The Electric Lamp for Railway Signals*

Methods of Testing, Directions for Installation and Operation to Secure Long Life

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WE HAVE conducted an extensive research and have secured some interesting and, we hope, valuable data which we present here for consideration and counsel as to future procedure.

Where signal lamps are operated from primary or storage batteries, the cost of power is relatively high, and it is desirable to use as low wattage lamps as practicable. The most commonly used combination is a 3.5 volt, 0.3

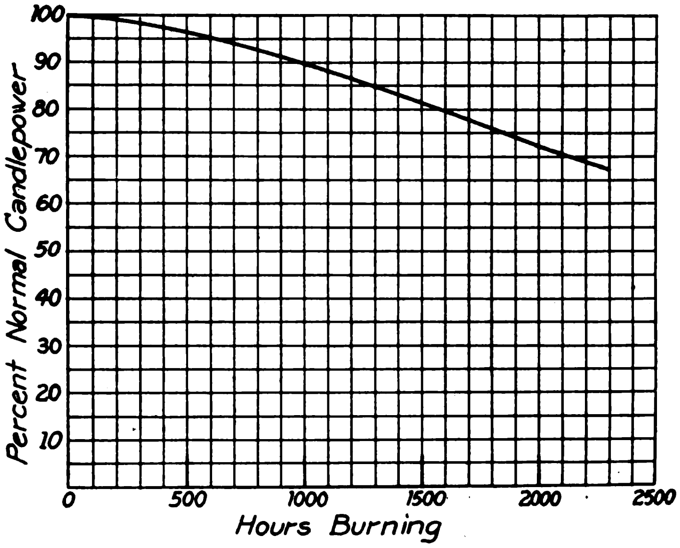

Fig. 1—Candle Power Maintenance Curve of 3.5 Volt, 0.3 Amp. C-2 Filament with S-11 Bulb

amp. (1 watt) lamp operated from four cells of primary battery. Other common combinations are 8, 10, 12, and 13.5 volt, 0.25 amp lamps operated from four or five cell of storage battery, or a 16-cell primary battery.

Early signal lamps were made with carbon filaments and consumed a large amount of energy for the small amount of light emitted. Such filaments have now been almost entirely replaced by the drawn wire tungsten filament of the Mazda lamp. The diameter of the filament wire used for the 0.25 amp. lamp is .0013 in. Any slight change in the diameter results in a material change in resistance with a resulting change in the current flow in the finished lamp, a change in filament temperature and a change in the life of the lamp. The wire when first drawn has a tensile strength greater than that of steel piano wire. However, when the lamp is lighted, this wire is almost instantly raised from a temperature of say, 70 degrees Farenheit to 2,741 degrees. The cold resistance of tungsten is only about one-tenth that of hot tungsten, so that when the current is first turned on, there is momentarily a large inrush of current. This is reduced rapidly to normal as the filament heats up and the resistance increases.

From the moment a lamp is first lighted, the filament gradually becomes more and more brittle, and it gradually reduces in size, while there is a tendency for the lamp to blacken, due to a deposit on the glass bulb. The candlepower decreases with age, due to the absorption of light by the deposit, and also due to the decreased current flow on account of the increasing resistance of the wire caused by the decreasing size.

Another factor that enters into lamp performance is the question of exhaust. An absolutely perfect vacuum is an exceedingly difficult thing to obtain. After all the air is pumped out of the bulb, the filament itself and the lead-in wires begin to exude small amounts of gas. Sometimes traces of water vapor come out of the glass bulb, and this vapor is disintegrated by the high filament temperature, forming a slight amount of oxygen which is very detrimental to good lamp performance. Fig. 1, indicates the candlepower maintenance that may be expected of a typical signal lamp throughout its life. The average life of a lot of say, 1,000 lamps, can be pretty

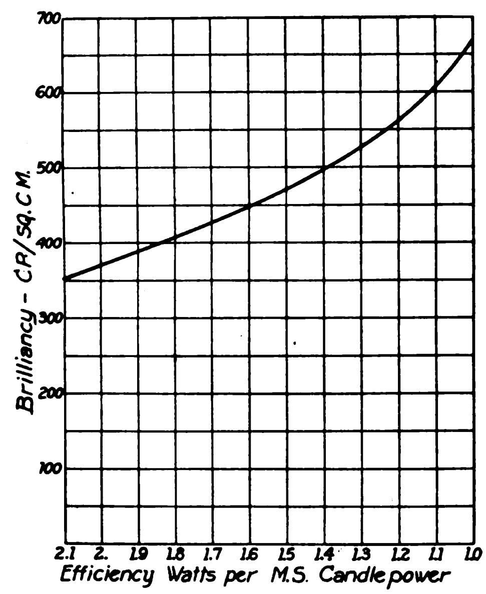

Fig. 2—Curve of Variation of Filament Brilliancy with Efficiency of Lamp

well calculated, but out of these 1,000 lamps some will fail early and others will last beyond their expected life.

