Study on Installation of Runway Status Lights

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Abstract. Runway Status Lights (RWSL) System uses light to send information to aircraft pilots and vehicle drivers to enhance their situational awareness, so installation and layout of runway status lights are of crucial importance. Based on the common configuration of the runways/taxiways of the domestic airports, we analyze the requirements imposed by the applicable standards on classification and installation of runway status lights and, on the basis of facts, select the optimal strategy for practical installation in Runway Status Lights System Verification Project implemented at Shanghai Hongqiao Airport. Actual testing indicates that lights can effectively send information from the view of pilots. The above analysis and study indicate that a runway status lights system with rationally arranged lights is able to inform aircraft pilots and vehicle drivers of runway safety status and plays a positive role in preventing runway intrusion incidents.

1. Background
Lincoln Laboratory of MIT first proposed the concept of runway status lights system in 2002, for the purpose of minimizing impact of human factors and effectively preventing runway intrusion. Then Federal Aviation Administration (FAA) conducted continuous research into that system in figure 6.

![Figure 1](https://www.faa.gov/air_traffic/technology/rwsl/). The airports in USA that had installed and operated RWSL system as of 2019.
In 2005, Dallas-Fort Worth International Airport conducted Runway Entrance Lights (RELS) and Takeoff Hold Light (THLs) prototype system verification. The pre-installation and post-installation statistics of the system indicated that the probability of runway intrusion was reduced by 70% [1]; in 2009, Los Angeles International Airport also conducted Runway Entrance Lights and Takeoff Hold Light prototype system verification; in 2010, Boston Logan International Airport conducted Runway Intersection Lights (RILs) system verification test; as of 2019, 20 airports in USA had installed Runway Status Lights System, as shown in figure 1.

2. Classification of runway status lights
In 2011, FAA published Engineering Brief #64D, which classified runway status lights into three types according to the installation scenarios. They are runway entrance light, take off hold light and runway intersection light. Runway entrance lights are installed at the selected runway/taxiway intersection and faces toward the taxiway that intersects the runway. When the runway entrance lights are lit, it tells the pilots and drivers that it is unsafe to enter or cross the runway; take off hold lights are installed at the designated takeoff hold area on the runway and intersection area and they are linked with runway entrance lights. If it is unsafe for aircraft to take off on the runway, the array of takeoff hold lights are lit; runway intersection lights are subject to the same standard as takeoff hold lights [2] and are installed at runway/runway intersection and send instructions to flight crew and vehicle operators. If it is unsafe to enter or cross runway/runway intersection, the array of runway intersection lights is lit.

Specification for Runway And Taxiway Light Fixtures (AC 150/5345-46E) published by FAA in 2018 classifies runway entrance light as L-852S [3] and take off hold light and runway intersection light as L-850T[3]. In the same year, International Civil Aviation Organization (ICAO) published the Convention on International Civil Aviation--Annex 14: Aerodromes--Volume 1: Aerodrome Design and Operations (eighth edition), section 5.3.30 [4] of which explains two basic visual components of runway status light: “The two basic visual components of runway status light are runway entrance lights (RELS) and take off hold lights (THLs)”.

In comprehensive analysis, it is easy to draw the following conclusion. The visual lights of the Runway Status Lights System stipulated by FAA and ICAO actually include two types: runway entrance light and take off hold light. A takeoff hold light installed at runway/runway intersection can also be identified as runway intersection light.

3. Requirements for installation of runway status lights
Design and Installation Details for Airport Visual Aids (AC 150/5340-30J) published by FAA in 2018 stipulates the requirements for installation of runway entrance lights and takeoff hold lights in common runway/taxiway configuration. The Convention on International Civil Aviation--Annex 14: Aerodromes--Volume I: Aerodrome Design and Operations (eighth edition) published by ICAO in the same year also offers generalized requirements for installation of runway entrance lights and takeoff hold lights. In comparison, both standards of FAA and ICAO specify the installation methods. The only difference lies in the sizes at installation position, where FAA uses both british units of size and metric units of size, while ICAO uses metric units of size.

