APPENDIX.

ART. XLI. — *On the Efficiency of Edison's Electric Light;* by Professor H. A. ROWLAND of the Johns Hopkins University, and Professor GEORGE F. BARKER of the Univ. Pennsylvania.

THE great interest which is now being felt throughout the civilized world in the success of the various attempts to light houses by electricity, together with the contradictory statements made with respect to Mr. Edison's method, have induced us to attempt a brief examination of the efficiency of his light. We deemed this the more important because most of the information on the subject has not been given to the public in a trustworthy form. We have endeavored to make a brief but conclusive test of the efficiency of the light, that is, the amount of light which could be obtained from one horse power of work given out by the steam engine. For if the light be economical, the minor points, such as making the carbon strips last, can undoubtedly be put into practical shape.

Three methods of testing the efficiency presented themselves to us. The first was by means of measuring the horse power required to drive the machine, together with the number of lights which it would give. But the dynamometer was not in very good working order, and it was difficult to determine the number of lights and their photometric power, as they were scattered throughout a long distance, and so this method was abandoned. Another method was by measuring the resistance of, and amount of current passing through a single lamp. But the instruments available for this purpose were very rough, and so this method was abandoned for the third one. This method consisted in putting the lamp under water and observing the total amount of heat generated in the water per minute. For this purpose, a calorimeter, holding about $1\frac{1}{4}$ kil. of water, was made out of very thin copper: the lamp was held firmly in the center, so that a stirrer could work around it. The temperature was noted on a delicate Baudin thermometer graduated to $0^{\circ}{\cdot}1$ C.

As the experiment was only meant to give a rough idea of the efficiency within two or three per cent, no correction was made for radiation, but the error was avoided as much as possible by having the mean temperature of the calorimeter as near that of the air as possible, and the rise of temperature small. The error would then be much less than one per cent.

A small portion of the light escaped through the apertures in the cover, but the amount of energy must have been very minute.

In order to obtain the amount of light and eliminate all changes of the engine and machine, two lamps of nearly equal power were generally used, one being in the calorimeter while the other was being measured. They were then reversed and the mean of the results taken. The apparatus for measuring the light was one of the ordinary Bunsen instruments used for determining gas-lights, with a single candle at ten inches distance. The candles used were the ordinary standards burning 120 grains per hour. They were weighed before and after each experiment, but as the amount burned did not vary more than one p. c. from 120 grains per hour, no correction was made.

As the strips of carbonized paper were flat, very much more light was given out in a direction perpendicular to the surface than in the plane of the edge. Two observations were taken of the photometric power, one in a direction perpendicular to the paper, and the other in the direction of the edge, and we are required to obtain the average light from these. If L is the photometric power perpendicular to the paper, and l that of the edge, then the average λ will evidently be very nearly

$$\lambda = \mathrm{L}\int_{\frac{1}{2}\pi}^{0} \cos\alpha \sin\alpha \, d\alpha + l\int_{\frac{1}{2}\pi}^{0} \sin^2\alpha \, d\alpha$$

$$\lambda = \tfrac{1}{2}\,\mathrm{L} + \frac{\pi}{4} l$$

In the paper lamps we found $l = \frac{1}{3}\mathrm{L}$ nearly; hence $\lambda = \frac{3}{4}\mathrm{L}$ nearly.

The lamps used were as follows:

No.	Kind of carbon.	Size of carbon.	Approximate resistance when cold.
580	paper	large	147 ohms.
201	"	"	147 "
850	"	small	170 "
809	"	"	154 "
817	fiber	large	87 "

The capacity of the calorimeter was obtained by adding to the capacity of the water, the copper of the calorimeter and the glass of the lamp and thermometer. The calorimeter and cover weighed 0·103 kil. and the lamps about 0·035 kil.

First experiment, No. 201 in calorimeter and No. 580 in photometer; capacity of calorimeter $= 1{\cdot}153 + {\cdot}009 + {\cdot}007 = 1{\cdot}169$ kil. The temperature rose from 18°·28 C. to 23°·11 C. in five minutes, or 1°·75 F. in one minute. Taking the mechanical equivalent as 775·, which is about right for the degrees of this thermometer, this corresponds to an expenditure of 3486 foot pounds per minute. The photometric power of No. 580 was 17·5 candles maximum, or 13·1 mean, λ.

When the lamps were reversed, the result was 3540 foot pounds for No. 580, and a power of 13·5 or 10·1 candles mean.

The mean of these two gives, therefore, a power of 3513 foot pounds per minute for 11·6 candles, or 109·0 candles to the horse power.

To test the change of efficiency when the temperature varied, we tried another experiment with the same pair of lamps, and also used some others where the radiating area was smaller, and, consequently, the temperature had to be higher to give out an equal light.

We combine the results in the following table, having calculated the number of candles per indicated horse power by taking 70 per cent of the calculated value, thus allowing about 30 per cent for the friction of the engine, and the loss of energy in the magneto-electric machine, heating of wires, etc. As Mr. Edison's machine is undoubtedly one of the most efficient now made, it is believed that this estimate will be found practically correct. The experiment on No. 817 was made by observing the photometric power before and after the calorimeter experiment, as two equal lamps could not be found. As the fiber was round, it gave a nearly equal light in all directions as was found by experiment.

Lamps used in		Photometric power		Capacity of Calorimeter in pounds.	Rise of temperature in degrees F.	Energy per minute in foot-pounds.	Mean number of candles per horse power of electricity.	Mean number gas jets of 16 candles each per horse power of electricity.	Mean number of gas jets per indicated horse power.
Calorimeter	Photometer	measured perpendicular to paper, L.	Average, λ						
201	580	17·5	13·1	2·57	1°·75	3486·	109·0	6·8	4·8
580	201	13·5	10·1	2·82	1°·62	3540·			
580	201	38·5	28·9	2·74	2°·44	5181·	204·3	12·8	8·9
201	580	44·6	33·5	2·76	2°·29	4898·			
850	809	19·0	14·3	2·81	1°·14	2483·	133·4	8 3	5·8
809	850	12·2	9·2	2·79	1°·54	3330·			
817			17·2	2·73	1°·28	2708·	209·6	13·1	9·2

The increased efficiency, with rise of temperature, is clearly shown by the table, and there is no reason, provided the carbons can be made to stand, why the number of candles per horse power might not be greatly increased, seeing that the amount which can be obtained from the arc is from 1000 to 1500 candles per horse power. Provided the lamp can be made either cheap enough or durable enough, there is no reasonable doubt of the practical success of the light, but this point will evidently require much further experiment before the light can be pronounced practicable.

In conclusion, we must thank Mr. Edison for placing his entire establishment at our disposal in order that we might form a just and unbiased estimate of the economy of his light