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CIVIL AERONAUTICS ADMINISTRATION

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AIRPORT LIGHTING

CIVIL AERONAUTICS BULLETIN No. 10

REVISED MARCH 1, 1941

UNITED STATES DEPARTMENT OF COMMERCE
JESSE H. JONES, Secretary

CIVIL AERONAUTICS ADMINISTRATION
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AIRPORT LIGHTING

INTRODUCTION

In this bulletin an effort is made to give a comprehensive picture of the lighting systems of airports, according to present day standards, and to explain the importance and function of each unit which goes to make up the complete lighting system.

In many landing fields, all types of lights and lighting units are not necessary, but there should be uniformity in those used, for the very evident advantage it gives the pilot, who thus can be familiar with the meaning and interpretation of the lighting on any airport he may visit.

Airports vary so widely that each airport will present a separate problem. The size and shape of an airport, the terrain, the amount of traffic, the types of aircraft to be used, and the nature of the soil or runway surface, all will play important parts in affecting the number, type, and extent of the lights which should be used.

In discussing airport lighting equipment, the functions of the lights can be considered as falling into three divisions. These are:

1. Airport identification lights.
2. Aids to landing or taking off.
3. Miscellaneous lights, not coming under divisions 1 or 2.

It will be seen that some of the lights have functions falling into more than one division and must be considered as having a double function. The classification by divisions is as follows:

Type of light:	*Divisions*
1. Airport beacon	1
2. Illuminated wind-direction indicator	2
3. Boundary lights	1, 2
4. Range lights	2
5. Contact lights	2
6. Approach lights	2
7. Obstruction lights	2
8. Roof marking	1
9. Ceiling projector	3
10. Landing area floodlights	2
11. Apron and exterior floodlighting	2, 3
12. Interior lighting	3
13. Temporary marking	2

In addition to the above types of lighting, various other matters affecting lighting, such as the emergency power supply, wiring standards, operation, and costs, will be discussed.

The division listed as No. 1, or identification lights, has as its primary function the indication of the location of a lighted landing field.

The lighting units under division 2, or aids, serve to aid the pilot in landing and taking-off from the field. It will be noticed that certain types of lights fall both in this division and in division 1, performing a double function of helping to identify the field and aiding the pilot in maneuvering his plane into and out of the landing area.

AIRPORT BEACON

The first under the heading of "Identification lights" is the airport beacon. This is a powerful beam light, visible for miles to the pilot of an airplane and telling him that there is a lighted field available.

The airport beacon serves air traffic in much the same way that lighthouse lights serve marine traffic. There is further analogy in that the basic principles are the same in each, but the aeronautical beacon offers peculiar problems which the nautical does not.

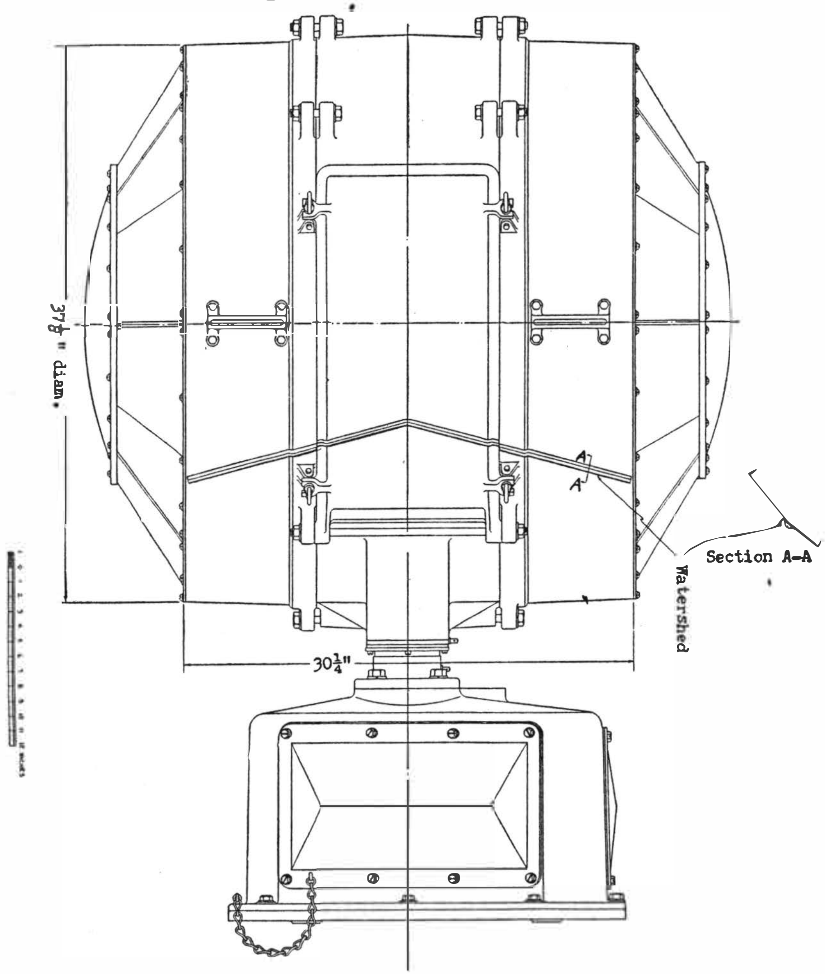
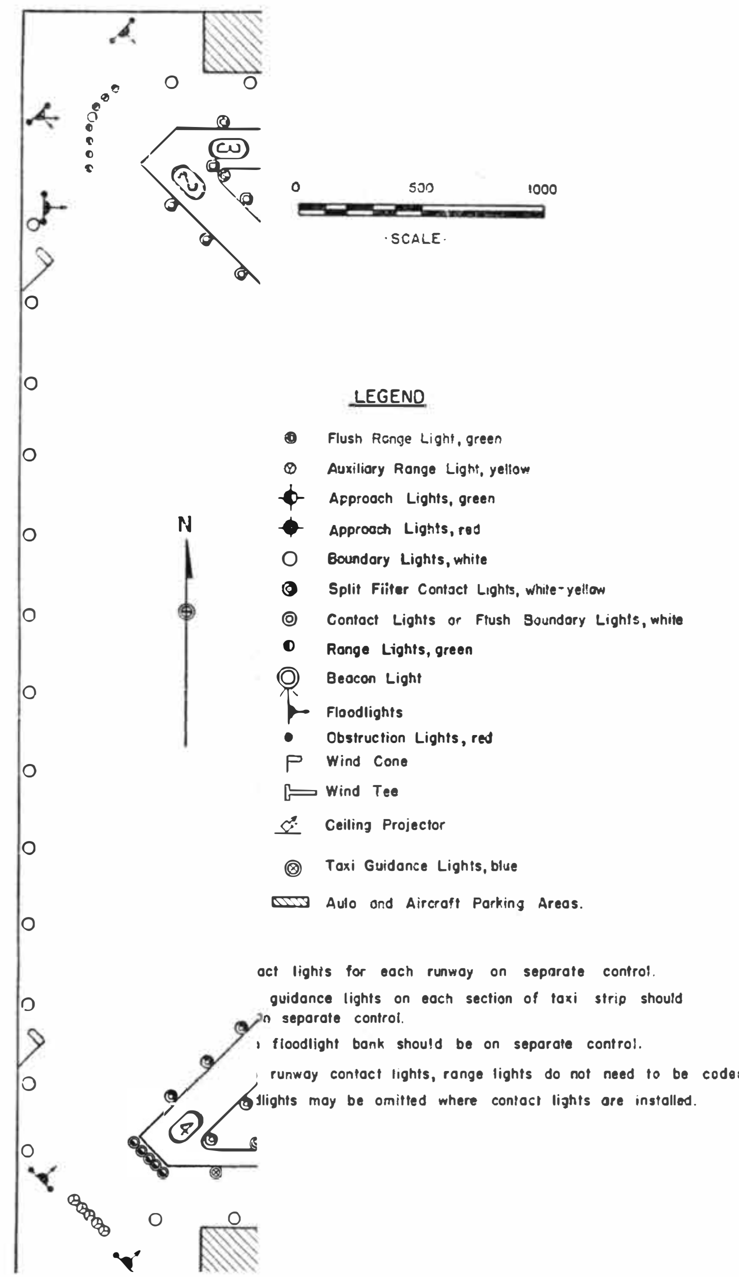


Figure 2.—Outline of 36-inch double-end rotating beacon.

It must be remembered that the airplane travels through a three-dimensional medium at speeds which are very great when compared with that of nautical vessels. Also, where the nautical light is more or less isolated from other lights, the airport beacon may be situated in an area dotted with myriads of lights of varying intensity and arrangement. The airport beacon, therefore, must be distinctive to enable the pilot to locate it and identify it immediately and without error.



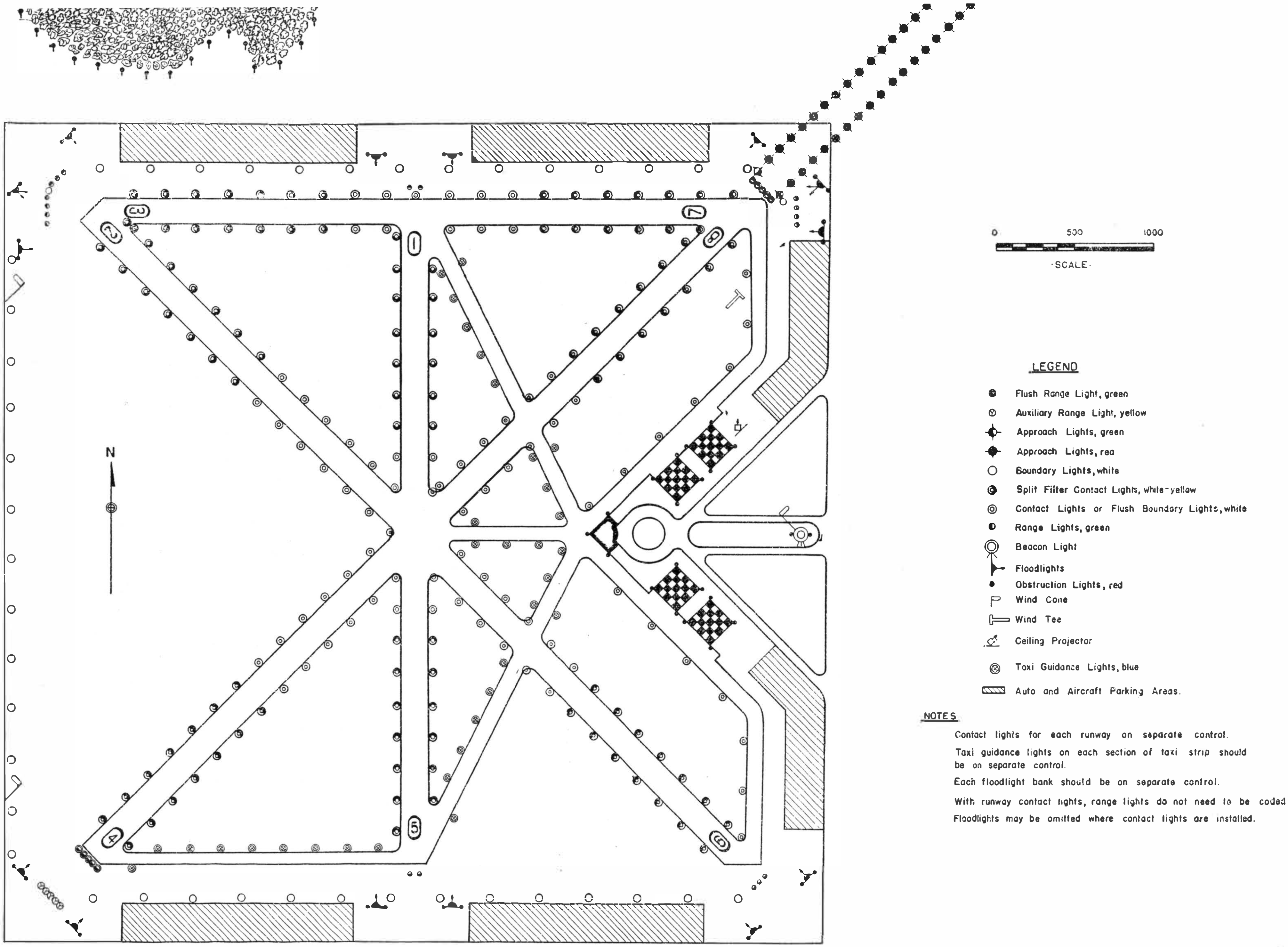


Figure 1.—Typical plan for an airport-lighting installation.

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Under the provisions of the Civil Aeronautics Act of 1938, beacons are given ratings by the Administration as "aeronautical lights," in that they are aids to air navigation. Reports of all new beacons and all changes of beacon characteristics should be made to the Civil Aeronautics Administration, Washington, D. C., on forms which will be supplied upon request.

