BOLIGOPVARMNINGSUDVALGETS MEDDELELSE NR. 5

EN MIKROKLIMATOGRAF

AF

AUGUST KROGH

KØBENHAVN

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Boligopvarmningsudvalgets Medlemmer
Members of the committee for the study of domestic heating.

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CONTRIBUTION NUMBER 5 FROM THE COMMITTEE FOR
THE STUDY OF DOMESTIC HEATING, COPENHAGEN

A MICRO CLIMATE RECORDER

BY

AUGUST KROGH

COPENHAGEN

1948

De i denne Beretning omhandlede Undersøgelser er udført paa Universitetets „Zoofysiologiske Laboratorium".

Herved anmoder jeg om, at denne Beretning bliver offentliggjort som et Led i Boligopvarmningsudvalgets Publikationer.

The investigations dealt with in this report were performed in the Zoophysiological Laboratory of the University of Copenhagen.

I hereby submit that the report is included among the publications of the Committee.

August Krogh.

Boligopvarmningsudvalget ønsker at offentliggøre denne Beretning. Forfatteren er ansvarlig for Beretningens Resultater og Konklusioner.

The Committee for the Study of Domestic Heating has found it desirable to publish this report, the results and conclusions of which are given on the author's responsibility.

August Krogh
Formand

Carl Bruun	*Sven Christiansen*		*J. Falck*
Gunnar Gregersen	*P. Hempel*		*O. M. Henriques*
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En mikroklimatograf.

Det nedenfor beskrevne apparat konstrueredes 1938—39 til bestemmelse af temperatur og fugtighed under klæderne hos mennesker i forbindelse med de undersøgelser som Boligopvarmningsudvalget dengang forberedte. Det har været anvendt ved en række af disse undersøgelser samt ved tilsvarende undersøgelser i Sverige og U. S. A. og vil formentlig ogsaa i fremtiden kunne finde nyttig anvendelse paa forskellige felter.

Meget lette apparater til registrering af temperatur og andre data har været anvendt i meteorologiens tjeneste. De blev sendt tilvejrs med smaa balloner og registrerede paa en sodet glasplade der bevægedes af et Bourdonrør som reagerede for trykfaldet. De blev aflæst under mikroskop. I 1938 beskrev Weickmann en saakaldt „Taschenthermohygrograph" bygget paa grundlag af et ur, i hvilket en registrerflade drejedes af den axe, der normalt bærer timeviseren og registrering skete ved hjælp af et bimetal termometer og et haarhygrometer, der førte smaa penne hen over registrerfladen. Dette instrument var for stort og klodset for vore formaal. Idet vi kombinerede principet i Weickmanns instrument med de meteorologiske apparaters mikroregistrering kom vi frem til den løsning af problemet, der beskrives og afbildes nedenfor.

Motoren er urværket i et almindeligt armbaandsur, 23 mm i diameter og 5 mm tykt. Værket monteres i en messingdaase (1, fig. 1) og indrettes til at trækkes op med nøgle. Hullet (2), hvor nøglen kan indsættes, holdes lukket for at beskytte uret, navnlig mod fugtighed. Timeaxen rager op i daasens øverste rum (3) og bærer her den gennembrudte skive (4, fig. 1 og 2) paa hvilken de registrerende anordninger er monterede. Apparatet til temperaturregistrering er en bimetallisk spiral (5, fig. 2) der retter sig lidt ud ved stigende tp. og overfører denne bevægelse gennem en fin metaltraad (6) til en skrivearm, der forstørrer spiralens bevægelse ca. 3 gange. Fugtighedsregistreringen besørges af et enkelt menneskehaar, 20 mm langt (8), der virker paa en anden skrivearm

