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SOME MICROCLIMATOLOGICAL DIFFERENCES BETWEEN AN OAK WOOD AND A *CALLUNA* HEATH

by

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INTRODUCTION

One of the aims of plant ecology is to investigate the connection between vegetation and habitat factors. The specific habitat of a vegetation type is partially determined by the microclimate, of which one can form an idea by many micro-meteorological measurements.

The micro-meteorological investigation of a plant-community gains much in value if the data obtained can be compared with those of another community. This comparison can be made by compiling long series of observations by means of a statistical method. A second method is a comparison of direct measurements, taken at the same time, in the same way and at stations, which are not so far apart that differences in the weather exist. Irrespective of the fact that long series of observations are not available, the latter method has the advantage to be more illustrative, although the small number of directly comparable observations, which is given here, does not allow to draw definite conclusions. It shows how from the macro-weather, as determined by position of the sun, temperature, humidity, wind and clouds at a greater height, each community specifically forms its own micro-weather.

In the summer of 1955, the authors made micro-meteorological observations in and above an oak wood and a *Calluna* heath. Only the series of observations, made simultaneously, are compared here.

DESCRIPTION OF SITES

The oak wood of "Doorwerth" lies on the southern border of the "Veluwe" between Arnhem and Wageningen in the eastern part of the Netherlands. The wood is situated on the higher part of a slope with a 2% inclination to the West. The stand comprises 80% of *Quercus robur*, 15% of *Quercus petraea*,

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and 5 % of *Betula pubescens*. The oaks, which originated from an oak coppice, are of rather poor quality.

The mean height of the trees is 13 meters. The canopy covers 80 %. A middle storey is absent.

The herb layer consists of *Deschampsia flexuosa*, 90 %, and *Pteridium aquilinum*, 40 %. *Vaccinium myrtillus*, *Galium saxatile* and *Lonicera periclymenum* occur occasionally. The plant-community can be described as a *Querceto-Betuletum typicum*.

The heath is situated 2 km. east of the village of Stroe, south of the railroad Amersfoort-Apeldoorn. The site is an almost flat *Calluna* heath, gently sloping to the West (inclination 0.5 %).

The soil is a fine sand with a weakly developed podsol profile. The surface is covered by a raw humus layer, 3–4 cm. in depth. The vegetation may be classified as a fragmentary *Calluneto-Genistetum*. *Calluna* makes up almost the whole shrub layer. The ling is 40–50 cm. high and covers 80–100 % of the ground. The moss layer, formed by *Hypnum cupressiforme* and *Cladonia impexa*, covers 60 % and is 1–2 cm. thick. Bushy oaks and low stunted pine trees occur scattered over the area.

METHODS OF MEASUREMENT

Air temperature was measured by means of thermometers placed in small screens, which were devised and tested at the Royal Netherlands Meteorological Institute at De Bilt (KRAMER c.s., 1954). The screens are made of Astralon, a white plastic of very high reflectivity and low heat conductivity. They carry three thermometers, a standard meteorological thermometer, a maximum and a minimum thermometer (fig. 1*).

During the day the thermometers in the small screen indicate a somewhat lower temperature than those in the usual STEVENSON screen, i.e. the former give better approximation of the real air temperature.

Soil temperatures were measured by means of mercury thermometers, inserted to the desired depth, evaporation with PICHE evaporimeters with discs of green blotting paper, 3.5 cm. in diameter, and vapour pressure of the air was measured with the ASSMANN aspirated psychrometer.

Arrangement of instruments

In the oak wood thermometer screens and evaporimeters were attached to a tower of open construction (figs. 2* and 3**). The sets of instruments were placed at four different levels: 13.5 m. high, just above the canopy, 8 m. high, under the canopy, and at 2 m. and 0.10 m. above the ground surface.

On the heath a thermometer screen was placed at a height of 2 m., another at a height of 0.50 m., just above the heath, and a third one at 0.10 m.. Evaporimeters were placed with their discs at 1.80, at 0.50 and at 0.10 m. above the ground.

Weather conditions on the days of measurements

August 4th–5th: The morning of August 4th was very cloudy (7/8). At 13.40 M.E.T. 4/8 of the sky was covered. Cloudiness decreased strongly during the following hours. Only an extensive cirrus veil could be observed. At 16.40 most of the cirrus had disappeared and the sky was practically clear.