Operation in Signal Service

It is essential to renew the lamps at the end of their rated life to secure a minimum of failures. As the lamps are designed to outlast the life of the battery, with some factor of safety, the best practice would be to renew the lamps each time the battery is renewed. Some early burnouts must be expected, but just how serious this is to signal practice, or what means are to be used to replace these early failures is something the signal engineers will have to answer. The lamp manufacturers will co-operate in trying to solve the problem, but we do not believe that the solution lies in the lamp itself.

The average life of an incandescent lamp depends to a

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large extent upon the circuit on which it is burned. Lamps can be designed to give any desired average life when burned at any predetermined constant voltage. If a lamp is burned at a higher voltage than that for which it is designed, its life will be shortened. If it is burned under voltage, the average life is lengthened, but at the expense of candlepower, brilliancy and efficiency.

Two Factors, Current Consumption and Lamp Renewals

Extremely long life can only be obtained at a great sacrifice of efficiency; that is, by reducing the candlepower output for a given wattage consumption. The cost of electric lighting consists of two main items; namely, the cost of current and the cost of lamp renewals. In operating a lamp so as to give excessively long life, as

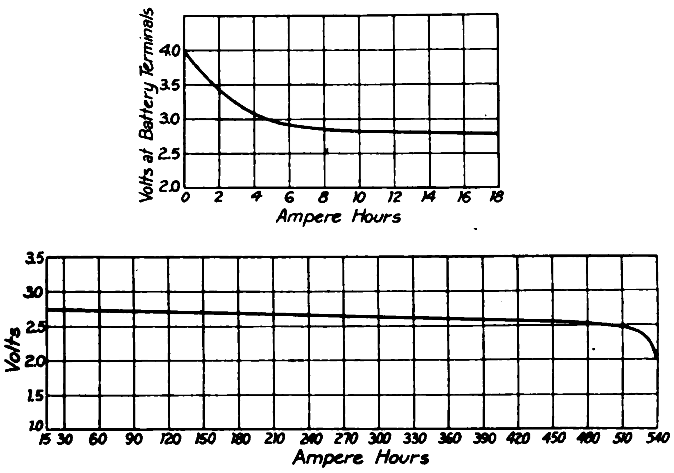

Fig. 3—Discharge Curve of 4 Cells of 500 a. h. Battery, Continuously on a 3.5 Volt, 0.3 Amp. Lamp

for example, by operating it below its labeled voltage, the cost of lamp renewals is, of course, reduced, but the cost of current for a given candlepower is materially increased. In most installations, particularly where the source of current is a battery, the cost of the current consumption by a lamp during its life, far exceeds the cost of the lamp, so that the operating of lamps under their labeled volts is usually an uneconomical practice. The lamp user may save a few cents in lamp renewals, and spend many additional dollars in current consumed. There is a most economical life and efficiency at which to operate lamps for each condition. Data is now being accumulated, on the basis of which we hope to be able to present recommendations. Burning lamps under voltage has very little effect on the percentage of early burnouts.

Variations in Voltage

Lamps are designed differently for use with different sources of current supply. For example, if a lamp is to be operated by a transformer from a 110-volt lighting circuit, it will have practically a constant voltage applied to it, whereas, if it is burned on a primary battery, it is subject to varying voltage. The voltage being high when the battery is new, and gradually decreasing throughout the life of the battery. Fig. 3 illustrates this condition.

If the lamp is to be used on a battery, it must be so designed as not to burn out at the peak battery voltage, and also to give ample light at the end of the battery discharge. A few minutes burning at the peak voltage will have the same effect on the lamp, i.e., use up as much of its life as a few hours' burning towards the end of the discharge.

Discharge curves are taken from batteries under actual operating conditions, and from these curves some one specific voltage is figured out at which, if the lamp is burned on such a constant voltage, the life performance would be the same as if the lamp was burned over the varying voltage of the entire battery discharge. This is called the equivalent design voltage, and all life figures are based on these voltages. For example, the 3.5 volt, 0.3 amp. lamp designed for approach lighting on four cells of primary battery is actually designed at 3.3 volts, although from the battery curve we see the voltage may vary from 4 to 2.5. These lamps burned at a constant voltage of 3.3 are designed to average 1,200 burning hours' life. This same result will be obtained if they are burned on the varying voltage of the battery throughout its life.

