# NEW METHODS TO MAKE TURBULENT AIRSTREAMS VISIBLE BY USE OF FLOATING PARTICLES.

Thesis

by

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We may distinguish between particles which are illuminated with a source of light and particles radiating by themselves. The illuminated particles may show a selective reflexion in a few directions of the space or a dispersion of light.

Selective reflexion can be obtained from particles with fairly plane and very shiny surfaces. Particles which fulfill these conditions can be obtained by carbonizing thin cellophane. The cellophane is cut in strips and packed very closely, then toasted at 300°C and carbonized for three hours at 550°C to get a stiff and brittle material. The product is squeezed against asbestos paper; the obtained particles can be separated in the usual way.

We have to consider the optical properties of this material. With a pointlike source of light and a perfect plane surface of the particle, the probability that the particle is seen is equal to the spacial angle under which the receiving optical system appears at the place of the particle. ($w = \omega/2\pi$). The amount of light received is independent of the distance and the aperture. This still holds for the real case when the condition (a), $d_p/r_p \ll d_o/r_o$, is fulfilled, where $r_p$ is the minimum radius of curvature of the particle, $d_p$ the diameter of the particle in the plane of maximum curvature, $r_o$ the distance of the camera or the eye, and $d_o$ the diameter of the objective. A condition (b), similar to (a), holds for a finite extension of the source of light. If (a) and (b) are mere inequalities the brightness of more and more seen particles becomes dependent upon the distance.

These particles can only be used to make distinct points of their path visible, because they change their orientation very fast; but obviously their brightness at the point of favorable orientation exeeds highly the brightness of any light dispersing particle of similar size. These thin leaflets have the further advantage that their sinking speed as compared with the size of the reflecting surface is low. They can be applied where an accurate counting and a photographic registration of particles passing planes or beams of light is reqired, though the number of particles coming into observation is small.

For observations of streamlines, light dispersing particles or particles reflecting to all directions of the space can be used. U. Schmieschek[1] gave the following method to obtain light dispersing particles. Vapor arises from a block of metaldehyd against which a hot piece of copper is pressed. A fan is provided to cool down the vapor and blow it into the airstream under consideration. The metaldehyd condenses to tender flakes of cristal needles. This method may be adapted to the use in wind tunnels by introducing the vapor through a tube containing a heating coil, (fig.1), which holds the temperature of vapor and tube high enough to prevent condensation. Blowing in of a gas allows lower temperatures and a certain regulation of the size of the particles. This method gives particles of different

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[1] Zeitschrift fuer techn. Physik, Bd. 17. 98-100.

shape and size; the visibility of the particles is very good.

Highly regular particles of poorer visibility are soap bubbles obtained by the following method. Lacking dispersion they are visible by the reflexion of light. The production is shown in fig. 2. From the small orifice A a stream of bubbles is released, whose size is regulated by the width and shape of A, whereas their frequency is controlled by the gaspressure. Coming to the surface they form films which are allowed to thin out by giving off superfluous liquid in room B. The film enters the glass tube C. The soap films form in C highly regular patterns as shown in fig. 3. The films move through the rubber and glass tubing of arbitrary length forming bubbles at the nozzle D, which are taken off by the aircurrent. The proper nozzle is picked out according to the velocity of air and the size of bubbles desired. Sharp, small, and slender orifices give small bubbles with slow velocities of the air current, wide and thick ones give large bubbles with comparativly high velocities. (Fig.3). Regular size of the bubbles is obtained when the airspeed is low enough to allow the separation of the bubble from the following soapfilm. If the velocities are too high the bubble is torn off irregularly or destroyed.

The total volume of bubbles per second is limited by the maximum film velocity in the tube and the cross section of the tube. The maximum permissable speed was found to be fairly independent of the diameter of the tube; it reached with good soapsolutions 3 cm/sec.At higher speed the films were destroyed in the tube.