* Plate 1 ** Plate 2

The night was clear until about 1.40, but at 3.40 the sky was overcast. It was still overcast at sunrise. There was a light wind of about 3 Beaufort, from the N.N.W.. Later in the afternoon the wind force decreased. At sunset and during the night the wind force was zero.

August 30th–31st: August 30th was a warmer, and more humid and cloudy day than August 4th. There was a light wind of 2 Beaufort from the South-West. Later in the afternoon the clouds disappeared and the wind velocity diminished to zero. After sunset a heavy ground mist formed, which remained till the next morning at dawn.

Results of measurements

Air temperatures

The air temperature measurements are plotted in figures 4 and 5. In table 1 maximum and minimum temperatures of the oak wood and the heath are compared with data from the nearest meteorological stations. The measurements illustrate the following general features of the microclimates of the two vegetation types: Above the heath, highest temperatures were recorded nearest to

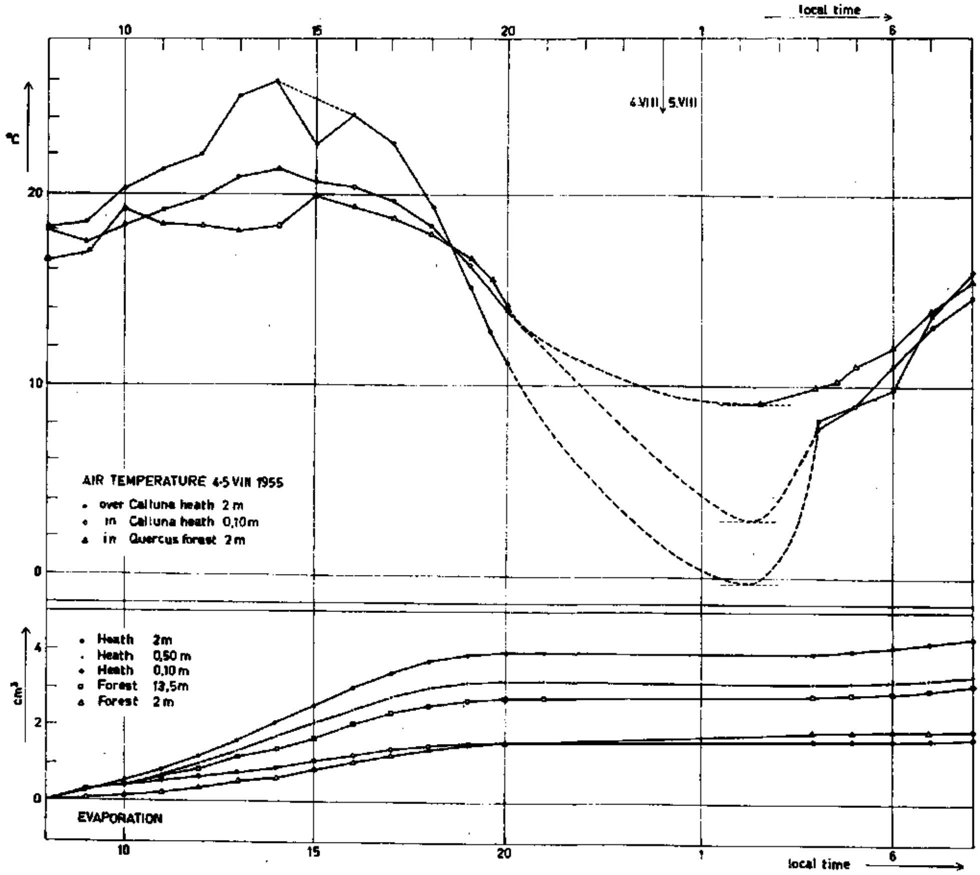

Fig. 4

TABLE 1. Maximum and minimum temperatures and temperature amplitudes in °C on 4th-5th and 30th-31st August in and above oak wood and heath compared with data of the meteorological stations in the neighbourhood: Wageningen, De Bilt and Deelen (Arnhem).

