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New Generation Runway Visual Range (RVR) Category IIIb Evaluation Report

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16. Abstract <p>This document provides results of the Category IIIb Evaluation of the New Generation Runway Visual Range (RVR) system. The evaluation was conducted from September 29 to October 8, 1994, at Mt. Washington, NH. The primary purpose of the evaluation was to obtain data indicating RVR performance during actual Category IIIb visibility conditions.</p> <p>The evaluation consisted of comparing RVR system measurements with those of human observers viewing runway lights in dense clouds and fog. Observer and RVR measurements were obtained simultaneously and recorded for statistical analysis.</p> <p>Approximately 500 observations were made during the evaluation under day and night conditions. In addition to using runway lights, "black targets"—dark colored objects, were used in observations and compared with RVR measurements. The black targets were used during light conditions where they would be more visible than runway lights. Results indicated that RVR accuracy was generally within 100 feet or one reporting unit of the observed visibility.</p>					
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EXECUTIVE SUMMARY

The New Generation Runway Visual Range (RVR) system was evaluated for Category IIIb performance from September 29 to October 8, 1994, at Mt. Washington, NH. Testing was classified as delta Operational Test and Evaluation (OT&E) and involved representatives from the Volpe National Transportation Systems Center, Mt. Washington Observatory, and FAA Technical Center.

Testing was intended to compare RVR readings with measurements from observers viewing runway lights in dense clouds and fog. Observer and RVR measurements were obtained simultaneously and recorded for statistical analysis. Additional Category IIIb tests are planned for the spring of 1995. These tests will compare RVR readings with a United Kingdom Meteorological Optical Range transmissometer.

A total of 508 observations were made during OT&E. Approximately 50 percent of these observations were made during the day, with the remainder performed at night. In addition to using runway lights, "black targets"--dark colored objects, were viewed and compared with RVR measurements during conditions where a black target is more visible than a runway light.

Although no operational problems occurred during test scenarios, visibility sensor shutdowns occurred during the initial system installation and between test scenarios. The shutdowns appeared to be caused from failures of the visibility sensor hood heaters or in the heater control circuitry. The heater failures had no effect on data collection or the validity of test results.

Preliminary results indicate that RVR accuracy was generally within 100 feet of the observed visibility. An in-depth analysis of the collected data is being performed by the Volpe National Transportation Systems Center. The results of this analysis will be distributed in a separate report.

1. BACKGROUND.

This was the second Category IIIb test conducted at Mt. Washington. The first was conducted during the fall of 1993. The results of the first test indicated that Runway Visual Range (RVR) sensors were generally within specification when reporting visibility in the Category IIIb range. The first test compared RVR readings with an Optec transmissometer and test team observations.

In addition to using observers and a transmissometer as references for visibility readings, two versions of RVR visibility sensors were evaluated. Commonly referred to by the direction of their optics, the sensor configurations are identified as "look-across" and "look-down." Test results showed that measurements from the look-down sensor were closer to observer readings and that this configuration was more resistant to high window contamination resulting from precipitation.

Although the first Category IIIb test fulfilled its purpose, limitations in testing as well as problems encountered created a need for additional testing. Difficulties included:

- a. Inability to test the entire Category IIIb range;
- b. Uncertainty of fog homogeneity at the sensors and around observers; and
- c. Frequent calibration failures and poor performance in weather conditions at Mt. Washington resulted in the loss of the transmissometer as a reliable reference for testing.

In addition to these issues, subsequent modifications to the RVR sensor and algorithms further justified the need for additional testing.

1.1 PURPOSE.

This report will detail the activities and results of the Category IIIb Evaluation of the New Generation RVR at Mt. Washington, NH. Testing was conducted from September 29 to October 8, 1994.

1.2 SCOPE.

This report will present the initial results of the Mt. Washington test. Problems, potential solutions, and recommendations will also be discussed. An in-depth analysis of the test data is being performed by the Volpe National Transportation Systems Center. The results of that analysis will be distributed in a separate report.

2. REFERENCE DOCUMENTS.

This document was developed in accordance with FAA-STD-024B and FAA-ORDER-1810.4B.