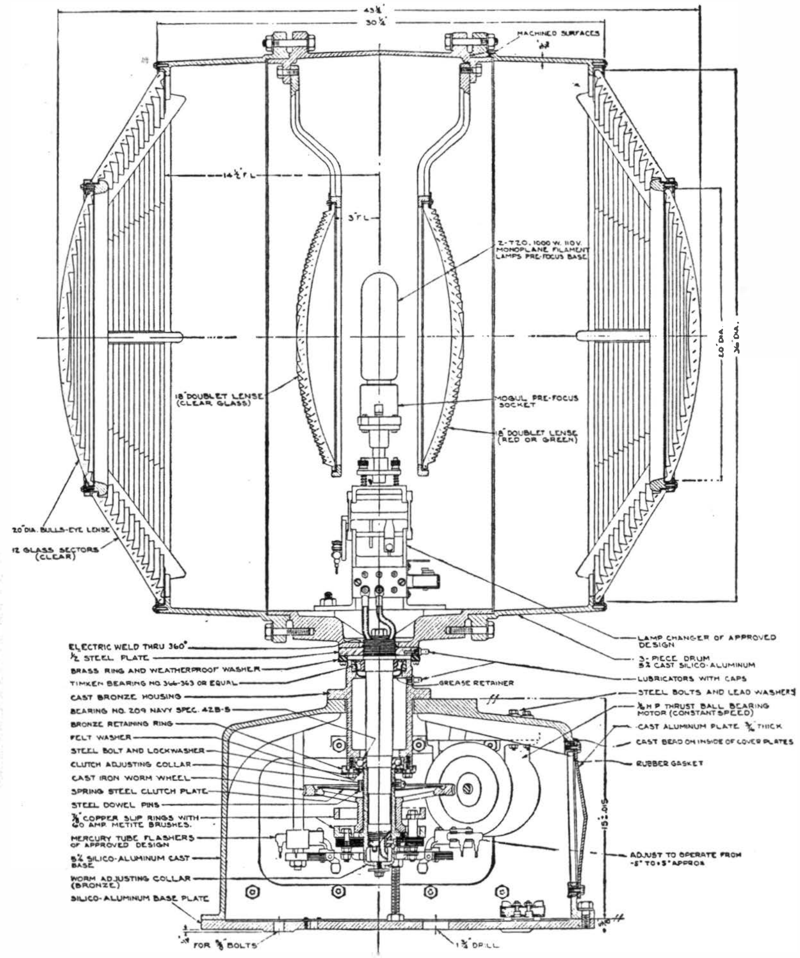


Figure 3.—Section through 36-inch rotating beacon.

The beacon is designed to give a definite periodic flash, or sequence of flashes, visible to a pilot from any angle of approach. The colors, sequence of colors, frequency, intensity, duration, and direction of the flash or flashes are the controllable factors, and are factors which must be standardized.

The standards adopted for rotating airport beacons are as follows:

There shall be a clear main flash, followed by a green auxiliary flash. The main flash shall occur at 10-second intervals, and the auxiliary flash shall follow the main flash by either 2.5 or 5.0 seconds. The main flash shall have a beam intensity of at least 1,000,000 candlepower, and

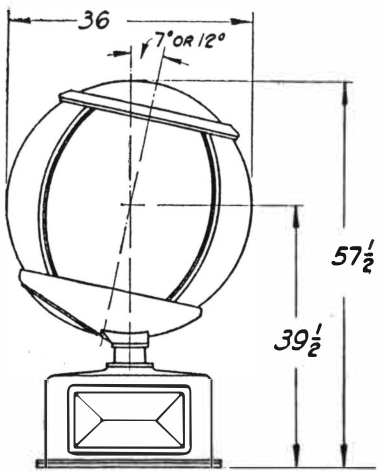


Figure 4.—Thirty-six-inch spherical rotating beacon.

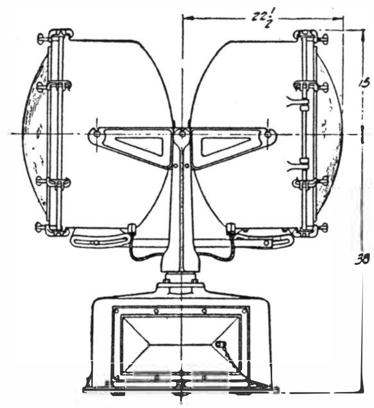


Figure 5.—Twenty-four-inch double-end rotating beacon.

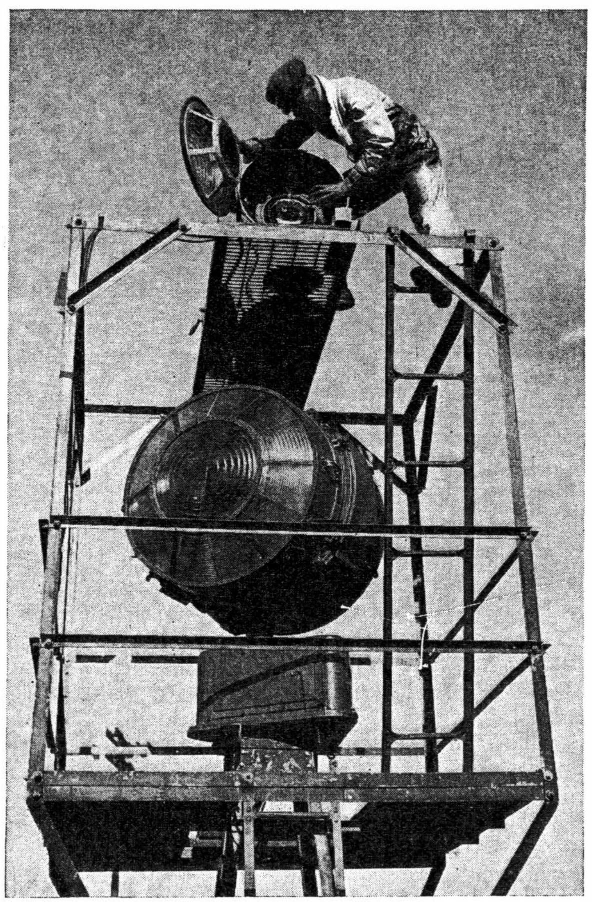


Figure 6.—Close-up of 36-inch double-end beacon with course light above it.

the auxiliary flash of at least 200,000 candlepower. These flashes shall have a minimum duration of 0.25 seconds, and shall be directed at an angle of from 1¼° to 3° above the horizontal.

Other types and characteristics of beacons may be adopted and approved for airport use. For such types, refer to the Civil Aeronautics Administration.

The beacon normally consists of a searchlight-type projector mounted on a pivot and rotated by a motor. The projector has a lamp, a stand-by lamp in an automatic changer, and an optical system consisting of a reflector in the case of a single-end projector, and a system of lenses in the case of a double-end projector. Two single-end projectors are frequently mounted back-to-back, and rotated as a single unit. A beacon normally weighs about 500 pounds.

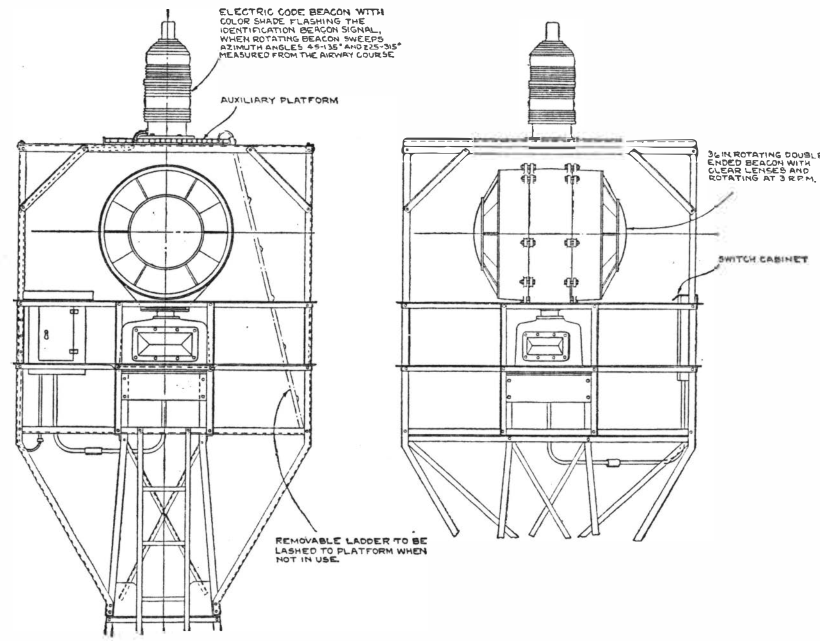


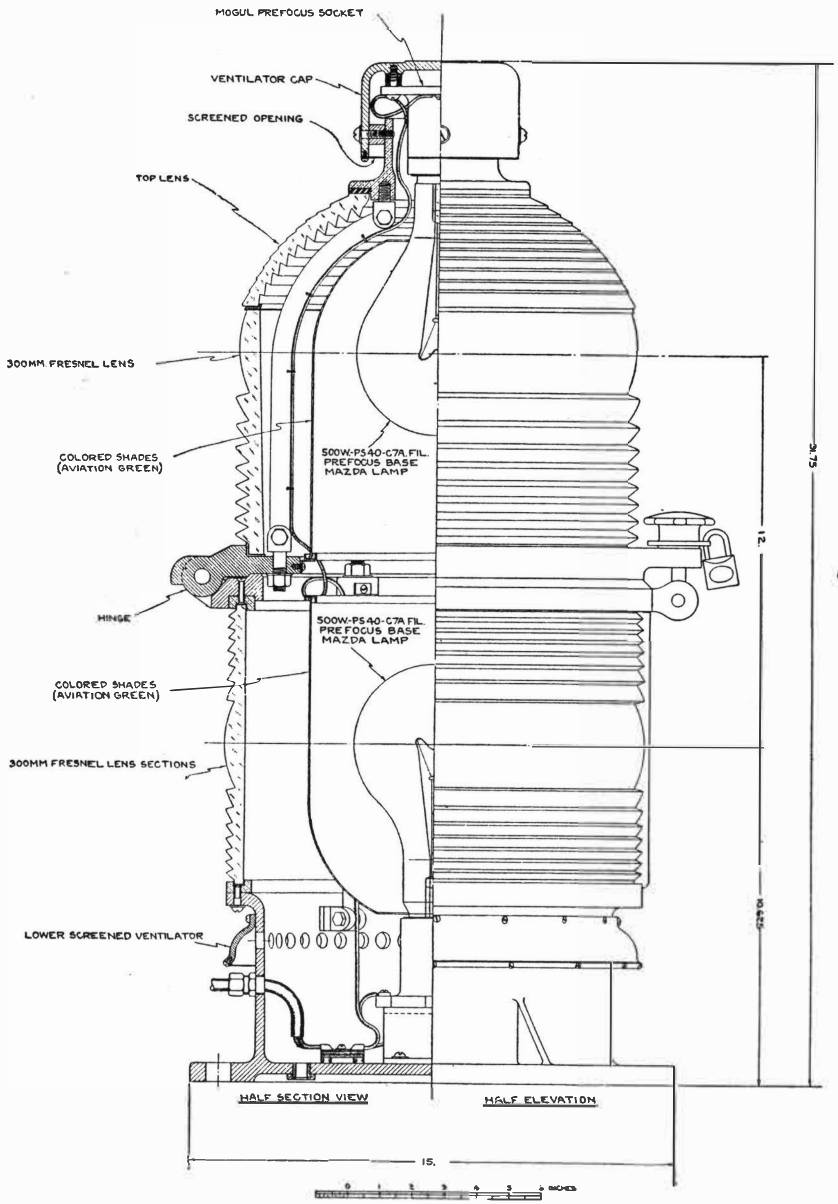
Figure 7.—A suggested method of mounting a rotating beacon and an auxiliary airport beacon to permit unobstructed view of both lights.

The location of the beacon should be established in consultation with the Civil Aeronautics Administration, as there are a number of factors, such as proximity to a lighted airway, to other airports, terrain around the airport, preference of approaches, possible confusion with marine or other lights, etc., to be considered. In general, the beacon should be as near as possible to the landing area, should always be in unobstructed sight from the airport, and should form as little added obstruction as possible.

Where beacons serve two functions, as a unit along an airway as well as an airport, or where the terrain makes it advisable, it sometimes is necessary to locate a beacon off the airport. If the beacon is so located, there should always be a green, flashing, auxiliary beacon, or code beacon located at the airport, and in most cases, a course light on the beacon, directed toward the airport. In some cases, code beacons are installed on airports in addition to standard rotating beacons.

Beacons should be mounted on towers, set either on the ground, or on top of one of the buildings. In any case, the beacon should be at least 20 feet above any building or surrounding structure. The towers are generally of steel, and they should be provided with a platform from which the beacon can be serviced. This platform should be at least 6 feet square.

The transformer, distribution cabinet for the circuits to the beacon lamps, the motor, obstruction lights, etc., may be mounted in a housing in the base of the tower, or on the platform.



The beacon lamps are generally either 115 or 30 volts, the lower voltage lamps with the more concentrated filament giving a more concentrated beam of higher candlepower. These lamps are generally 500 watts for each projector of a single-end beacon, and 1,000 or 1,500 watts for a double-end beacon.

The beacon is generally fed by a 115-volt circuit directly from the control panel. If the distance is excessive, a high-voltage circuit is used, and a transformer installed at the tower. The circuit is generally run in lead-covered wire in an underground duct.

An auxiliary code beacon is a lantern, equipped with two drum-type Fresnel lenses, designed to throw a green light in all horizontal directions. The light is required to have a minimum beam intensity of 5,000 candlepower, which can be produced by a 500-watt lamp in each lens, the two lamps burning simultaneously. The code beacon is flashed in dots and dashes to give an identifying code letter or letters in International Morse Code. The identifying code signals are assigned by the Civil Aeronautics Administration to prevent duplication. The code flasher is motor-driven, and is incorporated in the base of a rotating beacon, if the code beacon and rotating beacon are located adjacent to each other. All such flashers must be designed to give a minimum of radio interference.

