FLOODLIGHTING AND ITS APPLICATION
IN A RAILWAY FREIGHT YARD.

A thesis submitted to the faculties of
The School of Engineering and the Graduate School
of The University of Kansas

For

DEGREE OF ELECTRICAL ENGINEER

By

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Preface

In this thesis the writer has attempted to present a few of the many perplexing problems that have confronted the Electrical Engineers of steam railways in their attempt to provide satisfactory illumination in freight yards in order that the hazards of workmen might be lessened and the speed of handling traffic at night increased.

The floodlight installation discussed in Chapter IV was put into operation in March 1929. It has not been in service a sufficient length of time to assemble comparative operating cost data showing economies effected.

The writer takes pleasure in acknowledging the many helpful suggestions offered by Mr. L. L. King in designing the project.

The photographs included with this paper were made by Mr. C. Henri Strawn for the purpose of studying the typical illumination effects provided and to show the tower locations relative to the yard tracks.

Leon E. Edwards.
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During the World War period many industries and utilities, including railways, found it necessary to increase their production far beyond the capacities for which their plants and facilities were developed. Facilities were expanded as rapidly as possible and every effort exerted to build up production to meet the extraordinary demands. Production was carried on day and night in many industries where night work was thought impracticable, if not impossible. Illumination of large areas was being demanded in the police protection of vital industries. These conditions were the impetus that caused the rapid development of the floodlighting projector and its associated equipment.

"Floodlighting" is a term applied to a lighting system used for illuminating large areas. The type of lighting unit commonly used in this class of service consists of a powerful light source, used in combination with a reflector and lens, for directing a major portion of the emitted light on the area it is desired to illuminate. This unit is referred to as a "floodlight projector" or "floodlight." In comparison with the searchlight, with its extremely narrow angle of distribution designed for long range projection of light, the floodlight has a relatively wide angle of distribution and short projection range. With the exception of those developed especially for airport service, floodlights have distribution angles varying between eight and seventy-five degrees and an effective projection range less than three thousand five hundred feet. An incandescent lamp is
commonly used for the light source. These are constantly increasing in size and are now commercially available in as large as five thousand watt capacity. However, lamps larger than fifteen hundred watt size have been used on special applications.

Projector reflectors are usually parabolic in shape, although many combinations of curves are being developed. These are frequently stippled to eliminate filament shadows.

Commercial lenses are usually plain convex shapes, although some are arranged with moulded prism combinations for changing the beam pattern of the reflector.
Floodlights find many applications in the field of steam railroads. They are used to illuminate shop yards, turntables, substations, depot platforms, freight yards, roundhouse interiors, coach cleaning tracks, ice docks, etc. Their most valuable application, however, is in the illumination of freight yards. Most of the large yards are operated on a twenty-four hour schedule, with the peak switching load occurring between the hours of six o'clock in the evening and two o'clock in the morning. This condition is caused by shippers loading cars during the normal working day and turning them over to the railroad for handling as soon as they are loaded. Cars must be assembled into trains and started to their destination with as little delay as possible, since quick delivery is paramount in this highly competitive period.

On account of the constantly changing load factors in freight yards it has been extremely difficult to evaluate the benefits of floodlighting on a monetary basis. Although dealing in intangibles the following benefits may justly be credited to floodlighting:

1. Decreases handling time per car, thus improving service to the customer and increasing the yard capacity without the expense of adding tracks, locomotives or men.

2. Decreases average cost of damage per car handled at night.

3. Decreases personal injuries.

4. Aids policing of yard, thus reducing loss from pilfering.
5. Improves morale of workmen, resulting in more careful work and lowering rate of labor turnover.

