

Electrets

[Electret Capacitor Based Battery Charging System](#)



[Electrets](#)

How to Make an Electret

the Device That Permanently Maintains an Electric Charge
by C. L. Strong

Scientific America, November, 1960

Danger Level 4: (POSSIBLY LETHAL!)

[Alternative Science Resources](#)

Electret

THE HISTORY OF SCIENCE IS A TREASURE house for the amateur experimenter. For example, many devices invented by early workers in electricity and magnetism attract little attention today because they have no practical application, yet these devices remain fascinating in themselves. Consider the so-called electret. This device is a small cake of specially prepared wax that has the property of permanently maintaining an electric field; it is the electrical analogue of a permanent magnet. No one knows in precise detail how an electret works, nor does it presently have a significant task to perform. George O. Smith, an electronics specialist of Rumson, N.J., points out, however, that this is no obstacle to the enjoyment of the electret by the amateur. Moreover, the amateur with access to a source of high-voltage current can make an electret at virtually no cost.

"For more than 2,000 years," writes Smith, "it was suspected that the magnetic attraction of the lodestone and the electrostatic attraction of the electrophorus were different manifestations of the same phenomenon. This suspicion persisted from the time of Thales of Miletus (600 B.C.) to that of William Gilbert (A.D. 1600). After the publication of Gilbert's treatise *De Magnete*, the suspicion graduated into a theory that was supported by many experiments conducted to show that for every magnetic effect there was an electric analogue, and vice versa.

"In 1339 Michael Faraday suggested that it should be possible to polarize a dielectric material so as to produce 'a Dielectric Body which retains an electric moment after the externally-applied electric field has been reduced to zero.' In Faraday's time, however, other workers were so busy with such ideas as the telegraph and the arc light that they paid little attention to his device. An exception was Oliver Heaviside, who discusses it in his *Electrical Papers*. Finding Faraday's 19-word description a bit cumbersome, Heaviside coined the word 'electret,' by analogy to 'magnet.' Adorned with this name, the electret remained no more than a scientific concept until 1922, when the first electrets were produced by Mototaro Eguchi, professor of physics at the Higher Naval College of Tokyo.

"The analogy between the magnet and the electret is striking, and this includes the way in which they are fabricated. For example, a magnet can be made 'cold,' but the strength and permanence of its magnetism is enhanced if the material is placed in a magnetic field while it is in the liquid state and is then allowed to cool while the field is maintained. The same is true of the electret, though of course the effect and the field are electrical.

Dielectrics (extracts from the webpage <http://ufophysics.com/dielec.htm>)

A dielectric is a non-conducting material which has the unique ability of preventing electrical conduction but is at the same time capable of absorbing electric charge. Indeed, it will carry on absorbing charge until its saturation capacity is reached, whereupon, if its power source is still connected and still trying to pour more electricity into it it will rupture and a path will be created through it for current to discharge. This phenomenon, called dielectric breakdown is most certainly to be avoided for it renders the solid material useless thereafter. If, however, before it ruptures the charge accumulated within the dielectric rises toward its saturation point and reaches a level of voltage higher than the voltage of the charging circuit, then the dielectric's voltage will discharge itself (just like a short circuit - very violently) back through the power source.

From the very earliest days of electronics discoverers such as Faraday, Maxwell, and Lord Kelvin found that dielectrics didn't merely insulate; and that even the humble Leyden jar condenser was found to hold significantly more electricity, surface area for surface area, than a flat-sheet condenser with air between its sheets - because it had a dielectric of glass sandwiched between its electrodes. Dielectrics were found to exhibit what was then termed 'elastic stress' which enabled its structure to absorb unusually large quantities of charge.

Thomas Townsend Brown, the pioneer of electrokinetics, or as he called it the 'electrogravitic' effect, discovered that certain dielectrics perform much better when charged up at a slower rate of oscillation than others* and it was he who originally devised, in 1958, the science of 'doping' dielectric materials with higher-mass particles (the higher atomic-mass particles he used were lead oxide granules) to enhance the dielectric's electric charge absorption. To understand how this occurred, if you can imagine that such particles create 'interfaces' with the main structure of the dielectric and that opposite polarity charges accumulate at each side of those interfaces, then what Brown invented was a cluster of mini capacitors held inside the dielectric body (which in itself was connected inside a capacitor).

