CHAPTER VII

CHARACTERISTICS OF INCANDESCENT LAMPS

THE introduction of the drawn wire tungsten metal filament is undoubtedly the most important advance that has yet been made in the production of incandescent electric lamps. The lamp with the squirted or pressed metal filament created quite a sensation when it was introduced, as it was a wonderful improvement over the carbon lamp, absorbing but little more than 25 per cent. of the power absorbed by the latter, yielding a whiter light, or a light more closely resembling daylight, and further, having a much longer life than its rival.

The disadvantages attending the use of such lamps were, and still are, made much of, and are occasioned by the fact that the filaments, by reason of their construction, are fragile and delicate, and so render themselves liable to easy breakage when handling, fixing, or cleaning, is undertaken.

These drawbacks, however, have been completely overcome by the production of the drawn wire filament which, while retaining all the good points of the pressed filaments as regards life, efficiency, colour of light and regulation, is, in addition, strong enough to withstand ordinary treatment such as, without special instructions are issued, is generally meted out to all goods in transit.

The filament being practically a new departure, it becomes of interest to study carefully life and efficiency tests that have been carried out on numerous examples, and by the courtesy of the *Electrical Review*, the author is enabled to reproduce results of tests published by him in a paper appearing in the issue of that journal, dated September 20, 1912.

Life Tests.—In life tests the lamps to be tested are arranged in a pendant position, and the rated voltage maintained absolutely constant by regulating apparatus, for a period of not less than 1000 hours.

This period is now very often extended, and quite recently the

Osram Company published the result of life tests which had been continued for 2000 hours.

It is essential that the voltage be maintained constant during the test, as the life of a lamp is greatly reduced if the pressure is subject to variations.

Carbon lamps especially will blacken much more quickly on a varying voltage circuit than they will do if the pressure is maintained constant.

The reason for this is that when the voltage increases the temperature also increases, and the rate at which evaporation of the filament proceeds is hastened.

In almost all cases the useful life of the lamp is ended, or the "smashing point" reached when the candle-power has fallen 20 per cent. of the original rated value, and it cannot be too strongly urged upon users of incandescent lamps that it pays in the end to replace lamps at this point. The cost of the lamp in no way compares with the increased energy cost necessary to obtain adequate lighting of the premises in question.

During a life test numerous candle-power and power-consumption measurements should be taken at regular intervals, care being taken to ensure that the correct voltage is accurately maintained. Against such tests can be urged the great cost and prolonged period of waiting for final results, while the necessary attention is no small item. It is on this account that an estimate of a lamp's behaviour is sometimes arrived at by over-running it, but it is doubtful if such a method is of value. The characteristics of a certain type of lamp should be obtained, as will be explained later, and it is then sufficient to test a batch of lamps chosen haphazard as occasion demands.

The candle-power having been obtained, and the power consumption in watts noted, the so-called efficiency of the lamp can then be expressed in watts per candle. It is customary to rate lamps in terms of their mean horizontal candle-power, so that the efficiency will necessarily be expressed in watts per mean horizontal candle-power.

For example, a metal lamp, with a mean horizontal candle-power of 25, absorbing 35 watts, would have an efficiency of 1·4 watts per candle, while a carbon lamp of 16 mean horizontal candle-power, absorbing 64 watts, would be rated at 4 watts per candle.

It will be noted that the higher the efficiency the poorer the lamp—a contradiction of terms surely. Inefficiency or specific consumption would more accurately express the performance, and confusion no doubt would thereby be avoided.

Life tests are valuable as affording a general indication of the life performance of a certain type of lamp, but too much value must not be placed on the results of individual tests.

Lamp testing, undertaken on a small scale, is apt to prove very misleading, and as a result of such tests incorrect conclusions are frequently drawn. In all lamp tests, and indeed in all cases of comparison, whether lamps are immediately concerned or not, a sufficient number of tests should be undertaken to ensure a true average result being arrived at. If a single lamp is tested, it may be a very good one or quite the reverse, and the result in either case would be misleading, whereas the average of the tests made on a large batch of lamps would supply a good deal of useful information.

Contractors frequently base their opinions on single tests, and the author has in mind quite a well-known engineer who insisted on the installation of a proved poor lamp, because one particular specimen, installed over his desk, had run for close on 2000 hours. That it had blackened considerably during this period seemed a minor detail to him, although obviously the efficiency had been considerably impaired.