3.1. Requirements for installation of runway entrance lights
Due to diversity of runway/taxiway configuration, runway entrance lights are subject to relatively complex installation requirements. FAA and ICAO standards identify three common installation scenarios of runway entrance lights [5] (now taxiway is specifically referred to as the segment from the runway hold position to the runway):

- Basic Configuration (straight taxiway perpendicular to the runway)
- Angled Configuration (straight taxiway not perpendicular to the runway)
- Curved Configuration (curved taxiway at a varying angle to the runway)
Common runway/taxiway configurations in China mostly fall in the basic configuration, as shown in figure 2. This paper mainly focuses on installation of runway entrance lights in the basic scenario. In the metric system, FAA and ICAO have no size difference in installation requirements for runway entrance lights, therefore this paper uses the metric units of size.

**Figure 2.** Installation requirements for runway entrance lights in basic configuration.

In the basic configuration, runway entrance lights are installed opposite to the taxiway centerline lights (if installed). They are horizontally 0.6m from taxiway center line and are installed along the line parallel to the taxiway center line. The first runway entrance light is installed 0.6m ahead of the hold bar marking; installation of runway status lights in horizontal direction with equal intervals shall conform to table 1; The penultimate runway entrance light is installed 0.6m ahead of runway edge line; The last runway entrance line is installed 0.6m ahead of the runway centerline at the opposite side. All light beams from the runway entrance lights must be directed toward the taxiway direction.

| Requirements for installation of equally spaced lights between the first and penultimate runway entrance light | Minimum longitudinal spacing (m) | Maximum longitudinal spacing (m) |
|--------------------------------------------------------------------------------------------------------|---------------------------------|---------------------------------|
| --------------------------------------------------------------------------------------------------------| 3.8                             | 15.2                            |

Note 1: At each intersection, the spacing shall be determined according to the distance between runway hold position marker and runway center line and the planned quantity of lights to be installed. The empirical calculation formula: \( D = \frac{2L1 - H}{2(M - 2)} \), where \( D \) is the longitudinal spacing between lights, \( L1 \) is the distance between runway hold position marker and runway center line, \( H \) is runway width and \( M \) is the planned total quantity of lights installed.

3.2. Analysis on empirical calculation formula for equal spacing between runway entrance lights

The distance between runway hold position and runway center line is affected by the design parameters and specifications of the airport [6], so if the equally spaced installation requirements of the second and penultimate runway entrance lights are to be followed, the calculated equal spacing will theoretically vary intersection by intersection at the same airport. Therefore the standard only specifies the range of equal spacing (3.8m~15.2m) of installation, while the designer will design the spacing based on the actual conditions at the airport.
In a sense, the flexibility of the standard makes it difficult for the designers to design an actual project. On the basis of meeting the standard, this paper makes analysis and concludes that if the quantity of runway entrance lights (M) is known, the longitudinal equal spacing D and the distance L1 between runway hold position and runway center line are determined by the equation below:

\[(M - 2) \times D + \frac{H}{2} = L1\]  

(1)

where L1 is the distance between runway hold position marker and runway center line and H is the runway width.

Therefore the following empirical calculation formula for longitudinal equal spacing D is obtained.

\[D = \frac{2L1 - H}{2(M - 2)}\]  

(2)

During design based on experiences, it is recommended that the quantity of lights and the equal spacing value that enables easy installation and measurement be comprehensively considered. It is recommended that the total number of runway entrance lights at each intersection be in the 8~15 range and the middle number be selected. The following is an actual engineering calculation example:

There is a 45m wide runway with typical minimum spacing of 90m. If the planned total number of lights is 17, the longitudinal spacing is 4.5m; If the planned total number of lights is 7, the longitudinal spacing is 13.5m. To make it easy for construction, the design may use 7.5m spacing in installation and the planned total number of lights is 11.

3.3. Requirements for installation of takeoff hold lights
The start base line for takeoff hold lights installation is ahead of runway aiming point marker. The first line of takeoff hold lights is 115m±7.5m from runway threshold and these lights are 7.5m staggered from the center line lights of the existing runway. Each line has 2 takeoff hold lights and are symmetrically arranged on opposite sides, each being 1.8m from the runway center line. Takeoff hold lights are spaced by 30m and arranged in 16 lines. The entire takeoff lights set is 450m long. The overall deployment and installation requirements for takeoff hold lights are shown in figure 3. FAA and ICAO standards slightly differ in terms of installation size of takeoff hold lights, thus this figure shows sizes in both British units (FAA) and metric units (ICAO).