At D due to the decreasing cross section of the nozzle tip considerably higher velocities are allowed. The maximum number of bubbles depends likewise upon the closest package of films which still allows regular formation of bubbles. With four bubbles at the ~~esee~~ section satisfactory results could be ~~ab~~ obtained. With the dimensions of the nozzle in fig. 3.3 this gave some 120 bubbles per second.

The sinkingspeed of the bubbles is independent of the radius r and is proportional to the thickness d of the film. Filling with hydrogen makes it possible to maintain the trim of sufficiently large bubbles. The specific weight of the bubbles in air and for a specific weight of air equal 1 is:

$$\sigma_b = \frac{3\, d\, \sigma_e \cdot 10^3}{r \cdot 1.23}$$

where the specific weight of the solution. With $\sigma_e$ =1.1 we get $\sigma_b$=2.7 $10^3$ d/r. The lower limit for d for a film stable enough is about 0.8$\mu$. With this value we get a lower limit for r, the radius of the bubble which will just float when filled with hydrogen. We obtain r=2mm.

This calculation was made in order to consider the use of small clusters of bubbles, filled with hydrogen, because the clusters have a far better visibility.

The visibibility of the bubbles depends upon their reflectivity which is not very high. Point-like sources of light or more diffused sources make little difference. With the available arc lamp no satisfactory pictures could be taken in an aircurrent of about 16 m/sec.

It may be noted that illumination with an arclamp run by ~~alter~~ alternating current or with a thyratron allows a very exact determination of the speed to be made, by the observation of the dark spots of the traces.

Without the application of very powerful sources of light, all these methods are not satisfactory to take pictures of high speed air currents because the reflected or dispersed light intensity distributed over the path is very small. There is the possibility to improve this by a large factor when using radiating particles and redsenstive photographic films. Sufficient radiating energy can be obtained by a burning particle. It is obvious that the burning up of these particles has to go on slowly in order to give traces of sufficient length and to avoid recoil effects from air heated up at one side. That makes it impossible to use substances like magnesium powder. The conditions can be fulfilled by porous specimens of charcoal, obtained p.e. by carbonization of balsawood and the pith of yucca. The apparent specific weight should be as low as possible to allow a higher mass, the total radiation being proportional to the mass. For equal sinkingspeed the mass is proportional to $1/\sigma^{3/2}$, where $\sigma$ is the 'specific weight' of the carbon. With yucca pith a charcoal with $\sigma$=.027 could be achieved. When the particles are abtained by a very slow carbonization at low temperatures they have low temperatures of ignition.

With carbonization at 220°C charcoals can be obtained with an ignition temperature of 360°C in air and 230°C in pure oxygen. When the particles are blown out through a tube in the airstream they can be ignited by a heating coil in the tube.

A modification of this was used for the pictures 1 and 2. Here the carbon particles were blown through a little hydrogen flame which was kept burning at the opening of the tube protected by a tube of asbestos paper which allowed sufficient air to come through to keep the flame burning. The flame can be kept well back from the open end of the asbestos tube.

Attempts were made to get a more satisfactory way of ignition by using pyrophoric particles to avoid any heating of the air. These are particles supposed to start to burn when coming in touch with air. Phyrophoric substances can be made with colloidal phosphorus, the metals of the iron group, and antmony. The metals have to be prepared with very large surfaces. The heat developped by the immediate oxydation of this surface suffices to start the burning.

The most successful method was the following: small carbon particles from balsa wood were treated several times with a hot concentrated solution of ironoxalate which was cooled down with the particles. The particles were carefully dried in a sand bath. The reduction in the hydrogen current of the iron-compound to iron was done at a temperature of 450 °C in four hours using an electric heating element. In most cases the method did not yield products pyrophoric over a long enough time. This perhaps may be ascribed to contaminations of the available technical hydrogen. The hydrogen has to be very pure because the substance is held under hydrogen and blown out with it, after it cooled down.

Conclusions;

New methods are suggested and developed to make turbulent air currents visible.

Metaldehyd flakes and soapbubbles can be applied for direct observation and photography to not too high air current speeds; the former give better visbility and the later a better approach to the streamlines, especially when trimmed with hydrogen. The production of shiny and plane leaflets was described which allow exact quantitative measurements of distributions. Lastly suggestions were given for the production and use of radiating paticles to make possible the direct observation of very fast air currents.