When there are so many good and reliable lamps available, the manufacturers of which are only too pleased to furnish results of exhaustive tests, it seems a pity that such stupidity is allowed to sow prejudice and work a possible injury to the electrical industry.

Life tests indicate that the candle-power of lamps varies considerably during the first 50 hours or so of the run, and this interval of time constitutes a period of instability.

A filament, when new, exhibits a surface that has a metallic lustre, but which under the microscope appears rough, and in the case of tantalum presents a porous appearance.

During the initial stages of the test the structure of the filament may change slightly, leading to a decreased resistance, and an increased current with increase in candle-power. It is quite possible that the vacuum may be improved, and an improved vacuum by reducing conduction and convection losses would give rise to an increased efficiency.

Gradual evaporation of the filament, however, due to its continued operation at a high temperature sets in almost immediately, resulting in a change taking place in the filament surface.

Instead of presenting a smooth surface the evaporation taking place leads to one which is pitted and crinkled in an irregular manner and the radiation area being increased, the lowered temperature results in a decreased lamp efficiency.

As previously mentioned, the vaporised filament deposits on the comparatively cool interior of the glass bulb, the resulting layer absorbing a considerable quantity of light during the later stages of the run.

In this connection it must be again emphasised that lamps which blacken rapidly are unfit for use in view of the increased energy cost for equal light outputs, although it must be stated that good present-day lamps do not blacken to any appreciable extent after 1000 hours' run, the exceptions merely indicating the presence of a poor vacuum or the presence of water vapour.

The result of these ageing processes is indicated by a gradual decrease in the candle-power of the lamp, and a proportionate increase in the consumption, or watts per candle.

The filament further undergoes structural changes and loses some of its mechanical strength, the result being that, especially with the pressed filament type, a sudden blow may shatter it.

Care must be exercised when lamps are cleaned, and, if it is possible to avoid it, lamps should never be removed from their sockets after once switching them on to the circuit. Haphazard changing of lamps, the removal of one to replace another in a different part of a building, incorrect pairing, if series running is adopted, and many other causes lead to innumerable breakages, and harsh words being said about metal filament lamps. If large numbers of lamps are used, it will be found a very good plan to appoint some one to take complete charge of the lamps themselves, and to issue orders to the effect that no unauthorised person must interfere in any way with the installation.

In schools and offices especially the lamps receive very rough treatment at the hands of scholars or clerks as the case may be. Lamps are changed and replaced, and if series running is the system in use a 25 C.P. is frequently paired with a 16 C.P. lamp, the general result being that much unpleasantness is caused to the agent or manufacturer as well as to the user.

Typical life and efficiency curves are indicated in Fig. 22, and the period of instability is clearly shown.

A study of these curves will make it clear that when the lamp has attained what may be termed its true candle-power, the latter remains fairly constant, in some cases for several hundred hours.

The gradual fall in candle-powder that is noticed when dealing with carbon lamps, and which was also a noticeable feature during the life of metal lamps, is in many cases now not to be observed,[1]

[1] "Proceedings of Institution of Electrical Engineers," Feb., 1907. Paper by D. H. Ogley and H. F. Howorth.

and in this connection it may be noted that the smashing point of metal lamps does not come within the 1000 hours' limit, and in general is determined by the rupture of the filament.

The curves shown in Fig. 22 further indicate that the lamp efficiencies remain practically constant during the greater portion of the life tests. In the case of the Mazda lamps the candle-power remained almost the same for 600 hours, while published tests of