The airport beacon and the auxiliary beacon should burn from sundown to sunup. They may be controlled manually, but automatic control, either by an astronomic time clock or by a photoelectric relay, is recommended.

For detailed specifications on beacons and beacon light characteristics, refer to the Standard Airport Lighting Specifications, issued by the Civil Aeronautics Administration.

ILLUMINATED WIND-DIRECTION INDICATOR

The first consideration with wind indicators is that they give the true direction of the wind at all times, and next, that they should be readily visible at all times to aircraft approaching from any direction. There are two basic types of illuminated wind-direction indicator in general use: The illuminated wind cone and the illuminated wind **T**.

The illuminated wind cone is a device of metal and open weave fabric which is filled by the wind and streams out with the large end of the cone, by which it is anchored, facing the direction of the wind.

The cone should be at least 3 feet in diameter at the large end by 12 feet in length. The first 3 feet, approximately, may be of metal and the rest fabric.

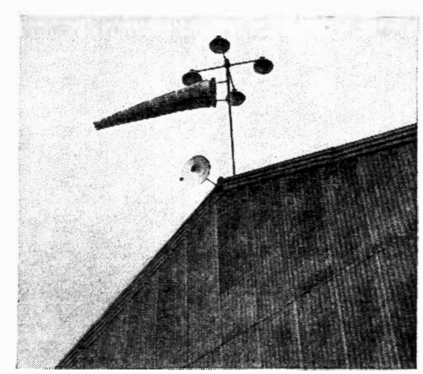


Figure 9.—View showing externally lighted wind cone.

The lights for the wind cone are four in number, mounted above the wind cone in reflectors. They may be mounted horizontally or at an angle. These lamps should be at least 100 or 150 watts.

There is also an internally illuminated wind cone which is lighted by a lamp or lamps placed in a reflector system inside the fabric cone, close to the swivel, making it visible by light transmitted through the fabric. The total lamp wattage in this case should be not less than 200. There should be an obstruction light mounted above a wind cone, unless the cone is protected by adjacent obstruction lights.

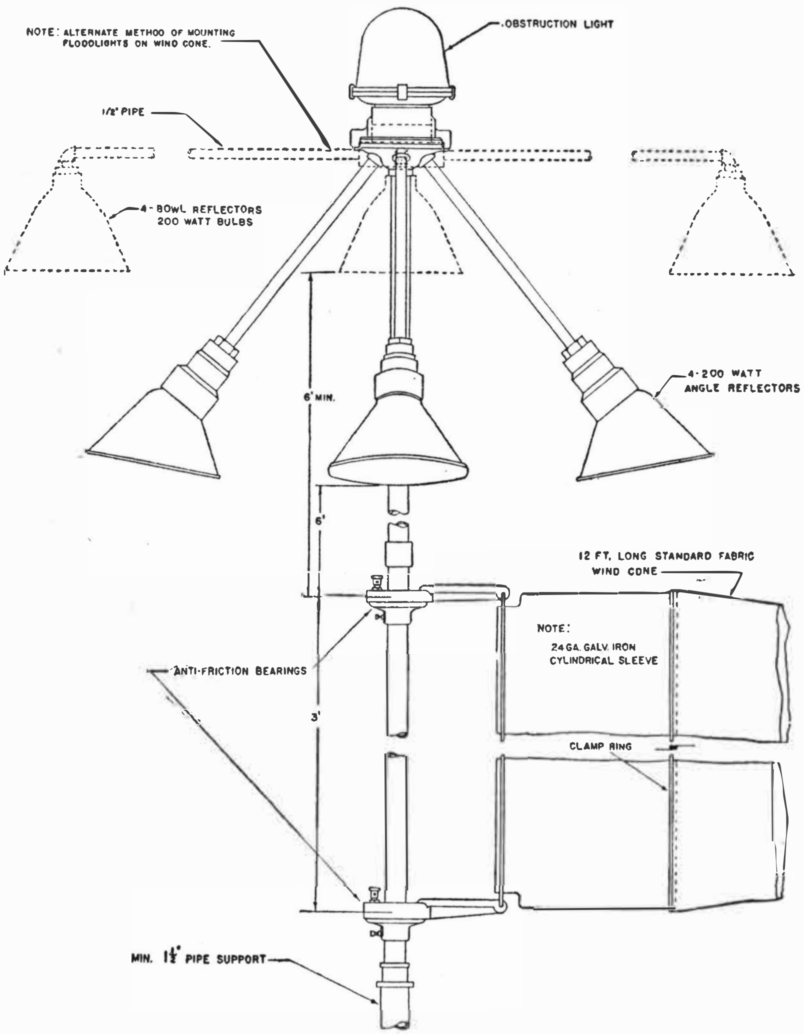


Figure 10.—Drawing of externally lighted wind cone.

The illuminated wind **T** is a **T**-shaped body, mounted on a pivot so that it rotates with the wind. The position indicates the direction of the wind, as the cross member of the **T** always faces the direction from which the wind blows. The **T** appears somewhat like an airplane on the ground and headed into the wind. The **T** should be not less than 18 feet long with a 12-foot cross member, and should be painted international orange. By alining his airplane with the **T**, a pilot assures himself of landing directly into the wind.

The wind **T** should be designed so that it is balanced, and swings freely about the pivot.

Wind **T**'s should be illuminated, either by outlining the **T** with 25-watt incandescent lamps, in green cover glasses, or by gaseous discharge tubes. If a gaseous discharge tube is used, a green color

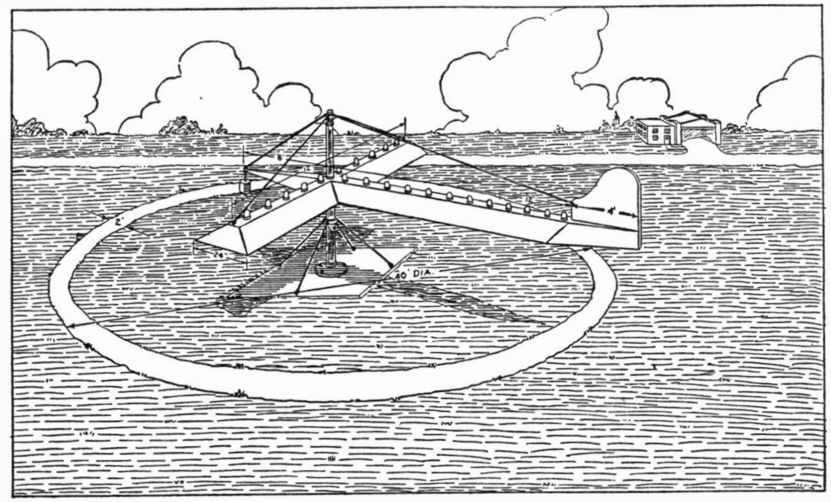


Figure 11.—Suggested design for illuminated wind T, using 25-watt incandescent lamps with green weatherproof hoods spaced on 12-inch centers. Note dimensions shown on sketch.

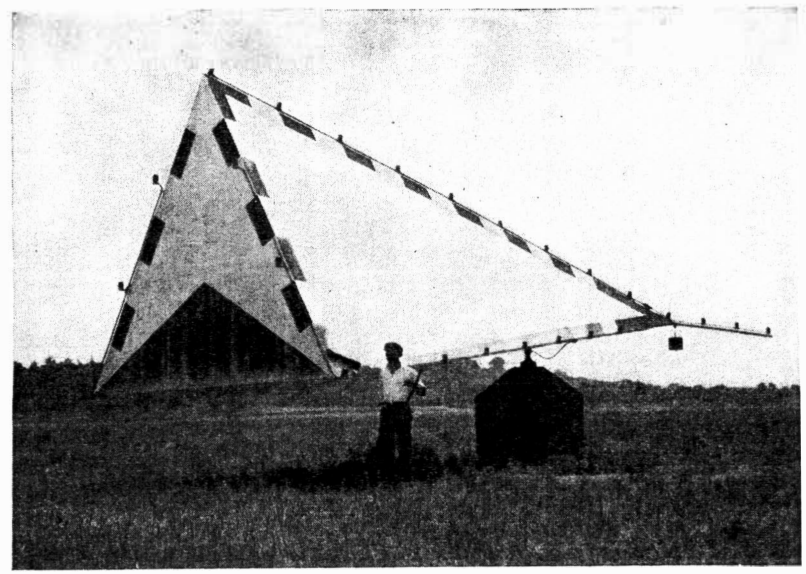


Figure 12.—Illuminated tetrahedron wind indicator.

NOTE.—Gaseous discharge tubes are frequently not satisfactory for operation at temperatures approaching zero Fahrenheit. Owners should determine that suitable tubes are available which will operate and retain the specified color in such low temperatures as are to be expected at the airport where the instalhas been found to give the most satisfactory results, and is the only color approved. Such tubing should be in duplicate, with duplicate transformers. The wind **T** may be fed from the boundary circuit or from a separate circuit, whichever is more convenient.

A **T** should be so located that it does not form an obstruction on the landing surface, so it is generally located near the line of the boundary circuit. Unless it is mounted on the roof it should be sufficiently remote from buildings to give a true indication of wind direction.

Where a wind **T** is mounted on the ground, a 40-foot circular band of white stone, or concrete, 4 feet wide, should be installed around it. The circle helps to identify the **T** from the air.

There is an additional type of wind indicator, which is used largely on Army fields. This indicator is in the form of an elongated tetrahedron, about 36 feet long and 15 feet along the equilateral sides of the base. This tetrahedron is pivoted to swing freely in the wind, and assumes a position with the point up wind. It is lighted with incandescent lamps along the edges, with one side green and the other side red.

Wind **T**'s are made sometimes so they will return to a definite bearing when the wind drops below about 5 miles per hour. Such designs should not be gravity operated, as such operation might cause the **T** to assume an intermediate attitude, showing neither the true wind direction nor the desired no-wind position.

Smoke generators also are used as wind indicators and give a satisfactory indication of the direction and nature of the wind.

BOUNDARY LIGHTS AND RANGE LIGHTS

As the name implies, boundary lights outline the entire available landing area of the airport. These lights are spaced not more than 300 feet apart and are served by an underground distribution system. It is important that this 300-foot interval be maintained, as it gives the pilot a definite picture of the size and shape of the field. Ten such lights along one side will indicate that the field is approximately 2,700 feet long.

These lights, in conjunction with the airport beacon, serve to identify the field. A pilot can often see this blank space outlined when in a heavily lighted district and, used with the beacon, it is a double safety measure in the location and identification of a landing field. In marking the outlines of a landing area and in order to have it readily distinguishable from the air, a boundary light should be located at every corner, and the lights run as nearly as possible in straight lines between them. As few corners and curves as possible should be used.

Clear lights are used as boundary lights, and green range lights are set in the line of the boundary lights, to mark the ends of runways or favorable landing directions. These range lights should be arranged in groups, with the same number of lights at both ends of the same runway. These groups should consist of different numbers for each runway, with the largest number marking the most important runway. Range lights should be spaced 50 feet apart in the groups, and each group set at right angle to the axis of its runway.

Boundary and range lights are normally mounted on sheet metal cones, so that the light is approximately 30 to 36 inches above ground

These cones should be proportioned and painted as indicated in figure 13.

Where a runway has hard surfacing which stops more than 300 feet inside the line of the boundary, the range lights should be moved into within 50 feet of the end of the paving, and flush-type units should be used. As these lights have little visibility from the ground, and have no daytime visibility, there should be installed a similar group of auxiliary range lights in the boundary circuit. These auxiliary range lights are mounted on standard range cones, but are equipped with yellow globes instead of green, to warn the pilot of

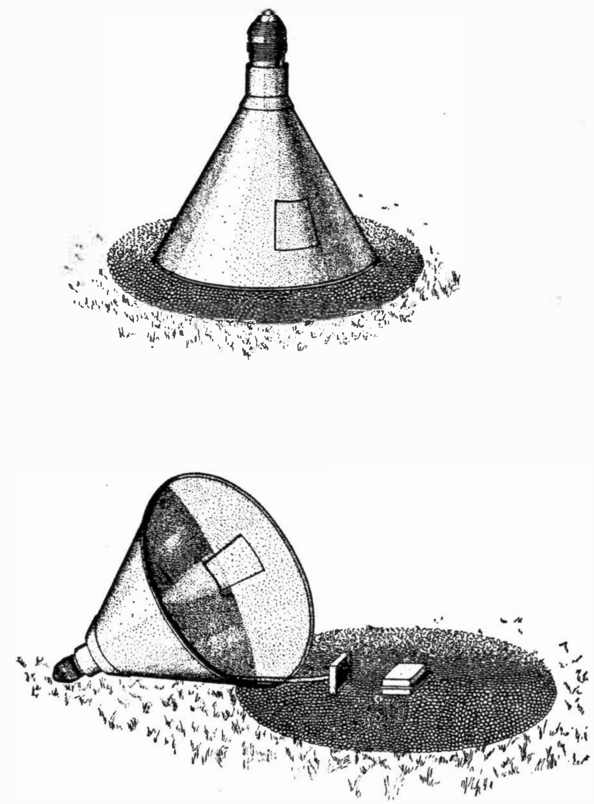


Figure 13.—Drawing showing turn-over type of series boundary unit.

the unpaved area. In some instances flush boundary light units are used where it is desired to continue a line of lights past an apron or taxiing area.

No obstructions should be allowed inside the area marked by the boundary lights.