The Committee on Illumination of the Association of Railway Electrical Engineers first mentioned floodlighting in their report submitted to the Association in the meeting held during November, 1923. The report on floodlighting was very general in character; the relative merits of the old type lighting system, employing pendant reflector units distributed throughout the yard, versus floodlighting was discussed. Furthermore, two types of floodlighting systems were involved, namely the distributed and concentrated methods of installations. The system using pendant reflectors was favored by certain of the Association members on account of its low first cost and absence of glare. It was admitted that with this system it was usually impracticable to install sufficient units to provide comparable light distribution with floodlighting, but if practicable, that the operating cost for energy consumption and lamp renewals greatly exceeded those costs in floodlighting installations.

In the distributed type floodlighting installation it was recommended that projectors be placed on each side of the yard at approximately five hundred foot intervals, with one unit per pole mounted from thirty-five to sixty-five feet above the ground, the light from this unit being thrown in the direction of traffic movement. Theoretically this arrangement provided the most uniform lighting distribution without objectionable glare, since the light was projected
only in the direction of car movement. Obviously this system was only practicable in yards having uni-directional movement and not in flat yards operated with switching engines. It also possessed most of the objectionable features of the pendant system, namely high operating and installation cost.

The concentrated or centralized system of flood-lighting consisted of mounting projectors in batteries of four to sixteen units on structures sixty to eighty-five feet high, with structures spaced from two thousand to three thousand feet distant in the yard, the lighting units directed toward each other. Proponents of this system claimed for it, low installation and operating cost, also better lighting efficiency than the other systems. Opponents of this method maintained that it was impracticable on account of objectionable glare from the centralized light sources.

The Committee concluded its report in the following manner (Proceedings of the Association of Railway Electrical Engineers, Volume XIV):

"In view of conflicting claims for the various systems and lack of reliable comparative data as to their relative merits your committee has deemed it inadvisable to present at this time definite views on the advantages or disadvantages of these various systems of yard lighting. However, based on observations it would appear that the distributed system of floodlighting projectors in which they face along the direction of traffic does
not give as desirable results as the system laid out
to give background illumination with silhouetting
effects and reasonably sharp shadows.

"Your committee would recommend that the study
of this subject be continued with a view of present-
ing in next year's report more complete data on
existing modern yard lighting installations as well
as present definite recommendations as to what
constitutes the best practice as based on further
experience and engineering studies of the problem."

At the time the above report was rendered project-
ors equipped with reflectors larger than sixteen inches in
diameter were not thought practicable; reflectors were avail-
able in mirrored glass or silver-plated copper. Glass re-
fectors were subject to heat cracking and rapid protective
cover deterioration on account of high temperatures produced
by the large lamps. Silver-plated reflectors required fre-
quent polishing and resilvering, since they discolored rapid-
ly from the sulphur gases produced by coal smoke so prevalent
about railway yards.

Projector housings were made of lead-coated sheet
iron or iron castings. Although more expensive the cast
cases were preferable on account of their rust-resisting
qualities and greater mechanical strength. Since the cases
were relatively small in conformance with reflector diameters
it was necessary to provide openings in them to permit air
circulation and avoid excessive internal temperatures which
accelerated reflector failures. From a maintenance standpoint the ventilated cases proved undesirable, since the circulating air deposited a sufficient quantity of dust on the reflectors to require very frequent cleaning if illumination efficiency was to be maintained.

The two types of lamps available in the early stages of floodlighting development were not entirely satisfactory. The so-called "special floodlighting lamp" with its medium concentrated filament in a G-40 bulb provided very good beam characteristics, but its burning life was about four hundred hours while its cost was considerably higher than the standard lamp. The standard lamp in the PS-52 bulb, while moderate in price and rated on a one thousand hour burning basis, was furnished with a comparative large filament not well adapted for floodlighting.