3. SYSTEM DESCRIPTION.

3.1 MISSION REVIEW.

The mission of the RVR is to support low visibility takeoff and landing operations that are planned for today's airports. The RVR's mission also requires that it improve accuracy, provide easier installation, and reduce maintenance typically associated with current RVR systems. The system will support future development of the National Airspace System (NAS) as well as expansion of the airport.

3.2 TEST SYSTEM CONFIGURATION.

3.2.1 Hardware.

The RVR system hardware consisted of the following components:

- a. Three look-down Visibility Sensors (VS),
- b. One Ambient Light Sensor (ALS),
- c. One Runway Light Intensity Monitor (RLIM),
- d. Sensor Interface Electronics (SIE) for each sensor, and
- e. One Data Processing Unit (DPU).

Refer to table 1 for a listing of serial and part numbers for the components listed above. With the exception of the controller display¹, these components comprise a complete RVR system for an airport with one runway. Airports with multiple runways would require additional visibility and runway light sensors.

3.2.1.1 Hardware Configuration Modifications.

There were no hardware configuration changes made during Category IIIb testing.

¹ Since the controller display has no impact on RVR product calculations, its use during these tests was not required.

TABLE 1. MOUNT WASHINGTON CATEGORY IIIb HARDWARE

COMPONENT	RUNWAY LIGHT FIXTURE	RUNWAY LIGHT	RUNWAY REGULATOR
Manufacture Identification	L-850B	L-861	31360-044-5
Part number	20581P-c-s	40938-c-45-14-pg	n/a
Specification	5,000 candelas	5,000 candelas	0 - 6.6 Amps, 240 Volts
Type	high-intensity centerline	medium-intensity edge	five step
Quantity	4	2	1
COMPONENT	ISOLATION TRANSFORMER	ISOLATION TRANSFORMER	BLACK TARGET
Manufacture Identification	33001	33003	n/a
Specification	45 watt, 6.6 amp	65 watt	18" X 30" X 9" (l x h x w)
Type	medium-intensity edge	high-intensity centerline	rectangular
Quantity	2	4	2
COMPONENT	VISIBILITY SENSOR	VISIBILITY SENSOR	VISIBILITY SENSOR
Test Identification	"01"	"02"	"03"
Transmitter ID	715	921	479
Receiver ID	694	883	685
Yoke ID	389	495	509
COMPONENT	VS SIE	VS SIE	VS SIE
Test Identification	"03"	"02"	"01"
Controller card P/N	860523-2 Rev C	860523 Rev C	860523-2
Controller card S/N	214	278	342
Personality module P/N	860526-1 Rev C	860526-1 Rev E	860529-1 Rev E
Personality module S/N	214	765	73
Interface Assembly P/N	860584-1 Rev F	860584-1	860584-1
Interface Assembly S/N	252	195	378
FET CCA P/N	860575-1	860575-1	n/a
FET CCA S/N			n/a
SIE Enclosure ID	116	141	289
COMPONENT	AMBIENT LIGHT SENSOR	MASTER CALIBRATOR UNIT	
Identification	85	22	
SIE Enclosure ID	39		
Assembly	45		

3.2.2 Software.

Software versions used in the DPU, VS, ALS, and RLIM are listed as follows:

a.	Maintenance Processing Unit	0512946040,
b.	Product Processing Unit A	0503945040,
c.	Product Processing Unit B	0802945040,
d.	Visibility Sensor 01	0430942040,
e.	Visibility Sensor 02	0823942040,
f.	Visibility Sensor 03	0823942040,
g.	Ambient Lighting Sensor	0602943042, and
h.	Runway Light Intensity Monitor	0430944040.

3.2.2.1 Software Configuration Modifications.

There were no software configuration changes made during Category IIIb testing.

3.3 INTERFACES.

The RVR contains interfaces to communicate with the following external systems:

- a. Maintenance Processor Subsystem (MPS),
- b. External Users (EU),
- c. Maintenance Data Terminal (MDT),
- d. Automated Surface Observing System (ASOS)², and
- e. Tower Control Computer Complex (TCCC)³.