[* NOTE: TT Brown first patented this idea in 1928 (British 300,311), and in his US patent 1,974,483 of 1934 he wrote of the kinetic reaction he had discovered, "It is evident from consideration of [the figures] that any type of dielectric under the conditions revealed therein produces both direct and reactive forces as shown. These forces, however, are different with dielectrics of different physical characteristics and are roughly proportional to the massiveness."

Indeed, his research into 'massiveness' was a key element of Brown's work through to the 1950's. He wanted to continue the work of C.F.Brush, a physicist who had discovered certain anomalies between mass and gravity in certain materials, and had concluded that;

"the ratio of mass to weight is not the same for all kinds of matter, as has been supposed, and the mass-weight ratio is not constant even in the same kind of matter." (For Brush's research see Proc. Amer. Philosophical Soc. Vol LIII (1914) p118; Vol LX (1921) p43; Vol LXI (1922) p167; Vol LXII (1923) p75; Vol LXIII (1924) p57; Vol LXIV (1925) p36; Vol LXV (1926) p207; Vol LXVII (1928) p105; Vol LXVIII (1929) p55. Journal of Franklin Inst. Vol. 206 (1928) p143. Physical Review Vol 31 (1928) p 1113 (abstract); Vol 35 (1930) p296 (associated abstract); Vol 37 (1931) p460 (associated abstract); Vol 38 (1931) p1920 (associated abstract)).

And another extract from <http://ufophysics.com/elstress.htm>

A 'DIELECTRIC' is defined as a material which has the unique ability of absorbing electrical energy and 'charge' without ordinarily passing this energy on to neighbouring materials. Some dielectrics are able to absorb enormous quantities of electrical energy (also referred to as 'ELECTRIC STRESS') without discharging, provided that the energy is fed into the dielectric slowly and at low potential. Still others can be charged and discharged at extremely high potential at a rate of several thousand times each second. Townsend Brown concerned himself principally with this latter type. Using just such a dielectric, Brown constructed disc-shaped (or saucer-shaped) condensers, and, by applying various amounts of high-voltage direct current, witnessed the [Biefeld-Brown ²] effect in action. With the proper construction and electrical potential (in the kilovolt range) the disc-shaped 'airfoils' were made to fly under their own power, emitting a slight hum and a bluish electrical glow as they did so. More scientifically, perhaps, this process of 'flight' might best be described as 'motion under the influence of interaction between electrical and gravitational fields in the direction of the positive electrode'.

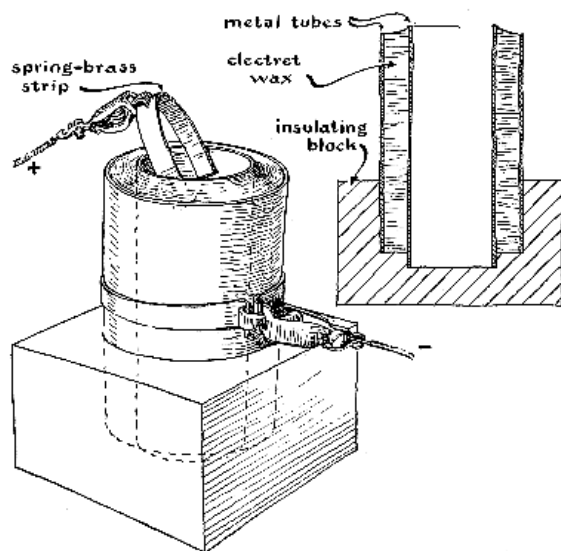


Figure 1: An electret devised by E. P. Adams of Princeton University

removed from the field, it will retain a charge. The strength of the charge depends on a number of factors, including the composition of the wax and the rate of cooling. However, even crudely made electrets can maintain a charge of several hundred volts. Just as some magnetic materials have a higher permeability than others, certain waxes make better electrets. One of the more efficient formulas for electret material is: carnauba wax, 45 per cent; water-white rosin, 45 per cent; white beeswax, 10 per cent.

"In the present state of the art this formula is subject to imponderables of the sort that make horse-racing popular: It is more a matter of opinion than of certainty. Some experimenters advocate the substitution of 'halowax' for the water-white rosin. Others who agree go on to point out that if halowax is substituted for the rosin, the beeswax may be omitted. The beeswax is added only to reduce the brittleness of the final electret, and equal parts of halowax and carnauba wax do a fine job. The carnauba-halowax mixture gives the finished product a creamy, ivory texture with a nicely polished surface, and it shrinks sufficiently upon cooling to come easily out of the mold. On the other hand, halowax is somewhat hygroscopic, and electrets containing it must be protected against humidity.