The curves of Fig. 3, made with a continuous discharge, do not give so high an average voltage as is maintained with intermittent burning. Each time the load is taken off from the battery the EMF rises, and the lamp is again subject to high voltage the next time it is lighted. It is this intermittent burning that requires such a high design voltage as 3.3.

Shape of Filament Important

When starting to study the approach signal lighting problem, experiments were made to determine the best shape of filament for the various signal lenses and re-

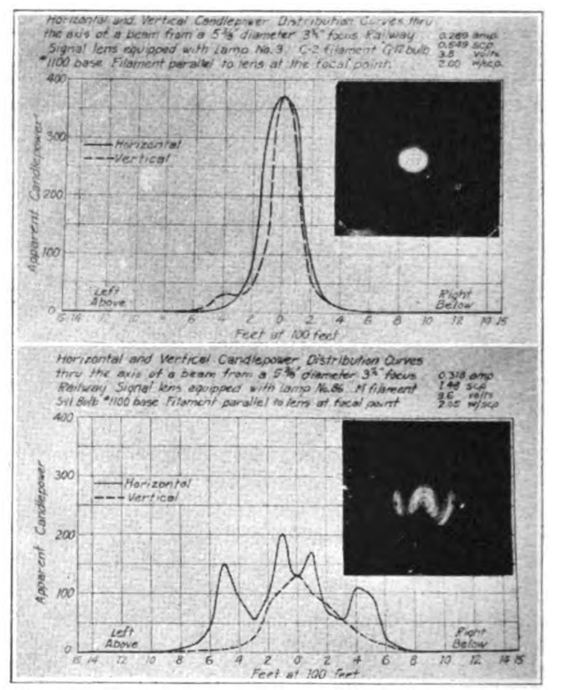

Fig. 4—Curves and Image Showing Effect of Filament Shape

flectors. The lamp manufacturers had over one hundred distribution curves made at the Electrical Testing Laboratories in New York City to determine the effect on the distribution of light from the signal lamps, using different filament shapes, and different voltage lamps. Curves were made showing horizontal and vertical distribution across the axis of the beam with the lamp in focus, and at various distances ahead of, and behind the focus. Photos were also taken of the projected spot of light. Fig. 4 illustrates two typical tests.

The next steps was to determine how closely a lot of lamps would come to an average distribution curve. For this work, use was made of the photo-electric cell, Fig. 5, in the Research Laboratories of the General Electric Company. The oscillograph was used to determine how long it took for the filament to come up to full brilliancy after the current is turned on; the curves showed that 0.2 sec. were required.

Experience Gained on the Railroads

The next step was to go out on the road and find out what service conditions would do to the lamps. An extensive study was made of actual voltage conditions on approach lighting. Some very interesting curves were obtained showing how the battery voltage drops as the lamps light up on the approach of a train, and how it builds up again after the signal clears. It is interesting to note in Fig. 6, that the more frequent the train or signal operations, the lower the average battery voltage; the low point being reached in the later afternoon when commuters' trains are frequent. The peak voltage occurs in the early morning when the trains are few and far between.

Another factor which had to be taken into consideration in the final design of lamps is, the average voltage drop in the leads between the battery and the lamp terminals. To determine this, simultaneous voltage readings were taken at the battery and lamps on a number of signals. Thes tests were made with four cells of Edison primary battery operating two 3.5 volt, 0.3 amp. Edison signal lamps. The tests showed an average drop of .099 volts between the battery and the lamp, with a maximum of 0.24 and a minimum of .05. No small percentage of this drop may be attributed to the socket. For the best service it is essential to use a high-class socket, preferably one in which the plunger spring does not carry any of the current. From this standpoint the single contact bayonet socket offers many advantages, as it can be made mechanically stronger, and has one less contact point to cause resistance.

Some time after large numbers of the 3.5 volt lamps had been in service, we began to receive reports of failures. Many lamps were tested, both new ones and ones taken back from service, to try to determine the cause. It seemed evident that at least some of the lamps were failing, due to static discharges, caused by lightning. Therefore, the lightning arrester departments were set to work on the problem of preventing these failures. While this research is not yet complete, we are making progress. I believe also that one of the signal engineers has found

