ART. II.—*Contributions from the Physical Laboratory of Harvard College*; No. III. *On the Electrical Condition of Gas Flames*; by JOHN TROWBRIDGE, Assistant Professor of Physics.

PROF. H. BUFF, of the University of Giessen, has published in the *Annalen der Chemie und Pharmacie*, vol. lxxx, 1, and in the *Phil. Mag.* of Feb., 1852, an investigation of the electrical properties of flames. He reviews at first the different

theories in regard to the subject; Becquerel, for instance, finds electric opposition in all directions in flames which depend upon the difference of the temperature of the metals immersed in them. Pouillet recognizes a motion of electricity only from the interior to the exterior, and hence also from the base to the summit of the flame; Hankel, however, finds a motion the reverse of this in the flames produced by the ignition of spirits, and states that it is independent of the temperature of the immersed conductor.

Prof. Buff then gives the following as the results of his investigation:

1. Gaseous bodies which have been rendered conductible by strong heating are capable of exciting other conductors, solid as well as gaseous, electrically.

2. When a thermo-electric circuit is formed of air, hydrogen or carburetted hydrogen, alcohol vapor, charcoal, or finally a metal, whether combustible or incombustible, an electric current is developed, which proceeds through the air from the hottest place of contact to the less warm place.

3. The development of electricity which has been observed in processes of combustion, and particularly in flames, is due to thermo-electric excitation, and stands in no immediate connection with the chemical process.

4. The products of combustion do not therefore, by any means, occupy the relation to the burning body which has been assumed by Pouillet; if positive electricity rises with the ascending gases, it is only in the degree in which the air exterior to the place of hottest contact is connected by a proper conductor.

The following are the results which I have obtained in testing the electrical condition of the flame of a Bunsen burner with a Sir William Thomson's quadrant electrometer. The degrees given refer to the arbitrary divisions of the scale, upon which a spot of light is reflected from the mirror of the instrument.

Upon connecting the testing plate of one pair of quadrants of the instrument with the flame, while the other pair were connected with the metallic burner and with the earth, the flame was found to be negatively electrified.

The following are some of the experiments selected from a series that were made.

Exp. 1. Flame 12 c. m. high; plate at the height of 7 c. m. A negative indication of 130° , very steady.

Exp. 2. A platinum wire, substituted for the plate, and meeting the flame 3 c. m. above the burner, gave a deflection of 30° in a negative direction.

Exp. 3. With the testing plate just above the tip of the

flame, the instrument showed a positive deflection of 70 to 80 degrees.

Exp. 4. With the testing plate 5 mm. from the outer surface of the flame, on all sides, a feeble positive charge was obtained, the air in contact with the flame being apparently charged positively, the indication in no case exceeding fifty or sixty degrees on the scale of the electrometer.

Exp. 5. The metallic tip of the burner was found to be charged positively, giving an indication closely agreeing in the number of degrees with that corresponding to the negative indication of the flame. This indication was quite constant.

Exp. 6. When a glass tip was substituted for the metallic tip, no charge was found upon it. This was the case when any non-conducting body formed the tip.

Exp. 7. A glass tip having been substituted for the metallic one, a platinum wire was inserted below the orifice and carefully pushed upward until it occupied the centre of the interior cone of the flame. A very feeble indication of negative electricity was the result.

While, with the Bunsen burner, the flame and the metallic tip are in decided electrical opposition; the one having a negative charge and the other a nearly equal positive charge; in spirit flames the two opposite states recombine, the wick of the lamp and the fluid contained in the vessel connecting the two charges. The flame, therefore, merely takes the potential of the atmospheric electricity at the place where it is situated.

The electrical condition of the flame of a Bunsen burner when tested by a sensitive galvanometer gives in the main the same results as those obtained by Prof. Buff from spirit flames. The quantity of electricity in the current passing from the flame to the tip is exceedingly small; whereas we have seen above that the terminal immersed in the gas flame has a tension a little exceeding that of the negative pole of a Daniell's element.

The air in the room, at the time the above experiments were first performed, was charged positively to about the tension of the positive pole of twelve Daniell's elements. The experiments were afterward repeated when the air in the room indicated a negative charge, with no difference in the results.

At the suggestion of Dr. Wolcott Gibbs, Rumford professor, I tried the above experiments with a Bunsen blast lamp, by means of which I could increase the heat and the flow of air and gas at pleasure. Slight deviations in the scale readings were obtained by this means: the flow of air appeared to affect the charge of electricity upon the metallic tip, rendering it less constant. The above experiments were in the main confirmed. The nature of the metallic plate submitted to the flame and

the degree to which it was heated appeared to have a very slight influence upon the charge.

Sir William Thomson, in the proceedings of the Literary and Philosophical Society of Manchester, March, 1862, has a paper upon the electricity of the air in rooms. He finds that it is generally negative. By placing a spirit lamp upon the prime conductor of an electrical machine, he was enabled to change the tension of the air from a positive to a negative state and the reverse. He carefully separates the results obtained from the *idioelectric* effect of the flame, which, he states, in no case gave a tension equal to either pole of a Daniell's element.

During the past winter observations made in the laboratory tend to confirm these views. I have, however, found on some days the air within strongly positive. The room is in the north-west corner of the building, and there was a strong north-west wind blowing at the times this was observed. I noticed, also, while experimenting with the flame of a Bunsen burner placed near the water dropper used by Sir William Thomson in investigating the electrical state of the atmosphere, that the positive charge of the air in the neighborhood greatly decreased, and in some instances became feebly negative, by the presence of the flame.

The popular idea that great fires are followed by a change in the atmosphere inducing rain, does not seem to be unwarranted from an electrical point of view. The electricity of the air during cloudy and rainy weather is generally negative or at the most feebly positive. The flames being negative would tend to change a strong positive charge in clear weather to a negative one, and thus bring the air to the state noticed in cloudy and rainy weather.

The following are the conclusions to which the above experiments lead:

1. The flame of a Bunsen burner is negative while positive electricity accumulates on the burner itself, if it is a good conductor. With orifices made of non-conductors, no charge was found upon the tip.

2. The stratum of air in contact with the outer cone of flame is slightly charged with positive electricity. The partly consumed gas of the interior cone is neutral.

3. The presence of flames tends to change the nature of the atmospheric electricity at the given place, reducing a positive tension to a feebly negative one.