wa

$$(\Delta h)_g=-\int_{h_0}^{h}\frac{\Delta g}{g}\,dh$$

de ataerareru. Ima tonde oru Tihô de Kaimen ni okeru Dyûryoku wo g'_0 to sureba,

$$g'=g'_0-\beta h$$

to oite yoi; tadasi, β wa 1000 m. ni taisite $0\cdot 31$ cm./s². no Ooisa wo motu Zyôsû de aru. [β ga konnani tiisai kara, h to Kaimen karano zissaino Takasa to no Tigai wa kangaenakute yoi.] Sitagatte,

$$(\Delta h)_g=-\int\frac{g'_0-\beta h-980}{980}\,dh=-(g'_0-980)\,\frac{h-h_0}{980}+\frac{\beta(h^2-h_0^2)}{2\times 980}.$$

Ima korerano hutatuno Husi wo $(\Delta h)_g'$, $(\Delta h)_g''$ to kaki, mata

$$-\frac{h}{980}=A,\quad \frac{\beta h^2}{2\times 980}=B$$

(1) Kono Hyô de -30°C. yorimo hikui Ondo ni taisuru Atai wa ôyosono *Extrapolation* no Kekkwa de aru.

Hyô III. $(\Delta h)_v + (\Delta h)_g$ no Keisan no Hinagata.

[Schedule for calculating $(\Delta h)_v + (\Delta h)_g$].

h	t'	$.378 \times 4 \times p_v$	p	f	$\cdot 387 \times 4 \times p_v \times \frac{f}{p}$	$\delta(h\Delta)_v$	$(h\Delta)_v$	$(\Delta h)_g$		$(\Delta h)_v + (\Delta h)_g$
								$(\Delta h)^{g'}$	$(\Delta h)_g''$	
96	2.8	8.5	751	84	.95	$\times \frac{304}{400} = .8$	0	0	0	0
400	4.6	9.6	725	,,	1.11	1.0	.8	− .4	0	+ .4
800	2.2	8.2	691	,,	.99	.9	1.8	− .9	.1	+ 1.0
1200	− 1.5	6.2	658	,,	.78	.7	2.7	− 1.4	.2	+ 1.5
1600	− 5.5	4.6	626	,,	.62	.8	3.4	− 2.0	.4	+ 1.3
2000	− 0.5	6.6	596	,,	.93	.9	4.2	− 2.5	.6	+ 2.3
2400	− 3.4	5.5	567	,,	.82	.8	5.1	− 3.0	.9	+ 3.0
2800	− 5.3	4.7	539	,,	.73	.7	5.9	− 3.6	1.2	+ 3.5
3200	− 7.3	4.0	513	,,	.65	.6	6.6	− 4.1	1.6	+ 4.1
3600	−10.7	3.1	487	,,	.58	.5	7.2	− 4.6	2.0	+ 4.6
4000	−11.8	2.8	462	,,	.51	.5	7.7	− 5.2	2.5	+ 5.0
4400	−14.1	2.4	439	,,	.46	.4	8.2	− 5.7	3.1	+ 5.6
4800	−17.0	1.9	416	,,	.38	.3	8.6	− 6.2	3.6	+ 6.0
5200	−20.6	1.4	394	,,	.30	.3	8.9	− 6.8	4.3	+ 6.4
5600	−24.0	1.1	374	,,	.25	.2	9.2	− 7.3	5.0	+ 6.9
6000	−27.8	.7	354	,,	.17	.2	9.4	− 7.8	5.7	+ 7.3
6400	−32.2	.5	335	,,	.13	.1	9.6	− 8.3	6.5	+ 7.8
6800	−85.4	.4	317	,,	.11	.1	9.7	− 8.9	7.3	+ 8.1
7200	−38.7	.3	299	,,	.08	.1	9.8	− 6.4	8.2	+ 8.6
7600	−42.3	.2	283	,,	.06	.0	9.9	− 9.8	9.1	+ 9.2
8000	−46.0	.1	267	,,	.03	—	9.9	−10.5	10.1	+ 9.5
8400	−49.8	.1	252	,,	.03	—	,,	−11.0	11.1	+10.0
8800	−53.9	.0	238	,,	0	—	,,	−11.5	12.2	+10.6
9200	−56.8	—	224	—	—	—	,,	−12.1	13.4	+11.2
9600	−58.9	—	211	—	—	—	,,	−12.6	14.6	+11.9
10000	−61.4	—	198	—	—	—	,,	−13.1	15.8	+12.6
10400	−64.3	—	186	—	—	—	,,	−13.7	17.1	+13.3
10800	−64.1	—	175	—	—	—	,,	−14.2	18.4	+14.1
11200	−64.7	—	164	—	—	—	,,	−14.7	19.9	+15.1
11600	—	—	154	—	—	—	—	—	—	—
12000	—	—	145	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
11495	−62.0	—	—	—	—		9.9	−15.1	20.9	+15.7

