A Light Weight Cup Anemometer with Wind Vane for Weather Report Stations and Calibration of some Cup Anemometers in a Wind-tunnel

by

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In 1948 I was asked to construct for the meteorological stations of the synoptic network in Finland an inexpensive combined anemometer and wind vane that will require little attention and will measure the speed of wind and indicate the direction thereof. It was considered unnecessary to have a recording anemometer and wind vane at most of the meteorological stations. However, an apparatus easily convertible into a recording one was desired.

In devising the apparatus I arrived at the following points: For determining the wind speed for synoptic weather reports a rotation cup anemometer provided with electric contacts and adapted to give the mean velocity of wind with an accuracy of one knot is suitable. For determining the direction of wind the most simple and reliable means is a wind vane provided with direction indicating arms and so constructed as to be readily visible in the dark also. Both the anemometer and the wind vane should be combined in one and the same device which should be made so light in weight the same can be mounted on an easily felled wooden mast to be erected at the weather station. The device must not require maintenance more than once or twice a year at the most. A flashlight cell of 4.5 V. should suffice as power source of the anemometer. The indicator in the room of the observer should automatically count the contacts; at synoptic times it should be possible to set into operation for a certain period of time, during which the other weather observations should be made.

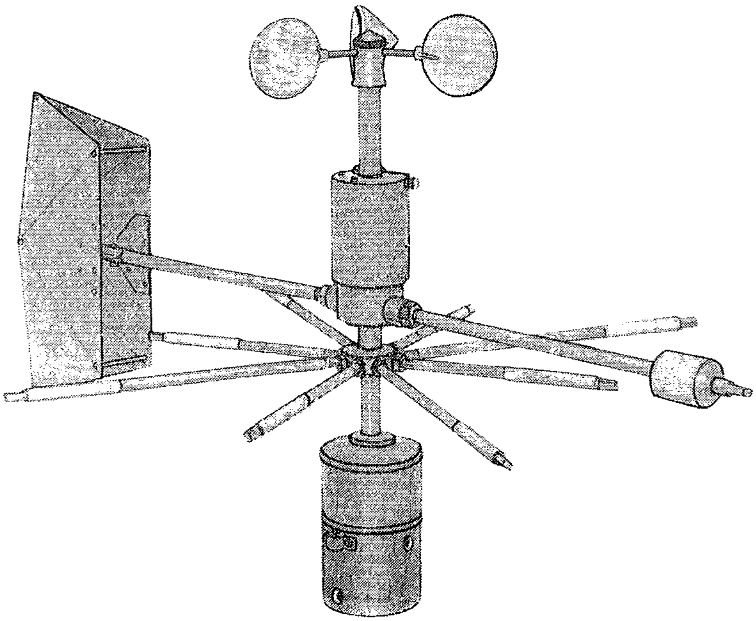

Fig. 1. A combined cup anemometer and wind vane used at the synoptic stations of Finland

With the above mentioned points in mind I constructed the now to be described device. This anemometer (Fig. 1 and 2) is made of brass which material is easy to finish and very resistant to weather elements. Rusting metals are not at all used. The spindle of the rotor is hard-chromatized. The bearings of the spindle are self-lubricating sliding bearings (Swedish »Glissa» bearings) saturated with cold-resistant silicon oil. The upper and lower bearings are 4 × 4 mm and 2 × 4 mm, respectively. The spindle tip rests on a steel ball head. The cups of the three-cupped rotor are conical and cast of plastic (polystyrene). The cups measure 50 mm in diameter and the diameter middle is spaced 70 mm from the rotor center. Each one of the cups weighs 2.4 g wherefore the moment of inertia of the rotor is small. The cups can easily be replaced with new ones, insofar as the same break. Due to uniform plastic casting it is unnecessary to counterbalance the rotors.

The spindle worm engages a 40-toothed worm wheel. A pin projecting from the one side of said worm wheel is adapted to push a brass weight shaped to form a sector and is movably coupled to one and the same shaft with the worm wheel. When the brass weight during the rotation of the