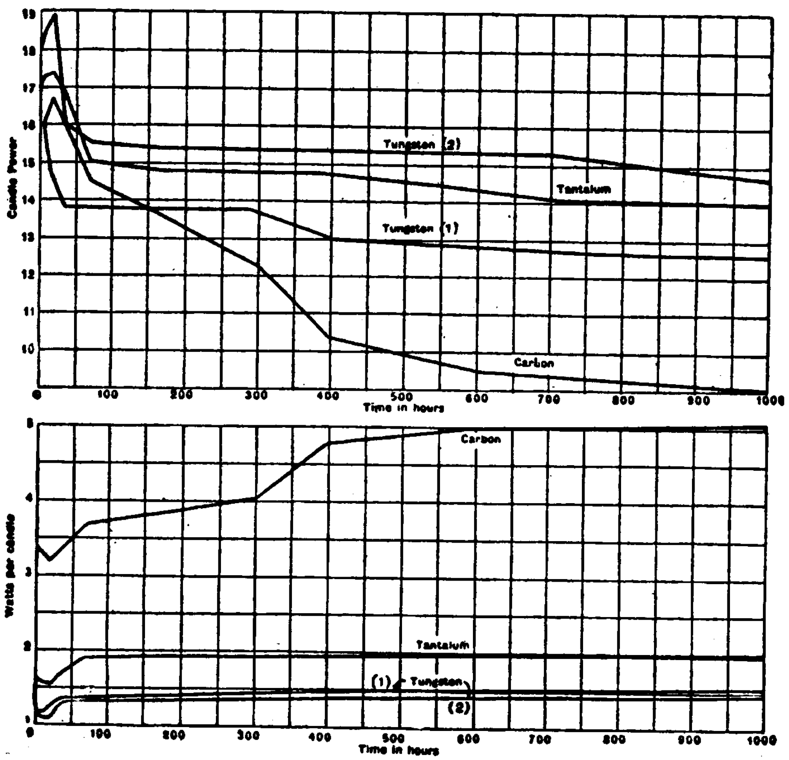

FIG. 22.

Osram lamps indicate that similar results have been obtained with lamps of that particular variety.

From these results it wou'd appear that aged tungsten lamps would serve admirably as photometric substandards, it being necessary, of course, to check them at intervals against a recognised standard.

Before leaving the subject of life tests it should be clearly understood that the curves shown are not chance curves, but are the results of tests made on a large number of lamps of every kind;

that the ones shown do closely resemble the individual curves indicates that great uniformity at the present day attends lamp manufacture.

Voltage and Candle-Power Variation.—It has long been known that for given pressure changes the percentage variation in the candle-power of a carbon lamp exceeded that of a metal lamp of equal rating, and the question naturally arises as to the extent of the variation.

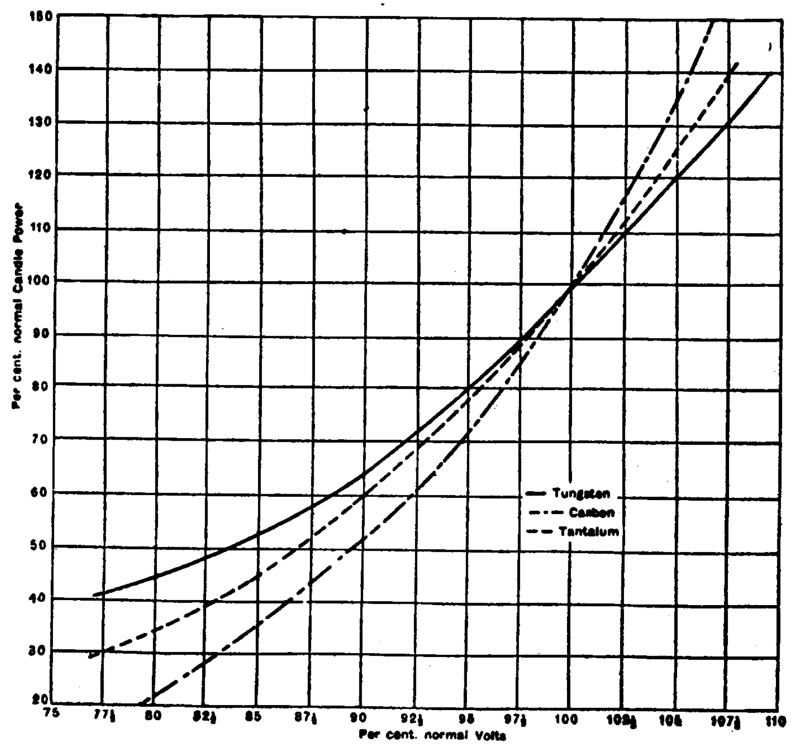

FIG. 23.—Relationship between Candle-Power and Volts.

In making such a test the lamp should be arranged in series with a resistance of such a value that considerable variation in lamp pressure is possible.

The candle-power may then be accurately measured in the usual manner and the results exhibited by means of curves, showing the relationship between candle-power and applied pressure.

Several curves obtained in this manner are indicated in Fig. 23, and it will be at once apparent that the curve for the carbon lamp is much steeper than either the tantalum or tungsten lamp curves.

In the paper previously referred to the voltage index obtained for the various types was as follows—

Lamp.	Volts Index.
Tungsten	3·5–4·1
Tantalum	4·1–4·3
Carbon	6·7–7

and the superiority of the metal lamp, as regards a permanent change in voltage, is made clear.