The lamp manufacturers have constantly improved their products, making them better adapted to floodlighting service. The one thousand and fifteen hundred watt special floodlighting lamp now has a rated burning life of eight hundred hours. The filament size has been very materially reduced in the one thousand and fifteen hundred watt standard lamp in the PS-52 bulb. A clamp has been added to the base of this lamp to afford more rigid mechanical support for the bulb. This has been a valuable improvement as it has practically eliminated lamp failures by the bulb loosening from the metal base.
In order to meet the demand of the railroads for a more satisfactory floodlighting projector one manufacturer in 1925 produced a projector equipped with a twenty-three inch diameter mirrored glass reflector in a combination cast and sheet aluminum case. The reflector was moulded to a parabolic shape and polished. On account of prohibitive manufacturing cost it was not ground to an accurate parabola. Because of its greatly increased radiation area it was practicable to use this projector without ventilation. The projector-supporting trunnion and base had been improved to incorporate convenient pre-set stops on both the horizontal and vertical adjustments. The focusing mechanism had been simplified to the present conventional one-way type. When equipped with the medium concentrated filament lamp the distribution angle was approximately ten degrees; when used with the standard lamp in PS-52 bulb the distribution angle was seventeen degrees. Although radically different in design and approximately one hundred per cent more expensive than its predecessors this floodlight was received with general favor by the railways.

Within a year after the projector described above had been placed on the market numerous other manufacturers had developed projectors having similar lighting characteristics.

Several types of reflectors have been tried experimentally with but two types having been placed on the market, these being mirrored glass and chromium plated metal. Mirrored glass reflectors may be divided into two types, one
using crystal glass and the other uranium impregnated glass. Many superiority claims have been made for the uranium impregnated glass reflector. It is said to produce an essentially monochromatic light falling in the yellow-green portion of the spectrum, which enables details to be seen with a lower illumination intensity than with so-called "white" light. The monochromatic yellow-green light is said to reduce largely the glare effect of floodlights without sacrificing any projection efficiency. The crystal glass reflectors are similar to the type described above with the exception that their reflected light is not materially different in color from the light source.

Floodlight manufacturers have experienced considerable difficulty with the large glass reflectors from backing failure and breakage. Improvements have been made constantly in the manufacturing processes of these reflectors until they are now sufficiently perfected to be considered commercially successful.

In comparing chromium-plated metal with silver-plated metal and glass reflectors, it possesses certain points of superiority. The chromium surface is corrosion resistant and does not discolor when subjected to the smoke gases present in a freight yard. The surface is hard enough to withstand cleaning with ordinary abrasive polishing compounds without injury. Obviously it is free from the breakage trouble mentioned in connection with glass reflectors. Chromium has a reflective factor much lower than silver,
which may account for the hesitancy of most floodlight manufacturers in recommending it as a reflecting surface.
In designing a freight yard floodlighting installation the engineer is confronted with many perplexing problems. He must determine tower locations and heights, fix the number and size of projectors required, plan the distribution system, wiring details, etc.

Tower locations must be selected with particular care. If they are not properly located the illumination effect will be unsatisfactory, regardless of the number and type of projectors used; furthermore, the light from improperly located towers may create sufficient objectionable glare to greatly defeat the primary purpose of the installation.

Glare in floodlighting parlance may be defined as "brightness within the field of view, of sufficient intensity and such character as to cause interference with vision and physical discomfort." In the writer's opinion and experience, glare is largely psychological. This has been demonstrated repeatedly by having several men make observations at particular points in floodlighted yards where complaints had been made of objectional glare. From a large number of such complaints that have been called to attention and investigated but one case was found where brightness actually interfered with vision. A further proof that glare complaints are invariably psychological is that a complaint is seldom registered after the lighting system has been in operation ten days.