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Fig. 1.

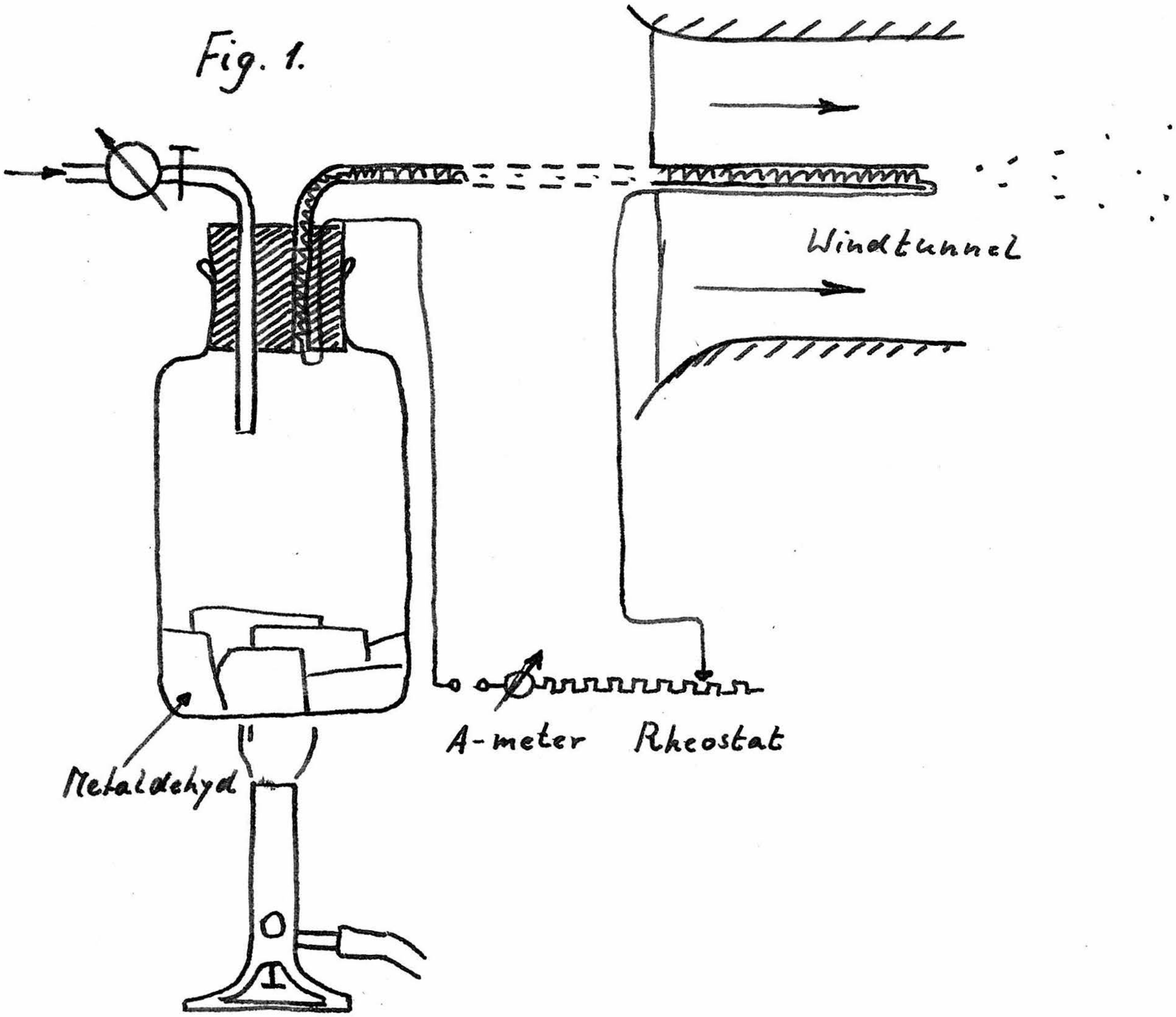



Fig. 2.