Where an airport boundary fence or a dike parallels a line of boundary lights, the lights should be placed at least 10 feet inside the fence or dike, or if necessary, more than 10 feet, so that a glide angle of 1-in-20, taken through the center of the lights, will clear the top of the fence or dike. This does not apply to a line of poles, or a noncontinuous obstruction.

Where a group of flush range lights is fed from a multiple boundary circuit, the units must be multiple, and an isolating transformer for the group is recommended.

Range and boundary cones should be set on a circle of concrete, crushed stone or other granular material, which should be kept whitewashed or painted white. This adds to the visibility from the air, keeps weeds and grass from growing up around the cone, and simplifies the maintenance.

Cones are generally made of light sheet metal. For series circuits where the units come within 300 feet of the center line of a runway, the cones should be of the turn-over type, with a waterproof disconnect plug and receptacle at the ground, and a flexible-cable connection from the plug to the light fitting. An access door should be provided in the side of the cone, to allow the plug to be replaced. This type of cone also should be used for all series-boundary units

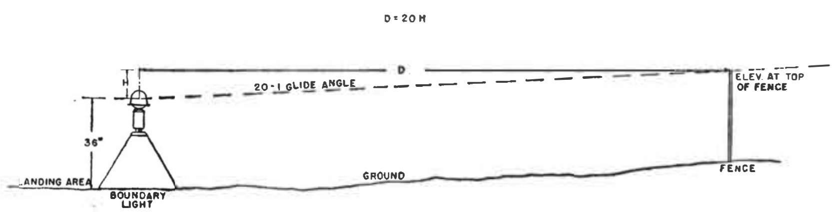


Figure 14.—Sketch showing distance from boundary light to fence.

Elevation of top of fence above landing area at boundary light	Distance boundary light should be located from fence	Elevation of top of fence above landing area at boundary light	Distance boundary light should be located from fence
Feet	*Feet*	*Feet*	*Feet*
4	20	10	140
5	40	11	160
6	60	12	180
7	80	13	200
8	100	14	220
9	120	15	240

on an all-way landing field. Turn-over types of cones rest on the base, and fixed types of cones, which are used for multiple circuits, and for series circuits where remote from runways, are supported from and braced to a conduit, run up from an underground junction box to the lamp fixture.

The lighting fixture should be mounted securely on the top of the cone. This fixture has a lamp socket and terminals, and provides threads for holding an enclosing globe. The fixture should be of nonferrous metal, or should be treated to prevent rust, and should provide for easy removal of the globe for lamp replacements. It is advisable to design the fixture so that the globe can be removed in its holder without unscrewing, as this will reduce breakage. For series lamps, a film cut-out socket is required.

Globes should be of prismatic glass, and designed to offer as little opportunity for retaining dust and dirt as possible. It is found that a 15-watt lamp, properly located in a prismatic globe, is more effective than a 25- or 40-watt lamp in a plain globe.

With prismatic globes a 15-watt multiple lamp or a 320-lumen series lamp should be used for boundary lights, and a 60-watt multiple lamp or a 1,000-lumen series lamp, in a green globe, for range lights.

Normally boundary and range lights are fed by the same circuit. This circuit may be either series or multiple, depending on the load and the length of circuit. Series circuits should be 6.6 amperes, and multiple circuits may be 2-wire 120-volts, 3 wire 115-230 volts, or higher voltage, with individual transformers at each unit. With a multiple circuit, the voltage drop should be limited to 5 percent. Since this involves added copper costs, circuits longer than 12,000 feet are generally made series. Multiple circuits can be fed from both ends, in the form of a ring, or can be fed by tap feeders. Each unit on a series circuit should be provided with a film cut-out, and

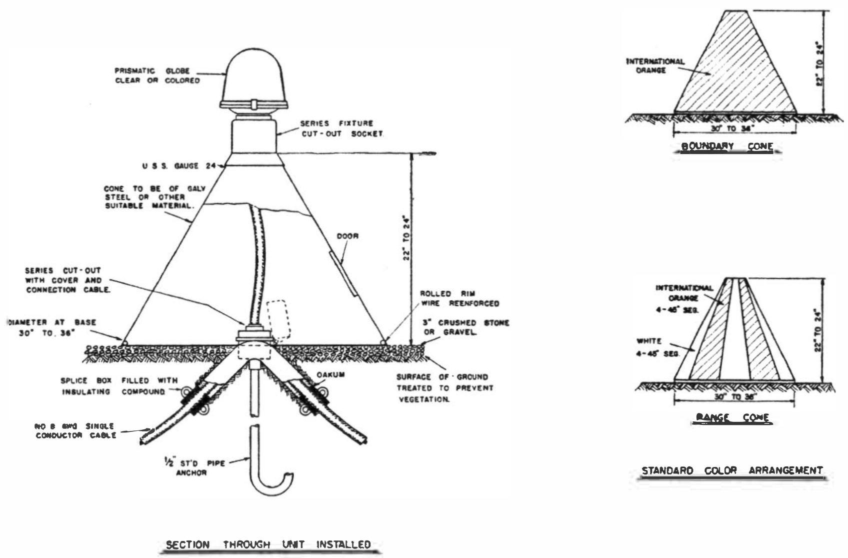


Figure 15.—Series disconnecting range and boundary light unit.

any branch circuits fed from this circuit should be fed from a series to series or a series to multiple transformer, mounted in compound, and installed under the ground.

The only auxiliary circuits normally fed from the boundary circuit are obstruction lights and wind indicator. Floodlights, beacons, ceiling projectors, and such lights should be on separate circuits.

The series circuit is fed by a series regulator, generally at or near the administration building. This regulator should be protected by a series relay, to open the primary if a secondary open circuit occurs. It also should be controlled by a remote control electric contactor, operated from the control point.

Boundary circuits are generally run by means of underground cable. This should be parkway cable, lead-covered and armored with flat steel tape. In some instances where soil conditions are unfavorable for steel armor, nonmetallic armor or rubber-sheathed cables should be used.

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Insulation should be in conformance with Federal Specification JC–106,[1] and the lead and armored cable should conform to Federal Specification JC–121.[1] For nonmetallic armor, a satisfactory specification is available in the Civil Aeronautics Administration Standard Airport Lighting Specifications and such cables should be specified in preference to commercial types of cable. For series circuits, the insulation should be sufficient to protect the cable against the full open circuit voltage of the regulator. All splices should be in approved underground splice boxes.

Detailed specifications of all equipment are available in the Civil Aeronautics Administration Standard Airport Lighting Specifications.

CONTACT LIGHTS

Contact lights are flush marker lights which are installed along the runways to assist pilots in effecting landings and take-offs.

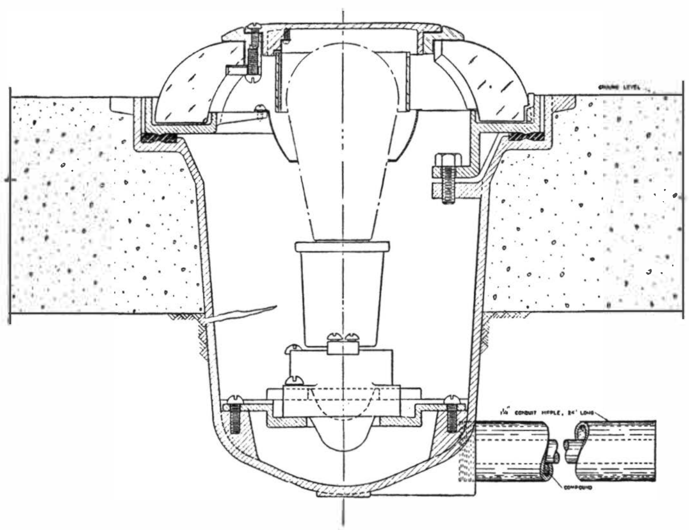

Figure 16.—Section through flush-type marker or contact light.

These light units consist of heavy cast housings, which are set in concrete blocks, flush with the surface of the ground. These housings mount sockets, lamps, and reflectors, and are provided with bolted watertight covers, which mount a relamping plate and a lens. The top of the cover should not project more than 2 inches above the ground level. The housings are provided with tapped hubs, and underground cable connections are made through 1¼-inch conduit nipples, which normally are long enough to extend beyond the edges of the 4-foot concrete block. The cable entrances and the nipples should be poured full of pothead compound, to seal against the entrance of water. (See figs. 16, 17, and 18.)

Flush marker lights are of two types, one with symmetrical horizontal distribution, and the other with asymmetrical distribution, and with the light largely concentrated in two powerful horizontal

[1] Obtainable from the Government Printing Office, Washington, D. C. Price, 5 cents.

beams. The symmetrical type is used for flush boundary units, and the asymmetrical type is used for flush contact lights, flush range lights, and flush runway-traffic controls.

Contact lights should be installed along the edges of the runways and approximately 200 feet on centers, as shown in figure 1. The

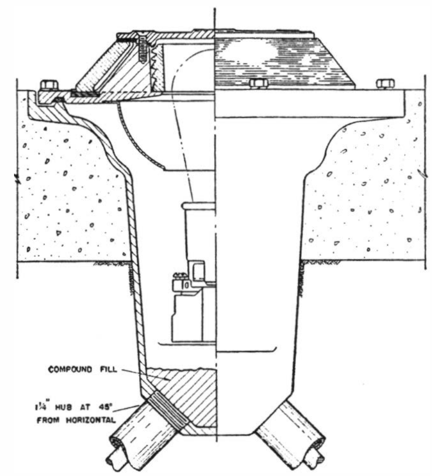

Figure 17.—Section through flush-type marker or contact light.

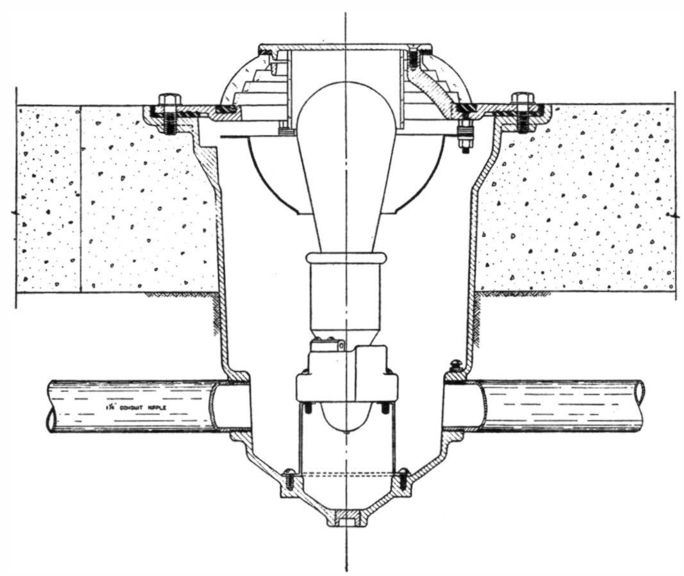

Figure 18.—Section through flush-type marker or contact light.

lights are arranged in pairs, i. e., each opposite another on the other side of the runway. Where other runways intersect, the lights which normally would occur in the runway surfaces are omitted. The contact lights on each runway are controlled separately and only one runway at a time is illuminated.

The color of the contact lights is white all along the runway, with the exception of the final 1,500 feet, which should be yellow. As this same condition is required for operations in both directions, it is necessary to install split filters in the units in the final 1,500 feet, which show yellow in one direction and white in the other. This condition also can be accomplished by using duplicate white and yellow units on the ends, and putting them on separate controls.

Series circuits normally are used for contact lights, so that the grounding of one or more units will not put the entire circuit out of service. This same result can be achieved by the use of isolating transformers for each unit.

The contact lights should be on a separate circuit for each runway, with a separate control, as only one runway is lighted at a time, and then only when an airplane is making a landing. These circuits are fed from a series regulator, as described for the boundary circuit, but one regulator may be installed to feed several different runways, one at a time, by means of remote-control short-circuiting switches.

The cable for flush contact lights should be installed underground, as described for boundary circuits.

APPROACH LIGHTS

Approach lights are lights located outside the landable area, and arranged to indicate a favorable or preferred direction of approach.

The principal use of approach lights is to mark a lead-in or approach lane for instrument landing. The Civil Aeronautics Administration is testing various methods and has installed all these approach lanes to date on an experimental basis. The approach light lane now in use consists of a line of horizontal red gaseous-discharge-tube lights spaced 100 feet apart and extending 1,500 feet from the approach end of an instrument landing runway. Lights consist of red neon tubing 72 inches long, set horizontally at right angles to the direction of flight. The last unit of the line, as it reaches the airport, is green, and consists of a course-light projector, set up at an angle. This line is located 85 feet to the left on the axis of the runway, as the pilot approaches the runway. Experimental work on lighting approaches to runways is continuing and reports will be issued from time to time covering the results of these investigations.

OBSTRUCTION LIGHTS

The policy of the Civil Aeronautics Administration is to recommend the removal of all obstructions from airports whenever possible and to have future airports built free from these hazards wherever this can be done. However, existing obstructions which cannot be removed must be marked properly and obstruction lighted for safety.

Obstruction lights should clearly mark with red lights all obstructions surrounding an airport. Either incandescent lamps with red globes or gaseous discharge lamps of distinctive red color may be used.

Obstruction lights consist of weatherproof fixtures and prismatic glass globes, as described for boundary lights, but with a red cover globe, to give an aviation red light from all angles above 15° below the horizontal to the zenith.

Obstruction light lamps should be either 60 or 100 watts for multiple circuits. There are available special traffic-signal lamps, rated 67 and 111 watts, corresponding to 60 and 100 watts, but with three times normal life.