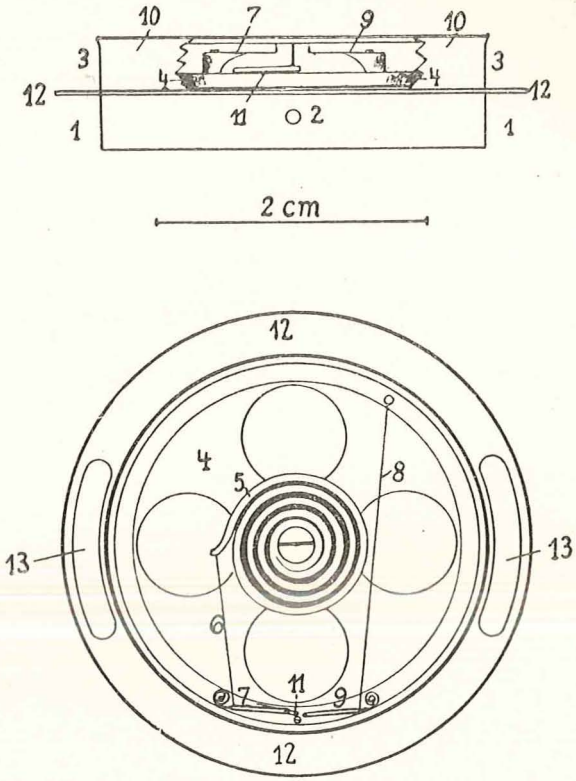

Fig. 1—2. Mikroklimatografen fra siden og ovenfra.
Micro climate recorder from the side and from above.

(9). Skrivearmene er udstyret med meget spidse lodrette staalskrivestifter, der tegner linier i soden paa en glasplade (10, fig. 1) som lukker apparatet foroven. En tredie skrivestift (11), anbragt imellem de to, tegner en grundlinie, til hvilken de andre liniers afstand kan maales. Daasen har en fremspringende krave (12) med aflange huller (13) til et elastisk baand, hvormed apparatet fastgøres til de ønskede steder paa kroppen. Luften har adgang til rummet (3) gennem flere spalter i væggen, der ikke er vist paa figurerne. Disse tjener ogsaa til at give væggen den fornødne elasticitet, saa at den sodede glasplade let kan indsættes og løftes af. Til hvert apparat hører 5 saadanne nøjagtigt kredsrunde glasplader. Hver af dem har paa oversiden en ætset cirkelflade (6, fig. 3) paa hvilken der kan skrives med blyant. Glaspladernes underside sodes *ganske let* over gasflammen fra en Bunsenbrænder uden lufttilførsel, en lille petroleumsflamme eller lignende.

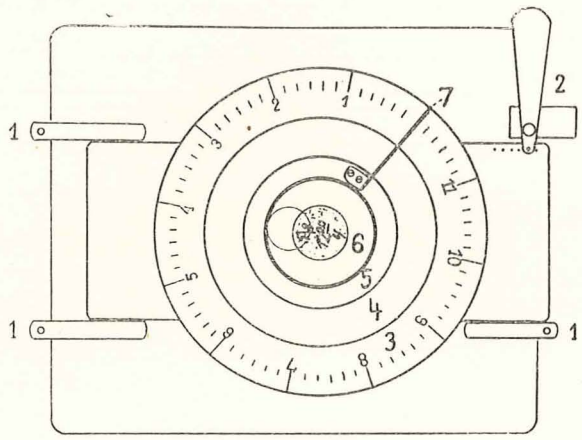

Fig. 3. Objektbord til aflæsning af de i soden tegnede kurver.
Table for reading curves under the microscope.

Hovedsagen er at sodlaget bliver ensartet og ikke tykkere, end at det netop er synligt. De linier, som skrivestiften trækker i soden, skal være saa fine at de næppe er synlige med blotte øjne. Det har vist sig fordelagtigt at hærde sodlaget ved at anbringe de frisk sodede plader et minut i æter. De opbevares i smaa runde papæsker og holdes adskilt ved tynde ringe af messingtraad.

Naar apparatet skal bruges trækkes uret op, og aabningen for nøglen lukkes igen. En glasplade tages ud af æsken ved hjælp af den sugeskaal, der om lidt skal beskrives, og anbringes paa klimatografen. Fra pladens midte henimod skrivestifterne trækkes en blyantslinie og dato, time og minut noteres paa den ætsede flade tillige med klimatografens nummer (6, fig. 3).

Efter registreringen, som naturligvis ikke maa strække sig over mere end 12 timer, løftes glaspladen af ved hjælp af en sugeskaal og kan nu enten med det samme anbringes under mikroskopet til aflæsning eller i en af papæskerne.

