6.6 SEVERE WINTER WEATHER PERFORMANCE OF RUNWAY VISUAL RANGE (RVR) SYSTEMS AT FIVE ALASKAN AIRPORTS

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1. INTRODUCTION

Operational data from new generation Runway Visual Range (RVR) systems were collected and archived by the Volpe Center at five Alaskan airports beginning in the autumn of 1997. The intent was to determine whether any light transmission clogging occurs from snow blowing and accumulating on the sensor optical heads of either the visibility sensor (VS) or ambient light sensor (ALS). Data were conveniently recorded on palmtop computers and sent back to the Volpe Center in 1998. This data were then transferred to a personal computer (PC) for processing and analysis.

TABLE 1

Site	Latitude	Longitude	BLSN (hrs/yr)
Bethel	60° 49'	161° 49'	173
Cold Bay	55° 10'	162° 45'	217
Fairbanks	64° 50'	147° 50'	4
King Salmon	58° 40'	156° 50'	45
Nome	64° 30'	165° 30'	160

Data were gathered at the following sites: Bethel; Cold Bay; Fairbanks; King Salmon; and Nome, Alaska. Four of these sites were selected for the experiment from among all Alaskan RVR-equipped airports, since they had the most frequent occurrence of blowing snow as determined from five years of hourly surface weather observations. Fairbanks was selected as a reference site, because it had Airways Facilities (AF) maintenance support more readily available. A list of latitude and longitude and the relative frequency of blowing snow in hours per year (BLSN) for these sites is shown in Table 1. All the sites have one VS and one ALS except Fairbanks, which has three VS and one ALS.

Exact test periods for each site are given in Table 2; note that the start of testing at King Salmon was delayed because the ALS was being moved to a new location at the airport. In Table 2, the column 'SN' is the number of days with snow reported according to METAR reports; the column 'BLSN/DRSN' is the days with blowing or drifting snow but with no falling snow; the column 'Mixed Prcp' is the number of days with mixed snow and rain reports.

1.1 RVR Operation - All five Alaskan sites use the RVR systems developed by Teledyne Controls in collaboration with the Volpe Center and the FAA Hughes Technical Center. Each RVR system has one or more visibility sensors (VS), an ambient light sensor (ALS) and one or more runway light illumination monitors (RLIMs). Input from each sensor is used to calculate RVR, defined as the greatest distance at which an object can be seen. The VS measures extinction coefficient (σ). RVR is related to σ by Koschmeider's law for black targets in daytime and by Allard's Law for runway lights at night. The ALS measures the background brightness, and the RLIM reports the runway light intensity setting.

TABLE 2

Site	Code	Test Period 1997-1998	SN	BLSN/ DRSN	Mixed Prcp
Bethel	PABE	9/18-7/27	133	2	2
Cold Bay	PACD	9/16-8/08	135	1	8
Fairbanks	PAFA	9/19-6/17	73	0	1
King Salmon	PAKN	11/04-7/01	92	1	6
Nome	PAOM	9/15-8/11	124	9	0

The VS at all five Alaskan sites are forward scattermeters consisting of transmitter and receiver heads mounted on a yoke. Each VS measures σ in units of km^{-1}. A $\sigma = 0$ km^{-1} corresponds to clear sky with no obstructions to visibility while a $\sigma = 1.9$ km^{-1} corresponds to a visibility of one statute mile based upon the applicability of Koschmieder's Law (Burnham et al., 1997). Similarly, $\sigma = 4.5$ km^{-1} corresponds to a visibility of 2,400 feet which is the threshold between Category I and Category II[1] RVR Instrument Landing Systems (ILS) operations in the absence of runway lights.

Both VS heads are heated and are pointed down about nine degrees to minimize clogging from blowing snow and freezing rain. The standard orientation of the VS has the receiver head pointing north and transmitter pointing SW.

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[1] Category I RVR events are defined for 2,400′ ≤ RVR ≤ 6,500′; Category II is for 1,200′ ≤ RVR < 2,400′ and Category III is for RVR < 1,200′.