All obstructions projecting above a glide angle of 30 to 1, from the end of a runway or landing strip, or any obstruction which is upstanding above adjacent objects and is within ½ mile of the airport, should be marked by means of obstruction lights. On the approaches to the runways of terminal airports, prominent obstructions within 2 miles of the airport should be marked. An extended obstruction, like a line of trees, should be marked by obstruction lights not over 150 feet apart.

A high obstruction, like a radio tower, extending more than 70 feet above its surroundings, should be marked by lights at the top, and at the one-third and two-thirds levels. Suitable weatherproof units as described should be used, mounted in each case above the highest point

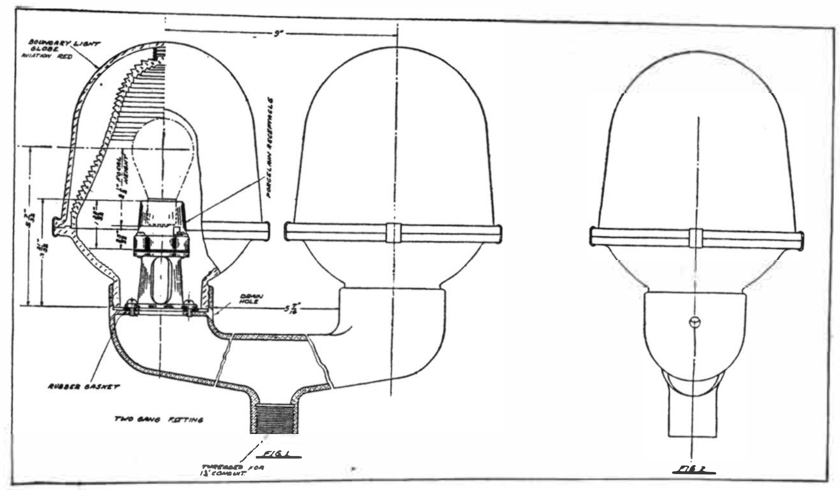

Figure 19.—Detail of double multiple obstruction light fixture.

of the obstruction or on poles of corresponding height placed alongside the obstruction. Obstruction lights may be served from the boundary circuits or carried on separate circuits as circumstances may dictate. Flashing mechanisms are not recommended and should not be used except when the obstruction light is isolated from all other lights. If flashing lights are grouped, they should be controlled to flash in unison.

In marking a pole line, a red obstruction light should be placed on each pole along the airport and on at least three poles beyond the airport in each direction. Where there is more than one pole line along the same side of an airport the obstruction lights should be placed on the poles of the highest lines. If the poles carrying the line cannot be used for mounting these lights, separate poles should be set. Two obstruction lights should be placed on end poles and on corner poles; otherwise, the burning out of the single light in such locations may lead to a serious accident. Where double obstruction lights are used, a throw-over relay may be employed, so that only one light at a time will burn.

Individual floodlight units or banks of units, if extending above a glide angle of 20 to 1, should be marked with double obstruction lights.

Chimneys and stacks should be treated as high obstructions, but due to the difficulty of keeping the lights free from soot, they are frequently lighted by floodlights arranged around the base with narrow beams concentrated on the stacks. Stacks should be floodlighted to an intensity of at least 15 foot-candles.

There are available disconnecting hangers for fixtures which are so mounted as to be difficult to service from the ground. These hangers allow the entire fixture to be lowered to the ground by means of a cable, operated from the ground. Disconnecting hangers are recommended for obstruction-light units mounted on stacks or other high obstructions.

Where a dike or bank parallels closely the edge of an airport, and the line of boundary lights is moved in to clear a 20 to 1 glide angle, a row of red obstruction lights mounted on boundary type cones should be installed along the top of the bank or dike. This line of obstruction lights does not take the place of boundary lights along the parallel side of the landing area. Similarly, obstruction lights on a pole line along one side of an airport cannot be considered as replacing the boundary lights along this side.

A single building, such as a hangar, should be lighted by lights on all corners of the roof. If the building is more than 150 feet in extent, intermediate lights should be installed to avoid spacing over 150 feet. A group of buildings may be treated as an extended obstruction, with lights spaced to indicate the over-all extent and outline, rather than each individual building.

When installing obstruction lights on the poles of telegraph, telephone, or power lines, careful attention should be given to running the feed wires. Three possibilities exist: (1) These wires may be run underground, with a tap at each pole; (2) they may be run upon a cross arm located below the existing wires; (3) they may be run above the existing wires by making use of the top cross arm or by mounting an extension upon the pole.

Figures 20 and 21 show wires run up the pole in conduit from underground cable. Such conduit should be covered with wood molding where it passes through the space occupied by cross arms. (The National Electrical Safety Code, published by the National Bureau of Standards of the United States Department of Commerce, calls for such covering within 4 feet of line wires and for voltages exceeding 7,500 volts, 6 feet.)

Figure 20*c* shows the construction where the wires are mounted upon the lowest arm or upon vertical racks below the arm. Here again the conduit should be covered with wood molding. This location is desirable where the existing arms carry circuits of higher voltage.

Where space can be made available upon the top cross arm, and there will not be higher voltage wires below, this is a desirable location. It sometimes can be made available by substituting a longer arm for the existing one, placing the existing wires on one end of the new arm, and placing the feed wires on the other end of the arm. This is especially recommended where three primary wires are carried and there is no room for an additional arm on the pole.

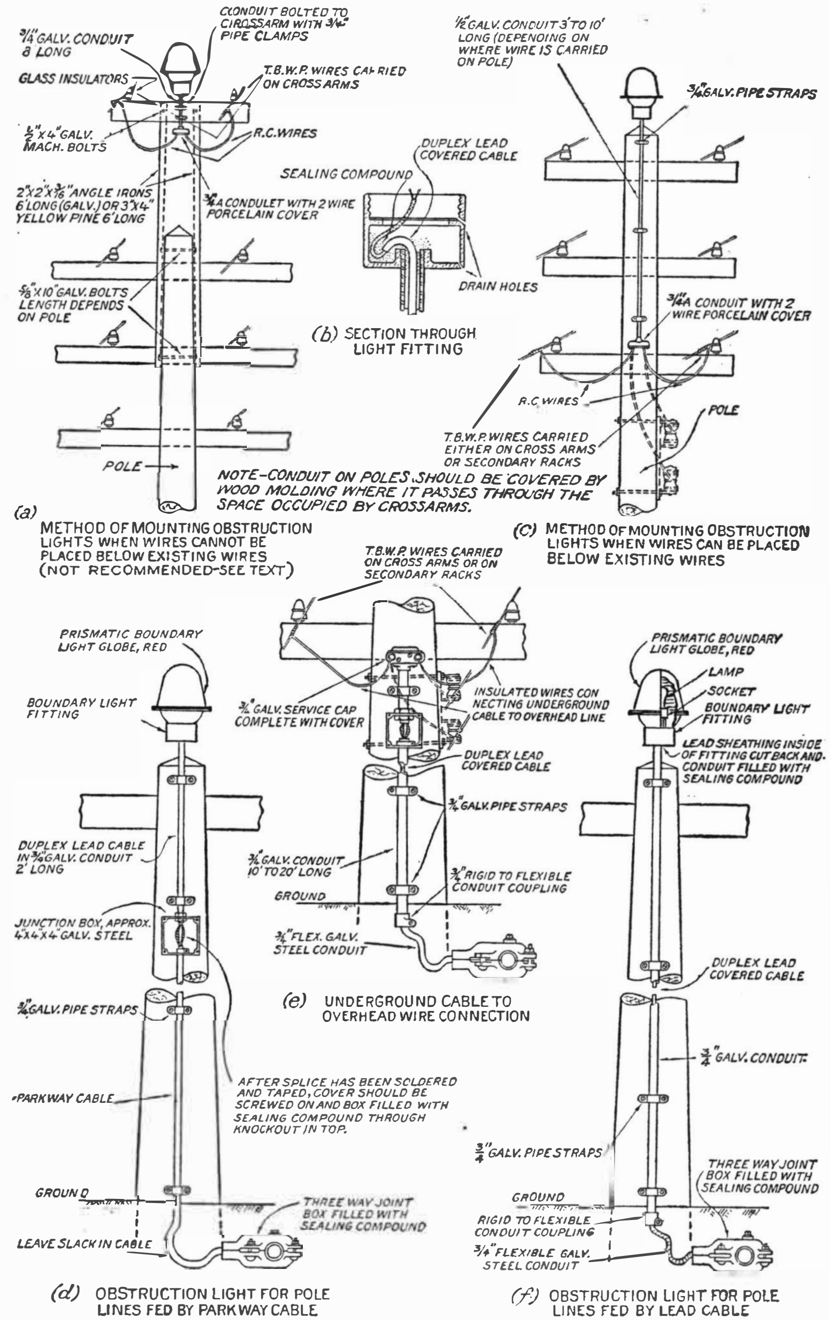

Figure 20.—Methods of installing obstruction lights on pole lines.

In general, as the amount of illumination in the vicinity of the air-marker is increased, it is necessary to increase the visibility of the marker. This can be accomplished through colors, increased candlepower, or by flashing the lights.

In planning the illumination of markers, care should be exercised to provide well-divided circuits with the least possible voltage drop, as a slight drop in voltage will materially reduce the output of the lamps. It is advisable to use wire of ample size to carry at least twice the proposed load, as it may later be found necessary to increase the wattage of the lamps. It is recommended that the entire electrical installation be made in accordance with the rules of the National Electrical Safety Code.

CEILING PROJECTOR

A projector concentrating a narrow beam of light and mounted at a fixed angle of elevation, generally 90°, is used to determine the height of the ceiling (the under surface of the lowest cloud or mist layer) above the airport at night by a simple system of triangulation. The ceiling projector should be located at a fixed distance, preferably 1,000 feet, from the point at which the clinometer readings are made. This light should be controlled by a switch located at the observation point.

The projector consists of a searchlight projector, mounted on a pedestal, and using a 35-ampere 12-volt lamp. The transformer for the lamp is mounted in the base.

Readings are made with a clinometer, which is held in the hand, and shows the angle between the horizontal and the luminous spot on the clouds. A table can be prepared for the length of base line used, for converting the angle read into the height in feet of the cloud layer.

LANDING AREA FLOODLIGHT SYSTEM

The landing-area floodlight system should be so designed as to provide an even distribution of illumination (free from abrupt changes in intensity and shadow areas) over the portion of the landing area to be used in making a landing. If the airport is to handle the maximum volume of traffic with proper regard for safety and reliability, landing facilities must be available for use at all times, both day and night, and the illumination of the landing area should be such that a pilot unfamiliar with the field can land with safety under all ordinary weather conditions.

It is important that the floodlight system offer a high degree of reliability and require a minimum of skilled attention. It should be immediately available for use through the operation of a control located at a convenient point, and should be sufficiently elaborate or flexible to permit landing under all conditions of wind direction without the necessity of landing toward the light source. There should be sufficient light to illuminate any objects that may be on the landing area as well as objects and obstacles in the direction of the beam in the immediate vicinity of the airport. In addition, the floodlight unit should be so designed and installed as to eliminate glare and blinding of the pilot. Glare is very confusing to the pilot as it results in the loss of perspective and detail and hence makes him uncertain of his altitude.

The lighting equipment should give a soft, steady light, free from any tendency to flicker or change in intensity or color. The intensity of illumination should be such as to reveal the details of the surface and make depth perception readily possible from a minimum altitude of 30 feet in the center of the lighted area.

The intensity of illumination should be not less than 0.20 foot-candles, measured in a vertical plane, throughout an area not less than 500 feet wide and 60 percent of the length available for landing in length. This length, however, is not required to be more than 3,000 feet, and should be not less than 1,800 feet.

The light should come from behind the pilot, or from one side, and the light source should not be visible to the pilot within an angle of 40° to his line of flight, to avoid glare. These conditions will be met satisfactorily by a completely-directional floodlighting system, and they will also be met by a single concentrated floodlight unit, fitted with a shadow bar, to provide a path of shadow enveloping the airplane, which is controlled to move with the airplane.

It must be realized that each airport, with its particular physical characteristics, presents an individual problem in lighting and that the floodlight system should be laid out only after a careful study of local conditions, such as the topography of the landing area and surrounding terrain; the aerial approaches to the landing area, including the location of obstructions; and the directions and velocities of prevailing night winds. In this connection, it should be noted that the windrose representing average wind directions and velocities for the night hours may differ somewhat from the windroses representing average conditions for the daytime hours and for the entire 24 hours.

There are five general methods of arranging floodlighting. These are illustrated in figures 22 to 26. The selection of the method best adapted to any particular airport will depend on the elements outlined above. It is recommended that all floodlight lay-outs (whether prepared by floodlight manufacturers or by others) be submitted to the Civil Aeronautics Administration for checking, before the equipment is purchased.

Floodlight standards should not be located in line with any runway, or within 100 feet of the axis of any runway, unless the standards are set back at lease 200 feet from the end. In this case, they may be pulled in, but not within the extended edges of the runway, nor less than 150 feet apart. All such units must be kept below a 20-to-1 glide angle measured from the end of the runway.

In all cases, it is essential to keep the floodlight units as low as possible, and to arrange them so that they create as little obstruction as possible. All such structures shall have double obstruction lights on top of them.