Til apparatet hører to forskellige sugeskaale (fig. 4) hver med en gummislange gennem skaftet. Naar denne slange lukkes med en finger kan sugeren fastholde glaspladen, som slippes i det øjeblik man giver luften adgang. Den sugeskaal, der har et fladt haandtag parallelt med skaalen, er bestemt til at tage glaspladerne fra mikroskopets bord.

Aflæsninger foretages under mikroskop ved hjælp af et okularmikrometer. Vi har benyttet et ca. 1" objektiv og fundet en forstørrelse hvorved 40 mikrometerinddelinger omtrent svarer til 1 mm at være passende. Det særlige aflæsningsbord, der er vist

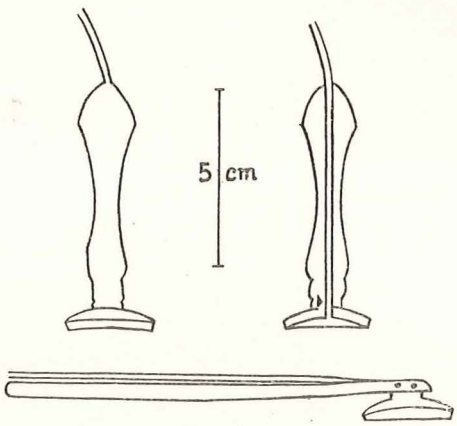

Fig. 4.

i fig. 3 kan anbringes paa det almindelige firkantede mikroskop-bord, saa at det kan glide mellem 3 skrueklemhaner (1). I det højre øverste hjørne sidder en særlig klemme med et haandtag

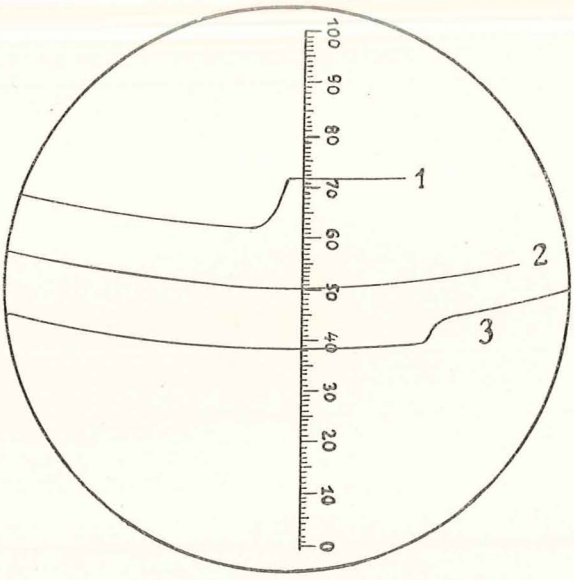

Fig. 5. Kurver, der viser en samtidig ændring af tp. og fugtighed.
Curves showing simultaneous changes in tp. and moisture.

ved hvis hjælp man kan forskyde bordet lidt i sideretningen. Af-læsebordet har to bevægelige (3, 5) og en fast ring (4) monteret paa en rektangulær messingplade med et hul, som er nogenlunde

centreret under objektivet. En glasplade (6), der skal aflæses, anbringes i den indre ring med den sodede flade nedad og blyantslinien pegende mod synsfeltet. Idet man ser gennem mikroskopet, bringes begyndelsespunktet f. ex. af temperaturkurven (1, fig. 5) til at falde paa mikrometerskalaen, idet man drejer den indre ring ved hjælp af den dertil bestemte viser (7, fig. 4) og derefter drejer den ydre ring, der er inddelt i timer og minutter, saa at viseren peger paa den tid, der er noteret paa glaspladen (7, fig. 3). For at finde tp. svarende til ethvert andet tidspunkt drejes den indre ring hen til den tilsvarende inddeling og bordet flyttes ved hjælp af haandtaget (2, fig. 3) til grundlinien (2, fig. 5) dækker en bestemt delestreg paa skalaen (50) og temperaturliniens delestreg aflæses og noteres sammen med tidspunktet. Paa fig. 5 er temperaturaflæsningen 71.3. Vi har, naar vi skulde bruge baade tp. og fugtighed, fundet det bekvemmest at foretage alle temperaturaflæsninger i en serie og derefter foretage en ny indstilling til fugtighedsaflæsningerne.