In order to make a field test of the merits claimed for the uranium impregnated glass reflector versus the crystal glass reflector, an installation was made in which both types
of reflectors were used in approximately equal numbers. Projectors with crystal reflectors were grouped on towers so that their projected light would be in opposition with projected light from towers equipped with uranium impregnated glass reflectors. But one man in addition to the writer realized that an experiment was being tried, which permitted an excellent opportunity to study the glare complaints registered. According to records as many glare complaints were made against the light from the uranium impregnated reflectors as were registered on the opposite type. When looking directly at the light source it was possible to observe a slight difference in the quality of light, but this was not noticeable on the tracks or cars illuminated. This installation was put into service in June, 1926, and was therefore one of the first to utilize the twenty-three inch diameter glass reflector. Unfortunately the reflectors developed protective backing disintegration and all were replaced by the manufacturers after they had been in service two years. The new reflectors were all crystal-clear glass and to date no comments regarding the change in lighting effect have been noted. The results of this test must convince one that the so-called monochromatic yellow-green light from the uranium impregnated glass reflector does not serve the purpose for which it is intended in a freight yard floodlighting project.
It is a most difficult problem to select floodlight projectors on an absolutely sound engineering basis from data that is indisputable. On economic theory one should select the projector that will provide the greatest number of lumens uniformly distributed over the area it is desired to illuminate, assuming all other conditions equal for the lowest cost per effective projected lumen. Obviously the selection cannot be made on the basis of the total or beam efficiencies, since the projector having the lowest cost per equated beam lumen may not have a beam pattern of the proper shape to efficiently light the desired area. Furthermore, the procedure prescribed by the Association of Railway Electrical Engineers in Volume 18 of their proceedings, while intended to make the photometry of floodlights an exact science, has proven to be insufficiently comprehensive. This was demonstrated when an independent laboratory, which is understood to be the best equipped independent laboratory for photometry tests in the United States, was called upon to recheck the test on a particular projector. According to the procedure the check test was run under precisely the same conditions, yet there was a discrepancy of approximately ten per cent in their calculated efficiency with considerable variations in other results. Officials of the Illumination Laboratories of the General Electric Company have advised the writer that they have collaborated with other laboratories in projector tests with results similar to those described above.