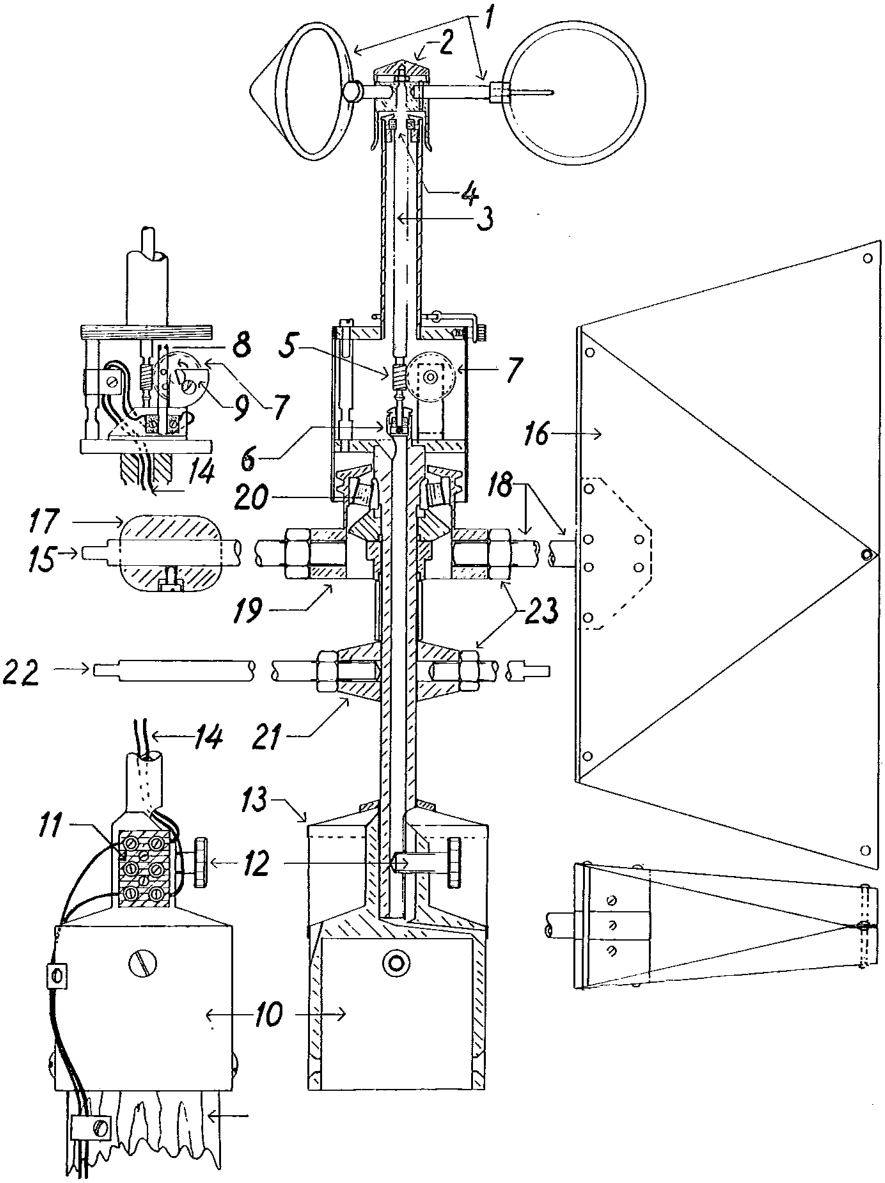

Fig. 2. A sectional view of the anemometer of Fig. 1. Scale 1 : 3

anemometer reaches its uppermost position it falls freely to its lowermost position. Protruding from one side of the weight is an ebonite pin whose outer edge is curved and concentric with the weight, said ebonite pin being adapted to press a contact spring provided with two silver points. Alongside this contact spring is a second, split contact spring, also provided with two silver points. During the fall of the weight the contact points move into contact of about 0.2 seconds duration. This period of time is quite sufficient for actuating the electrical counter. This contact method has the following two advantages as compared to contacts of other prior known anemometers of simple structure of which I am aware: When the anemometer stops the contacts will never stay in engagement. Double contacts are never produced because the contact period of time is short and independent of the velocity of wind. — The two pairs of silver points are provided for ensuring the making of contact.

The wind vane and the 8-armed direction indicating means underneath said vane are comparatively large in size because it must be possible to observe the direction of the wind from quite a distance and even in poor lighting conditions. The tail carrying arm measures 300 mm in length and the arms of the direction indicator are 8 mm thick. The vane is provided with a conical roller bearing (SKF 30203) composed of 2 parts and is, consequently, easy to clean. The bearing, however, is well protected and lubricated with silicon oil. It requires attention possibly every 5th year only. The arms of the direction indicator and the pointer of the vane are covered with »Scotchlite» sheeting (Scotchlite Reflective Sheeting Type 2). This sheeting reflects light back into the direction from which it arrives independently of the angle of incidence. The vane must be illuminated in the dark, e.g., with a flashlight. Illuminated surfaces covered with »Scotchlite» are about 100 times as bright as white surfaces identically illuminated. Only pouring rain and thick fog render it impossible to detect the vane in the dark. The direction indicator is located adjacent to the vane and shades the bottom part of the tail. Practise will show that this arrangement does not impede the movements of the vane but notably enhances accurate observation of the position of the vane.