![Figure 3. Requirements for installation of takeoff hold lights.](image)

4. Installation practice of Hong qiao Airport
Domestic technological development of Runway Status Lights System started late as so far no airport has conducted any field technical testing or verification. In the aftermath of “10·11” Runway Intrusion Incident at Shanghai Hongqiao International Airport, CAAC East China Regional Administration
initiated the science and technology project "Runway Intrusion Prevent Research and Demonstration" and worked with the Second Research Institute of CAAC and Shanghai Hongqiao International Airport to study on Runway Status Lights System. They conducted field deployment, installation, testing and verification at Hongqiao International Airport at the end of 2018. By the end of 2019, the project research team had completed two flight tests at Hongqiao Airport and the technical verification of the system saw initial success. This project achieved the first application of Runway Status Lights System at a domestic operational airport.

4.1. Installation area selection
Hongqiao Airport is one of China's gateway composite hubs and a Class 4E civil international airport. This airport has two runways in north-south and east-west directions, one 3400×60m (east runway, 18L/36R) and the other 3300×60m (west runway 18R/36L). By using testing and verification experiences from foreign countries and following the step-by-step implementation method, several partners made discussions and decided to install 1 set of takeoff hold lights and 1 set of runway entrance lights during the preliminary implementation, as shown in figure 4. Based on the actual takeoffs and landings, Runway 36L (west runway) is mostly used for takeoffs and with high frequency of takeoff, so in the technical verification of the system, the south end of the west runway was first used for installing takeoff hold lights; There are 8 taxiway/runway intersections (in 4 groups) used for crossing/entering runways, i.e. H1, H3, H5 and H7. H3 intersection has relatively higher frequency of crossing/entry, so the H3 intersection to the east of west runway was used for installing runway entrance lights.

![Figure 4. Installation of runway status lights at Hongqiao Airport.](image)

4.2. Runway entrance lights installation
The runway hold position at H3 intersection to the east of west runway of Hongqiao Airport is 90m from center line of west runway. This runway is 60m wide. According to the installation requirements and empirical formula described in Section 2.1, H3 intersection is designed to install 10 sets of runway entrance lights and they are equally spaced by 7.5m. The aerial view of the installed runway entrance lights are shown in figure 5.

![Figure 5. Aerial view of installed runway entrance lights.](image)
4.3. Takeoff hold lights installation

FAA once organized assessment of the optimal installation scheme for Takeoff Hold Lights Subsystem of Runway Status Lights System [7]. The assessment result provided supporting data for specifying the takeoff hold lights installation requirements in Specification for Design and Installation of Visual Navigation Aid Equipment at Airport (AC 150/5340-30J). Therefore takeoff hold lights installation at Hongqiao Airport mostly referenced the aforesaid standard, but the actual implementation had to deal with choice between single-line and double-line schemes and the problem of runway threshold inward relocation.

For the purpose of judicious verification, a design schemes that uses single-line installation but reserves space for double-line installation was chosen for takeoff hold lights installation, which reduced pavement holes used for preliminary verification and also verified how single-line lights installation would visually inform pilots and drivers. Besides, this scheme also supported expansion to double-line installation, which laid foundation for further testing and verification of the system; As for runway threshold inward relocation, the researchers read the relevant technical requirements of ICAO and adequately communicated with the airport's technicians. They agreed that, with the actual takeoff operation mode of Hongqiao Airport, the scenario of runway threshold inward relocation should not be the optimal option for verification of the takeoff hold lights installation. The aerial view of the finally installed takeoff hold lights are shown in figure 6.

![Aerial view of single-line takeoff hold lights installation.](image)

5. Conclusion

Now domestic airports mostly prevent runway intrusion by using manual commanding in the manner of voice communication between air traffic controller and pilot. As more and more flights have been commissioned in recent years, runway intrusion incidents occurred at several airports. The parties concerned are paying more attention to preventing runway intrusion incidents by using technological means. This paper summarizes and addresses the classification of runway status lights and lights installation requirements in common runway configurations recommended by foreign relevant standards, and explains the lights installation during the first domestic technical verification of Runway Status Lights System at Shanghai Hongqiao Airport, which can be used for reference in similar projects in the future. The field testing results indicates that a runway status lights system with rationally arranged lights is able to inform aircraft pilots and vehicle drivers of runway safety status and plays a positive role in preventing runway intrusion incidents.

References
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