Two general types of floodlights are now available. One consists of a drum type projector, with a lamp, a mirrored reflector, and a cover glass designed to spread the light to any desired angle, from 10° to 80°; the other consists of a wide-angle unit, consisting of a lamp and reflector in a housing. The control of the light distribution is effected by means of ground Fresnel lens sections, or by the design of the reflector. For 90° units, the lamp is incandescent, and

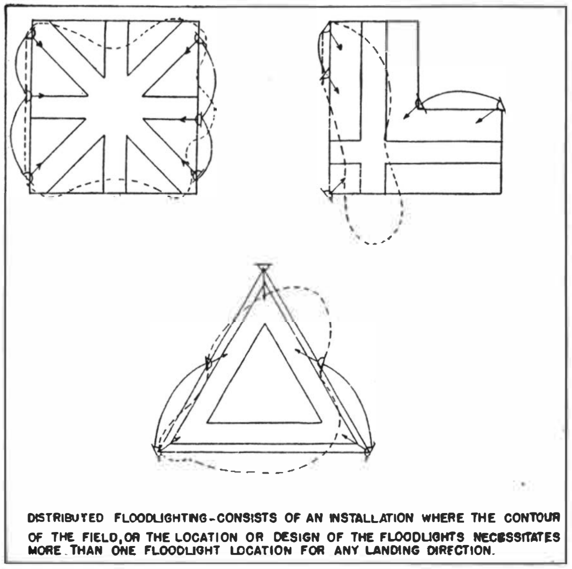

Figure 22.—Typical floodlighting lay-out.

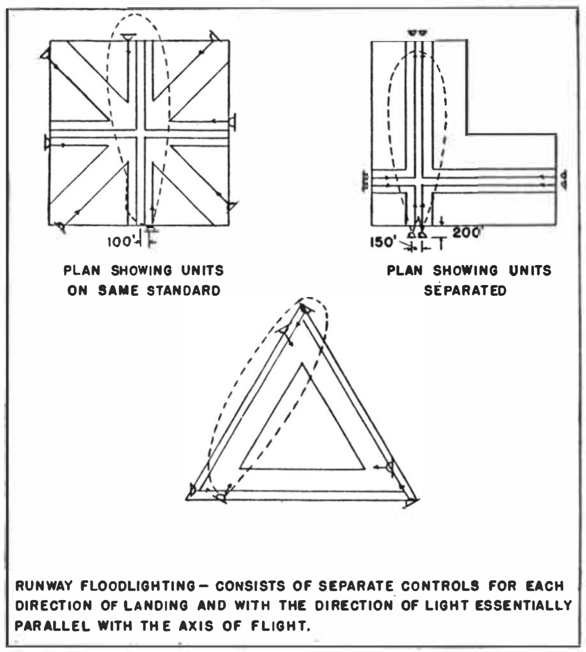

Figure 23.—Typical floodlighting lay-out.

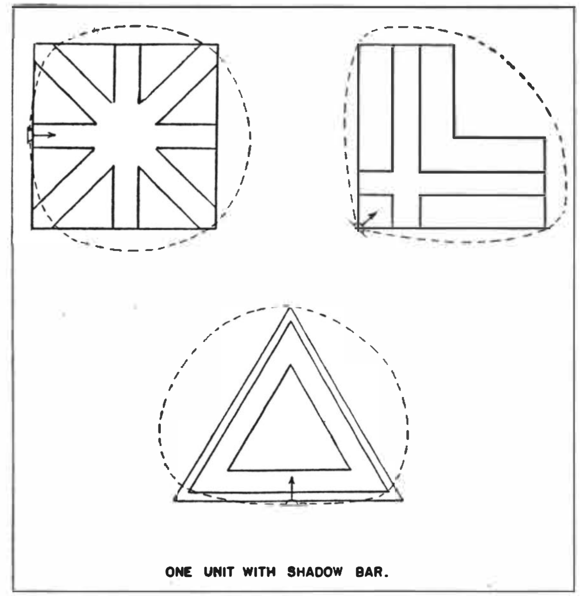

Figure 24.—Typical floodlighting lay-out.

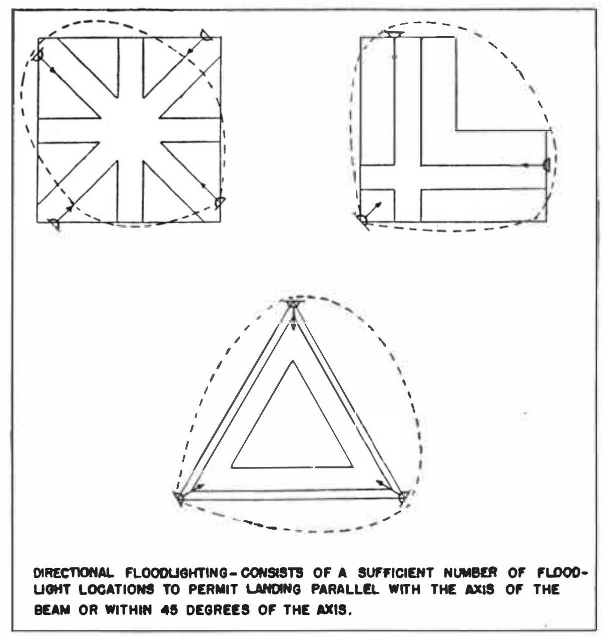

Figure 25.—Typical floodlighting lay-out.

for 180° units, an arc light is generally used. The optical systems of all floodlights must be accurate, so that the light is spread evenly, and so that the top of the beam has a sharp cut-off, to avoid spill light into the air.

A shadow bar is effective only on a floodlight where all of the light is projected from a single source, as it is in the larger 180° Fresnel lens units. Other types of floodlights are generally used with two or more together, superimposing their beams on the same area, or overlapping them to cover a wide area of ground. Where a floodlight bank uses only a single light source, there should be a stand-by lamp or light source, arranged to be operated automatically in the event of the failure of the main light source.

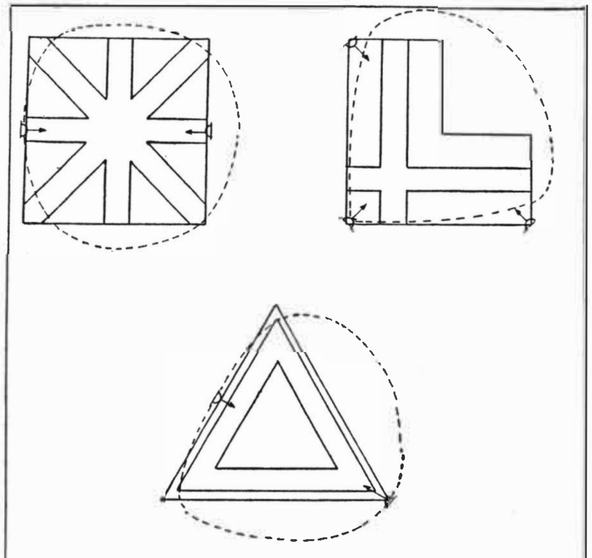

Figure 26.—Typical floodlighting lay-out.

Floodlight lamps are either 1,500-watt or 3,000-watt 32-volt, with a T-24 or T-32 bulb, and a C-13-B filament, with bipost base. These lamps have a rated life of 100 hours.

The 180° arc floodlight is generally mounted on a platform in a special structure which houses the transformers and motor generator set for the arc. Other units are mounted on concrete or steel standards. These standards should be bolted to a concrete base or to the top of a small concrete transformer house. The base of the standard should not be set solidly in the base, on account of the difficulty of replacement. The standard is hollow, to provide for the feeders to the floodlights and the obstruction lights. Provision should be made for a platform or ladder from which the floodlight may be serviced.

A transformer vault or house should be provided for each bank of floodlights which is installed away from the main power supply.

This vault may be used as a base for the floodlighting standard. Figure 31 shows a suggested detail for this vault.

The circuits feeding floodlights are high voltage, either 440, 550, or 2,300, run from a bus bar through underground cable to a transformer for each bank. There may be a separate feed to each floodlight bank, or a combined feeder to two or more banks. In the former case the feeder is normally controlled by a remote control

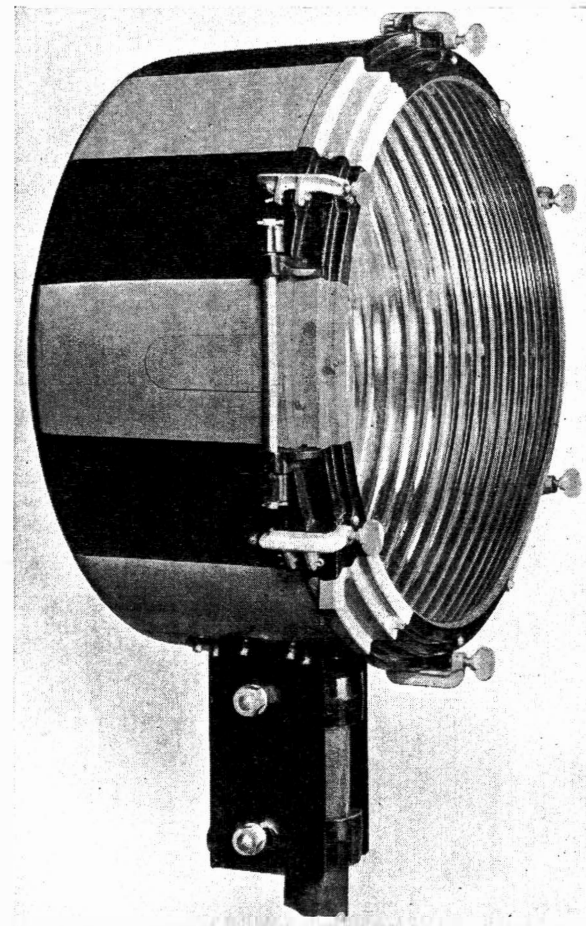

Figure 27.—Three-kilowatt drum type floodlight projector. Spread is varied by using spread-lens fronts.

oil switch or contactor located at the distribution center, and in the latter case, by remote control oil switches or contactors located in the transformer vault. It is generally preferred to use the former method, and group all of the contactors at the distribution center, for ease in maintenance. Where the bus has a grounded conductor, it is permissible to use a three-conductor cable to feed two banks, with the grounded conductor as a common lead. Use of a common conductor fed by an ungrounded bus is not recommended, as this results in a live conductor on one bank when the other is in use.

Cable should be lead-covered, steel-armored, conforming to Federal Specification JC–121 and laid not less than 18 inches underground. Where a number of cables are run together, the lead-covered cable is run in ducts. In some cases, where soil conditions are unfavorable for steel, rubber-sheathed or nonmetallic armored cable should be used. This cable should conform to the requirements of the Standard Airport Lighting Specifications.

Transformers must be used to reduce the feeder voltage to 32 volts. These transformers should be equipped with 2½-percent

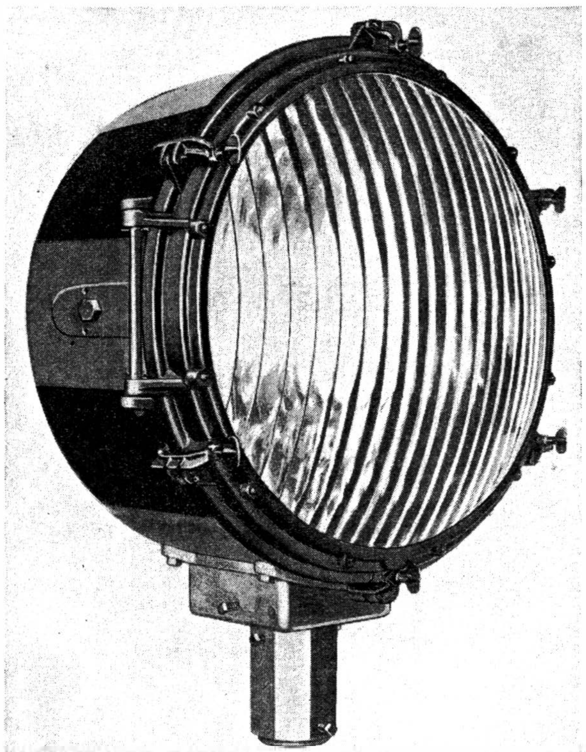

Figure 28.—Three-kilowatt drum type floodlight projector. Spread is varied by using spread-lens fronts.

taps, and should be oil-cooled for primary voltages over 440. The transformers are generally mounted on the floor of the vaults and must be equipped with primary cut-outs. One transformer can be installed to feed a bank of floodlights, even if the units are as much as 200 feet apart. For distances greater than this, the size of wire needed to keep the voltage drop within 2 percent becomes too large to be economical. A separate fused switch should be installed at the transformer for each individual floodlight. All floodlight controls should be grouped at the control tower or control room.