The base part of the anemometer consists of a sleeve-like member having an inner diameter of 60 mm and adapted to receive the top of the wooden mast. The device may easily be removed from this sleeve by loosening a hand screw and detaching the electricity wires. Hence, the sleeve need not be removed from the mast when attending to the device.

Super-cooled drizzle or rain, wet snow etc. tend to freeze the anemometer rotor and render the same immovable. To prevent this, the lower edge of the rotor center is turned 4 mm outwards. The horizontal distance between the vane center and the lower edge of the anemometer casing is 5 mm. Practise shows that while some other types of anemometers freeze immoveable the described device still operates. — The whole device weighs 3.6 kg.

The contacts counter (Fig. 3) is located within a wooden box adapted to be rigidly secured to a wall and has disposed therein a 4.5 V. flashlight cell and on one side the said box is arranged an electric switch. The contacts

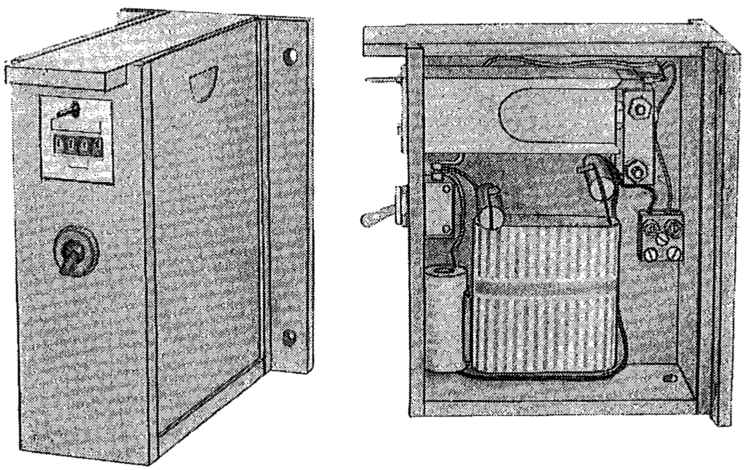

Fig. 3. Contacts counter of the cup anemometer

counter (of the type L. M. Ericsson RSA 1103) includes a 25 Ω coil and is provided with a resetting lever. An electrolytical condenser of 16 mFd and a resistance of 6 Ω in series therewith and coupled interbetween the coil ends of the counter serve as an effective contact spark remover.

To date, 27 anemometers of the kind above described have been made. Two of these are provided with direction contacts also. The upper part of the vane center has space for 8 direction sectors fixed to the ebonite disc. The contact fixed by means of an annular spring to the vane center is adapted to move into engagement with the said sectors. — Further, 7 anemometers without a wind vane and provided with an extra gear of 1 : 4 have been made. Hence, contact is effected always after 160 revolutions. The contacts are recorded on a moving tape of paper.

A pencil is adapted to shift 2 mm sidewards at each contact and return to its initial position after 10 contacts.

In the wind tower of the Ilmala Observatory in Helsinki all the aforementioned anemometers have been calibrated as follows: five anemometers together with the Fuess no 28 892 anemometer of precision work and calibrated in a wind-tunnel were arranged in a row and spaced 50 cm apart. The contacts were recorded during a period of time of about 3 months and from the hourly mean values were selected the ones wherein the direction of the wind was substantially perpendicular to the row of anemometers. The results show the indications of the anemometers to deviate from each other about ± 1 %. The anemometers having an extra gear rotate 9 % more than the others. This is naturally due to the fact that the anemometers with extra gear do less work; they raise the contact weight less frequently in the ratio 1 : 4. Hence the weight provided contact means appreciably retards the speed of the rotor. The consequent so-called increase in starting speed is about 0.2 m/sec. Provisory tests with a windmill anemometer show, namely, that without the contact weight the anemometer starts rotating in the wind at a speed of 0.7 m/sec., while with contact means the anemometer starts rotating at a speed of 0.9 m/sec. when the loading effect of the contact weight is at its maximum. In my opinion this fact, however, is without practical significance insofar as the starting speed does not exceed 1 m/sec. The braking effect of the contact means may be proportionally decreased by making the rotor greater, but for reasons previously stated endeavours have been made to avoid this.

