or disc.—Diameter of driver = revolutions per minute of follower x diameter of follower ÷ revolutions per minute of driver; diameter of follower = revolutions per minute of driver x diameter of driver ÷ revolutions per minute of follower.

To find the velocity ratio in a train of wheels.—Multiply together the number of teeth in each driving wheel, multiply together the number of teeth in each follower; the first product will be the number of revolutions the first driver makes, while the second product is equal to the number of revolutions the last follower makes in the same time.—From Rules and Definitions by Wallace Bently, A.I.Mech.E.

LONG BURNING ENCLOSED ARC LAMPS.*

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The major factor of expense coupled with the operation and maintenance of arc lamps arose from renewing the carbons, which, in the sizes adopted in practice, had a life of some seven or eight hours only. As the all-night lighting of streets demanded that lamps should be capable of giving an uninterrupted service of from twelve to fourteen hours' burning, various means were devised whereby this period could be covered by a single trimming of carbons. Innumerable types of lamps were designed with this end in view, but there remained to be adopted as standards the double carbon lamp, which burned two successive pairs of eight hour carbons and, as an alternative, the single carbon lamp fitted with circular or elliptical carbons of sufficient cross section to insure a life of fourteen or sixteen hours. Aside from the matter of trimming, however, the carbons themselves were a source of heavy expense, and early endeavors were made to perfect some means whereby their life could be materially prolonged without at the same time incurring a sacrifice of the light. It was clearly understood that the rapid wasting away of the carbons was caused mainly by their combustion in the open air, and it naturally occurred that if the arc could be maintained in a transparent chamber, from which the oxygen of the air had been excluded, that this combustion would cease and that then the only waste would be that due to vaporization. Experiments along these lines were conducted and the results would undoubtedly have been encouraging had it not been chiefly for the fact that, in burning in an enclosing chamber, such a deposit soon accumulated on its inner surface as to seriously obscure the light and thus render the arrangement unpractical and, therefore, as these attempts to increase carbon life proved futile, fourteen or sixteen hours per trim was, until very recently, accepted as the burning period of an arc lamp. The great demand within the last eight or ten years for interior arc lamps operating from incandescent lighting circuits was met by a marked improvement in carbon manufacture, until finally a practically pure article was obtainable, the advent of which made possible the maintenance of an arc in an enclosing chamber and allowed of the development of the long burning lamp as we have it to-day in which a carbon in size equal to the eight-hour carbons of open arc lamps has a life of one hundred and fifty hours or more.

This longevity is effected by preventing combustion by a removal of the oxygen from the space immediately surrounding the arc, the oxygen not being literally removed by exhaustion, but rather by a process of chemical conversion wrought by the action of the arc itself. The carbons are surrounded by a glass globe of small area, closed at the base and only sufficiently open at the top to allow of a free passage of the upper carbon. On the formation of an arc the air contained within this globe is heated and rarified, the surplus finding an outlet through the upper opening, the remaining oxygen is reduced by combustion with the carbon to carbon monoxide (C.O.), a gas which is somewhat lighter than air, having a specific gravity of .969, and although combustible will not support combustion. This, together with the nitrogen which is liberated, completely fills the chamber and prevents further combustion of the carbon, although a small amount of air diffuses through the upper opening—a condition essential to satisfactory operation, as otherwise the vaporized carbon would condense and appear as a sooty deposit on the inner surface of the globe, while as it is, the oxygen of the entering air unites with this vapor and forms a gas. A slight deposit of silicon accumulates, which, however, does not seriously absorb the light, and which may be readily wiped off during trimming.

As a result of the absence of oxygen in the enclosing globe the ends of the carbons do not become tapered by burning but remain flat and blunt, and the device could not be adapted successfully to the existing lamps in use, which maintain a potential difference of some 45 volts across the arc, as, in the small separation of one-eighth inch or under consequent upon this voltage, too much of the light would be intercepted by the lower carbon. It was therefore imperative, in order to obtain proper distribution, that the carbons be more widely separated, and it was found that in the enclosure an arc of approximately ⅜-inch in length could be maintained with an E.M.F. of some 75 or 80 volts. Meanwhile it is necessary that the current employed should not exceed 6½ or 7 amperes, for obvious reasons associated with the cleanly burning of these lamps for long periods, and in order further that the watts expended may correspond with those expended in an open arc lamp of like rating. While a so-called 2,000 c.p. lamp of the latter type operates with a current of 10 amperes at an E.M.F. of 45 volts or 450 watts, an enclosed lamp of like rating may operate at 6.5 amperes and 70 volts, or at 5.5 amperes and 82 volts, the higher E.M.F. and reduced current resulting within certain limits in better operation. Enclosed arc lamps in general require special features in the feed mechanism, although the governing principles are identical with those obtaining in the open lamps. As it is necessary to separate the carbons from ⅜ or ½ inch it is usual to have the magnets act directly on the upper carbon without the intervention of levers, and this calls for a long range magnet of considerable power. In order also to obtain good regulation it is desirable that the moving armature be of considerable weight, as compared with the weight of the carbon to be lifted, as therefore decrease in weight of the carbon is not accompanied by an appreciable lengthening of the arc. Enclosed lamps will operate efficiently in series on direct constant current circuits employing currents not greater than 6.8 amperes, and on alternating current circuits in conjunction with constant current transformers. In these instances the lamps must be of the differential or shunt feed type, and must be further provided with short-circuiting cut-outs such as are found in the well-known open series lamps. A similar type of lamp is required for operating in series multiple on street railway and power circuits, but in place of the short-circuiting cut-out a device for shunting a resistance, equalling that of the arc, across the terminals is used in order that if one or more lamps cut-out or proved defective the current traversing the remainder would not rise. It is necessary also that a steadying resistance be placed in series with each group of such lamps.

Enclosed lamps for operating in parallel on direct and alternating current incandescent lighting circuits require a very simple feed mechanism and contain neither shunt magnets nor cut-outs. For adjusting the carbon a single magnet only is required connected in series with the arc. Such a magnet responds to variations in the current strength and tends to maintain this factor constant irrespective of variation in terminal voltage, but as this latter is a constant factor the magnet therefore in keeping the current factor constant must likewise keep the arc resistance and length constant also. A retarding device such as a dash pot is required in these lamps to allow of a gradual separation of the carbons, alternating lamps especially demanding a comparatively slow separation. As direct current lamps usually operate on circuits of 110 volts it is necessary to interpose a resistance in order to reduce this to about 80 volts as required across the arc, and, while this resistance wastes energy, yet it is necessary to the successful operation of the lamps. The alternating lamps are more fortunate in this respect inasmuch as a reactance coil may be placed in series with the arc which will reduce the voltage to that required across the arc with but little waste of energy. They may also be operated direct from transformers delivering the necessary arc voltage, or from economy coils, or auto-converters.

A type of lamp which represents simplicity in the extreme is that in which the separation and feeding of the carbon is effected by the expansion and contraction of a strip of metal interposed in the path of the current. Such a device, while not satisfactory when used in conjunction with open arc lamps, appears to be excellently adapted to parallel burning enclosed lamps, in which the arc is protected from draughts of air, and which feeds only

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