Aflæsninger foretages i reglen uden fixering. Hvis det ønskes at fixere en registering, kan det gøres ved at dyppe den sodede flade et øjeblik i en opløsning af celluloselak 1—25 i acetone. Der kan fremstilles kontaktaftryk af de fixerede registrerplader paa fotografisk karton, men hvis der tages aftryk af flere sammen, maa sodlagene være nogenlunde lige tætte. Aftrykkene maa skæres nøjagtigt ud for at passe i aflæsebordets ring, og aflæsningen kræver temmelig stærk belysning ovenfra.

Glasskiverne kan let renses med vand og sæbe.

Kalibrering af mikroklimatografen.

Aflæsningerne sker i vilkaarlige enheder og gælder kun for den anvendte optik og mikrometerskala. Aflæsningerne omsættes til temperatur- og fugtighedsgrader ved hjælp af kalibreringskurver. Temperaturkurverne er rette linier, men der maa konstrueres særlige kurver for hvert apparat, og disse maa hyppigt kontrolleres. Til kalibrering indesluttes klimatografen i en lille vandtæt metalæske, og denne anbringes afvekslende ved to vel bestemte temperaturer, der holdes konstant i thermoflasker, i hvert fald i 15 minutter. Som passende temperaturer anbefales 0° C., der vedligeholdes ved fint knust is, og en tp. ca. 1—2 grader under den forhaandenværende stuetp., der paa grund af fordampningen let holdes konstant; men en kalibrering, der samtidig viser at kurven er

retlinet, kan ogsaa opnaas ved at anbringe klimatografen i vand ved f. ex. 35°, lade vandet langsomt afkøles, idet det blandes ved en svag luftstrøm og aflæse temperaturen med passende, nøjagtigt noterede, mellemrum. En nøjagtighed paa ± 0.2° kan let opnaas ved omhyggelig aflæsning, og de fleste fejl vil ligge indenfor 0.1° C., hvilket er tilstrækkeligt for næsten alle formaal. Desværre har det vist sig, at de anvendte bimetalliske spiraler gennem længere tid ikke er helt konstante, og det tilraades derfor at foretage kontrolbestemmelser med ca. 1 uges mellemrum. Da eventuelle kurveforskydninger er parallele, er det tilstrækkeligt i tilslutning til et forsøg at anbringe klimatografen en kort tid ved en nøje kendt temperatur.

Termografernes træghed er af størrelsesordenen 1—2 minutter, men kan ikke være fuldt konstant.

Haarhygrometre anses i almindelighed ikke for at være præcisionsinstrumenter, men der kan naaes meget naar de behandles paa den rette maade, som beskrevet for mere end et aarhundrede siden af Gay Lussac.

Gay Lussacs originale meddelelse er meget vanskelig at finde, da den er publiceret i Biot: Traité de Physique, Tome II, Paris 1816, som et „Supplément à l'hygrometrie" der omfatter side 199—208. De tabeller, der afledtes af maalingerne, findes i T. I p. 532—33. Maalingerne blev, saavidt det kan ses, foretaget med et enkelt haarhygrometer ophængt i en glasbeholder over forskellige opløsninger af NaCl, $CaCl_2$ og H_2SO_4, hvis vægtfylde og damptryk blev omhyggeligt bestemt. Alle bestemmelser blev foretaget

Tabel 1.

Inddelinger Divisions	Procent Fugtighedsgrad Per cent moisture
10	4.6
20	9.5
30	14.8
40	20.8
50	27.8
60	36.3
70	47.2
80	61.2
90	79.1
100	100.0

ved 10° C., og Biot antager øjensynlig at forholdet mellem haarlængde og relativ fugtighed vil variere noget med temperaturen. Disse antagelser er ikke blevet bekræftet af senere undersøgelser, men burde maaske prøves igen. Et haars forkortelse ved aftagende fugtighed er ikke omvendt proportional med fugtighedsgraden, men forøges eftersom luften bliver mere tør. For et hygrometer, hvis skala viser 0 i fuldstændig tør luft og 100 i dampmættet, har Gay Lussac givet følgende værdier i procentisk mætning svarende til inddelingerne fra 0—100 (Tabel 1).