Calibration of the anemometers in the wind-tunnel

In 1952 I calibrated anemometers in the wind-tunnel of the state-owned airplane factory (Valtion Lentokonetehdas) at Tampere. The wind-tunnel opening is 280 cm. by 200 cm. The velocity of the wind is determined with a micromanometer of the type Fuess 134b and a Brandtl type of pressure tube whose horizontal part measures 50 cm in length. The pressure tube was made in 1952 and ground with special care.

Prior to calibration I checked with a pycnometer the specific weight of the micro-manometer liquid. The result was sp.w. = 0.8003 at a temperature of 19° C. The manometer was calibrated for the value s = 0.800. Further, I checked the micrometer indications for different angles of incidence. This was done by interconnecting the U-manometer and the micromanometer with a rubber tube and blowing pressure into the tube. Notable systematic errors were not obtained in the comparison observations.

The anemometer contacts were counted with electrical counters. The time was determined with a seconds watch, the even motion of which had been checked. Each test lasted from 0.5 to 2 min. The manometer indication was observed at the outset, middle and end of each test. The zero (0) point of the manometer was determined at the outset and end of each test. The velocity of the wind was computed by means of the formula:

$$v = k \sqrt{\frac{2\ gh}{\gamma}},$$

wherein: v m/sec = velocity of wind
γ kg/m³ = density of air
h mm water pillar or kg/m² = difference pressure
g m/sec² = acceleration of gravity
k = constant which for the Brandtl tube is 1.

Fig. 4 is a graphic presentation of the calibration results of the two types of anemometers described above. The anemometer »IKL no 17» is provided with a gear 1 : 40 and the anemometer »Imatra no 1» with an extra gear 1 : 4 wherefore the speed total is 1 : 160. Otherwise the devices are similar. The curves show that the latter less loaded anemometer rotates faster. However, the load does not notably affect the curvature of the curve.

At the Ilmala Observatory in Helsinki a 4-cupped anemometer no 101 constructed in 1896 is in continuous use. At the Sodankylä Observatory is used an identical anemometer no 104 made in 1901. Both were made by the mechanic Falck-Rasmussen of Helsinki.[1]) The anemometer cups are of copper, the spindle of steel and the bearings of bronze. The cup measures 99 mm in diameter while the cup supporting arm is 196 mm long and 8.3 mm thick. In 1949 both anemometers were intercompared in the wind tower of the Ilmala Observatory, at which identical indications were obtained. Originally the contact means of the anemometer 101 entered into contact after every 500 rotations, but subsequently it was changed to enter into contact after every 50 rotations and in 1932 thereto was added a gear to effect contact after every 200 rotations.

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[1]) Osc. V. Johansson: Über die anemometrischen Windstärkemessungen in Finland. Öfversigt af Finska Vetenskaps-Societens Förhandlingar, XLVII 1905—1906 no 18.