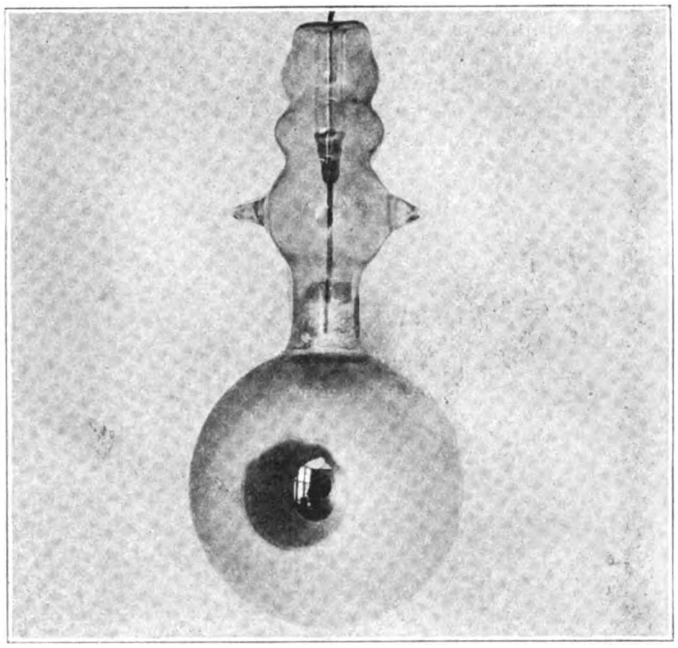

Fig. 5—Photo-Electric Cell

that by grounding the DNL relays, he has materially reduced failures from lightning.

With the thought that possibly some of the lamp failures might be due to exhaust troubles, a third leading-in wire has recently been introduced into some of the lamps. A high voltage discharge is sent into the bulb over this

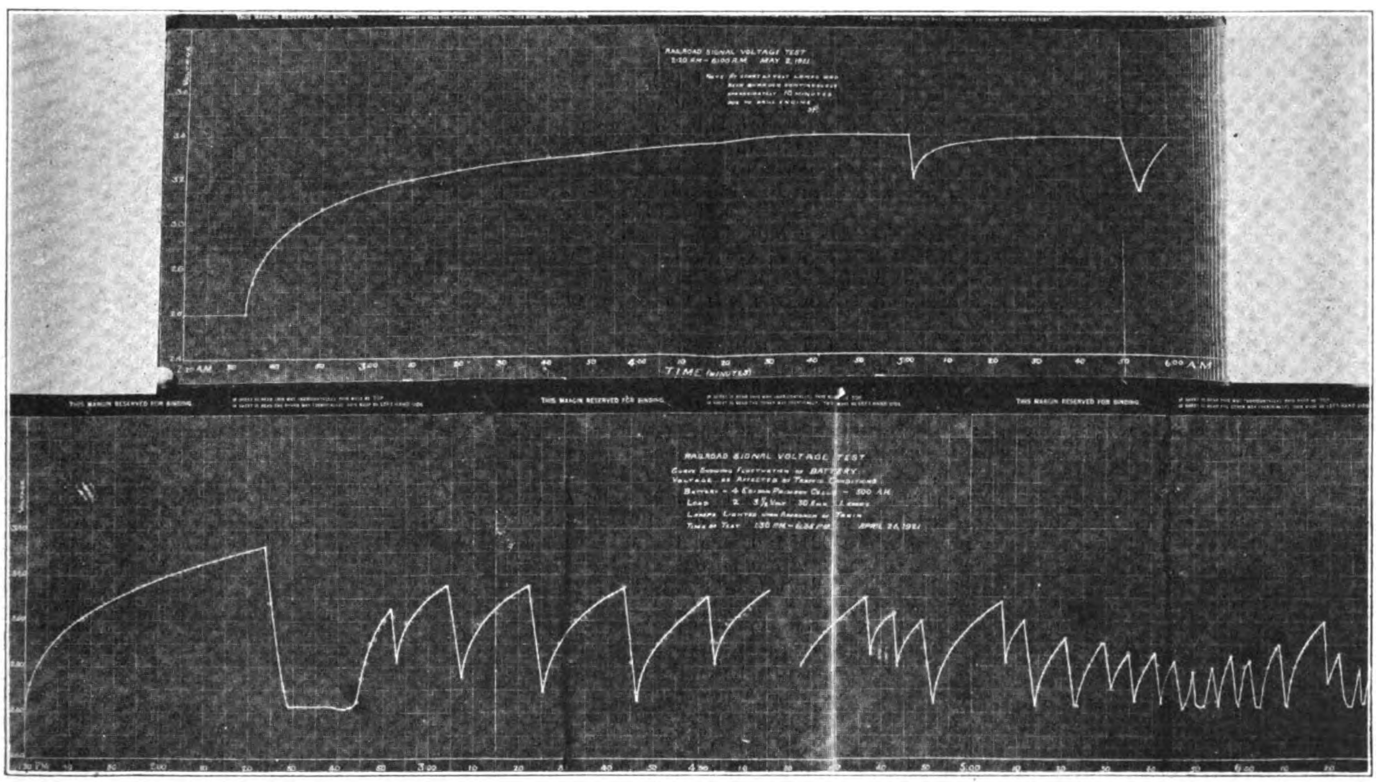

Fig. 6—Curves Showing Fluctuation of Battery Voltage as Affected by Traffic Conditions, 2 p. m. to 6:30 p. m.

wire during the process of exhaust, with the possibility of some slight improvement in the vacuum.