Haar bør ikke udsættes for fugtighedsgrader under 20 %, hvor reaktionen bliver ret langsom, og haaret kan lide en blivende forandring, og desuden foreskriver G. L., at de anvendte haar for at give rigtige resultater med visse mellemrum maa udsættes for mindst 95 % fugtig luft. Jeg har fundet at disse mellemrum kan sættes til ca. 3 dage. Naar disse betingelser overholdes synes hygrometre at være uafhængige af temperatur og tryk. Trægheden ved forandring af fugtighedsgraden inden for de normalt forekommende intervaller ligger antagelig under 10 minutter.

Det antages almindeligt at G. L.'s tal er middeltal, og at de enkelte haar reagerer forskelligt. Jeg har selv antaget dette og er ikke i stand til at modbevise det, men jo nøjere jeg har fulgt G. L.'s forskrifter, desto bedre er overensstemmelsen blevet med G. L.'s tabel for de 4 haar jeg har studeret nøjere.

Jeg tror derfor at en sikker kalibrering kan foretages paa grundlag af G. L.'s tal. Til dette formaal maa to punkter paa kalibreringskurven, af hvilke det ene naturligvis er mætningspunktet, bestemmes experimentelt, medens kontrolbestemmelser kan tilvejebringe mellemliggende punkter.

Vel definerede fugtighedsgrader kan opnaas over mættede opløsninger af visse vandabsorberende salte, og jeg har fra International Critical Tables udvalgt følgende som velskikkede. $MgCl_2$ giver ved 20° C. 33 % og ved 40° 35 % fugtighed, K_2CO_3 ved 18,5° 44 % og ved 24,5° 43 %, NaCl 76 % næsten uafhængigt af temperaturen. Naar bestemmelser gøres ved 22—25° er tilsvarende fugtighedsprocenter 33 for $MgCl_2$, 43 for K_2CO_3 og 76 for NaCl.

De rene salte anbringes i en passende beholder (exsikkator) og befugtes med saa meget vand at en meget uregelmæssig overflade kan formes med en spatel. Hvis overfladen er flydende naaes ligevægt alt for langsomt. Selv naar disse forskrifter overholdes, tager det et par timer at opnaa fuldstændig ensartet fugtighed i hele beholderen.

Til bestemmelse af de to nødvendige kalibreringspunkter anbringes klimatografen først indpakket i fugtigt filtrerpapir i et fugtigt kammer, aftørres efter 2 timer og overføres til exsikkatoren med $MgCl_2$. Det er raadeligt at bringe den frem og tilbage mindst to gange og lade den opholde sig mindst to timer ad gangen i hver beholder. Følgende resultater fandtes i et bestemt tilfælde:

100 % 27,0, 28,0, 28,0 middel 27,7
33 % 47,3, 46,7 „ 47,0

Differensen 19.3 benyttes paa følgende maade. Efter G. L.'s ovenstaaende tabel er der konstrueret en kurve paa hvilken de relative længder svarende til kendte fugtighedsprocenter kan aflæses. Kolonne 2 i tabel II giver disse tal for 10 % intervaller og desuden for fugtighedsprocenter svarende til mættet NaCl (76 %), K_2CO_3 (43 %) og $MgCl_2$ (33 %). Af tallene i kolonne 2 beregnes tallene i kolonne 3, idet den aflæste differens for 100° — 33° = 19.3 divideres med 43.7 og multipliceres med tallene i kolonne 2. Tallene i kolonne 3 giver endelig tallene i kolonne 4 ved addition af middelaflæsningen (27.7) ved 100 % fugtighed. Interpolation kan foretages ved hjælp af tabellen eller grafisk, naar den tilsvarende kurve konstrueres. Den opnaaelige nøjagtighed varierer fra ca. 2 % ved lavere fugtighedsgrader til ca. 5 % nær mætningspunktet.