Table I is reproduced to show one Electrical Engineer's attempt to select projectors on results of tests made by the Electrical Testing Laboratories of New York on projectors submitted by various manufacturers. To avoid any possible injustice, manufacturers' names have been omitted from the table. The test procedure was as specified by the Association of Railway Electrical Engineers. In calculating costs from the test data, only photometric results were considered. While perhaps of secondary importance, the writer believes the calculations would have been more fair had the depreciation and obsolescence rate been made a variable commensurate with the mechanical construction of the projectors and their ability to withstand railway service.
<table>
<thead>
<tr>
<th>MANUFACTURER</th>
<th>A</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflector diameter</td>
<td>14&quot;</td>
<td>24&quot;</td>
<td>18&quot;</td>
<td>23&quot;</td>
<td>20&quot;</td>
<td>16&quot;</td>
</tr>
<tr>
<td>Beam spread horizontal</td>
<td>22°</td>
<td>14°</td>
<td>30.5°</td>
<td>22°</td>
<td>24°</td>
<td>34°</td>
</tr>
<tr>
<td>Beam spread vertical</td>
<td>12°</td>
<td>10°</td>
<td>15.5°</td>
<td>20°</td>
<td>20°</td>
<td>24°</td>
</tr>
<tr>
<td>Beam candle power</td>
<td>175000</td>
<td>470000</td>
<td>165000</td>
<td>272000</td>
<td>160000</td>
<td>110000</td>
</tr>
<tr>
<td>Beam lumens</td>
<td>4860</td>
<td>5560</td>
<td>7950</td>
<td>7940</td>
<td>8620</td>
<td>6920</td>
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<tr>
<td>Total lumens</td>
<td>13000</td>
<td>14330</td>
<td>14590</td>
<td>14670</td>
<td>14660</td>
<td>12350</td>
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<tr>
<td>Efficiency, beam</td>
<td>23.2%</td>
<td>26.5%</td>
<td>37.8%</td>
<td>37.8%</td>
<td>41.0%</td>
<td>33.0%</td>
</tr>
<tr>
<td>Efficiency, total</td>
<td>63.0%</td>
<td>68.0%</td>
<td>69.5%</td>
<td>70.0%</td>
<td>70.0%</td>
<td>59.0%</td>
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<tr>
<td>Units required</td>
<td>77</td>
<td>68</td>
<td>47</td>
<td>47</td>
<td>44</td>
<td>54</td>
</tr>
<tr>
<td>Cost of projector</td>
<td>$56.00</td>
<td>$124.00</td>
<td>$95.00</td>
<td>$121.40</td>
<td>$94.50</td>
<td>$42.90</td>
</tr>
<tr>
<td>Cost of projectors to produce 376,250 beam lumens</td>
<td>$4312.00</td>
<td>$4312.00</td>
<td>$4465.00</td>
<td>$4158.00</td>
<td>$3316.80</td>
<td></td>
</tr>
<tr>
<td>Cost per 1000 beam lumens</td>
<td>$11.52</td>
<td>$23.30</td>
<td>$11.95</td>
<td>$15.29</td>
<td>$10.97</td>
<td>$6.20</td>
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<tr>
<td>Interest at 5% per year on projector cost</td>
<td>$3.36</td>
<td>$7.44</td>
<td>$5.70</td>
<td>$7.28</td>
<td>$5.67</td>
<td>$2.57</td>
</tr>
<tr>
<td>Depreciation &amp; Obsolescence 10%</td>
<td>$5.60</td>
<td>$12.40</td>
<td>$9.50</td>
<td>$12.14</td>
<td>$9.45</td>
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</tr>
<tr>
<td>Energy cost per year plus 2 lamp renewals</td>
<td>$81.96</td>
<td>$92.84</td>
<td>$88.20</td>
<td>$92.42</td>
<td>$88.12</td>
<td>$79.86</td>
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<tr>
<td>Cost per 1000 beam lumens per year</td>
<td>$16.86</td>
<td>$16.69</td>
<td>$11.09</td>
<td>$11.64</td>
<td>$10.22</td>
<td>$11.54</td>
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<tr>
<td>Operating cost per year</td>
<td>$6310.92</td>
<td>$6233.12</td>
<td>$4145.40</td>
<td>$4343.74</td>
<td>$3877.28</td>
<td>$4312.44</td>
</tr>
<tr>
<td>Operating cost per year evaluated on cost of &quot;D&quot;</td>
<td>$2433.64</td>
<td>$2415.84</td>
<td>$268.12</td>
<td>$466.46</td>
<td>$00.00</td>
<td>$435.16</td>
</tr>
</tbody>
</table>