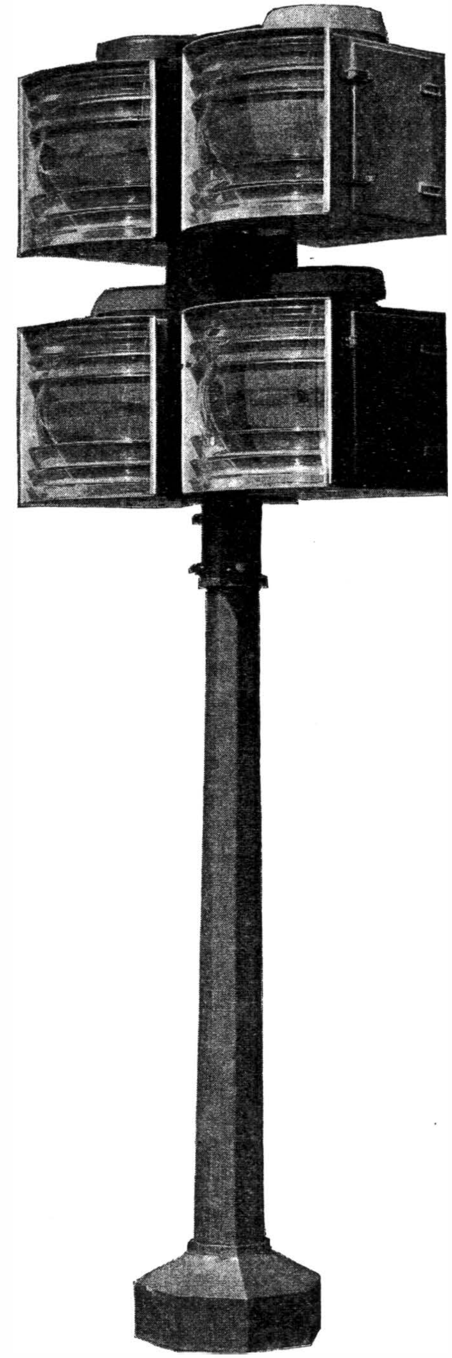

Figure 29.—Type of wide-angle floodlight, 90° spread Fresnel lens.

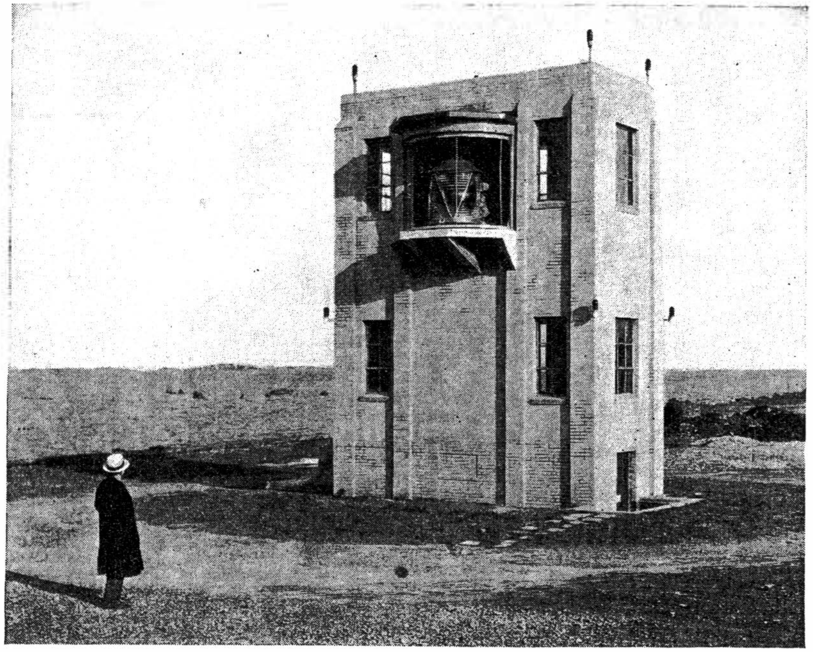

Figure 30.—Type of wide-angle floodlight arc with 180° Fresnel lens.

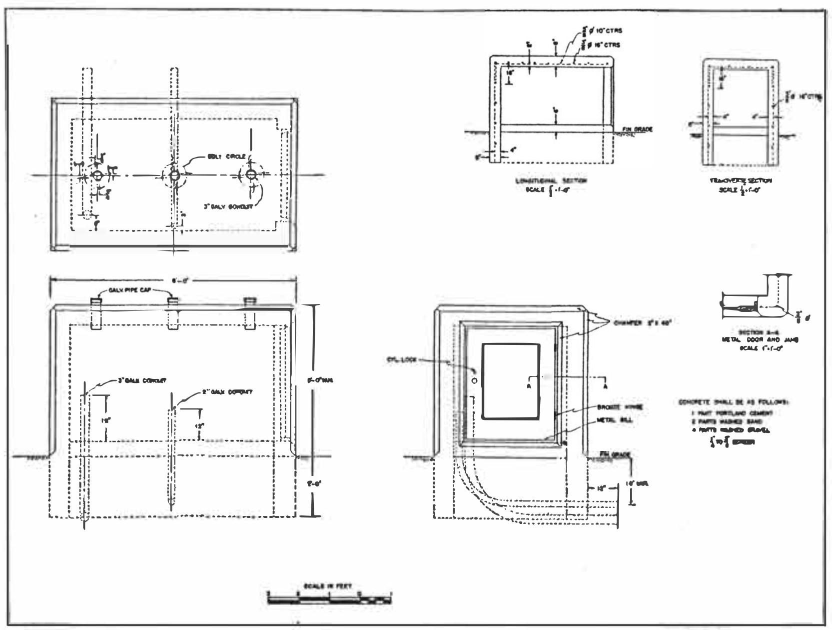

Figure 31.—Construction details, standard floodlighting transformer vault and mounting lens.

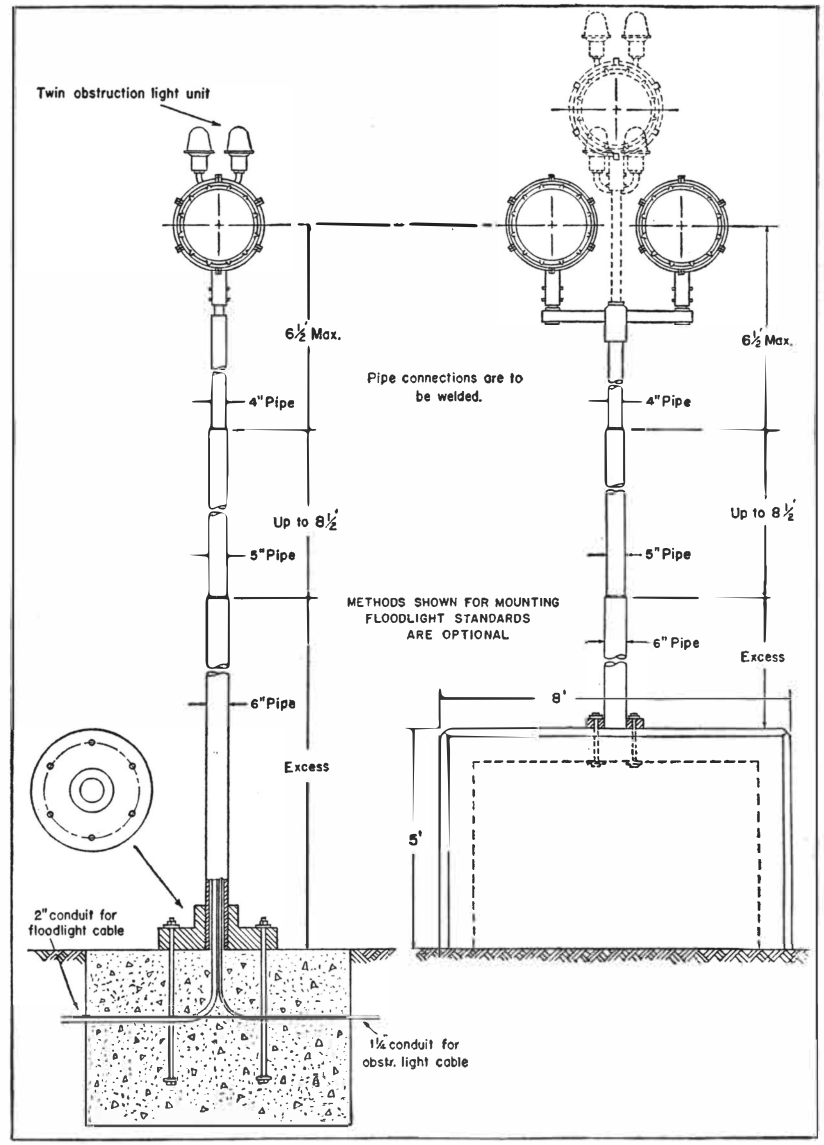

Figure 32.—Details of floodlighting mountings.

APRON AND EXTERIOR FLOODLIGHTS

The apron and loading space should be floodlighted for convenience in loading and servicing the ships. This lighting should be of even intensity and cover the entire area, extending under the wings and fuselage of the airplanes, but should not produce any glare to a pilot bringing an airplane in to a landing on any of the runways. It should also be arranged to avoid, as much as possible, glare in the faces of the passengers disembarking from the airplane. This flood lighting may be accomplished by means of wide angle projectors mounted on the face of buildings on short posts, or on the fence.

The floodlighting of the exterior of the administration building and other buildings serves three functions: It adds to the attractive appearance of the airport at night; it provides general illumination around the buildings; and it is a valuable aid to a pilot in obtaining perspective and determining the ground level. This lighting should also be designed to minimize the direct light spilled into the air, which might form glare for a pilot.

Fixtures for this floodlighting should be fully enclosed and of noncorroding material. Reflectors should be of high efficiency, and the cover glasses designed to be weatherproof. These fixtures may be either Fresnel-type lenses or enclosed projectors.

The apron should be lighted to a minimum intensity of 0.5 foot-candles, and the exterior of any building which is floodlighted should be lighted to a minimum intensity of 2.0 foot-candles.

INTERIOR LIGHTING

The lighting of the interior of the administration buildings and miscellaneous buildings offers no problem different from similar buildings for other purposes. The lighting of hangars, however, should be considered as a problem requiring special study. With large unbroken areas, general lighting from overhead units is essential for general illumination. As this method does not provide for lighting under the wings, it may be necessary to supplement it by floodlights on the wall or wide angle flush lights in the floor, where work is to be done on airplanes.

In paint and spray rooms, explosion-proof fixtures and fittings should be used; in other parts of a hangar, vaporproof fixtures are recommended.

Heavy-duty receptacles should be located around the work area, each one fed by a separate heavy-duty circuit. It is recommended that receptacles be set 60 inches above the floor, to be above the zone where explosive mixtures are most likely to collect.

At least one general light should be controlled by a switch at the entry, so that it is not necessary to grope through a dark hangar to the control point. All wiring should be in rigid conduit.

TEMPORARY MARKING

When portions of the landing area are temporarily unusable, either from wet weather or because of construction work, it is essential that they be marked adequately by night as well as by day. Such areas should be marked by night by being outlined by red lights, spaced and arranged to mark and define the areas. All corners should be marked, and lights spaced not over 150 feet apart, unless a line is straight for over 1,000 feet, in which case lights may be spaced 300 feet apart. If the unusual condition is of short duration, the lights may consist of oil lanterns with red globes.

It is of extreme importance that all temporary obstructions on or in the neighborhood of an airport be adequately marked by red lights. This means that sufficient lights be used and so located that the outline and extent of the obstruction is clearly indicated from any point from which a pilot may view it.

EMERGENCY POWER SUPPLY

Reliability of power supply to an airport is of extreme importance, because frequently the safety of an airplane and its passengers is completely dependent on the continuation of the lights.

This reliability may be obtained by connection to a power source of proven reliability, one of which service records show no interruptions, or only inconsequential outages, for the past several years. It may be obtained by interconnection with two or more independent and sufficiently reliable power sources, or it may be obtained by having a stand-by power supply.

This stand-by power supply should consist of a gas engine or a gasoline engine, coupled to an electric generator. It should have at least sufficient capacity to supply—

1. All boundary, obstruction, and range lights.
2. Wind cone and T.
3. Beacon and code beacon.
4. Landing aids for one direction of landing, i. e., one bank of floodlights or one circuit of contact lights.
5. Radio.

The power stand-by plant should be designed so that it may be started either automatically on the failure of the normal power supply or by means of a push-button control located at the control tower. It also should be designed so that it feeds into the normal power bus feeding the field lighting and should be of the same voltage and phase characteristics as the normal supply.

WIRING METHODS

Reference should always be made to the utility company serving the airport for voltage and characteristics of the service.

In general, all outside wiring on an airport should be run underground. This wiring should be done by lead-covered wire in duct or conduit, by steel-armored parkway cable, or by nonmetallic armored parkway cable. The main service should be in duct, and groups of cables between various buildings should be in duct. Boundary circuits and floodlight feeder-circuits may be in duct or may be parkway cable laid in the ground. Wherever cables cross under runways, taxi strips, aprons, or other paved areas, they should be pulled in ducts for that part of their run, so that they may be replaced without disturbing the paving. Ducts may be any approved electric duct material, and should be laid to drain to manholes. If the duct material lacks structural strength, the duct should be reinforced by a concrete envelope.

Parkway cable should be lead-covered and armored with flat steel-tape armor, except where soil is salt or acid and unfavorable for the use of steel. In such cases, a special nonmetallic fibrous armor or a special rubber-sheath armor should be used. Bronze-tape armor is also available, and should be used under conditions where steel is attacked and disintegrated.

Cables should be laid to a depth of not less than 18 inches, and where crossing roadways, not less than 36 inches. Where cable runs cross each other, 18-inch separation should be maintained. The trenches should be dug with sufficient width so that the cables can be installed without strain. In installing cable, it should be unrolled on the ground alongside the trench, and then lifted into the trench. It should never be pulled into a trench. It is recommended that a creosoted plank be laid over the cable before it is covered by the backfill. This will give protection against mechanical damage from stones, and will serve as a warning if the trench is being reopened.

Where provision is to be made for a future connection, a loop of cable should be left in the ground, to provide slack for the connection.

For inside wiring, standard practice should be followed, installing rubber-covered wire in conduit. Standard circuits, outlet boxes, and fixtures should be used, except in the hangar, where special consideration is required, as hereinbefore described.