Category IIIb testing involved the use of the EU and MDT interfaces. The EU interface was used to transfer RVR parameter values such as extinction coefficient, window contamination, etc., to a data acquisition computer. The MDT interface was used to monitor RVR parameters in real time. The remaining interfaces were not required for testing.

4. TEST DESCRIPTION.

4.1 TEST SCHEDULE AND LOCATIONS.

Installation activities for the RVR system took place from September 14 to September 29, 1994. Testing was conducted from September 29 to October 8, 1994, at the summit of Mt. Washington, NH.

² The ASOS interface was under development and was not available at the time of test.

³ The TCCC interface was under development and was not available at the time of test.

4.2 PARTICIPANTS.

Participating organizations included the Volpe National Transportation Systems Center, the Mt. Washington Observatory, and the FAA Technical Center (ACW-200B). These organizations functioned in the following capacities during testing:

Volpe National Transportation Systems Center

- a. Performed installation and configuration of RVR system and test equipment;
- b. Conducted the test and evaluation of RVR;

Mt. Washington Observatory

- c. Assisted in the installation of RVR and the test site setup;

FAA Technical Center

- d. Supported installation activities; and
- e. Conducted test and evaluation of RVR.

4.3 TEST AND SPECIALIZED EQUIPMENT.

Category IIIb test equipment consisted of the following components:

- a. Four high-intensity runway centerline light fixtures,
- b. Two medium-intensity runway edge lights,
- c. Isolation transformers for each runway light,
- d. One five-step runway light regulator,
- e. One data acquisition computer, and
- f. Two "Black Targets."

4.4 TEST OBJECTIVES AND CRITERIA.

The goals of this test effort were to:

- a. Design a more scientifically controlled test than conducted during the fall of 1993;
- b. Collect additional data to better determine RVR performance in the Category IIIb range;
- c. Assess severe weather limits of the national deployment sensors; and
- d. Provide data on the visibility of medium intensity runway lights and black targets.

4.5 CATEGORY IIIb TEST SETUP AND CONDUCT.

4.5.1 Test Setup.

A diagram of the test layout is shown in figure 1. Four high intensity runway centerline lights were installed as primary targets for testing. The locations of the lights were chosen to:

- a. Allow the observation path to be on level terrain;
- b. Allow viewing distances ranging from 150 to 750 feet from a path that was significantly smaller in length than the viewing distance; and
- c. Provide an accessible and safe area for conducting observations.

The runway lights were positioned vertically at a height of 5.5 feet. This height was selected to approximate the eye level of the observers. This was also done to aid in reducing fog density variances from the sensor to the observer.

A medium intensity runway edge light was also used during Category IIIb testing. This light was chosen because no measurements had been previously obtained with medium intensity lights. The light was placed near VS 02, as shown in figure 1.

During certain daytime conditions, the RVR will report readings related to the visibility of a black target if it is more visible than a runway light. To account for this operational function during testing, black objects were installed for use as secondary targets. These targets were used for visibility measurements during the day when the black target was more visible than the runway light. The black targets were placed at the same locations as the high intensity runway lights. The targets were rectangular in shape, constructed from wood and painted black to contrast daylight.

Vs were positioned to record measurements over the entire Category IIIb range--150 to 750 feet. VS 01 was placed next to one end of the observation path as shown in figure 1. This sensor measured a volume of airspace that was in close proximity to the observation area. VS 03 was positioned at the far end of the test site (i.e., location H2 on figure 1), approximately 750 feet from the furthest observation point. In addition to encompassing the Category IIIb range, this location was chosen to help ascertain the fog homogeneity across the entire testing area. To further assess fog homogeneity characteristics, VS 02 was positioned about half-way between sensors 01 and 03 (i.e., location H1 on figure 1).