	Max. temp. °C		Min. temp. °C.		Temp. amplitude °C.	
	4–5	30–31	4–5	30–31	4–5	30–31
Oak wood 13.5 m. . .	21.7	24.5	8.7	11.3	13.0	13.0
Oak wood 7 m. . . .	20.2	23.9	9.0	10.0	11.2	13.9
Heath 2 m.	22.2	25.1	2.7	8.1	19.5	17.0
Oak wood 2 m. . . .	20.0	23.5	9.0	10.0	11.0	13.5
Heath 0.10 m.	25.6	28.6	-0.2	6.4	25.8	22.2
Oak wood 0.10 m. . .	19.6	23.0	9.1	12.4	10.5	10.6
Wageningen 2 m. . . .	20.3	23.8	8.3	12.3	12.0	11.5
Wageningen 0.10 m. . . (above cropped grass)	22.7	26.0	5.0	10.4	17.7	15.6
De Bilt 2 m.	20.0	22.7	7.1	9.9	12.9	12.8
Deelen 2 m.	21.0	23.0	8.0	10.0	13.0	13.0

the vegetation, when the situation by day is concerned. At sunset the temperature distribution is reversed; a temperature inversion is formed. Above the lawn of

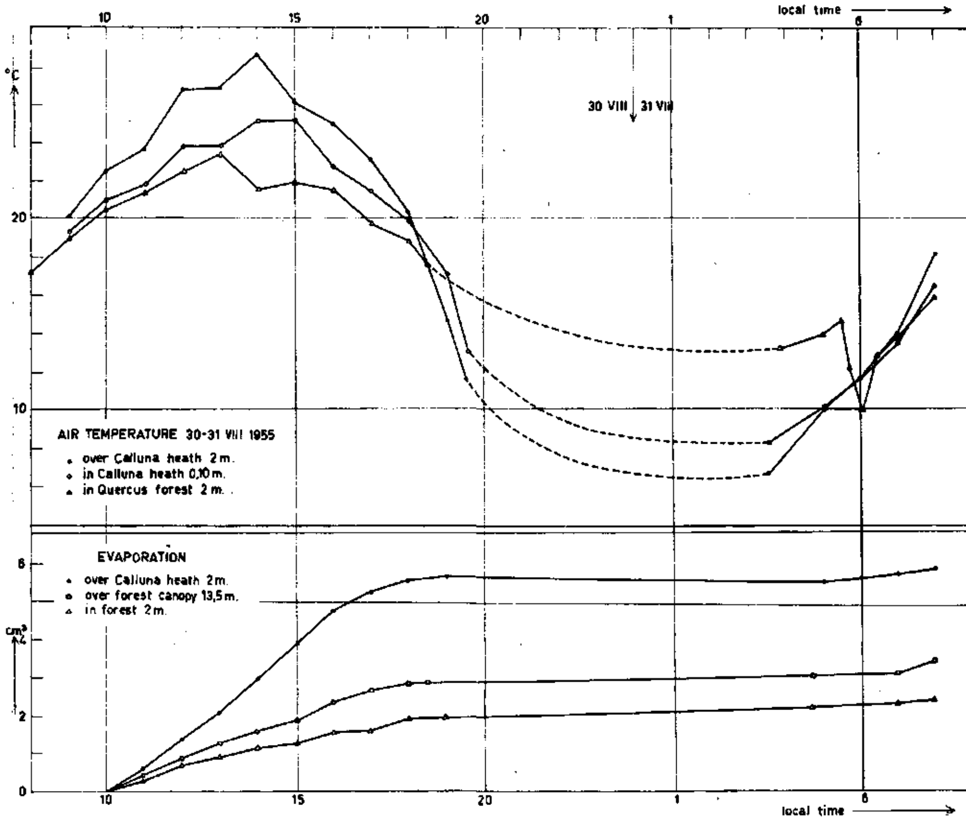

FIG. 5

the meteorological stations the situation is quantitatively the same, but qualitative differences are great.

In the oak wood, highest temperatures are registrated just above the canopy i.e. at the level, where most of the radiant energy is absorbed and transformed into heat. By night, lowest minimum temperatures are measured here. Differences with the lower levels are, however, small. Inside the oak wood temperature extremes are considerably reduced as compared with the data of the heath.

This effect is strongest near the ground. When above the heath, temperatures went down below zero, the minimum above the forest floor was 9°C. By day the maximum air temperature just above the heath was 6°C. higher than above the forest floor. Differences between actual plant temperatures must be still higher. The freely exposed heath tops must have reached temperatures several degrees above the ambient air temperature by day and below it by night. In the wood, plant temperature cannot differ very much from air temperature as the canopy forms a screen against incoming and outgoing radiation.

