transferring this measurement to the construction of the octagon, the angles of which were tested and found to be equal with an uncertainty of only one part in a million.

The determination of the velocity of light is thus reduced to the measurement of the distance between the stations and of the speed of rotation of the mirror. The former operation was carried out by the U. S. Coast and Geodetic Survey with the result 35,426.3 meters (about 22 miles) with an uncertainty of the order only two parts in a million.

The errors in the measurement of the speed of the revolving mirror were much greater, as no very effective means were employed to insure its constancy. (This defect will be eliminated in the continuation of the work next summer.)

Notwithstanding the inconstancy of the speed of the mirror, by choosing the most favorable moment, when the speed was that corresponding to the frequency of a control tuning fork, the resulting uncertainty of the measurements was of the order of one ten thousandth part, which is about that of the mean of all the previous measurements.

It is hoped that next year's work will furnish results four or five times more accurate.

The result of eight independent observations in the present preliminary work is, for the velocity of light in vacuo, 299,820 kilometers per second.

Following is a table of results of the more important investigations to date with an estimate of the weight which should be assigned to each:

Investigator	Method	Distance	Wt.	Velocity
Cornu	Toothed Wheel	23.0 Kilom.	1	299950
Perrotin	" "	12.0 "	1	299900
Michelson	Revolving Mirror	0.6 "	2	299895
Newcomb	" "	6.5 "	3	299860
Michelson	" "	35.4 "	3	299820

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A NEW TYPE OF ELECTRIC DISCHARGE: THE STREAMER DISCHARGE[1]

IN connection with a detailed study of the mechanism of electric discharges in argon we have observed some phenomena of remarkable beauty which may prove to be of theoretical interest.

A single loop tungsten filament of large diameter (0.5 mm) is mounted at one end of a cylindrical pyrex glass bulb 10 cm in diameter and 15 cm long with its axis horizontal. Rising vertically from this bulb is a tube 3 cm in diameter and 50 cm long which contains at its upper end a disk shaped anode. The tube is exhausted for an hour at 450° C., and the electrodes are freed from gas by induction heating and the tube is filled with extremely pure argon at a pressure of preferably 2 to 4 mm of Hg. The cathode is heated to about 2500° K and +250 volts is applied to the anode through a resistance. By approaching one terminal of a high frequency coil to the middle of the glass tube an arc of about one ampere is started through the tube, and the voltage difference between anode and cathode falls to about 25 volts.

The arc then fills the tube with a uniform pale reddish glow showing only lines of the red argon spectrum. A transverse magnetic field, from a hand horseshoe magnet with poles 4 cm apart, has practically no effect on the appearance of the arc.

The *streamer discharge* may now be started by opening the cathode heating circuit for *one half second,* allowing the current to return immediately to its former value. This lowers the cathode temperature momentarily and by decreasing the electron emission causes the voltage across the arc to rise from 25 to 100 volts or more for perhaps a second. The cathode drop sputters tungsten from the cathode in an amount which is estimated to lie between 10^{-6} and 10^{-7} grams.

This small dose of tungsten vapor has a profound effect on the arc. There are at first brilliant blue flashes of light from the lower end of the tube which show the tungsten spark spectrum. Simultaneously the arc begins to detach itself from the glass walls, starting at the lower end and gradually, in 5 to 15 seconds, extending up to the anode.

After 30 seconds or so the blue tungsten spectrum disappears and the arc quiets down but remains detached from the walls for its entire length. At first the arc is 1 to 1.5 cm in diameter and is bounded by a sharply defined luminous skin which emits a dull yellow light showing a continuous spectrum. The interior of the arc is reddish (argon spectrum), but is separated from the yellow skin by a dark space 1 or 2 mm thick.

Sometimes just inside this dark region there is a transient bluish white skin of considerable brilliancy which seems to show a mixture of continuous spectrum with the tungsten spectrum.

After perhaps 1 minute the yellow skin has disappeared and the arc has increased so much in cross-section that it seems at first as if it had returned to its original condition.