(Top View)

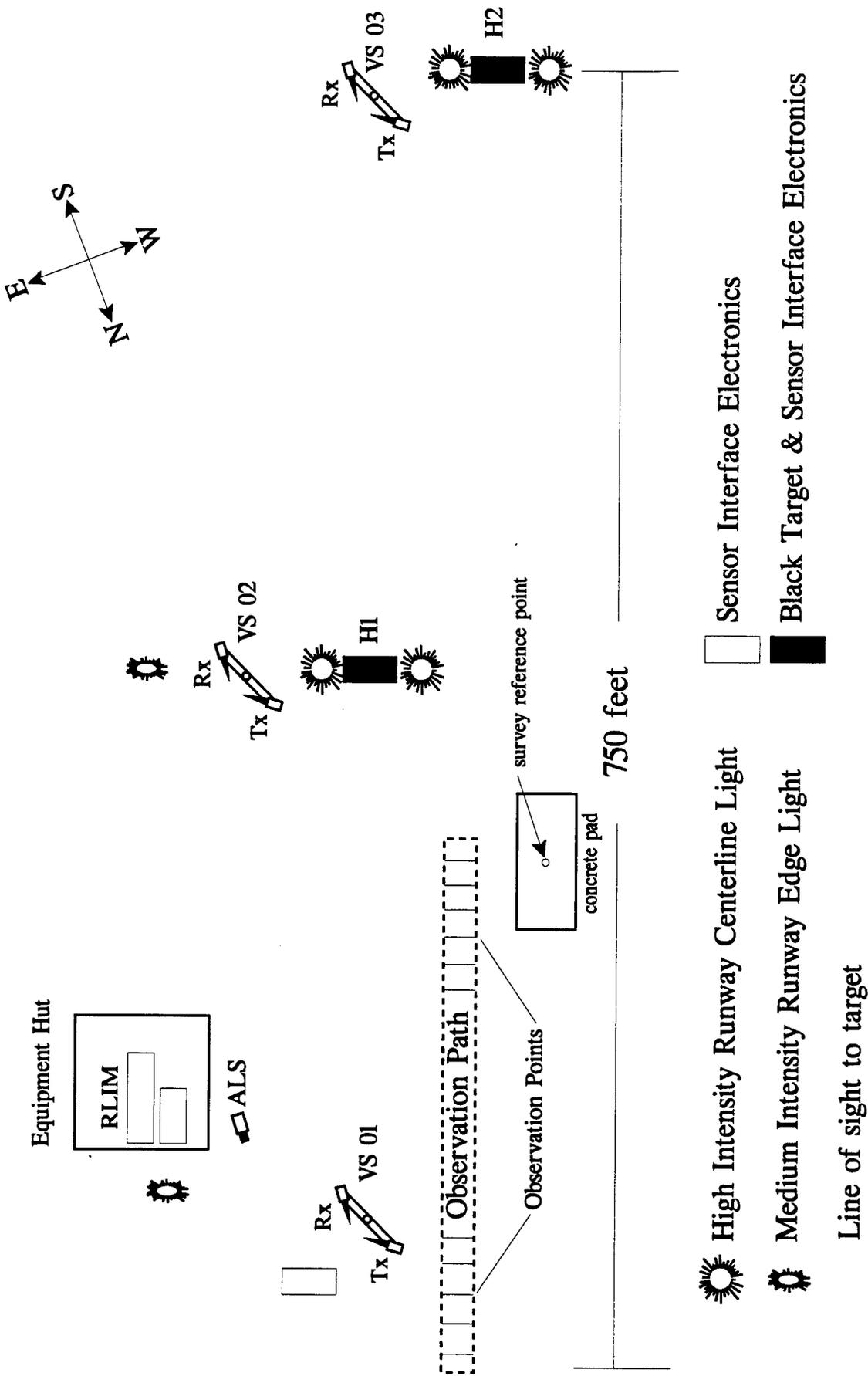


FIGURE 1. CATEGORY IIIb TEST LAYOUT

As mentioned, the observation path was a fairly level area chosen for viewing the targets. Measurement tapes were placed along the path so that observers could record their locations relative to the tapes. The tapes spanned a distance of 500 feet and were securely fastened to prevent movement during high winds.

A land surveyor was used to measure the distances of the targets to a reference point as shown in figure 1. Observer visibility readings were calculated by combining surveyed measurements with observation points collected by the observers.

The ALS was located next to the equipment hut and near the observation path as shown in figure 1. This sensor, along with all of the visibility sensor receivers, was pointed towards magnetic north.