Tabel 2.

1 Fugtighedsprocent Moisture	2 G. L.s tal G. L. figures	3 Klimatograf Diff. No. 5 Diff.	4 Aflæsning Reading
100	0	0	27.7
90	4.6	2.0	29.7
80	9.4	4.1	31.8
76	11.5	5.1	32.8
70	14.8	6.6	34.3
60	20.8	9.2	36.9
50	27.8	12.2	39.9
43	33.6	14.8	42.5
40	36.3	16.0	43.7
33	43.7	19.3	47.0
30	47.0	20.8	48.5
20	61.2	27.1	54.8

Vi har foretrukket grafisk interpolation og tegnet kurver for hvert apparat paa millimeterpapir med mikroskopaflæsninger som ordinater (hver okularinddeling = 2 mm). Til tp. inddeling paa abscisseaxen tager vi 5 mm pr. grad fra $-10°$ til $+40°$ og for fugtighed 2 mm pr. % fugtighed fra 0—100 %.

A Micro Climate Recorder.

The problem for which the recorder here described was constructed in 1938-39 is the study of the temperature and humidity relations inside the clothes of man, in connection with the general work of the committee. It has been used in several investigations and in corresponding studies in Sweden and the U. S., and it will probably be found useful also for other types of work.

Very light recorders of temperature and other data have been utilized in meteorology. They were sent up by pilot balloons and the records were made on strips of smoked glass moved by a device reacting to the decreasing pressure, and they were to be read under the microscope.

In 1938 Weickmann described a recorder called a „Taschen-thermohygrograph" built from a watch in which a chart was placed on the axle normally carrying the hour hand, and records were made on this by a bimetallic thermometer and a hair hygrometer. This instrument was too large and clumsy for our purposes.

Combining the principle of Weickmann's instrument with the microrecording of the meteorological devices I arrived at the solution here described and figured in the Danish text.

The motor is the clockwork of a fairly good wrist watch 23 mm in diameter and 5 mm thick. It is mounted in a special box (1, Fig. 1) and arranged for winding by a key instead of the usual knob. The hole (2) for inserting the key is kept shut so as to protect the clockwork against moisture. The hour hand axle projects into a separate compartment (3) of the box where it carries the disc (4) on which the recording instruments are mounted. This disc is shown from above in figure 2. The temperature recorder is a bimetallic spiral (5, Fig. 2), unwinding slightly by increasing temperature, connected by a fine metallic wire (6) to a recording lever (7) amplifying the movement of the spiral about 3 times.

The moisture recorder is a single human hair 20 mm long (8) actuating a second lever (9). The levers are provided with very fine vertical writing points tracing lines in the smoke on the glass-plate (10, Fig. 1) which closes the top of the instrument. A third writing point (11), intermediate between the two, traces a base line for reference. The box is surrounded by a rim (12) with oblong holes (13) for the elastic straps used to fasten the instrument on the body. The environmental air has access to the compartment (3), containing the recording instruments, through several narrow, vertical slits cut in the circular side wall and not illustrated in the figures. These slits serve also to provide needed flexibility so that the smoked glass discs can be readily inserted and removed.

For each recorder 5 circular glass discs, fitting into the top of the recording compartment, are provided. Each has on the upper surface an etched circle (6, Fig. 3) on which notes can be made in pencil. The lower surface of each disc is smoked *lightly* over the gas flame from a Bunsen burner with the air supply cut off completely. Smoking can also be performed over kerosene or other suitable lamps. The essential point is that the smoke coating must be uniform and only just visible. The lines traced by the writing points should be fine enough to be practically invisible to the naked eye. It has been found useful to harden the smoke film for 1 min. in ether. The smoked discs are kept in a small cardboard box separated by wire rings.

When a record is to be taken the clockwork is wound and the opening for the key closed again, the uppermost smoked disc is lifted out of the box by means of the sucker, presently to be described, and placed on the recorder. A pencil line is drawn from the center of the disc towards the position of the three recording points, and the date, hour and minute of beginning the record is noted on the etched area together with the number of the recorder (6, Fig. 3).