Hyô IV. $(\Delta h)_v$ no Keisan ni tukau $0378 \times 4 \times p_v$ no Atai.

[Values of $0{\cdot}378 \times 4 \times p_v$, for calculating $(\Delta h)_v$].

0°	6.9	13°	17.0	26°	38.0	0°	6.9	−13°	2.6	−26°	.9	−39	.3
1	7.4	14	18.1	27	40.3	−1	6.4	−14	2.4	−27	.8	−40	.2
2	8.0	15	19.3	28	42.7	−2	6.0	−15	2.2	−28	.7	−41	.2
3	8.6	16	20.6	29	45.3	−3	5.6	−16	2.1	−29	.7	−42	.2
4	9.2	17	22.0	30	47.9	−4	5.2	−17	1.9	−30	.6	−43	.2
5	9.9	18	23.4	31	50.8	−5	4.8	−18	1.7	−31	.5	−44	.2
6	10.6	19	24.9	32	53.7	−6	4.4	−19	1.6	−32	.5	−45	.1
7	11.4	20	26.5	33	56.8	−7	4.1	−20	1.5	−33	.5	−46	.1
8	12.2	21	28.2	34	60.1	−8	3.8	−21	1.4	−34	.4	−47	.1
9	13.0	22	29.9	35	63.5	−9	3.5	−22	1.3	−35	.4	−48	.1
10	13.9	23	31.8	36	67.1	−10	3.3	−23	1.2	−36	.4	−49	.1
11	14.9	24	33.8	37	70.9	−11	3.0	−24	1.1	−37	.3	−50	.1
12	15.9	25	35.8	38	74.9	−12	2.8	−25	1.0	−38	.3	−51	.1

Hyô V. $(\Delta h)_g$ no Keisan ni tukau A oyobi B no Atai.

[Values of A and B, for calculating $(\Delta h)_g$].

$$(\Delta h)_g = (\Delta h)_g' + (\Delta h)_g''.$$

$$(\Delta h)_g' = (g'_0 - 980)\,(A(h) - A(h_0)), \qquad (\Delta h)_g'' = B(h) - B(h_0)$$

h	A	B	h	A	B	h	A	B	h	A	B
0	0	0	4000	−4.08	2.53	8000	−8.16	10.12	12000	−12.24	22.78
400	−.41	.03	4400	−4.49	3.05	8400	−8.57	11.16	12400	−12.65	24.32
800	−.82	.10	4800	−4.90	3.64	8800	−8.98	12.25	12800	−13.06	25.91
1200	−1.22	.23	5200	−5.31	4.28	9200	−9.39	13.39	13200	−13.47	27.56
1600	−1.63	.40	5600	−5.71	4.96	9600	−9.80	14.58	13600	−13.88	29.25
2000	−2.04	.63	6000	−6.12	5.69	10000	−10.20	15.82	14000	−14.29	31.00
2400	−2.45	.91	6400	−6.53	6.48	10400	−10.61	17.11	14400	−14.69	32.80
2800	−2.86	1.24	6800	−6.94	7.31	10800	−11.02	18.45	14800	−15.10	34.64
3200	−3.27	1.62	7200	−7.35	8.20	11200	−11.43	19.84	15200	−15.51	36.54
3600	−3.67	2.05	7600	−7.76	9.14	11600	−11.84	21.29	15600	−15.92	38.49

to kakeba, .