"Some experimenters claim that good electrets cannot be made unless the mixture contains at least a trace of carnauba wax. Others insist that any wax that cools to a fairly hard, shiny surface will accept the electric charge and develop an external electric field. One explanation in support of the carnauba-wax view suggests that the relatively large shrinkage of carnauba wax places an additional stress on the finished electret, which adds a piezoelectric effect to the over-all static charge. In recent years, however, this view has been refuted. When the ceramics industry undertook the development of dielectrics, a whole special class of materials was created. Starting with ceramic capacitors, piezoelectric ceramics were developed for hydrophones, microphones and phonograph pickups. Ceramic magnetic materials appeared, and finally ceramic electrets. A ceramic electret made of barium titanate contradicts the notion that electrets do not work without carnauba wax.

"One form of electret is made by melting a mixture of waxes and permitting the batch to cool slowly between a pair of electrodes charged to a direct-current potential of several thousand volts. When the wax has cooled to room temperature and is

In 1953, Brown succeeded in demonstrating in a laboratory setting the flight of disc-shaped airfoils 2 feet in diameter around a 20-foot-diameter circular course. The process involved tethering these saucer-shaped craft to a central pole by means of a wire through which the necessary direct-current potential was supplied at a rate of 50,000 volts with continuous input of 50 watts. The test produced an observable top speed of an amazing 17 feet per second (about 12 miles per hour).

Working with almost superhuman determination and at great cost to his personal finances, Brown soon succeeded in surpassing even this accomplishment. At his next display, he exhibited a set of discs 3 feet across flying a 50-foot-diameter course with results so spectacular that they were immediately classified. Even so, most of the scientists who witnessed the demonstrations remained sceptical and generally tended to attribute Brown's motive force to what they called an 'electrical wind' - this in spite of the fact that it would have required a veritable 'ELECTRIC HURRICANE' to produce the lift potential observed! Nonetheless, pitifully few^a gave any credence whatsoever to ideas that the [Biefeld-Brown] effect might represent anything at all new to the world of physics. Government funding was sought to enable the work to continue, but in 1955, realizing that the money would not be forthcoming, a disgruntled Brown went to Europe in hopes that perhaps he might be able to generate a little more enthusiasm there.

Although demonstrations were given first in England, it was on the Continent, under the auspices of a French corporation, La Societe Nationale de Construction Aeronautique Sud Ouest (SNCASO), that things really began to look promising. During a set of tests performed confidentially within the company's research laboratory, Brown succeeded in flying some of his discs in a high vacuum with amazing results. Brown was ecstatic, for not only had he succeeded in proving that his discs flew more efficiently without air, but he had also shown that the speed and efficiency of his craft could be increased by providing greater voltage to the dielectric plates.

(see the original pages for the complete text on TT Brown)

Electrets History

Electrets are unique, man-made materials that can hold an electrical charge after being polarised in an electric field, much as a piece of iron can be magnetised after being exposed to a magnetic field. Researchers knew that as early as 1919 Japanese navy Captain Kawao Wantachi had been able to create an artificial membrane by mixing beeswax with Brazilian palm gum [usually carnauba wax] and resin [rosin]. The resulting material was then polarised in an electric field, and had maintained its charge for a long time afterward-resulting in the world's very first electret.

Mototaro Eguchi in 1925 developed a method to make an electret according to the work of Kawao Wantachi. (see the pdf links at the end of the page).

Between 1890 and 1930 the various tries and works where made with a half-wave rectified AC current (basically, with just a diode rectifier in one of the cables).

Usually the substance is heated before applying the charge. But AC current could also be used to reach the same goal, then a DC current will finish the work. Both heating and AC current could be used as method to prepare the dielectric substance (or move the molecules) at the beginning. The DC current will be used during cooling to fix the charge.

Pure DC is always required to finally fix the charge.

Since 1919 until 1970's thermal method was used (DC voltage applied by electrodes to heated samples).

The original method, using dipolar polarisation with space charge is linked to the "two-charge theory", applicable to waxes and to polymers like Mylar.

Electron beam method (low-energy beams of about 20KeV in vacuum) was used for controlled charging and for research application from the 1960's to today.

Nowadays (since 1970's), the usual method is to use polymer materials. Many modern electrets have only space or surface charge (like Teflon or Polypropylene electrets), but no dipole polarisation. The modern electrets need few kV (3 to 10) to be made. The voltage is applied through external electrodes to a piece of Teflon foil, 25 to 100 microns thick (preferably metalized on one side). Or, better a corona discharge operates with a needle voltage of 5 to 10kV. Then the non metalized side of the Teflon is charged. Polypropylene as well as Mylar can be used.