4.5.2 Test Conduct.

A software algorithm developed by the Volpe National Transportation Systems Center was used to record visibility measurements obtained by the observers. The algorithm was designed so that the time of the observation would match the time of a data sample taken by RVR sensors. Before conducting an observation, the observer would input parameters such as the viewing target, and observer identification.

The observation procedure for this Category IIIb test was altered slightly from the previous year's test. Previously, distances at which the target was visible for approximately 50 percent of the time were recorded as the viewing distance. This distance represented one observation point. For this test, however, one observation consisted of three viewing distances or three data points that are described as follows:

The first distance was determined by the observer starting from a location far enough away so that the target was not visible, and then moving towards the target along the observation path. The location at which the target was first visible was entered as a data point. From this location, the observer then moved away from the target while simultaneously viewing it. The distance at which the target was no longer visible was entered as the second data point. Before determining the third data point, the observer moved towards the target (along the observation path) so that it was again visible. Once the target was visible, the observer again moved away from the target. However, before viewing the target, the observer would first look away then try to refocus on the target. The third data point represented the distance at which the observer could not find the target after looking away.

The modified observation procedure and additional viewing distances were intended to provide additional data relating the

performance of RVR and alternate equations in calculating observed visibility. The procedure was also designed to more closely simulate pilot viewing patterns during low-visibility weather.

During pretest activities, it was found that four centerline lights were not needed to conduct measurements. As a result, one runway centerline light at location H2 was not activated. Also, to prevent interference from adjacent lights during test scenarios, lights not being viewed were covered, so only the desired target was displayed.

Since most airports use the higher runway light settings during reduced visibility, Category IIIb testing used runway light settings from step 3 to step 5. Observations were conducted under both daytime and nighttime conditions.

4.6 DATA COLLECTION AND ANALYSIS METHOD.

The following equipment was used for data collection during the Category IIIb test:

- a. One rack-mount computer, and
- b. One notebook computer.

The rack-mount computer was used as a data acquisition system to collect and store data from the EU port of the DPU. Data included parameters such as extinction coefficient (km^{-1}), window contamination (percent), and ambient light (foot-lamberts). The rack-mount computer was also configured to operate with an existing local area network at the Mt. Washington Observatory. The local area network will allow the data acquisition system to be monitored remotely throughout the winter of 1995 and 1996.

The notebook computer was used to automate the data entry process of the observations. A software algorithm was designed to record data such as:

- a. Target identification (i.e., black target, runway centerline light, runway edge light),
- b. Distance from target,
- c. Time stamp, and
- d. Observer identification.

Data analysis consisted of a statistical evaluation of the data. This analysis was performed at the Volpe National Transportation Center after testing concluded.

5. TEST RESULTS.

Preliminary results indicate that the accuracy of the RVR system was generally within a tolerance of 100 feet, or one reporting unit of the system. An in-depth analysis of system accuracy is being performed by the Volpe National Transportation Center. The results of the analysis will be distributed in a separate report.

Although there were no operational problems experienced during test scenarios, visibility sensor shutdowns occurred during the initial installation of the system and between observation periods. The cause of the shutdowns appeared to be failures in visibility sensor hood heaters or failures in the circuitry controlling the hood heater operation.

In a failure that occurred during the installation period, the power transistor circuitry over-heated and thereafter was not operational. This caused a total shutdown of VS 01. Diagnostic tests indicated that the supply voltage for the hood heater was faulty. As a result, the SIE enclosure was removed and replaced. Since the SIE electronic components were observed to be wet, moisture/condensation may have contributed to the failure. The possibility also exists that fluctuations in the circuit electrical characteristics, due to cold temperatures, may have contributed to the failure.

The failures that occurred between observation periods were not as severe. These failures were intermittent and the sensor continued to operate when failures were not present. Again, the failure appeared to be in the heater control circuitry or hood heater. Diagnostic tests indicated that the 28V supply voltage to the heater was in error. As in the previous failure, moisture was observed inside the SIE and could have contributed to the circuitry failure.

In addition to the heater problems noted above, a rime ice "ledge" developed on the receiver of one visibility sensor (figure 2) during a snow storm. The ledge extended from the bird spike to an area just below the front of the sensor hood. Although the ledge appeared to have no effect on the sensors extinction coefficient measurement, subsequent snow or ice accumulation could have resulted in degradation of system accuracy.