NOTE: Projector "E" had chromium plated reflector, all others mirrored glass; reflectors "A" uranium impregnated glass.
The Electrical Engineer selected projector "D" for his installation, since the calculations indicated it could be used for the lowest yearly operating cost. A few weeks after the project was completed the writer made a night inspection of the yard. It appeared that the illumination effect would have been materially improved had a combination of "A" twenty-four inch and "D" projectors been used. The twenty-four inch diameter reflector provides a much greater beam candle power, which would have been effective in providing better illumination on the ladder tracks.
In designing the floodlighting installation shown on photograph 11 it was desired to provide a reasonably high illumination intensity throughout the working limits of the yard with the ladder tracks particularly well lighted. Where practicable it was desired to have direct light on both sides of cars, with the shadows moderately soft but well defined. Objectionable glare must be avoided.

To meet the above requirements it was necessary to select tower locations with particular care in order to provide proper illumination on the ladder tracks and avoid a glaring condition on the main line running tracks.

The most interesting and difficult tower to locate was No. 1 at the north end of the yard. Most floodlighting specialists felt that its proper location was approximately one hundred feet east of the point where shown. See photograph 11 of the yard layout. Had the tower been located as suggested, the ladder track would have been as well illuminated as in the present arrangement and undoubtedly more direct lighting on the ground provided in the center portion of the yard. However, this location would have necessitated placing all of the projectors on the south of the tower so that the rays of their main light beams would be parallel with the main line running tracks. This, the writer believed to be very undesirable from a glare standpoint, considering the position of the locomotive engineers handling north-bound passenger trains. The engineers' position is on the right-hand side of the cab, which would have necessitated their
facing the rays of a concentrated light source of eight kilowatts. Furthermore, the road engineer would spend but a few minutes each week in entering or leaving a lighted yard while the switch engine operator, working daily in the yard, is soon accustomed to the floodlighting effect.

For one experienced in yard lighting and the operating problems of a freight yard the location of the balance of the towers was not difficult. For instance, Tower No. 2 was placed to provide a high intensity on the ladder tracks near the yard office marked "Junior", as well as to provide general illumination to the south of the tower and opposing light to soften shadows cast from Tower No. 1, as well as increase the intensity in the north portion of the yard. Light from Tower No. 3 serves the important purpose of illuminating the east side of cars that are within the range of its projectors and of neutralizing the extremely heavy shadows that would have been caused from Towers Nos. 1 and 2. Tower No. 4 is placed so that the ladder track laying to the northeast of it may be brightly illuminated and generally for the illumination of the trackage between it and Towers Nos. 3 and 5. Obviously Tower No. 5 was provided for lighting the extreme south portion of the yard. However, the question may occur to the reader, why was it not placed west of the main line tracks as was Tower No. 1? Had this been done the engineer on a south-bound train would have been required to face the direct beams of the projectors when leaving the yard; furthermore the portion of the yard served was deemed too
narrow from the standpoint of economy to require an additional tower for providing light on both sides of cars, so it was desirable to provide as much direct illumination between cars as practicable.

Due to the importance of Tower No. 1 from a yard operating standpoint, and the large number of projectors it carried facing in one direction, it was economically justifiable to fix its height at one hundred twenty feet. Since the other towers were so located that it was not necessary to project light more than two thousand feet from them, their height was fixed at one hundred feet.

In the selection of towers the market was searched for the one best adapted to certain requirements. Fundamentally, of course, the tower must meet requirements of mechanical stability. It should be safe and easy to climb to facilitate inspection and maintenance. To meet these stipulations the ladder should be inside the structure and mounted with a slight cant. Platforms should be provided for a resting place during ascent. The basket floor should have a trap door covering the entrance hatch and its side members arranged to nullify the possibility of a maintenance man falling. The last requirement may sound absurd to the layman, but it must be borne in mind that burned-out lamps must be replaced promptly, even if weather conditions are unfavorable. The tower selected is best illustrated in photograph No. 7. This picture shows Tower No. 4 located near Twenty-seventh Street.
In designing tower foundations a wind load of thirty pounds per square foot on twice the exposed area of one side of the tower was assumed, plus a concentrated exposed area of eighty-seven and four-tenths square feet at the tower top, representing the maximum area of projectors mounted thereon. The overturning moment on the one hundred foot towers, as calculated, was six hundred nineteen thousand and nine hundred pounds, and on the one hundred twenty foot tower was eight hundred twenty-five thousand pounds.

The direct loads, including foundations supported by the soil, was respectively two hundred fifty-eight thousand one hundred pounds and two hundred ninety-seven thousand two hundred pounds. Maximum soil pressures were two thousand seventy pounds per square foot and two thousand forty pounds per square foot. The foundations for the one hundred foot towers required fifty-three and eight-tenths yards of concrete and the one hundred twenty foot tower, sixty-two and five-tenths yards.