The beacon is normally fed by means of a 120-volt circuit, either rubber-covered in conduit, or parkway cable laid in the ground; or if the distance is too great, a high-voltage feeder is used, and a step-down transformer located at the tower.

The boundary lights may be fed by either a series or a multiple circuit. The individual fixture for a series circuit is more costly, and the unit cable cost is essentially constant, while the cable size and cost on a multiple circuit increases with the length of the circuit. For this reason, there is a circuit length below which a multiple circuit is cheaper, and above which a series circuit is cheaper. This circuit length is usually about 12,000 feet.

With the exception of the feed to series fixed boundary markers, which being remote from runways, may be of the nonturnover type, a series circuit should not be brought out of the ground after it leaves the regulator, on account of the danger of breaking the circuit and putting all of the lights on it out of service. Whenever a feed has to be taken from a series circuit to an obstruction light or a wind T, an isolating transformer should be installed, so that any damage to the exposed circuit would not result in the failure of the series circuit. For a circuit feeding contact lights, a series circuit is to be preferred, so that an accidental ground in one unit would not put the entire circuit out of commission, as it would with a multiple circuit. The same degree of safety would be attained with a multiple circuit, however, if an individual fused isolating transformer were used to feed each light.

On a series circuit, the insulation should be designed to withstand the open-circuit voltage of the regulator.

The feeder circuits to floodlights are generally high voltage, 440 or 2,300, run to a transformer for each floodlight or group of floodlights. This circuit may be individual to one floodlight group, and controlled by a remote electric-controlled oil circuit-breaker at the main switchboard, or one circuit may feed several floodlight banks, with remote-controlled contactors at each bank. In either case, the contactors are operated from the control tower. The secondaries of floodlight transformers are only 32 volts, so particular attention must be paid to the secondary conductors, to avoid excessive voltage drop.

Floodlights never should be fed from boundary circuits, as there is the possibility of an overload from the floodlight putting out all the boundary, range, and obstruction lights, just when they are most needed. The only lights which should be fed from the boundary circuit are boundary, range, and obstruction lights and wind T indicators.

The ceiling indicator is normally fed by a 120-volt circuit and a 120 to 12-volt transformer installed at the projector.

OPERATIONS

In general, the operation of the lighting of an airport will depend on the night traffic.

The beacons should be operating from sundown to sunup.

Boundary, range, and obstruction lights, and wind indicators should operate until midnight on airports where traffic is concentrated in the earlier hours of night, and from sundown to sunup on airports which have frequent operations after midnight. If there are only a few operations after midnight, these lights may be turned off at midnight, and turned on 10 minutes before each scheduled arrival.

All lighted airports should have attendants on duty all night, to turn on the lights on call from an incoming airplane.

Floodlights should be turned on only on call from the incoming airplane, and only those banks designed to illuminate the proposed direction of landing should be used.

Contact lights should be turned on only when an airplane is coming in to land, and only on the runway on which the landing is to be made.

CONTROL

All controls for airport lighting should be concentrated at the control station, where the airport operator is on duty. If a control tower is provided, the controls should be located at that point. In any case, the control station should be located so that the operator has a clear view of the entire landing area and the approaches.

The controls should be grouped on a panel or on a control desk, and pilot lights should be provided for each control switch. These lights should be as small as possible, so that they will not dazzle the operator when he is trying to see an airplane.

All fuses and circuit breakers in the control circuits should be grouped near the control point, to be readily accessible to the operator. Circuit breakers are to be preferred, rather than fuses, on these circuits.

Circuits controlling lights which are burning all night, such as beacons, range, boundary, and obstruction lights, may be controlled by an astronomic time clock or a photoelectric control, but in such cases it is recommended that manual control be provided in addition.

SEAPLANE BASES

Lighting for seaplane bases is still experimental, and tests are being conducted to determine the spacing and characteristics of the lighting units required.

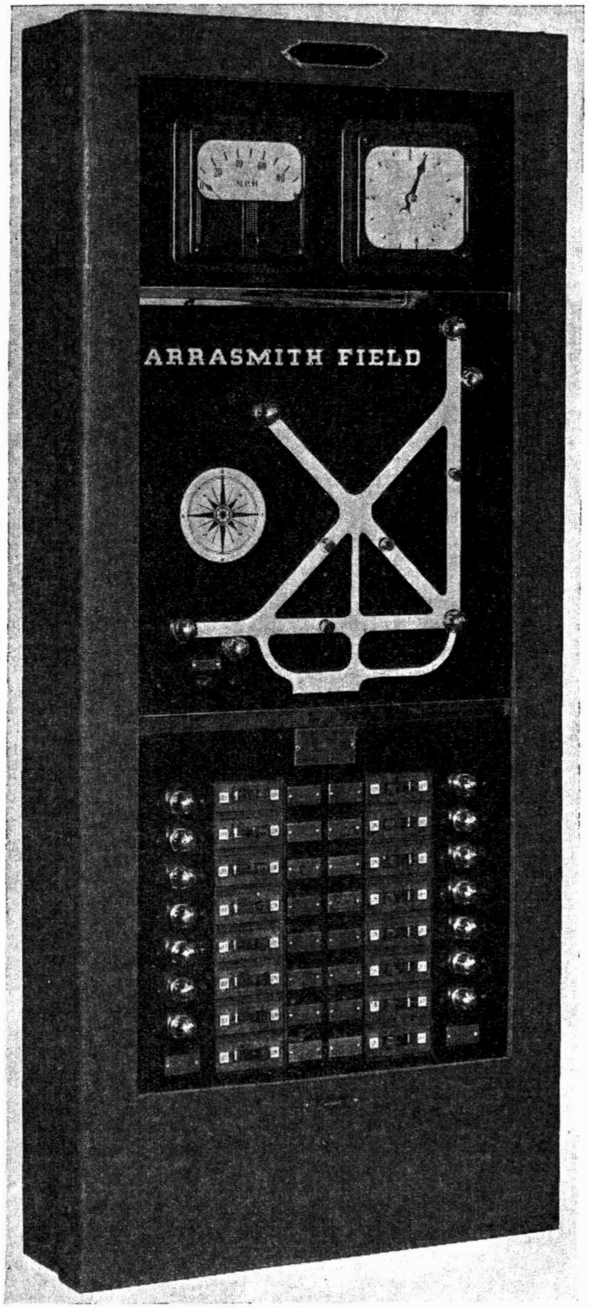

Figure 33.—Wall type airport lighting control panel.

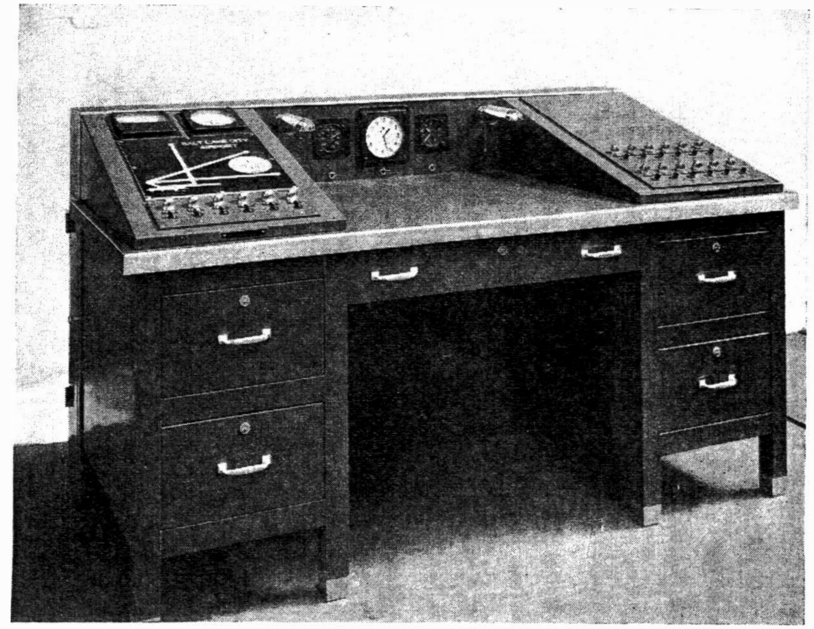

Figure 34.—Desk type airport lighting control panel.

COST OF AIRPORT LIGHTING SYSTEMS

The cost of complete airport lighting systems varies through quite a wide range and depends upon a number of factors, such as the size, shape, and topography of the landing area; number, nature, and location of obstructions to be marked; number and size of airport buildings flood lighted; type and number of landing area floodlighting units used; and refinements in the design of the lighting system.

For a general idea of costs, the following may be used as a rough guide:

Boundary and range lights: approximately $100, each, installed.
Beacon: approximately $1,200 each, installed.
Auxiliary beacon: approximately $300, each, installed.
Wind T: approximately $250 to $750, each, installed.
Obstruction light, single: approximately $7, not installed.
Floodlighting: approximately $1,500 to $2,500 installed per runway.

The following tables summarize the types, characteristics, and uses of airport lights.

Type of light	Location	Wattage and type of lamp	Color	Mounting	Spacing
1. Airport beacon	On airport or on prominent topographic feature within 2 miles.	500- to 1,500-watt bipost pre-focus, 30 or 115 volts.	Alternate white and green main flashes.	On tower, building, or other structure at least 50 feet high and sufficiently high for beam to clear surrounding obstructions.	
2. Wind direction "indicator" wind T	On hangar or prominent airport building or on ground outside landing area where true wind direction will be indicated.	25-watt 115-volt lamps with green cover glasses or green gaseous discharge tubes.	Green	Mounted on low friction bearings to swing freely with wind.	
3. Wind cone	On beacon tower, hangar, or other airport building roof.	4 100- to 150-watt 115-volt lamps for externally lighted. 1 200-watt with reflector for internally lighted.	White	Mounted on low-friction bearings to swing freely with wind.	
4. Boundary lights	Outline usable landing area	With prismatic globes, 15-watt 115-volt or 320 lumen 6.6 ampere series. With plain globes, 40-watt 115-volt or 600 lumen 6.6 ampere series.	do	On boundary cones. May be flush type along apron or loading platform.	Not over 300 feet.
5. Range lights	At end of runways or to indicate favorable landing directions on all-way fields.	With prismatic globes, 60-watt 115-volt or 1,000 lumen 6.6 ampere series. With plain globes, 100-watt 115-volt or 1,000 lumen 6.6 ampere series.	Green	Either flush type at ends of runways or on boundary cones. Runways are coded by using 2, 3, or more lights at each end of same runway.	50 feet or less as required, based upon runway width and number of lights used.
6. Auxiliary range lights.	In line of boundary opposite ends of runways, where paving stops more than 300 feet away.	do	Yellow	On range cones	Same as cone mounted range lights.
7. Contact lights	Along both edges of runway paving.	320 lumen 6.6 ampere series for white and yellow and for split filter units. Some yellow units use 6,000 lumen sodium lamps.	White on full length of runway except final 1,500 feet.	Mounted flush with pavement with heavy prismatic glass and steel cover.	200-foot spacing in rows for instrument along runways. Spacing between rows determined by width of runway.
8. Approach lights	At approach end of instrument landing runway.	Experimental—neon tubes	Experimental	Experimental	Experimental.
9. Obstruction lights	On all obstructions in vicinity of airport.	60 or 100 watts for multiple, 1,000 lumen for series, or gaseous discharge tubes of distinctive red color. Special traffic signal lamps rated at 67 and 111 watts may be used in place of 60 and 100 watts, respectively, on account of 3 times longer life.	Red cover glass	On level with top of obstruction to be marked or at top, 1/3 and 2/3 the height for structures over 70 feet high.	Not over 150-foot horizontal spacing.
10. Roof marking lights.	Sign on hangar or other airport building roof showing name of airport and name of city and State may be illuminated with exposed incandescent lamps, gaseous discharge tubing, or floodlights.	15- to 25-watt frosted sign, lamps or suitable floodlights. Gaseous discharge tubes may be used.	Usually white	Exposed incandescent lamps or gaseous discharge tubes placed along center line of the stroke of the letters or characters. Floodlights when used should be conveniently mounted to produce uniform illumination of 10 to 15 footcandles.	For exposed lamps, 12 inches for 15 watts and 18 inches for 25 watts.
11. Ceiling projector	At a known distance from observation point—usually 1,000 feet.	35-ampere 12-volt lamp	White	Projector mounted to direct beam upward at a predetermined angle, usually 90°.	
12. Landing area floodlights.	At edges of landable area, or outside of landable area. Must not be in line with runways.	1,500- or 3,000-watt 32-volt lamps. Also carbon arc.	do	Floodlights on standards of sufficient height to permit uniform illumination of runway or landing area without shadow pools. Height of standards should be minimum necessary for satisfactory distribution of light in order to reduce hazard of installation as obstruction.	
13. Apron and exterior floodlights.	On airport buildings or on ground as required.	As required to produce recommended intensity of illumination. Apron recommended minimum intensity 0.5 footcandles and building exteriors 2 footcandles.	do	Apron or loading platform floodlights usually mounted on administration building or hangar. Exterior floodlights usually mounted on standards.	As required.
14. Interior lighting	Usual ceiling lights	Depends on area to be illuminated	do	To permit working on airplanes in hangar, ceiling lights should be supplemented by floodlights mounted on wall at height to permit distribution of light under airplane wings.	Do.
15. Temporary lighting.	Outline unusable portion of landing area or mark temporary obstructions, such as construction equipment, etc.	Same as obstructions lights	Red	Temporary mounting should have sufficient strength and rigidity to lessen possibility of accidental breakage and still not be heavy enough to cause material damage if struck by a plane.	Preferably not more than 150 feet.