Vibration and Bump Tests

Trouble also developed in many of the 13.5-volt lamps in service. Those returned had the appearance of being subject to overvoltage, yet they were used under conditions that did not make this probable. Some of the lamps had badly sagged filaments. As this sagging did not show up on our stationary life test racks, it seemed possible that it might be caused by vibration on the signal poles. In order to study this we had a life test rack built that could be subjected to any desired period or amplitude of vibration. The lamps are mounted on this rack in any desired position. The motor in the case at the bottom is equipped with an unbalanced pulley which causes the rack to vibrate severely. To more closely meet service conditions, the lamps on this rack are also operated through a flasher, causing them to light up and go out in a manner similar to that in approach lighting service.

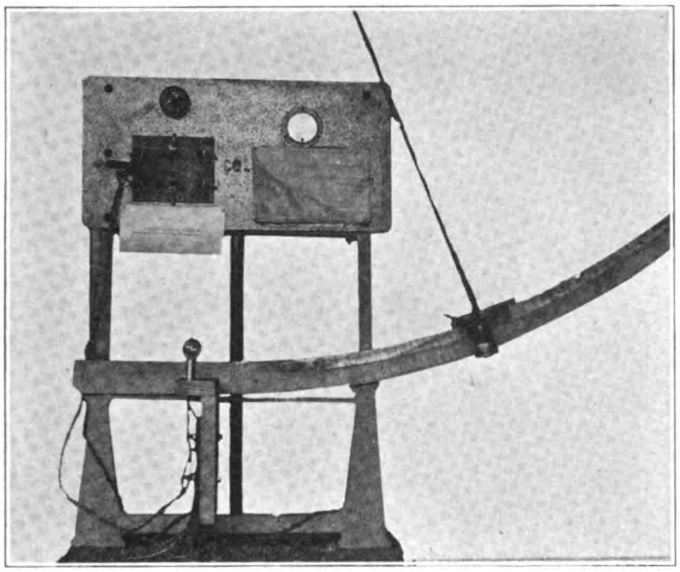

Fig. 7—Bump Test Machine

These tests indicated that apparently the filaments of the 13.5 volt, C-3 filament lamps were sagging over and short-circuiting, thus subjecting part of the filament to over-voltage and causing early burnouts. That difficulty was overcome by putting in two additional anchors.

It is true that as a filament ages, it slowly crystallizes and becomes increasingly brittle, and apparently this crystallization is much worse under conditions of vibration than otherwise. However, even under the severe vibration of the life test rack, the lamps averaged well over 1,200 hours' life, but continued to fail, out on the railroads in service.

Under certain conditions these results did not seem to check with results in service on lamps taken from the same lot. Evidently there was some other condition there which was not reproduced on the vibrating life test rack. It was felt that possibly in some cases where the dash-pot on the signal pole was out of adjustment, the severe jar received each time the semaphore blade drops might have something to do with lamp failures, or, that as a heavy locomotive hit the rails near the pole, a sharp jar resulted. Sockets were, therefore, rigged up in the laboratory on a board, against which a heavy weight could be swung from increasing heights, and allowed to strike the board (Fig. 7). With this machine the lamps were given severe bumps. Tests were made on lighted as well as unlighted lamps. These tests showed failures that were not caused by straight vibration. The results showed that the less the filament coil is stretched out, the stronger will be the lamp. These tests indicated that the C-3 filament which we originally advocated and put out, which was of such a size that it could be entirely contained within a ¼-in. sphere, was materially stronger than the somewhat larger filament advocated in the Corning tests in 1921. Even smaller filaments gave still better results, not a great deal being gained, however, by reducing the size below 5/32 in. wide and 5/32 in. high. Such filaments, apparently, are about 50 per cent stronger than the present filaments, which are being made ¼ in. wide by ¼ in. high.