One of the most striking effects of the microclimatological differences of the vegetation types is given by a comparison of some phenological data. The oak wood started to flush in 1955 in the week of 1st–8th of May. On the heathland however the oaks began flushing on the 30th of May.

At dawn, August the 31st, inside the wood a sudden temperature change was observed, of which details are given in fig. 6. This extreme temperature fall can be explained as follows: A layer of fog, formed after sunset, rests on the

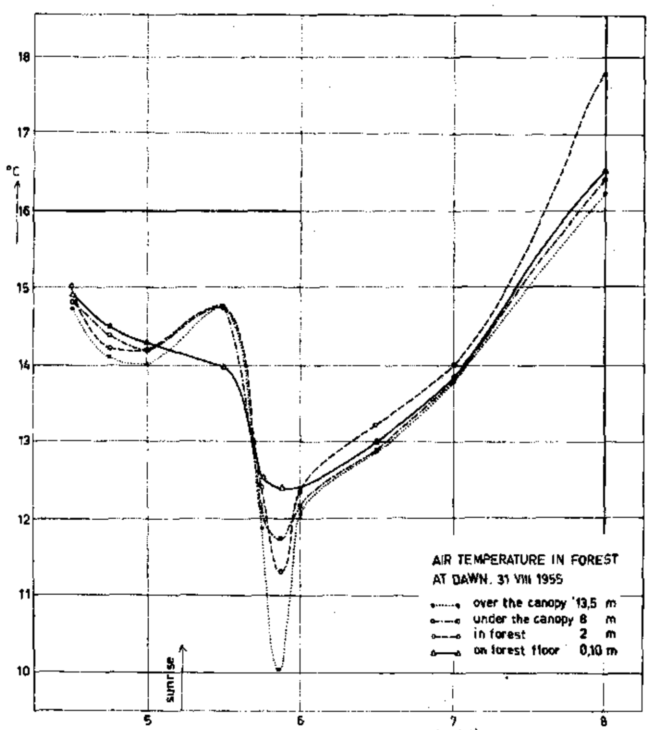

FIG. 6

canopy like a cold blanket. After sunrise the warm air inside the forest is suddenly replaced by air, which is 5°C. colder. That the warm air was not replaced before must be seen as a result of the resistance offered to air movement by the wood and probably by the mist as well. As long as nothing disturbs it this unstable state of equilibrium can exist. The warm air under the canopy breaks through the fog and is replaced by cold air. This cold air may have come from adjoining open areas or from the cold air resting on the fog layer. The lowest temperature is recorded not at the lowest level but at a height of 2 m.. Here resistance against air movement is less than near the forest floor, where the temperature drop is smallest. The warming effect of soil and vegetation may also have been of importance in this respect.

Soil temperatures

Comparable measurements of soil temperatures are collected in table 2.

TABLE 2. Soil temperatures. 4th–5th Aug. Depth: 5 cm

	Max. °C	Mean °C	Min. °C	Amplitude °C
Heath	15.0	13.3	11.7	3.3
Oak wood	17.0	14.7	12.5	4.5
Cropped grass (Wageningen) .	21.7	18.0	14.4	7.3

Maximum temperature at 15.40; Minimum temperature at 4.40.

In the sequence heath, oak wood, cropped grass there is an increase of maximum temperatures, minimum temperatures, mean temperatures, and amplitude.

The heath soil has the smallest temperature amplitude in contrast with the air over it. Other measurements showed, that this low amplitude of soil temperature is connected with a low diurnal heat exchange of the soil. Little heat is taken up by day and lost again by night.

Although the heat quantity in the wood is not so high as on the heath, a higher soil temperature by day is registrated, which is caused by the higher heat conductivity of the wetter forest soil.

The higher minimum temperatures during the night are consequently to be ascribed to:

a. the high heat capacity of the forest soil;
b. supply of heat from lower soil layers;
c. small nightly radiation, which is limited by the covering canopy.

Humidity of the air

The course of the absolute humidity of the air in the wood and on the heath on August 4th and the maximum possible humidities at the relevant temperatures are plotted in fig. 7. The vertical distance between the correspondent curves is the vapour pressure deficit of the air.

High humidity content of the air inside the forest is combined with low air temperature. On the heath the opposite phenomenon is encountered. Differences in vapour pressure deficit are considerable.