FIG	SITE	START DATE	START TIME	END DATE	END TIME	MET TIME	WDIR (deg)	WSP (kts)	GUST (kts)	VIZ (mi)	PRCP	OB2VIS	TEMP (deg C/F)
	PABE	11/26/97	0550	11/26/97	0600	0549	30	20		2	-SN		-13/9
	PABE	11/26/97	1710	11/26/97	1800	1715	10	22	31	.63	-SN	BLSN	-13/9
3	PABE	11/27/97	0210	11/27/97	0220	0214	360	15	25	1		BLSN	-13/9
	PABE	12/24/97	0100	12/24/97	0110	0055	30	21	30	.75	-SN	BLSN	-17/1
	PABE	12/24/97	1215	12/24/97	1220	1240	320	9		.75	-SN	BR	-12/10
	PABE	1/1/98	0750	1/1/98	0800	0757	350	3		1.5	SN		-15/5
	PABE	1/1/98	1430	1/1/98	1550	1429	310	17		2	SHSN	BLSN	-14/7
	PACD	11/26/97	1620	11/26/97	1630	1620	330	26	35	1.25	-SHSN		1/34
2	**PACD**	**11/27/97**	**0000**	**11/27/97**	**2350**	**0055**	**330**	**38**	**50**	**2**	**-SHSN**	**BLSA**	**-3/27**
	PACD	12/11/97	1920	12/17/97	1950	1950	360	11		3	-SHSN		-6/21
	PACD	12/17/97	0000	12/11/97	1700	0050	340	25	34	.25	-SHSN	BLSN BR	-3/27
	PAOM	12/4/97	2310	12/5/97	0130	2346	60	24	31	.19	-SN	DRSN	-7/19

TABLE 3

The ALS measures background illumination (sky brightness) using a sensor head pointed to true north six degrees above the horizon. The measurements of sky brightness are reported in foot-Lamberts. Zero foot-Lamberts correspond to darkness while readings over 2,000 foot-Lamberts imply bright sunlight. Because of the preferred orientation of the heads, in most locations the ALS is generally more susceptible to clogging from blowing snow than the VS. Both the VS and the ALS heads are heated to melt any incoming blowing snow and prevent ice buildup.

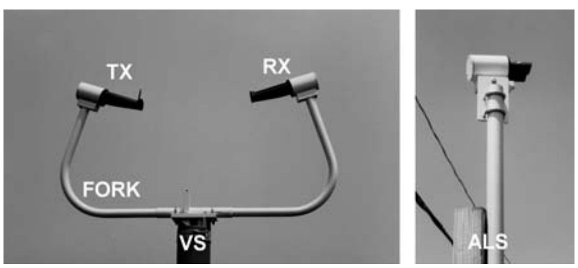

Fig. 1 – Teledyne VS and ALS

Fig. 1 shows photographs of the Teledyne VS and ALS sensors. Additional details on these instruments may be found in Burnham et al. (1997).

2. METHOD

Data acquisition system (DAS) software for each palmtop was written by the Volpe Center for installation at each site. The computer was connected to the Engineering Users' Port (EUP) at the site. The DAS software read the data from the RVR EUP and saved it in a binary format in order to conserve data storage space. σ, ambient light and window signals were recorded for each RVR system once per minute. The palmtops continued to gather data at the sites until early-to mid-summer of 1998. They were turned off and returned to the Volpe Center for archiving and analysis at that time.

Specially designed off-line processing software was used to plot σ and transmitter and receiver window signals from each VS and the ambient light signal and window signal from each ALS. In the sample shown in Fig. 2, the ambient light is plotted in foot-Lamberts at the top of the page. σ is plotted next in units of km^{-1}. Window signals are plotted in multiples of 10 with each multitude corresponding to 5% loss. "Hours of Day" are plotted on the horizontal axis in Greenwich Mean Time (GMT), which is nine hours in advance of Alaskan Standard Time. Transmitter and receiver window signals for the VS are plotted on the same grid. This same arrangement of axes and units are used in Figs. 2 through Figure 7.

3. EVENT CLASSIFICATION

Events are classified on the basis of official surface weather observations reported in METAR format from each of the five Alaskan sites. Regular reports from human observers or automated observing systems are issued hourly. In addition, special reports are issued anytime conditions warrant. Details related to METAR reports may be found in the Federal Meteorological Handbook No. 1.

Visibility events discussed here are classified as snow, rain, fog or mist. Snow includes both falling snow (SN), blowing snow (BLSN) and drifting snow (DRSN). Rain is designated RN; fog is FG; and mist is BR. Other data used from the METAR reports include wind speed in knots, wind direction in degrees (0 is calm, 90 is east wind, 180 is south, 270 is west and 360 is true north), temperature and dew point. Temperature and dew point are reported in degrees Celsius (prior to 1996 in degrees Fahrenheit).