Reducing the size of the filament reduces the spread of the beam somewhat, but increases the candle power on the axis. Distribution curves run on filaments ¼ in., 5/32 in. and 3/32 in. wide are shown in Fig. 8. The lamps from which these curves were made are shown

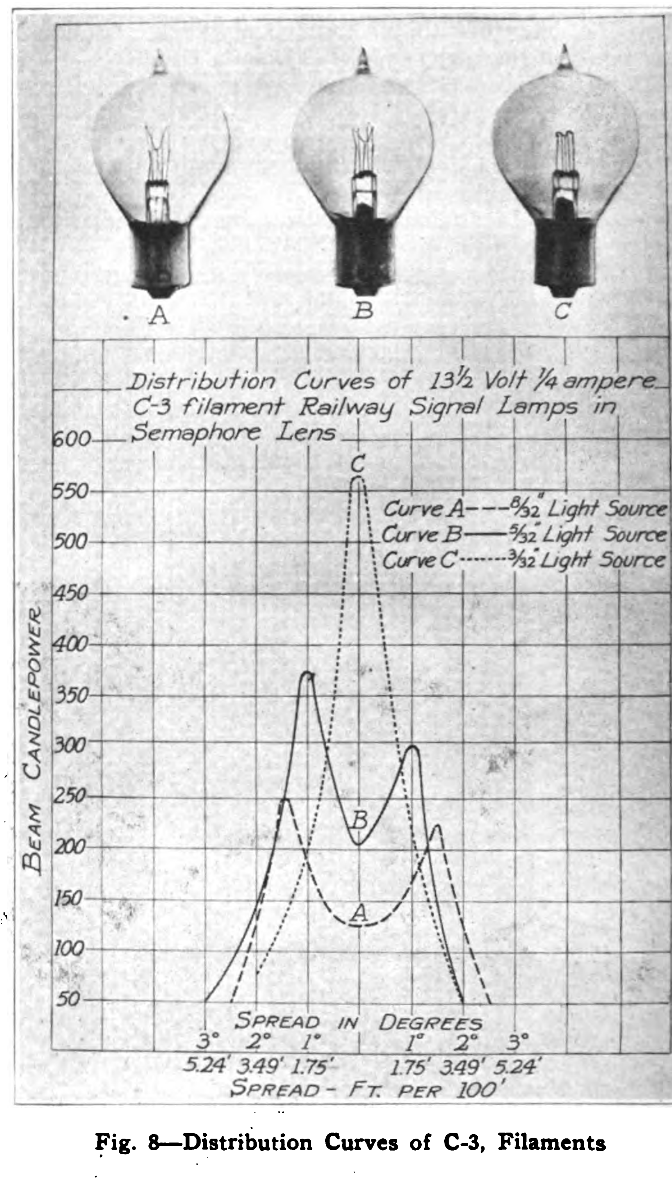

Fig. 8—Distribution Curves of C-3, Filaments

also. Even the smallest filament would probably be satisfactory if placed ¼ in. behind the focal point.

Supplementing these tests, and through the kind co-operation of the Primary Battery Division of the Thos. A. Edison, Inc., tests were conducted on an actual signal set up in their yard. The oil was entirely removed from the dash-pot, thus giving the signal the maximum possible jar when the arm dropped. A 13.5 volt, 0.25 amp. signal lamp was placed in the lantern, and another hung for comparison on a nearby building, which was not subject to the severe jar. In order to save time these lamps were burned at such a voltage as to shorten their life by a ratio of 10 to 1, i. e., one hour's burning at this forced life test voltage would be the equivalent of 10 hours' burning at normal voltage. The results obtained under these exceedingly severe conditions, although not as severe as our laboratory bump test, showed the lamp

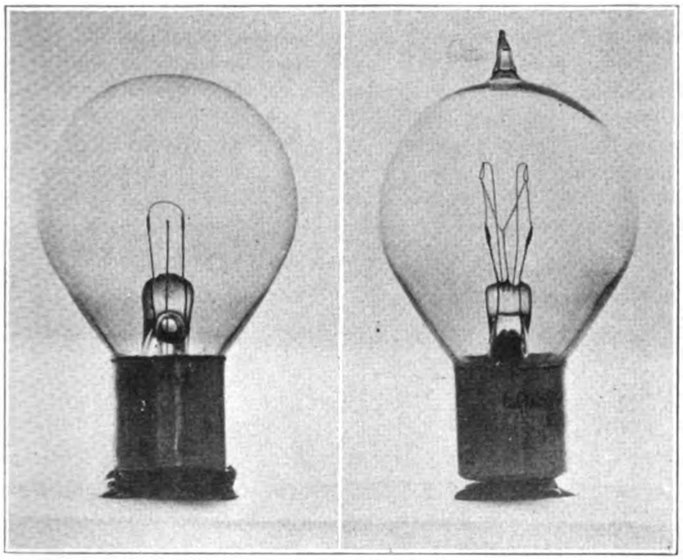

Fig. 9—Filament with No Anchor
Fig. 10—Filament with Two Anchors

still going strong after 33,970 bumps, at which time the signal mechanism went out of commission.