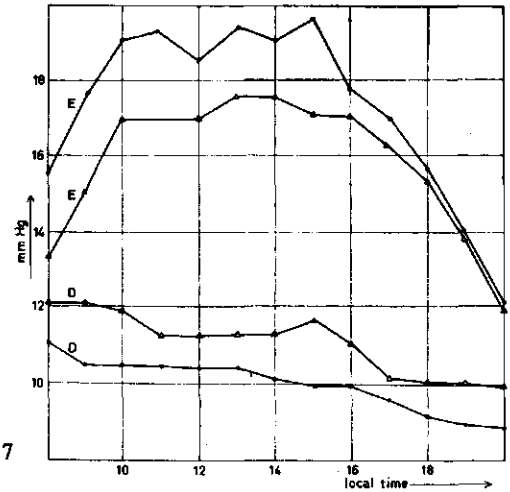

FIG. 7

• E Max. vapour pressure over Calluna heath 2 m.
▲ E Max. vapour pressure in Quercus forest 2 m.
• D Vapour pressure over Calluna heath 2 m.
▲ D Vapour pressure in Quercus forest 2 m.

Evaporation

Evaporation data are plotted in figs. 4 and 5. In Table 3 evaporation totals for the wood and for the heath are compared with those of standard evaporation stations in the neighbourhood, where evaporation is measured 30 cm. above a cropped grass surface. The evaporation discs used on these stations have a diameter of 4 cm. while ours have a diameter of 3.5 cm.. The evaporation ratio between 4 and 3.5 cm. discs is normally 1.3 but as the supporting clip of our instruments covered 1.5 cm.² of the discs a reduction factor of 1.4 was used.

TABLE 3. Evaporation totals in 24 hours in cm³. (first measurements at 8.40)

	Aug. 4–5	Aug. 30–31
Heath 2 m.	8.7	6.8
Heath top 50 cm. . . .	6.6	
Tree tops 13.5 m.. . . .	6.4	4.1
Bennekom (ev. station) .	6.3	4.5
De Bilt (ev. station) . .	4.4	1.8

As evaporation depend on wind force, vapour pressure deficit of the air and radiation (DE VRIES and VENEMA 1954) great local differences may be expected. The strongly reduced evaporation inside the oak wood is clearly due to the reduction of air movement, small radiation and low vapour pressure deficit, but the great difference between evaporation over the heath and over the wood canopy is unexpected.

No relevant measurements of wind velocity are available on these days, but observations on other days show that the greater windvelocity above the wood occurs at a height of 13.5 meters. Apart from a higher vapour pressure deficit above the heath the strong convective air movement is responsible for the high evaporation values.

The evaporimeter over the heath top showed a measurable rise of the water in the tube, owing to a strong dew formation on the disc.

Concluding remarks

Most of the observed micro-climatological properties of the vegetation types studied can be understood from their energy and water economy.

By day, the radiant energy received by a certain surface of vegetation is disposed of by the following processes:

1. Reflection by the vegetation.
2. Long wave heat radiation.
3. Changes of heat content of soil and vegetation.
4. Consumption of energy in transpiration.
5. Heat transfer to the air.

For a heath the energy used by reflection, by changes of heat content of soil and vegetation and by transpiration is certainly lower than for a grass vegetation. Consequently more heat is available for long wave radiation and for heat transfer to the air. The result is a higher air temperature and a strong convective air movement.

The low humidity and the strong evaporation fit into this scheme.

For the wood the only thing that can be said with certainty is that the changes of heat content of soil and vegetation is low, when one compares these phenomena with those of a grass vegetation. Most of the energy transformation takes place at a considerable distance from the ground, namely at the level of the tree tops, as indicated by the fact that highest temperatures are measured here.

The nightly radiation from the soil is absorbed in the atmosphere in a rather thick layer. The layer near the ground, respectively near the canopy, receives only a small part of it, otherwise the temperature near the ground would be the highest.

The heat loss by radiation is partly compensated by the upward heat flow from the soil and partly by heat taken up from the air. Thus, in clear, calm nights the lower air layers are considerably cooled. A soil of low conductivity has a small upward transport of heat by night, which means that more heat is taken from the air. The low air temperatures above the heath as compared with the temperatures above the lawn are thus explained.

It is not sure that the radiation from the canopy of the wood is smaller, judging from the higher minimum temperature. The high minimum temperature could be the consequence of replacement of cooled air by warmer air from a higher level (turbulence), or from the sides, by wind. The downward flow of cold air, and the replacement by warm air from the stand's interior would, however, be the main process in this respect.