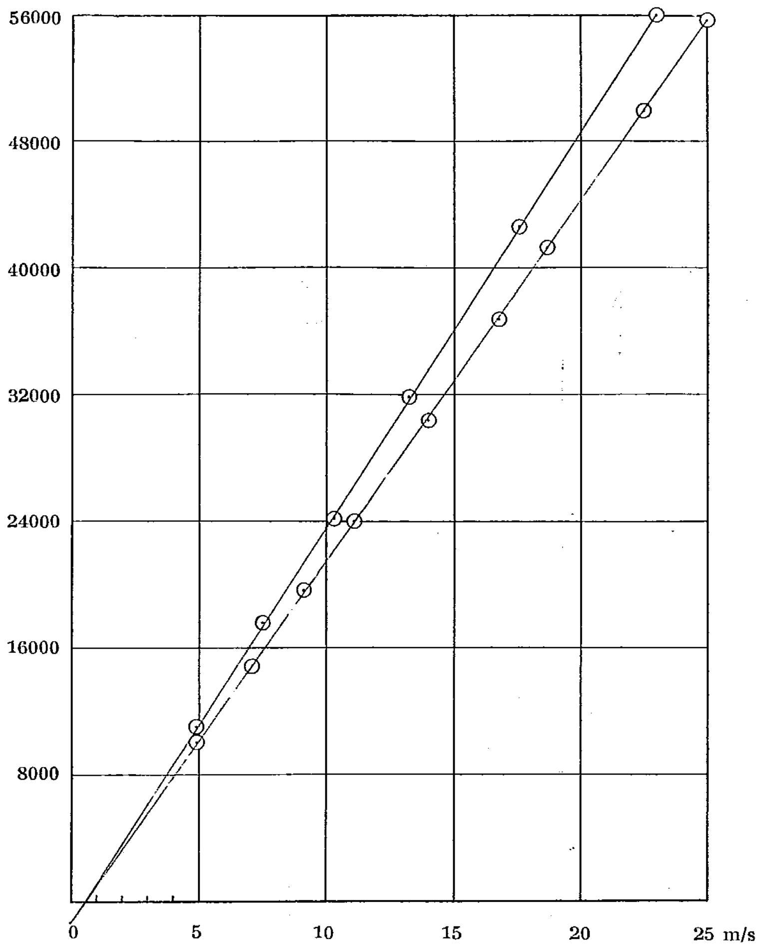

Fig. 4. Calibrations in wind-tunnel. Lower and upper curves respectively represent data for the anemometer of Fig. 1 (IKL no 17) and an anemometer otherwise similar to that of Fig. 1 but provided with 4 times greater gear (Imatra no 1). Rotations per hour serve as ordinate.

In 1902 the anemometer 101 was calibrated, by means of Combe's rotational apparatus, at the Central Observatory of Petersburg (Leningrad). The said rotational apparatus is rotated in both directions and 9 % is subtracted from the peripheral speeds for eliminating error due to the motion of accompanying air. In Combe's rotational apparatus the following speeds were used: 1.36 — 2.69 — 5.61 — 9.66 — 11.40 m/sec.

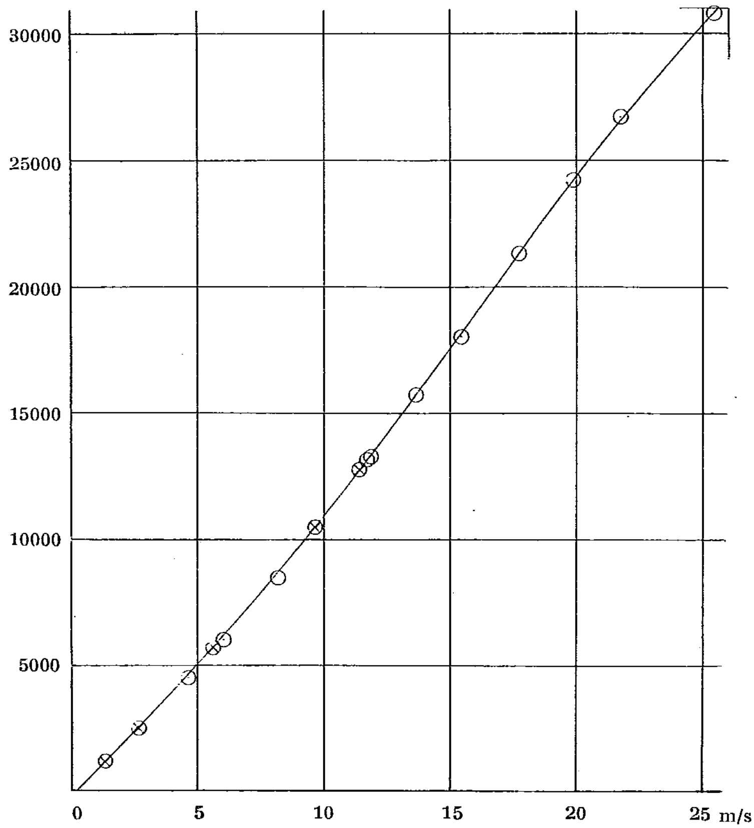

Fig. 5. Calibrations of the anemometer no 101 constructed in 1896. ⊗ = calibration in 1902 with Combe's rotational apparatus. ⊙ = calibration in wind-tunnel in 1952. Rotations per hour serve as ordinate

The said anemometer was calibrated the second time now 50 years later in the aforementioned wind-tunnel. Fig. 5 shows the results of both calibrations which in my opinion are compatible. This result serves as proof of the fact that the calibration of the cup-type anemometer is very stable provided attention is given to regularly lubricating and cleaning the device and to checking the sensitive operation of the mechanism. — The calibration effected in the wind-tunnel gives as a result a slightly inclined S-shaped curve. This obviously is due to the »old fashioned» structure of the anemometer with its long arms and comparatively small cups.