Tests have also been conducted to show the relative life of signal lamps on continuous burning or flashing signals. Contrary to what was expected, it has been found that the life of the low current lamps, 0.25 amp., is from 10 to 15 per cent shorter when the lamps are flashed than when they burn continuously. The lamps, however, are made with ample leeway so that the same lamps may be used on either continuous or intermittent service.

Tests made with the oscillograph on lamps flashed once a second for a period of one-tenth of a second, showed that the total energy consumed was one-sixth of the energy that would have been consumed if the lamp had burned continuously, instead of only one-tenth, as might be expected. This difference is due to the momentary excessive inrush of current at the instant that the current is turned on, when the filament is cold and the resistance low.

Equipment in Which Lamps Are Used

The characteristics of individual signal lamps cannot be expected to exactly duplicate each other. Signal lamps may be expected to vary one from another in the order of:

10 per cent in amperes at rated volts.
30 per cent in candlepower at rated volts.
30 per cent in watts per candle at rated volts.
10 per cent in watts at rated volts.

So much for the research that has been put into the signal lamp performance, and for general lamp characteristics.

The 3.5 volt, .3 ampere lamp is made with what is known as a C-2 filament (Fig. 9). The filament coil is 5 mm. long and 2 mm. high. This is an exceedingly small light source and, naturally, when it is used with a lens it must be located very accurately at the focal point of the lens to be most effective. A very slight deviation from that position will reduce the beam candlepower of the axis and change the spread in accordance with Fig. 11. The range of the signal will, of course, change with the beam candlepower. This necessity of accurate focusing is not quite so marked with the higher voltage lamps, such as the 13.5 volt, having the C-3 filaments, as these are larger, but even so, it is desirable. See Fig. 10.

It would be convenient if, when one lamp fails, that it could simply be removed and replaced by another one, and that one would be exactly in focus. Unfortunately, however, lamps which are made of pieces of glass, melted together, and pieces of wire welded together, cannot be reproduced as exactly as pieces of machined steel. There will be some variations in the light center length and in the axial alignment of individual lamps. In the past this variation has been in the order of 3/32 in. With modern, automatic mounting machinery, however, it is being steadily reduced. It is possible now to produce lamps in tipless bulbs in which the filament position will not vary

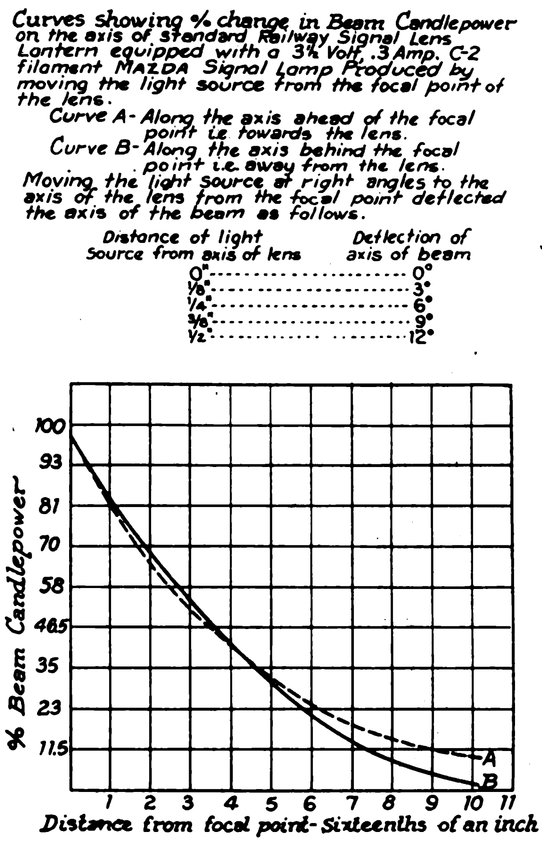

Fig. 11—Change in Candle Power

more than 1/32 in. Tests made on one of the railroads seem to indicate that such a variation will not throw the beam off sufficiently to be objectionable, even with the little 3.5-volt, C-2 filament. Lamps made to this close specification would not have to be focused each time a lamp is renewed. The time and labor saved may more than offset the additional cost of the precision lamps. This is particularly true in reflector equipment, where slight variations are not quite so serious as in lens work.

The first use of electric lamps for signals was to put them in the old lanterns designed for broad oil flames. This procedure utilized about 15 per cent of the total light flux of the lamp. Modern signal equipment makes use of short focus reflectors which utilize about 60 per cent of the total light flux. When such reflectors are designed with contours, such as to direct the light in the directions from which it is desirable to see the signal, and not to throw it up in the air or at points where it will be of no possible use, we have a really efficient and useful electric signal. Such reflectors combined with flashing devices, sun valves, etc., cut down the necessary energy consumption to the point where no other form of light source can compete.