To obtain a more detailed idea of the radiation processes in and above the wood a considerable number of energy determining factors have to be examined.

Literature

GEIGER, R.: Das Klima der bodennahen Luftschicht. Braunschweig, 1950.

KRAMER, C., POST, J. J. and WOUDENBERG, J. P. M.: Precision and reliability of open air temperature and humidity measurements with mercury thermometers. K.N.M.I. Mededelingen en Verhandelingen *60*, 1954.

VRIES, D. A. DE and VENEMA, H. J.: Some considerations on the behaviour of the PICHE evaporimeter. Vegetatio *5–6*,(1954). 225–234 (Jubilee-volume J. BRAUN-BLANQUET).

Plate 1

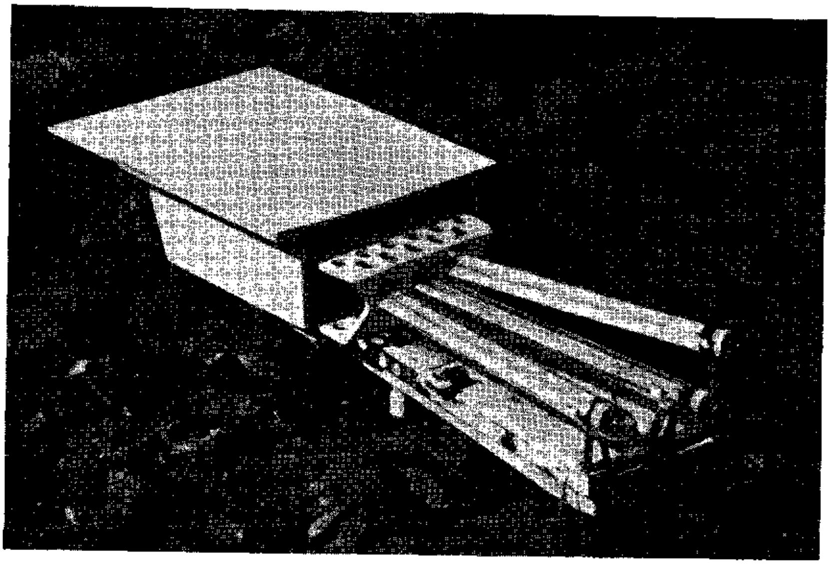

FIG. 1.

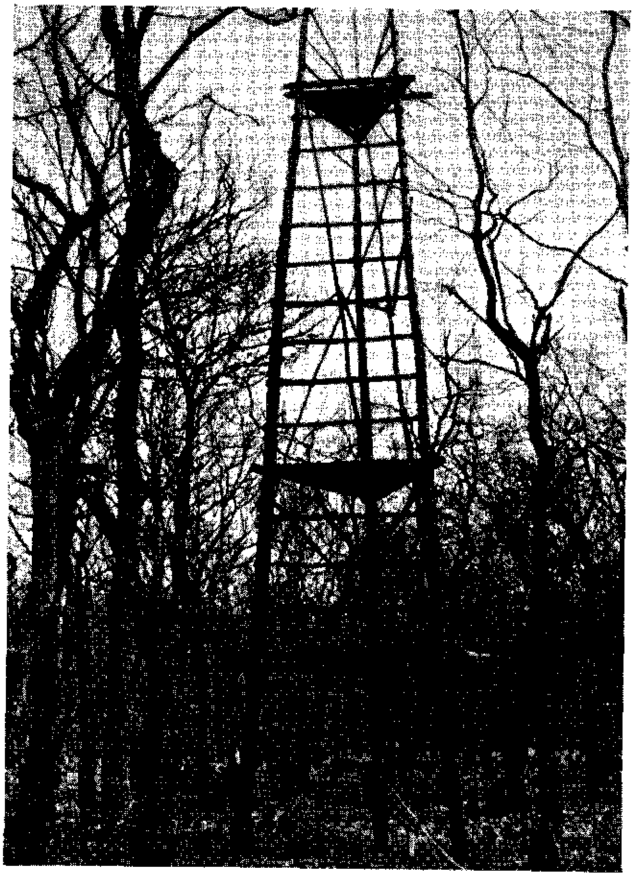

FIG. 2

FIG. 1
Thermometer screen of Astralon

FIG. 2
Tower of open construction

FIG. 3. Attachment of the thermometer screen on the tower