Corona method is preferred nowadays for industrial production, often applied at elevated temperatures.

"A major problem in the manufacture of electrets stems from the cussedness of wax dielectrics in general. The insulating property of waxes decreases as the temperature increases. This is a smooth and well-established relationship. When the wax enters the liquid phase, however, the insulation resistance begins to drop sharply. This effect can expose the experimenter to hazard. If a high-voltage supply with low internal impedance is used to provide the polarizing electric field, it is possible that the supply will deliver enough current through the melted dielectric wax to add to the temperature of the mass. Because the internal resistance drops with increasing temperature, the process becomes explosive. Ultimately enough current follows along one channel to provide a flash-arc path that can splatter flaming wax in a dangerous manner.

"On the other hand, a 'safe' high-voltage power supply (one that includes an internal resistance on the order of 50 megohms, say) will deliver only a fraction of its available voltage to the electret-forming terminals, because its ratio of internal impedance to external impedance acts to divide the voltage. The external load resistance also goes up as the electret cools and the strength of the polarizing electric field increases.

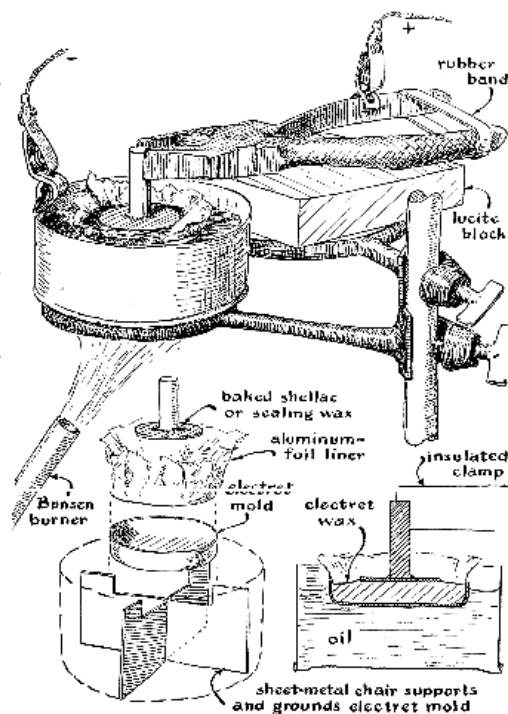


Figure 2: An electret devised by W. M. Cood and J. D. Stranathan of the University of Kansas

"The reason that the electret acquires a charge is fairly obvious. The molecules of the wax are electrically polarized, and they align themselves with the electric field just as the 'domains' of a magnetic material line up with a magnetic field. As the wax cools and solidifies, this alignment is maintained. Unlike metallic substances, however, waxes have no sharp melting point. Even when the wax is highly purified there is a span of many degrees between the solid state and the state in which the wax flows as a liquid. A mixture of waxes usually exhibits an even wider range of temperatures between the semiplastic and semifluid states.

The current required is usually less than 1 mA, since the materials are highly insulated and the current is therefore very small.

Concerning the ratio of applied voltage and output voltage :

It depends on the charging process and on many other parameters. In corona charging, surface potential of 2kV can be easily obtained with a needle voltage of 5 to 10kV. With contact charging electrodes, one could expect the resulting voltage to be about 50 percent of the applied voltage, up to about 1 to 2kV. No general rule can be given, since many parameters enter.

(For more technical informations, please see the book of G. Sessler "Electrets" - 1980).

The Carnauba wax Electret

According to the various elements given above, we would like to study more the carnauba wax electret (dipole) and the way to make it.

A source of variable high voltage as well as variable current should be the best to make different tests.

The range of voltage should vary up to 20kV with amps up to 5mA (just to settle the limits). Though the best results should be obtain between 5-15kV and 1-3 mA. A laser power supply could be used (sometimes up to 7000V) or a photocopier supply, but be careful for the external casing constitutes one pole. Be sure to use good groundings.

It is important to use a clean source of DC and not pulsed DC. So perhaps the best could be to use a HV power supply powered by batteries. It depends on the quality of your HV DC source. That's why it could be useful to test the output voltage with an oscilloscope, using a HV probe to divide the high voltage for the oscilloscope.