After the taking of the record, which must not of course exceed 12 hours, the glass disc is again lifted off by means of a sucker and can now either be placed directly under the microscope for reading or put in a cardboard box. The clockwork should be wound before each 12 hour period.

Two separate suckers are provided (fig. 4) each with a rubber tube passing through the handle. When this tube is closed by a

finger or by a clip the sucker can hold the glass disc which will be immediately released on opening the tube. The sucker with the flat handle parallel to the glassplate is used for lifting the disc from the microscope table.

Records are read under a microscope on a micrometer scale in the eyepiece. We have used a 1 inch objective and found a magnification by which 40 divisions on the scale correspond to about 1 mm. to be suitable. The special reading table shown in detail in figure 3 is fitted on top of the ordinary square microscope table so as to slide between 3 screw clips (1). In the upper right hand corner is a special clip (2) with a handle allowing the table to be moved slightly from side to side. The reading table carries two movable (3, 5) and one fixed ring (4), mounted on a rectangular brass plate with a hole which is approximately centered under the microscope objective. A disc (6) carrying a record is placed in the inner ring with the smoked surface down, and the pencil line indicating the beginning of the record pointing as nearly as possible toward the centre of the field of vision.

Looking through the microscope the beginning of the record, say of temperature (1, Fig. 5), is placed on the micrometer scale by turning the inner ring by means of the pointing handle (7, Fig. 3), and then the outer ring carrying divisions in hours and minutes is turned so that the position of the pointer corresponds to the time noted on the disc (Fig. 3).

To obtain the temperature for any particular hour and minute the handle of the inner ring is now turned to the corresponding division, the table is moved so as to make the base line (2, Fig. 5) coincide with a selected division on the scale (50) and the position of the temperature line (1) read off. In figure 5 the temperature reading is 71.3. We have found it most convenient to make all temperature readings in one series and then reset the table so as to make the beginning of the moisture record coincide with the starting time noted.

Records can be measured without fixing. If it is desired to make them more permanent they are held in the sucker and the lower surface dipped for a moment in a fixing solution. We have found a 1 to 25 solution of cellulose lacquer in acetone very suitable.

From the fixed records contact prints can be made on photographic cardboard. When a series of discs is printed simultane-

ously their smoke layers must be of approximately the same density.

The prints must be carefully cut out to fit into the ring of the reading table and the reading requires a fairly strong light from above.

The glassdiscs can be cleaned with soap and water.

The Calibration of the Micro Climate Recorder.

The readings as made are in arbitrary units and valid only for that particular microscope magnification, tube length and eye-piece scale.

The readings are converted into actual temperatures and moistures by reference to calibration curves. The temperature curves for these instruments are straight lines, but separate curves must be made out for each instrument and controlled at intervals. For calibration the recorder is enclosed in a small perfectly watertight metal box, and this it put alternately at two well defined temperatures maintained in Dewar vessels for periods of not less than 1/4 hour. As suitable temperatures 0° C. maintained by crushed ice and a temperature 1—2° C. below that of the room are recommended, but a calibration which insures at the same time that the curve is straight can be obtained by putting the recorder at, say, 35° C., letting the water cool slowly by keeping it mixed by an air current and making readings at carefully noted intervals of time.

An accuracy of ± 0.2° C. is obtained when the readings are carefully made. Most of the errors can be kept within ± 0.1° and the accuracy will be ample for almost all purposes. It has been found that the bimetallic spirals do not unfortunately keep quite constant and it is advisable therefore to control them about once a week. As the curves remain parallel it is sufficient to place the instrument after an experiment for a short period at a known tp. The time lag of the thermometer appears to be of the order of 1-2 minutes, but cannot of course be quite constant.

Hair hygrometers are not generally considered as instruments of precision, but a great deal can be accomplished when they are treated in the right way as described more than a century ago by Gay Lussac. The original communication of Gay Lussac is

quite difficult to find, being published in Biot: Traité de Physique, Tome II, Paris 1816 as a „Supplément à l'hygrométrie" comprising pages 199—208. The tables deduced from the observations are to be found in tome I p. 532—33.