$$(\Delta h)_g = (\Delta h)_g' + (\Delta h)_g'',$$

$$(\Delta h)_g' = (g'_0 - 980)[A(h) - A(h_0)], \quad (\Delta h)_g'' = B(h) - B(h_0)$$

de keisansareru.

A to B to no Atai ga Hyô V (maeno Pêzi) ni dasite aru.

Tatoeba, Tôkyô ($g'_0 = 979{\cdot}81$) to London ($g'_0 = 981{\cdot}20$) to de $h = 10000$ m. ni taisuru $(\Delta h)_g$ wa tugino yôni naru.

(Tôkyô) $(\Delta h)_g = +1{\cdot}9 + 15{\cdot}8 = 17{\cdot}7,$

(London) $(\Delta h)_g = -12{\cdot}2 + 15{\cdot}8 = +3{\cdot}6.$

Tyûi 1. g'_0 ga sirete inai naraba, sono Toti no Ido φ wo tukatte,

$$g'_0 - 980 = 0{\cdot}62 - 2{\cdot}59 \cos 2\varphi.$$

to totte yoi.

Tyûi 2. $(\Delta h)_g'$ wa $\varphi < 38°$ no Toti de $+$, $\varphi > 38°$ no Toti de $-$ de aru. Mata, $(\Delta h)_g''$ wa itumo $+$ de aru.

15. Keisan no Rei.

Ueno Keisan no Rei tosite, " Arbeiten d. K. Preussischen Observatioriums bei Lindenberg " IX, p. 277 ni aru Kwansoku wo totte miru. Kore wa Kwansokuten no Takasa no Hedatari ga amari ôkiku nai (1000 m. ika no) mono wo erabidasita no de aru.

Kono Kwansoku ni sirusarete aru p, t' oyobi Takasa h_L wa tugino Hyô no hazimeno mittuno Kudari no tôri de aru.

Mosi Kôdokei to Kandankei to ga hikituduita Kiroku wo ataete oru naraba, sore kara tyokusetuni $h = h_0$, 400, 800, ...ni taisuru t' wo totte Hyô II, III no Keisan wo suru koto ga dekiru no de aru ga, kono Rei dewa tobitobini p to t' ga wakatte iru no de aru kara, watasi wa madu, Hyô I ni yotte, ataerareta p ni taisuru h wo dasita ; sore ga kono Hyô no 4-banmeno Kudari de aru. Tugini, korerano h wo yokono Zahyô ni tori, sore ni taisite t' no Atai wo tateni totte, tugitugino Ten wo Tyokusen de tunagi, $h = 400$ m., 800 m., ...ni taisuru t' wo kimeta ; sore ga Hyô II oyobi III no t' de atte, Hyô II oyobi Hyô III wa

Hyô VI.

t'	p	h_L	h	Δh	$h' = h + \Delta h$	$h' - h_L$
2.8	751.4	116	96	+20	116	0
5.0	719	474	465	+ 8	473	−1
0.4	672	1020	1026	− 6.5	1019.5	− .5
− 5.7	625	1596	1620	−25	1595	−1
− 0.3	600	1918	1950	−32	1918	0
− 4.9	552	2580	2617	−38	2579	−1
− 5.7	525	2972	3013	−40.5	2972.5	+ .5
−10.8	486	3571	3615	−44	3571	0
−12.0	458	4025	4072	−46	4026	+1
−15.7	424	4601	4659	−47	4612	+11
−19.4	402	5010	5059	−48	5011	+1
−25.6	364	5739	5794	−54	5740	+1
−32.7	333	6375	6441	− 64	6377	+2
−37.3	306	6965	7046	− 79	6967	+2
−43.6	277	7645	7745	−100	7645	0
−50.3	249	8350	8480	−128	8352	+2
−55.3	233	8780	8930	−149	8781	+1
−58.6	214	9319	9498	−178	9320	+1
−59.0	208	9498	9686	−187	9499	+1
−65.5	182	10324	10555	−230	10325	+1
−64.0	176	10528	10770	−240	10530	+2
−65.1	166	10885	11141	−254	10887	+2
−62.0	157	11229	11495	−264.5	11230.5	+1.5