A wax electret is usually thick and therefore the current must flow through and stress it. That's why 1 to 5mA should be tested. A too small current would only flow on the surface of the electret, not through it. That's the case for instance with a Van de Graaf generator (about 200kV-400kV at 50microA). But test carefully a current higher than 3mA for it could cause "molten eruption of wax", which is dangerous. It could be logical to say that the thicker/denser the electret, the higher the current needed.

It should take weeks or even months to see a homocharge developed in the electret. An heterocharge should appear first... so, be patient!

Once you have your HV DC variable of fixed power supply, you can use the Eguchi method (see links below) Oleg Jefimenko (idem) made a lot of wax electrets to develop electret motors. He made a lot of tests and suggested the following proportions : 45 percent carnauba wax, 45 percent water-white rosin and 10 percent white beeswax.

Then, you have now all the needed information to test the [TT Brown "batteries"](#)...

Useful documents:

- The very first method to build an electret has been well explained by Mototaro Eguchi in 1925 - [click here \(pdf 54k\)](#)
- Informations from the books of Oleg Jefimenko - [Extracts \(pdf 245k\)](#) - [List of his books \(pdf 11k\)](#).
- A Japanese study of the carnauba wax - [click here \(pdf 22k\)](#)
- A simple manner to make an electret - [click here \(pdf 30k\)](#)
- The ancestor of the electret: the electrophorus - [click here \(pdf 76k\)](#)

Book: "Electrets" G. H. Sessler, 1980.

"The current-carrying mechanism in waxes consists of a migration of polar molecules from one electrode to the other, of the delivery of electrons from cathode to anode by true physical movement. The positive end of a polar molecule picks up an electron from the cathode; this causes a local neutralization of the positive end, but destroys the neutrality of the molecule, making it act as if it were a negative ion (anion). Conversely, the negative end of the polar molecule can lose an electron to the anode, causing a local neutralization of the negative end and a loss of over-all molecular neutrality. This molecule now behaves as if it were a positive ion (cation). Both processes can occur in a single molecule, resulting in a restoration of molecular neutrality but the loss of dipolar features. The partially neutralized dipoles exhibit only half as much tendency to align themselves with the electric field, and the neutralized molecules none at all. Add these conditions to the lowered electric-field intensity caused by the current, and to the molecular vibrations caused by the temperature of the material, and it is not hard to understand why electrets that are cooled quickly during manufacture exhibit fields of lower intensity than those that are cooled slowly. Slow, deliberate cooling enables the vibrating molecules in the electret to come to rest in alignments that result in the maximum subsequent field strength.

"A simple form of the electret was devised some years ago by Edwin P. Adams of Princeton University. It consists of concentric metal cylinders sealed at the bottom by an insulating base and containing a cylinder of wax, as shown in the accompanying illustration [above]. In 1939 W. M. Good and J. D. Stranathan of the University of Kansas devised the improved version depicted in the second illustration [Figure 2]. The large oil bath shown in this illustration provides a mass to retard the rate of cooling. Good and Stranathan also added electric heaters and an automatic temperature-control to lower the temperature gradually through the semiplastic state over a period of many days. This refinement is scarcely needed unless you embark on a program of meticulous research. When the oil bath is heated to the temperature that will cause a true fluidity of the electret material in the mold, it will cool slowly enough to give rise to an effective electret.

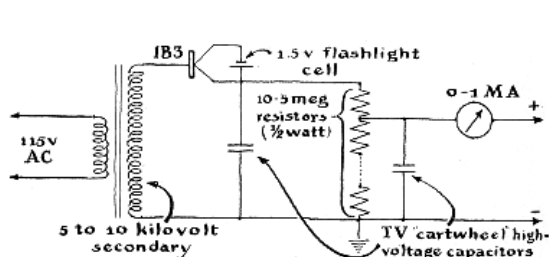


Figure 3: Circuit diagram of a power supply to polarize and charge an electret

"Any high-voltage supply can be used; if the one at hand chances to be capable of delivering more than a milliampere, it can be rendered

safe by adding resistors in series between the supply-terminals and the electret plates. This can best be accomplished by connecting the necessary number of two-, three- or five-megohm resistors in series for a total of 50 megohms. The resistors should preferably be of the two-watt size; they should not be smaller than the one-watt size. I concede that 1,000 volts across a five-megohm resistor dissipates only .2 watt. We are not concerned with the wattage, but rather with the voltage gradient across the resistor itself. The physical size of the larger resistors eliminates the high voltage-gradient and attendant internal electrostatic effects that cause fusing of the carbon granules. This process can cause a major change in the resistance value of small carbon resistors. The use of a string of two-, three- or five-megohm resistors also enables you to make a rough adjustment of the output voltage by coupling the output leads to intermediate points in the string.