[1] Abstract of an address by Irving Langmuir at the Centenary of the Franklin Institute, Philadelphia, September 18, 1924.

The arc, however, is now very sensitive to even weak magnetic fields. On bringing the horseshoe magnet within 10 to 15 cm of the tube, so as to produce a transverse field, the arc is deflected to one side of the tube in the same direction as any conductor carrying a similar current. Thus the arc is pushed up against the wall of the tube and at the same time the *yellow skin* reappears on the opposite side of the arc, that is on the side which is not in contact with the wall of the tube.

Upon bringing the magnet still closer the yellow skin becomes more brilliant and thinner, and then begins in a remarkable way to exhibit many of the characteristics of a liquid surface. In fact the appearance is strikingly similar to that of the surface of water dripping from the under side of a horizontal wet board. Little droplets of golden yellow liquid fire form slowly, move irregularly parallel to the direction of the surface and then break away and fall, as little spheres of light, in a direction perpendicular to the surface (into the arc). By regulating the intensity of the magnetic field these droplets, or globules, ranging from a few tenths mm up to 5 or 6 mm in diameter, can be made to form slowly and detach themselves singly from the skin of the arc. They usually move all the way across the arc and disappear when they reach the opposite boundary close to the glass wall. But by proper combinations of longitudinal and transverse field the globules may often be made to move upwards or downwards in the arc parallel to its axis for distances of 5–10 cm. The light emitted by the globules is nearly white and is enormously more brilliant than that from the yellow skin of the arc.

Under certain conditions the globules have been observed to move very slowly so that their motions through the arc could be easily followed by the unaided eye. But more often they move at velocities of 10 to 30 cm per second and thus appear as brilliant lines or filamentary streamers. As the field is increased the individual globules follow in such rapid succession along a single path that the streamers appear to be continuously visible. With stronger fields several streamers with nearly parallel paths are observed and then as the number of such streamers increases they join to form beautifully curved luminous surfaces. Finally by the multiplication of such surfaces there may appear to be certain regions which have a luminosity distributed throughout a volume.

By superimposing an alternating component on the direct current fed to the anode, or by heating the cathode by alternating current, the streamers or individual globules move in sinusoidal paths which reproduce accurately the wave shape of the current even at frequencies up to 1,000 cycles. Sometimes the arc-discharge itself oscillates at frequencies in the neighborhood of 1,000 cycles and the globules then increase and decrease periodically in brilliancy so that the streamer due to a single globule appears beaded.

By "stroking" the tube up or down with the magnet, the tungsten responsible for the streamer discharge can be concentrated at will at the upper or lower end of the tube.

All these effects persist for hours as long as the arc current is maintained at about one ampere without any necessity for replenishing the supply of tungsten vapor.

If the arc current is stopped for 5 seconds and restarted without lowering the filament temperature, the streamer discharge phenomena persist with only a moderate decrease in intensity. But if the arc is allowed to remain out for as much as 40 seconds practically all the effects due to tungsten vapor disappear. To restart the streamer discharge more tungsten must be introduced by sputtering tungsten from the cathode or from an auxiliary electrode at high negative potential or by vaporizing tungsten from a filament at temperatures of 3000° K or more.

Similar effects can be obtained by sputtering molybdenum, tantalum or carbon into the arc, but the phenomena seem to be more striking and more persistent with tungsten.

By focusing a concentrated beam of sunlight into the tube containing a streamer discharge the yellow skin of the arc (or with weak excitation a region just outside the yellow skin) scatters light which appears to be completely polarized when observed at right angles to the incident light. By this method the skin of the arc in presence of a magnetic field can be seen to extend far beyond the luminous yellow skin. In the presence of the field there is some light scattered from the whole of the non-luminous gas outside the arc, but the intensity increases rapidly as the skin is approached. No scattered light is detected from the interior of the arc except from the streamers or globules that pass through it and these give very intense scattering.