tumari kono Rei ni tuite Δh no Keisan wo sita mono de aru. h_0 oyobi h_1 wa muron Hyô VI no ue-sitano Hazi ni aru Atai de aru.

Hyô II no Keisan de, h'_0 wa motono Kazu ni sitagatte $h'_0 = 116$ to totta.

Hyô III dewa, sanbanmeno Kudari ga Hyô IV kara totta Kazu de aru koto, itiban sitano Basyo ni okeru f wo zentai ni tukatta koto wa maeni nobeta tôri. Onazi Hyô no $(\Delta h)_g'$ no Keisan niwa, g'_0 wo 981·3 to totte aru.

Hyô III de eta $(\Delta h)_v+(\Delta h)_g$ wo Hyô II no $(\Delta h)_0+(\Delta h)_T$ ni Kuwaete, Hyô II no Owari ni aru Δh wo eta.

Moto ataerareta iroirona Takasa h_L ni taisuru $h+\Delta h$ ga dô deru ka wo miru tameni, Hyô II ni aru $h=400$, 800, ...ni taisuru Δh kara *Interpolation* ni yotte, ataerareta Ten no h ni taisuru Δh wo dasita no ga Hyô VI no gobanmeno Kudari de aru. Kore wo tukatte tukutta $h'=h+\Delta h$ to h_L to no Tigai ga owarino Kudari ni aru. Kore wo miruto, tada hitotu $h_L=4601$ no Tokoro wo nozoita hoka wa 11230m. no Kuiki no doko demo 2 m. ika no Tigai sika simesite inai. $h_L=4601$ ni taisite $h'-h_L=+11$ to natte iru no wa, h_L no 4601 ga 4611 no Insatutigai de aru ni sôinai.

Motono Hôkoku ni aru h_L wa t' to p to kara Keisan ni yotte dasareta Kazu ni sôinai kara, ueno yôni site eta h' ga sore ni taihen tikai Atai wo ataeru no wa atarimaeno Koto da tomo ieru ga, sore ga dôzini Hyô II ya III no yôna Keisansikata demo—Ondo ni hukisokuna Kawari ga aru ni kakawarazu—sôtôni yoi Kekkwa ga erareru to iu koto wo simesu mono de aru.

16. Aturyoku no Tan'i no Tigai no Eikyô.

Lindenberg no Kiroku ni aru Aturyoku no Tan'i mm Hg wa $g=980{\cdot}665$ ni sôtôsuru mono de arô to omou kara, soko no tatoeba 719 mm. wa wareware no Hyôzyun-taiki no 719 mm. towa tigau. Sikasi, *kono Tigai — Aturyoku no Tan'i no buturitekino Ooisa no Tigai — wa, subeteno Memori ga onazi Tan'i ni yotte oreba, Takasa no Handan niwa Tigai wo okosanai.*

Kore wa, Takasa wa p/p_0 to iu Hi ni dake kwankeisite iru kara de aru. Kuwasiku ieba, hitotuno Tan'i (buturitekino Ooisa wo q de arawasu) wo tukatte (G) (H) (p. 330) no Siki ni yotte memorisita Kôdokei de handansite, subete Hyôzyun-zyôtai ni natte oru to omou Baai—sunawati, sono Kôdokei no Yomi ga h de aru Tokoro no Ondo ga (A) (B) (p. 326) no tôri de ari, Suizyôki wa nakute, Kûki ni hataraku Dyûryoku no Tuyosa ga $g=980{\cdot}00$ de aru Baai—niwa, (G) (H) no Siki ga tadasiku okonawareru kara, Aturyoku no Tan'i q ga hyôzyunno Ooisa to tigatte itemo, h no Yomi ni Matigai ga nai.