Summary of Lamp Failures

Originally 3.5 volt, 0.3 amp. lamps were made with filaments 3 mm. wide. These lamps gave excellent life performance. Some time ago these filaments were stretched out to 5 mm. in order to secure a little greater beam spread, but this weakened the filament slightly. About the same time the factory ran into exhaust troubles, and evidently some lamps have gotten into service with poor exhaust, causing early failures. This trouble has been corrected and every precaution taken to prevent its reoccurrence. We believe that the 3.5 volt, 5mm. filament as made today will give entirely satisfactory service. Decreasing the size to 3 mm. would make it still stronger, although probably not necessary.

The 8, 10, 12 and 13.5 volt lamps were originally made with 6/32 in. filaments. Most of these gave good service. After the Corning tests the filaments were increased to about 9/32 in., and troubles began to develop after the lamps had been in service some time, due to the larger filament sagging and short-circuiting (something that did not show up on our stationary laboratory life test racks). The sagging was overcome by the use of three anchors instead of one. This did not solve the trouble, although it helped. A special study of the wire was made and some improvement brought about by the use of selected wire. Study of the exhaust was made, and still further improvement was made there. Today these lamps can be made with 9/32 in. filaments that will give good service. We know, however, that a big improvement would be made by the use of 5/32 in. filaments, increasing the filament strength far beyond any lamps that have been made in the past. This would greatly reduce the early burnouts which have really been filament breakage failures. The 5/32 in. filaments give higher beam candlepower on the axis, a more uniform distribution of light with but very slightly reduced spread at the low intensities near the extreme edge of the beam when used with lenses. When used in properly designed reflectors, utilizing about 70 per cent of the total light flux from the lamp, instead of only 15 per cent, any desired spread can be obtained, it being merely a matter of reflector design.

Automatic Highway Crossing Signals Authorized in Place of Gates

AT Newfields, N. H., on the Boston & Maine, the Public Service Commission of New Hampshire has authorized the railroad company to install, at a crossing 300 ft. south of the station, an "automatic wig-wag flasher and bell warning" signal for the protection of wayfarers at the crossing, in place of gates, which gates, with an attendant 12 hours a day, have been in use 50 years; and this order is issued notwithstanding protests received from the citizens.

When the railroad company announced its intention, the selectmen of the town and, later, 118 citizens, entered a protest, and the commission held a hearing on October 2. Newfields is a town of about 500 inhabitants. It is on the main line between Boston and Portland, where the number of trains is large; but the highway travel is not heavy, consisting mostly of the people who live on the east side of the railroads, on their trips to and from the trading center of the village, which is on the west side.

The commission in its report discusses quite fully the question of reasonable protection, and decides that an audible and visual warning, in service 24 hours a day, properly maintained, is better than the present arrangement, the gates being unattended for 12 hours of the 24. The "automatic flagman" is on duty 24 hours and never forgets. "It has met with universal approval by all regulatory bodies and is fast displacing the gate and human flagman," says the report. The visual apparatus and the audible are each operated by separate batteries and the railroad company reports that, in its experience, there has been no case where both of these warnings at a crossing have failed simultaneously. The signal will be inspected daily; and, being near the station, failure to operate will be soon detected. As the view at the crossing is short, the road proposes to install two signals, one each side of the railroad.

Visual and Audible Signal at Oak Hill, Maine

The report of the commissioners, signed by William T. Gunnison, chairman, reminds the public that the duties of the traveler and of the railroad at a crossing are reciprocal; the traveler must exercise due care, the same as must the railroad; and "whichever party fails in the performance of this reciprocal duty is liable for injury done to the innocent party."

The signal to be installed at Newfields is like that shown in the illustration, which is in service on the same railroad at Oak Hill near Portland. As shown, the signal is out of order as indicated by the appearance of the word STOP. Normally, when a train is on the track circuit approaching the crossing, the stop disks swings back and forth, a bell rings and the six red lights at the top flash, successively, thus making three appeals to the attention of travelers on the highway. When no train is approaching the stop disk is normally hidden behind the case bearing the Look and Listen Sign, the bell is silent and the six red lights are dead.

More Cars Were Loaded with merchandise and miscellaneous freight during the first 40 weeks this year than ever before in the history of the railroads, according to a statement issued by the American Railway Association. In this period (nine months and seven days). 20,649,237 cars were loaded, an increase of 4.02 per cent over the corresponding period in 1920, and 13.87 per cent over the same period in 1921. Total loading of l. c. l. freight this year was 9,218,484 cars and of other freight 11,430,753 cars.