The observations were made apparently on a single hair-hygrometer which was suspended in a glass container over various solutions of NaCl, $CaCl_2$ and H_2SO_4, the densities and vapour pressures of which were carefully determined. All the observations were made at 10° C., and Biot apparently assumed that the relation between the length of hairs and the relative degree of moisture will vary somewhat with temperature. This contention has not been confirmed by later observers, but should perhaps be investigated again.

The increase in length of a hair with increasing moisture is not proportional with the moisture content, but is much larger in dry air. For a hair hygrometer showing 0 in absolutely dry air and 100 in saturated air Gay Lussac has given values in per cent saturation corresponding to the divisions from 0—100. (Tabel 1 Danish text).

Hairs should not be exposed to degrees of moisture below 20 per cent, where the reaction is quite slow and the hair may become permanently altered, and Gay Lussac prescribes further that in order to give correct results the hairs must at certain intervals be exposed to at least 95 per cent moisture. I have found these intervals to be about 3 days. When these conditions are observed hygrometers are, according to Gay Lussac, independent on temperature and pressure, and different hairs will give the same readings. The time required for a hair to attain the length corresponding to the degree of moisture is stated to be 10 minutes or less.

It is generally assumed, that Gay Lussac's figures represent averages only and that individual hairs react differently. I have thought so myself, and I am not prepared to deny the statement, but the more closely I have adhered to the conditions laid down the better has been the agreement with Gay Lussac's table for the small number of hairs (4) which I have studied closely.

I believe therefore that a safe calibration can be based upon Gay Lussac's figures. To do this two points on the calibration curve have to be determined by experiment, while control values can be obtained by determining more points in between.

Well defined moisture percentages are established over saturated solutions of certain water absorbing salts, and from the International Critical Tables I have selected the following as suitable. $MgCl_2$ gives at 20° C. 33 per cent and at 40° C. 35 per cent moisture, K_2CO_3 at 18.5° 44 per cent and at 24.5° 43 per cent, NaCl at 20° 76 per cent, almost independent on the temperature. When experiments are made at 22—25° the corresponding moisture percentages can be taken as 33 per cent for $MgCl_2$, 43 per cent for K_2CO_3, and 76 per cent for NaCl.

The pure salts are put into suitable containers (desiccators) and moistened just so much that the mass can be moulded with a spatula into giving a large irregular surface. A fluid surface makes the attainment of equilibrium too slow and must not be formed. Even when these directions are followed it takes a couple of hours to reach complete moisture equilibrium within the container.

For the determination of the two points necessary for a calibration the recorder is first wrapped in moist filter paper in a moist chamber and after two hours wiped dry and transferred to the desiccator containing $MgCl_2$. It is advisable to take it back and forth at least twice, leaving it not less than two hours in each container. The readings obtained in a particular case (No. 5) were at 100 per cent 27.0, 28.0, 28.0, average 27.7 and (at 33 per cent) 47.3, 46.7, average 47.0.

The difference 19.3 is used as follows:

From Gay Lussac's table given above a curve has been constructed from which the relative lengths corresponding to known degrees of moisture can be read off.

Column 2 in table II gives these figures for intervals of 10 per cent and also for the moistures corresponding to saturated NaCl (76 per cent), K_2CO_3 (43 per cent) and $MgCl_2$, (33 per cent).

From column 2 the figures corresponding to the observed difference between 100 per cent and 33 per cent saturation can easily be calculated (multiplying by the observed differences between the readings for 100 per cent and for 33 per cent moisture and dividing by 43.7, the corresponding figure in column 2) or read off on a slide rule. The figures for the difference 19.3 of the example are given in column 3, and in column 4 the readings obtained by addition of the reading for 100 per cent moisture 27.7. Interpolations can be made by means of the table or graphically when the

corresponding curve is constructed. The accuracy to be obtained varies from about 2 per cent in the lower range to about 5 per cent near the saturation point.

We have preferred graphical interpolation both for temperature and moisture and construct on millimeter paper a chart for each instrument with the readings as ordinates (each scale division = 2 mm.). For the temperature divisions on the abscissa we take 5 mm. per 1° C. from — 10° to + 40° and for the moisture scale 20 mm per 10 per cent moisture from 0 per cent to 100 per cent.

Litteratur.

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