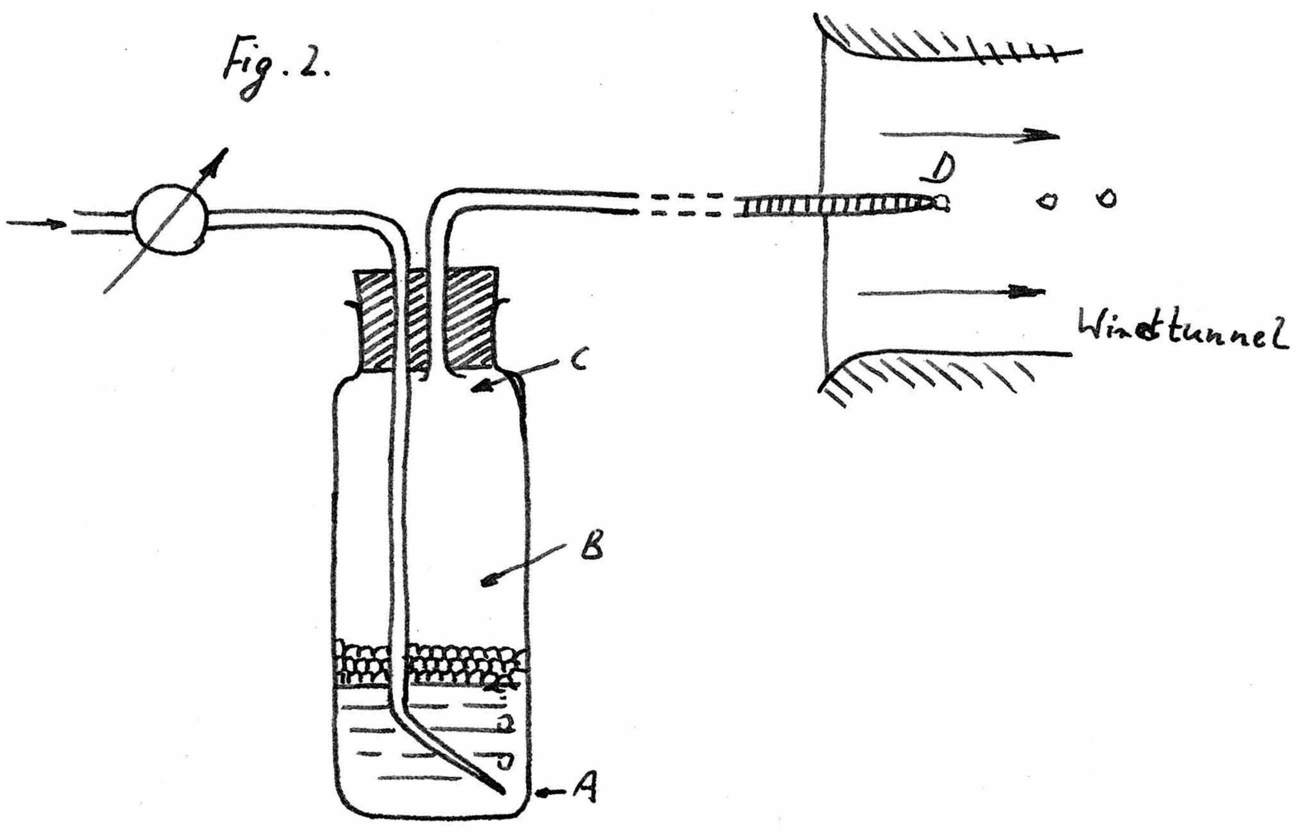
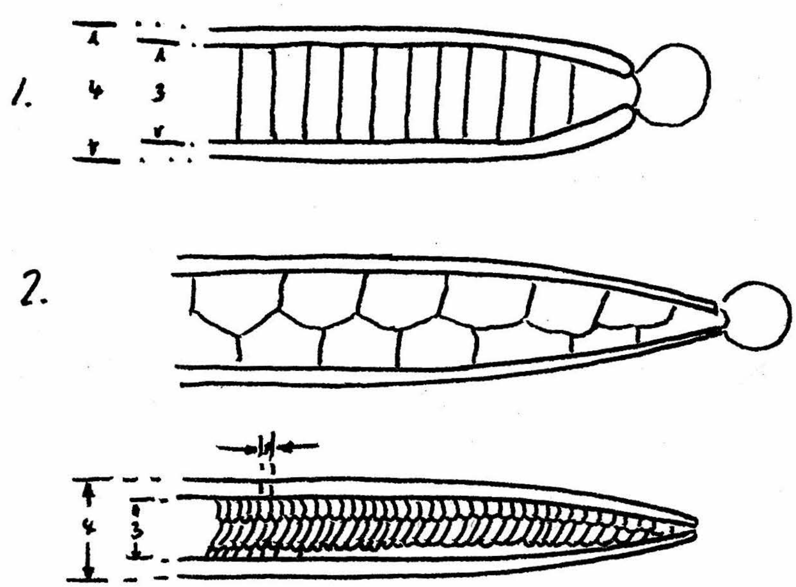
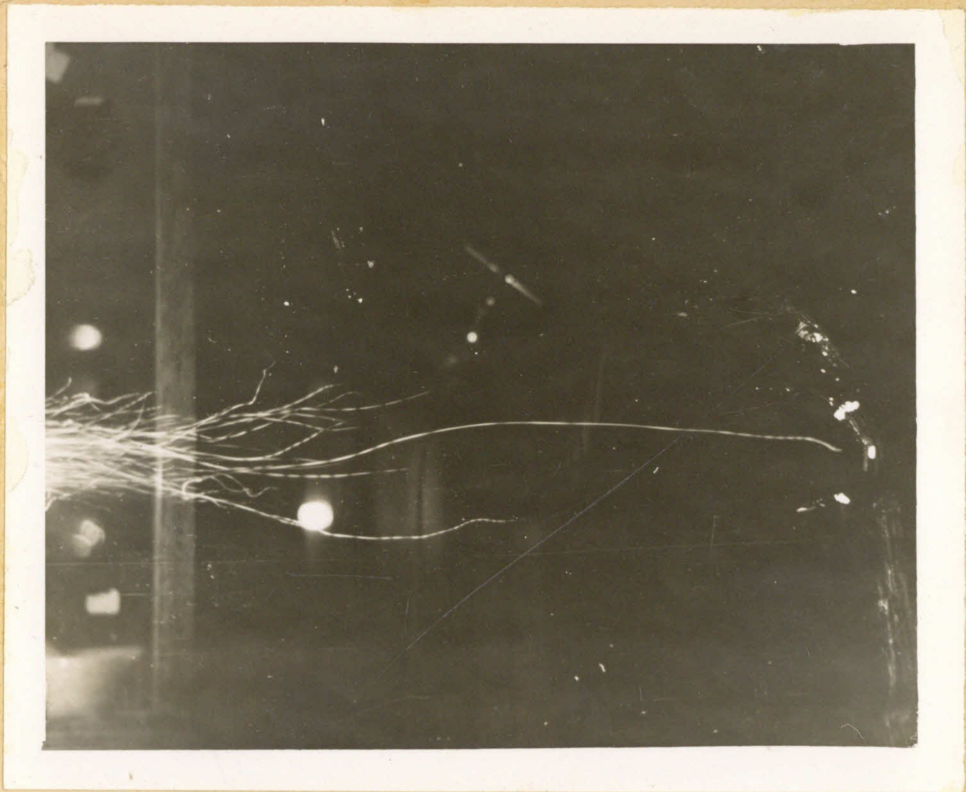


Fig. 3.



Pict. 1.



f: 5.6

distance 130cm.

M: 1:7.

Agfa Ultra Speed Pan.

t: 1/2 sec

Pict. 2.

f: 5.6

distance 130cm.

M: 1:7.

Agfa Ultra Speed Pan.

t: 4 sec.