5.1 TEST LIMITATIONS.

- a. There is no approved standard for comparing runway visibility as measured by the RVR system and the vision of observers. The absence of a standard means the data is inherently subjective;

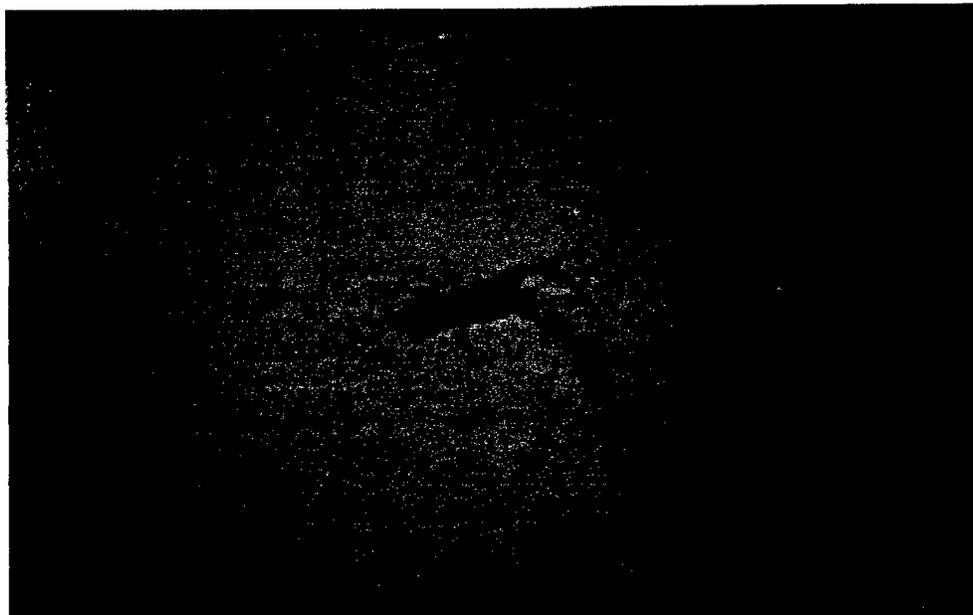


FIGURE 2. RIME ICE LEDGE ON RVR VS

- b. Although the test setup aided in reducing uncertainties concerning fog density, differences in fog homogeneity are likely to exist. These differences could create variations in test results as well as operational runway products; and
- c. Photometric data was not available for the new runway lights used. Intensity differences between runway lights used during testing and actual aged runway lights may inject additional errors in the test data.

6. CONCLUSIONS.

Modifications to the visibility sensor and algorithms appear to have no adverse effect on the Runway Visual Range (RVR) system's ability to accurately compute visibility. Although results suggest that RVR performance in the Category IIIb range is sufficient, the limitations expressed in section 5.1 substantiate a requirement for additional tests before final conclusions on system accuracy are made.

Continued testing, as well as development of a standard for assessing runway visibility as measured by an RVR system, will be necessary to completely define RVR system accuracy.

7. RECOMMENDATIONS.

It is recommended that comparison tests between the Runway Visual Range (RVR) and a meteorological optical range transmissometer be performed to complete the RVR accuracy evaluation. Photometric tests should also be performed on the runway lights used during testing to compare their output to an average high-intensity runway centerline light and medium intensity edge light.

It is also recommended that additional tests be performed on the visibility sensor and Sensor Interface Electronics (SIE) to determine with more certainty the cause of the shutdowns observed during the test effort. In particular, the possibility of condensation buildup with the SIE enclosure should be investigated.

8. ACRONYMS AND ABBREVIATIONS.

ALS	Ambient Light Sensor
ASOS	Automated Surface Observing System
DPU	Data Processing Unit
EU	External User
MDT	Maintenance Data Terminal
MPS	Maintenance Processor Subsystem
NAS	National Airspace System
OT&E	Operational Test and Evaluation
RLIM	Runway Light Intensity Monitor
RVR	Runway Visual Range
SIE	Sensor Interface Electronics
TCCC	Tower Control Computer Complex
VS	Visibility Sensor