"Sparking across the surface of the wax can be reduced or eliminated by increasing the series resistance. A meter of some sort should be connected in the load circuit so that you can observe the process. A zero-to-one milliammeter will prove far more informative than a volt meter that merely indicates the total polarizing field.

"The polarizing field should be maintained at a maximum. The current flowing through the melted electret wax should never be permitted to rise above .5 milliampere. At the dielectric material's most conductive phase the series resistance should be adjusted to limit the current to about .1 milliampere. It will not be necessary to readjust the resistance as the wax cools, because the internal resistance will rise to a safe limiting value. Simultaneously the polarizing voltage across the wax will increase to the maximum value.

"In computing the output voltage of your power supply, such as the one illustrated in the accompanying circuit diagram, remember that the voltage shown on the nameplate of the

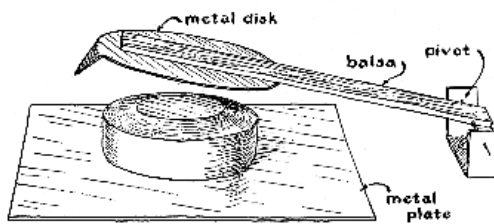


Figure 4: A simple device for testing an electret

transformer must be multiplied by 1.414. This is because in this application the load current is so low that the delivered voltage practically reaches the peak value, and the rated output of the transformer is always given as the root mean square value.

"In processing electrets the oil bath should be raised to operating temperature first, or at least started so that it will be at operating temperature by the time the electret formula is mixed. Melt and mix the waxes in a separate pan, stirring frequently to drive out air bubbles and moisture. Keep the electret-mix temperature well above the boiling point of water for at least half an hour. Be wary of touching tiny bubbles that cling to the walls of the container. These may be water droplets. Touching them with a stirring rod breaks the surface tension that has prevented the water from boiling into steam. When the tension is broken, the water explodes into steam with sufficient violence to splatter the hot wax.

"In the meantime line the mold with aluminum foil and smooth it out to remove as many of the wrinkles as possible. Tapering the mold slightly will facilitate the subsequent removal of the foil-encased wax. Next pour the melted mix into the mold. (The size of the finished electret is optional. A disk two or three inches in diameter and about half an inch thick is convenient.) The top plate should just touch the top surface of the electret material. This plate should be heated, too, by the way. When the wax wets the top plate, the high-voltage supply can be turned on. The electrostatic stress should cause an abrupt jump in the annular meniscus of the wax surface between the center plate and the mold walls. If sparks appear on the molten wax, turn off the power and connect the output leads for lower voltage. Then reapply power, turn off the oil-bath heater and permit the assembly to cool to room temperature. Observe the temperature with a thermometer, not by feel. *Stay away from any part of the apparatus when the high-voltage supply is in operation!*

"When the oil reaches room temperature, turn off the power supply and remove the electret. Immediately fold the aluminum foil forward over the surface in contact with the top plate, short-circuiting the electret. The foil acts as a 'keeper' and is analogous to the soft-iron bar placed across the open jaws of a horseshoe magnet to preserve the magnetic flux. Electrets properly short-circuited have kept for longer than five years without noticeable loss of charge.

"Now comes the puzzler that stumps the experts. If the electret's polarity is measured directly after its manufacture, its charge will be just what theory predicts it should be. The negative surface of the electret will be that which made contact with the positively charged polarizing electrode, and vice versa. This agrees with the north-south polarity of a bar of steel magnetized by contact with a permanent magnet. In contrast with the behavior of a magnet, however, the charge on the electret begins to diminish immediately, and in about a week it will have fallen to zero. The charge then begins to build up *in opposite polarity* to a final value that may be several times as large as the original charge. This may take as long as three months. The negative surface of the stabilized electret will be the face that made contact with the negatively charged polarizing electrode. In other words, the charge will correspond in sign to the polarity of the high-voltage field. Just why this reversal takes place has never been satisfactorily explained.

"Measurement of the electrostatic field that surrounds an electret requires a sensitive electrostatic meter, an instrument actuated by electrostatic attraction or repulsion rather than by the passage of current. The magnitude of the surface charge may be measured by passing a metal plate of known area at a known rate into the field until contact is made with the electret surface, the plate being connected to an electrostatic voltmeter. A voltmeter of this type can be made inexpensively by using an electrometer tube (essentially a vacuum tube designed for service in vacuum-tube voltmeters). The instrument will absorb substantially no power and can be calibrated by using a conventional voltmeter as a reference.