Onazi Mondai wo tugino yôni mitemo yoi. Ondo no Bunpai ga kattena Baai wo toru [$(\Delta h)_v$ to $(\Delta h)_g$ wa kangaenai]. Suigin no 1 mm. ga ataeru Aturyoku ga q de aru Aturyokukei wo tukatte (G) (H) ni yotte memorisita Kôdokei ga Yomi h wo simesu Basyo de, hokano Kôdokei—1 mm. ga Q de aru Aturyokukei de memorisita Kôdokei—ga Yomi H wo simesu to sureba, sono Basyo no Aturyoku wa

$$\text{Aturyoku}=q.\ 760\left(\frac{288-{\cdot}0065\ h}{288}\right)^{5{\cdot}253}$$

$$=Q.\ 760\left(\frac{288-{\cdot}0065\ H}{288}\right)^{5{\cdot}253}$$

de aru. Sitagatte, h to H to no Kwankei wa

$$288-{\cdot}0065\ H=(q/Q)^{\frac{1}{5{\cdot}253}}\ (288-{\cdot}0065\ h)$$

de ataerareru. Itiban sita de

$$h=h_0, \qquad H=H_0$$

de aru to sureba,

$$288-{\cdot}0065\ H_0=(q/Q)^{\frac{1}{5{\cdot}253}}\ (288-{\cdot}0065\ h_0).$$

Korerano Siki kara mieru tôri,

$$H-H_0=(q/Q)^{\frac{1}{5{\cdot}253}}\ (h-h_0)$$

ni natte, $H-H_0=h-h_0$ dewa nai. Konotoki $(\Delta h)_T$, $(\Delta H)_T$ wo siraberuto,

$$(\Delta h)_T=\int_{h_0}^{h}\frac{t'-(15-{\cdot}0065\ h)}{288-{\cdot}0065\ h}\ dh,$$

$$(\Delta H)_T=\int_{H_0}^{H}\frac{t'-(15-{\cdot}0065\ H)}{288-{\cdot}0065\ H}\ dH;$$

sitagatte,

$$h-h_0+(\Delta h)_T=\int_{h_0}^{h}\left\{1+\frac{t'-(15-\cdot0065\,h)}{288-\cdot0065\,h}\right\}dh$$

$$=\int_{h_0}^{h}\frac{273+t'}{288-\cdot0065\,h}\,dh.$$

Dôyôni,

$$H-H_0+(\Delta H)_T=\int_{H_0}^{H}\frac{273+t'}{288-\cdot0065\,H}\,dH.$$

Sikaruni, ueno, H to h to no Kwankeisiki wo bibunsureba,

$$\frac{dH}{288-\cdot0065\,H}=\frac{dh}{288-\cdot0065\,h}$$

ni naru. Mata, Sekibun no Sakai H_0, H wa h no h_0, h ni ataru kara,

$$H-H_0+(\Delta H)_T=\int_{h_0}^{h}\frac{273+t'}{288-\cdot0065\,h}\,dh$$

ni naru. Kore wa $h-h_0+(\Delta h)_T$ no Siki to mattaku onazi de aru.

Soreyueni,

$$H-H_0+(\Delta H)_T=h-h_0+(\Delta h)_T.$$

Sunawati, dotirano Kôdokei wo tukattemo, sore wo seitôna mono to site, Kimari no tôrino Reiten-no-Naosi oyobi Ondo-no-Naosi wo ireruto Dimen karano Takasa ga, onazi Kekkwa ni dete kuru. Iikaereba, *Aturyoku no Tan'i* (mm Hg) *no buturitekino Ooisa no Tigai ni taisitewa Naosi wo yôsinai.*