Since relatively slight reductions in pressure produce large decreases in candle-power the importance of close regulation is apparent, while although on the other hand a correspondingly great increase in candle-power results on an increase in pressure, the rapid deterioration of the filament renders the process a costly and unwarranted one.

It is evident, as before stated, that the pressure at which the lamp is to be continually operated must be so chosen that the ratio of the total light produced to the cost of energy, plus cost of lamp, must be a maximum, and this requires very careful selection of resistances and pressures.

Current and Candle-Power Variations.—Other useful relationships are those between candle-power and current, and power consumed and impressed voltage.

In Fig. 24 is shown the relationship existing between candle-power and current, and in this respect it will be observed that the carbon lamp is as good, if not better than any metal filament one.

The current index obtained for the various types was as follows :—

Lamp.	Current Index.
Tantalum	5·5–5·8
Tungsten	5·0–6·5
Carbon	5·2–5·4

and it will be seen that the variation amongst the tungsten filaments is very considerable, this probably being accounted for by the fact that the manufacturing processes differ slightly.

A study of these figures makes it clear that it is more important, from a fixed intensity point of view, to maintain the current constant, leaving the pressure to take care of itself. For instance, in using glow lamps as sub-standards in photometric work, the current should be maintained constant by means of potentiometer measurements, a special battery being very useful in this connection.

Power Characteristics.—The power characteristic, or the relationship between power and impressed voltage, was first

analysed by Steinmetz, who, on the results of tests made on a single tungsten lamp, stated that the power consumption varied as the 1·6th power of the impressed voltage.

The lamp follows the same law as the hysteresis loss in iron,

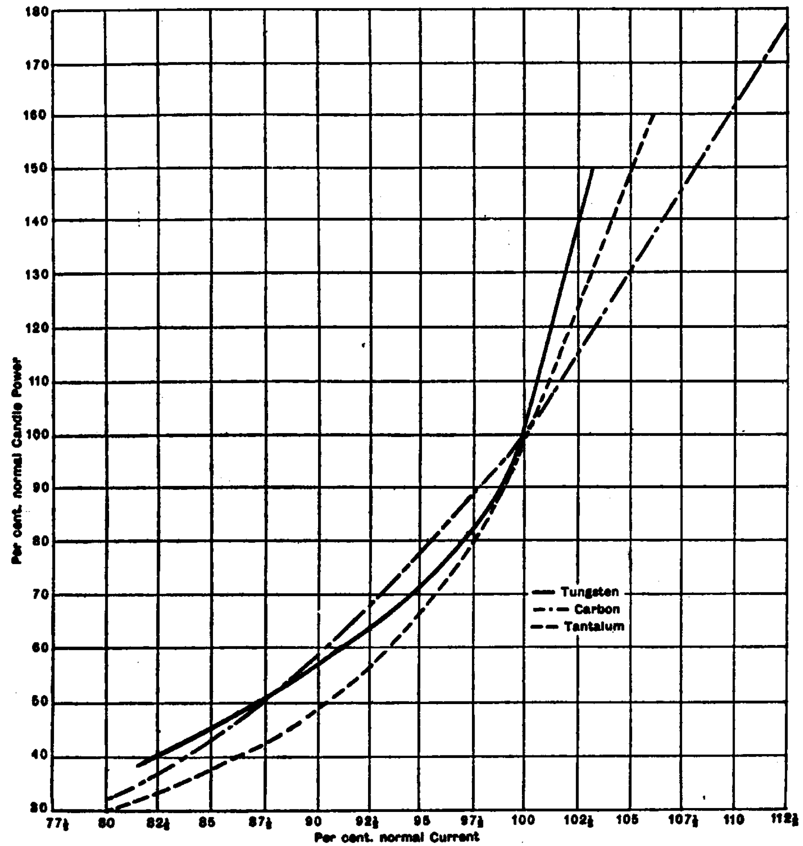

FIG. 24.—Candle-Power and Current.

the latter increasing as the 1·6th power of the induction, or stated in symbols

$$(1)\ W \propto V^{1\cdot6}$$

$$(2)\ W \propto B^{1\cdot6}$$

where (1) refers to the lamp, W being the power in watts, and V the pressure in volts, and (2) refers to the iron, W being the power in watts, and B the induction.

This law may be expressed as an equality

$$W = KV^{1\cdot6}$$

K being a constant.