When a short constriction is placed at a point in the tube carrying the arc and particularly when the tungsten has been concentrated in this constriction by stroking by a magnet, a brilliant light (continuous spectrum) is emitted from a thin skin which remains within a fraction of a mm of the wall even after the magnetic field is removed.

A fairly complete explanation of these phenomena together with quantitative data for testing the theory will be published in the *Journal* of the Franklin Institute. The following is a brief outline of the theory.

The walls of the tube are negatively charged and the tungsten atoms and particles in the region outside the arc also become negatively charged and thus can not deposit on the walls. In the arc there is a high concentration of free electrons moving in random directions while outside the arc the concentration is low. Thus, according to the Boltzman equation (or the Nernst electro-chemical equation), there must be a potential difference between the interior of the arc and the surrounding space (the arc being positive). The potential distribution must therefore be such that the potential gradient is zero at the axis of the arc, increases to a maximum near the skin of the arc and again becomes small near the walls. Thus from Poisson's equation near the boundary of the arc there must be an electric double layer consisting of an inner sheath having a positive space charge and an outer sheath with a negative charge.

Such a double layer in a gas can only be maintained if the positive ions which continually escape through the positive sheath disappear by recombination at the inner edge of the negative sheath. The presence of particles (or ions) which can take up negative charges will not only bring about such recombinations but will aid in the formation of the negative space charge. At the boundary between the positive and negative sheaths negative tungsten ions lose their charge and in the neutral state no longer repel one another. They can thus condense on one another to form minute solid particles.

The effect of the magnetic field is solely to produce convection currents in the argon due to the non-uniform distribution of current throughout the cross-section. The convection currents cause the arc to be carried to one side of the tube and cause the non-luminous gas carrying negatively charged tungsten ions and particles to flow into the arc on the side away from the wall. At the junction between the negative and positive sheaths all the negative ions and larger particles lose their charges and become either neutral or positive. The neutral atoms and particles then no longer repel one another and thus grow to larger aggregates. As these are carried into the positive sheath they are heated by the energy set free by the recombination of positive argon atoms and electrons and are ultimately disintegrated or evaporated by this positive ion bombardment. The resulting tungsten atoms become positively charged within the positive sheath, and migrate under the influence of the electric field in the opposite direction to that of the convection current. The tungsten thus accumulates at the boundary between the positive and negative sheaths in the form of minute solid particles or aggregates. If any transverse motion causes more rapid concentration at some places than others the increased recombination at these places makes the sheaths more sharply defined and still further increases the rate of accumulation of tungsten. When sufficient tungsten is present at any place to cause practically complete recombination of the positive ions, the skin projects into the arc and then because the direction of migration of the particles in the electric field becomes nearly perpendicular to the direction of the convection currents, the skin forms a kind of funnel from the narrow end of which the globules break away and are carried at the velocity of the convection currents into the body of the arc.

The structure of a detached globule is thus essentially similar to that of the detached arc itself except that it is turned inside out, as can be readily understood from its mode of function.

Thus we must conclude that the inside of a detached globule is negatively charged and that this is surrounded by a positive ion sheath. The tungsten is imprisoned inside the globule in the form of solid particles which are concentrated particularly at the boundary of the regions of positive and negative charge.

The recombination of ions furnishes the energy for the heating of the particles and the maintenance of the electric fields.

These glowing detached globules seem to have characteristics similar in many respects to those that have been described as belonging to ball lightning. It is perhaps not certain that ball lightning is anything more than a psychological phenomenon, but if it has objective reality it may possibly be due to causes similar to those outlined above: the presence of highly ionized gas, recombination of ions on catalytically acting solid particles which are held within the ball by their charges and the electric field at the surface of the ball.

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THE RACIAL ORIGIN OF ALMSHOUSE PAUPERS IN THE UNITED STATES[1]

DURING and since the war our lawgivers seem to have been more concerned about the racial heterogeneity of the American people than for many years before. Under expert eugenic advice a new immigration law has recently been passed by congress, care-

1 Papers from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health, The Johns Hopkins University, No. 110.