"For simple checks a gold-leaf electroscope will do an admirable job of measuring polarity. The polarity of the electret can be determined by charging the gold-leaf electroscope with a current of known polarity and observing whether the electret's approach adds to the charge (by causing the gold-leaf vanes to separate more) or subtract from the charge (by permitting them to fall closer together).

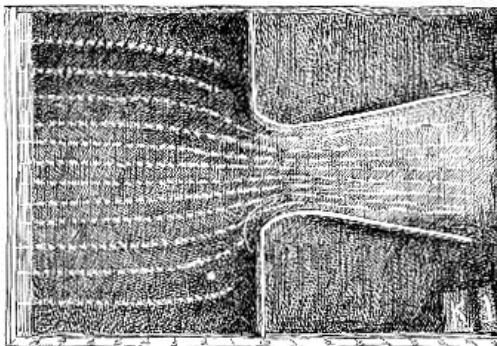


Figure 5: Pattern of smoke pulses passing through a nozzle in a homemade smoke tunnel

"Finally, at least one simple but spectacular test can be made. A metal disk with a point at the rim is cut just large enough to cover the electret. The disk is fastened to an insulating arm that is hinged to a metal base-plate as shown in the accompanying illustration [Figure

4]. The metal point

should be bent so that when the disk rests on the electret, a sheet of writing paper (.003 to .005 inch thick) will just drag a bit when passed between the point and the metal base-plate. The insulating arm may be made of lucite, or of dry wood (such as a length of model-airplane balsa) that has been boiled in paraffin or impregnated in oil until a fresh-cut surface will repel water. The arm is pivoted at the end to allow the plate to fall through the electrostatic field of the electret. If your hand is steady and your aim unerring, you can omit the lever assembly and merely drop the plate onto the electret surface! The falling plate picks up a charge from the field? and the charge is dissipated in a small but brilliant spark discharge between the point and the bottom plate. Try this with both surfaces of the electret. For some reason electrets are not symmetrical. One surface will deliver more energy than the other.

"The electret has not been entirely without practical application. It has been used to replace the high-voltage polarizing network employed for energizing some types of condenser microphones. The growth of radio broadcasting in the early 1920's, with its need for a microphone that worked on some principle other than the compression of carbon particles, seems to have spurred the original investigation of the electret. For some reason the condenser microphone grew up and passed into obsolescence without ever meeting an electret. But in 1935 Andrew Germant made an electret condenser-microphone for the engineering laboratory of the University of Oxford. Subsequently condenser microphones employing electrets were taken into the field by the Japanese army.

"The electret found another application a few years ago when the television industry was seeking a simple method for focusing picture tubes. Early picture tubes were focused by a magnetic coil that was adjusted by means of a costly power-potentiometer. Eventually the arrangement was replaced by a permanent-magnet focusing device adjusted by changing the magnetic gap. During one brief period, however, the picture tubes were made with an electrostatic lens, the focal length of which was adjusted by a potentiometer. At this point someone remembered the electret and reasoned that, if the electromagnetic focusing-coil could be replaced by a permanent magnet shunted by a mechanically adjusted gap, perhaps the permanent electret could similarly be put to work. Before the idea could be exploited, the development of the self-focusing electron gun solved the focusing problem and once again reduced the permanent electret to the status of a scientific waif.

Dillard Jacobs,
associate
professor of
mechanical
engineering at
Vanderbilt
University, has
developed a
novel accessory
for extending the
usefulness of
aerodynamic
smoke tunnels of
the type
described in this
department [see

SCIENTIFIC
AMERICAN, May,
1955]. The pattern
of air flow in such

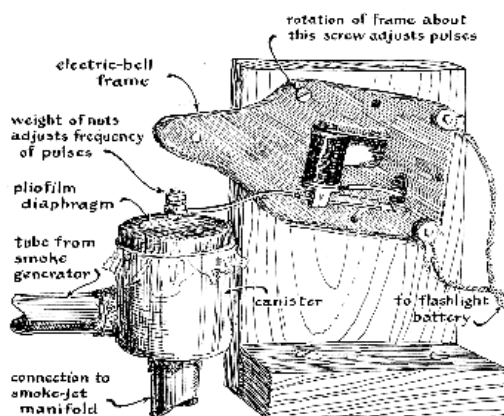


Figure 6: A simple device for pulsing the streams of smoke in a smoke tunnel

apparatus is made visible by a grating of smoke streamers admitted to the tunnel through a "rake" of small tubes near the inlet. The lines of smoke bend around test objects placed downstream, and enable the experimenter to approximate the distribution of forces acting on the object.