To avoid the possibility of tower or foundations being damaged by lightning or becoming charged through faulty conductor insulation, each was grounded in the following manner: In each corner of the foundation excavations a nine foot length of copper plated ground rod was driven. These were connected to corner members of the towers by means of five hundred thousand circular mil stranded copper cable brought up outside of the concrete foundations. The latter precaution was taken to avoid the possibility of splitting the concrete in dissipating a severe lightning discharge.
In selecting projectors those offered by three manufacturers whose equipment met the requirements were considered. Two companies submitted projectors equipped with mirrored glass reflectors, while the other offered chromium plated metal reflectors. Based on the writer's satisfactory experience with mirrored glass reflectors and the large difference in reflective efficiency it was decided to use glass reflectors. The optical characteristics of the two remaining types of projectors under consideration were similar and each capable of providing the desired lighting effect. The one chosen was superior mechanically. It included such features as, all-cast aluminum case, weather-proof terminal box, self-aligning hinges and daylight focusing device. The daylight focusing device is a very desirable feature, since without the use of such a device it is necessary to focus the lamps at night, which procedure is indicated each time the unit is relamped.

In this installation each projector was selected for the particular area it was required to illuminate. This may be illustrated by analyzing the equipment mounted on Tower No. 1. (See photograph of yard map II) South from the tower within a distance of eleven hundred feet the area is illuminated with two twenty-inch projectors equipped with one thousand watt lamps in PS-52 bulbs. For the succeeding six hundred feet one twenty-four inch projector equipped with a fifteen hundred watt lamp in PS-52 bulb having its beam center focused on the ladder track is used to gain a high
intensity there, but, on account of its relatively broad
distribution angle it furnishes ample illumination the full
width of the yard. The remaining one thousand lineal feet
of trackage, receiving light from Tower No. 1, is uniformly
covered with a high illumination intensity by three fifteen
hundred watt, G-40 bulb special floodlighting lamps in twenty-
four inch projectors. By taking advantage of the narrow
distribution angle afforded by this arrangement the projected
light was confined to the working area of the yard. Had
standard lamps been used, more lumens would have been pro-
jected but, because of the wider distribution angle, a large
per cent of the projected light would have been wasted on
non-working areas.

In studying the projector arrangement on Tower No. 2
it will be observed that, since the projection distance from
it does not exceed two thousand feet, only standard lamps
were used. However, on two projectors horizontal spread
lenses were indicated to provide greater beam spread and
ground coverage.

Comparisons similar to the foregoing could be drawn
for the entire installation, but since the details are clear-
y shown on the photostat, further details will not be covered
herein.

To one familiar with the ramification of railway
maintenance the making of lamp renewals would at first glance
seem undesirably complicated, since any one of four types of
lamps may have failed. This problem, however, was readily
solved by mounting a metal box on each tower in which is kept
one spare lamp of each type used on that particular tower, also extra fuses and cleaning equipment.

A two thousand three hundred-volt, three phase, sixty cycle primary circuit connected to an oil circuit breaker mounted on the switchboard in the Railway Company's power house serves exclusively the floodlighting load. Therefore, the responsibility for turning the lights on and off rests on the switchboard attendant. The lighting load is balanced as nearly as practicable on each of the three phases of the circuit. A transformer equipped with primary taps for voltage adjustment is provided near each tower structure for reducing the voltage to approximately one hundred twenty volts. The conventional three-wire Edison secondary connection was used, and the three-wire circuit extended from the transformer through a weatherproof fused switch mounted near the lower tower landing to a junction box in the tower basket. The vertical risers were supported in the junction box to relieve the strain on the soldered connections. The relatively large secondary conductors were extended around the circumference of the basket. These bus conductors were tapped at convenient intervals and connections made to receptacles for connection to the individual projectors through a fused plug and flexible two conductor cable.

In designing the wiring system particular care was taken to avoid excessive voltage drop in the secondary wiring. Tests indicated that the voltage drop at full load between the transformers and projectors did not exceed one and
one-half volts. To gain maximum lumen output without reducing the lamp life the full load voltage was adjusted to approximately one per cent plus or minus of rated lamp voltage.

From a study of the night view photographs it will be observed that sufficient lighting intensity was provided without objectionable glare to greatly facilitate night switching of equipment.