"Following your description of the smoke tunnel," writes Jacobs, "I promptly built one and can attest to the suitability of its design. The tunnel has been used extensively to produce photographs of fluid-flow phenomena for use in my classes. Some months ago I added a gadget to the tunnel which considerably broadens its utility as a scientific tool. This consists simply of an electric doorbell (with the gong removed) and a chamber with a diaphragm inserted in the smoke circuit just ahead of the 'rake.' When properly adjusted, the doorbell-and-diaphragm assembly acts as a chopper to send the smoke out into the tunnel in small puffs or pulses instead of in a continuous stream. I was able to measure the frequency of these pulses (780 per minute). With the pulse frequency known, one has only to measure the distance between puffs on test photographs to calculate velocities precisely. When an obstruction such as a divergent nozzle is placed in the tunnel, the increase in velocity through various regions of the constriction show clearly [see illustration below].

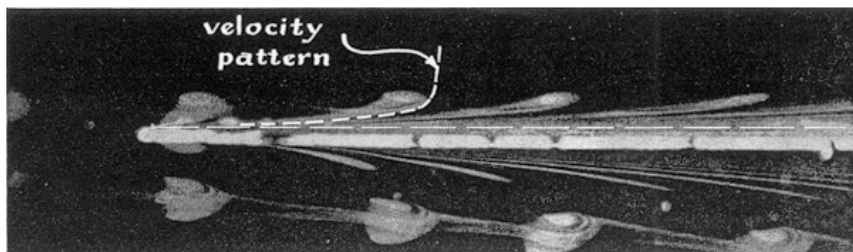


Figure 7: How pulsed smoke streams were used to investigate shearing in the boundary layer

"The modified doorbell is supported by a wooden bracket as shown in the accompanying illustration [above]. This provides an adjustment for altering the impact of the clapper on the pliofilm diaphragm, thereby controlling the amplitude of the smoke puffs. If the diaphragm action is too strong, the smoke pulses become smoke rings, an interesting but unsatisfactory effect. Although the bell was originally designed to operate from a six-volt battery, in this device it works best on a volt and a half. "I used an electronic stroboscope for timing the frequency of the pulses. This consists of a variable oscillator that triggers a high-speed gas-discharge lamp. The speed of the flashing lamp is varied until the smoke puffs appear to stand still. The flash rate is then read from a calibrated scale on the oscillator. If an experimenter does not have access to such apparatus, a motor-driven stopcock designed to operate at a known speed could be inserted in the smoke line.

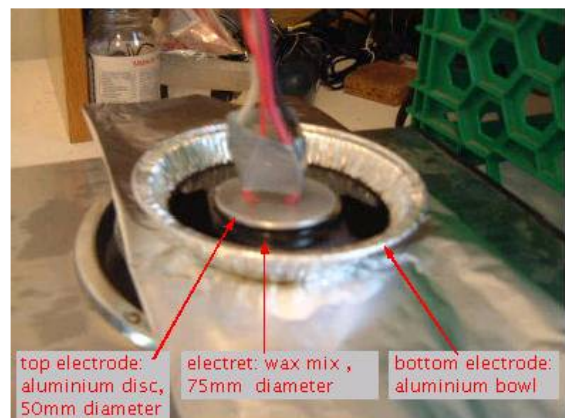
"Among the interesting phenomena opened to investigation by the pulsed smoke tunnel is the shearing action in the boundary layer between the fluid and a solid surface, as shown in the accompanying photograph [below]. Both the thickness of the boundary layer and the velocity distribution through it can be determined with fair precision. In this case the smoke velocity beyond the boundary layer is .79 foot per second. The transverse Reynolds number is 960."

Bibliography

FUNDAMENTALS IN THE BEHAVIOR OF ELECTRETS. W. E. G. Swann in *Journal of The Franklin Institute*, Vol. 255, pages 513-530; June, 1953.

[YouTube - Antenna Electret](#)
[YouTube - Why](#)

[Electrets](#)



top electrode:
aluminium disc,
50mm diameter

electret: wax mix,
75mm diameter

bottom electrode:
aluminium bowl