Window signal cases on either the VS or ALS are classified based on duration. Long duration events include possible clogging from blowing snow and are deduced through observations of baseline changes in the window signal. Short duration events are usually associated with wet window signals occurring on either the ALS or the VS.

Fig	Site Code	Date	σ (km^{-1})	MET Time (Z)	MET Vis (miles)	MET Pwx and Obstr	MET Temp (deg C/F)	Wind Angle (deg)	Wind Speed (knots)	Wind Gust (knots)	Affected Head	Max Loss (%)
6	PAOM	4/10/98	7	0350	0.5	-SN BLSN	-0/31	110	33	39	RX	16
	PAOM	4/11/98	9	0112	1	-SN BR	1/34	120	20	-	RX	11
7	PAOM	4/27/98	7	0450	0.75	-SN RA	0/32	110	24	-	RX	12
	PAKN	12/18/97	9.5	2234	0.125	SN BLSN	-16/3	340	22	28	TX	11
	PAKN	4/01/98	11	1819	1	-SHSN	-1/30	190	15	20	RX	10
5	PACD	12/24/97	8	0350	1	-SN BR	-1/30	270	26	35	RX	11

TABLE 4

4. RESULTS

4.1 Clogging and Failures

No evidence of major clogging, similar to cases at Otis Weather Facility (Burnham et al., 1997) or St. Johns, Newfoundland (West et al., 1995), was detected at any of the sites during the test period.

Possibly the closest event to a clogging case occurred on November 27, 1997 at Cold Bay as shown in Fig. 2. The ALS window signal first experienced a gradual buildup beginning around 1600 GMT on November 26th, reaching about 5% loss at 0000h on the 27th. It then experienced a rapid buildup early in the day and hovered near 10% loss between 0400-1230 GMT. There were no signs of the noisy signal preceding the high steady window signal that is characteristic of a major clog reported by West et al., (1995). This event was associated with winds of around 38 knots, gusting to 50 knots from the NNW as shown in Table 3 (bolded). These wind and snow conditions support the premise that clogging had started to build up on the ALS. The recovery of the ALS began around 1245 GMT and appears to have undergone a series of transient clogging steps followed by partial recoveries. These events were most likely due to bursts of snow showers occurring throughout the day.

In Table 3, the column 'OB2VIS' describe obstructions to visibility according to the official METAR reports. A number of sensor failures and anomalies also occurred during this observational period. Several of the failures seemed to be from window signals building up more or less gradually beyond a set threshold, usually at 10% loss for the VS and about 15% loss for the ALS. An example is shown in Fig. 3. Attention is drawn to the VS window signal and σ curves at the bottom of Fig. 3; a scale of 20 on the VS window signal corresponds to a 10% loss. Note the gaps in the value of σ and VS window signal traces at around 1715 GMT and 1840 GMT. These gaps signify an apparent loss of VS due to one of the window signals exceeding the hard alarm threshold. There is a loss in σ corresponding to the simultaneous gaps in the window signals. Some failures lasted for days or weeks before the window(s) were cleaned. In these types of cases of apparent window signal related failures, the sensor involved recovered either after human intervention or from a weather event, which appeared to cleanse some of the window contamination.

4.2 Window Signal Baseline Changes

Aside from the wet window signal cases on the VS listed above, there were many other events where the window signal baseline changed significantly. Cold Bay had the most recorded instances. The changes in some events were sudden; others were more gradual, spanning several hours to at least one day.

A sample plot is shown in Fig. 4. It shows the baseline of the VS transmitter window signal decreasing steadily from about 8% to about 2.5% loss within 14 hours during a snow event at Cold Bay on November 26, 1997. The window signal baseline decrease started at the same time as the start of the σ event. The initial weather conditions were 30^{o} wind direction, 20 knots wind speed, 10^{o} F temperature, visibility of 2.5 miles in light snow and mist at 0542 GMT.

4.3 Wet Window Signals

There were several apparent additional cases of wet window signals from windswept snow and rain. Most of these cases involved only the ALS, because it points slightly (six degrees) above the horizon. The ALS cases are listed in Table 3. There were a few cases involving the VS. Table 2 lists the number of snow days for each site. The 'Test Period' in Table 2 indicates the dates that data were collected at each site. Snow days were defined as those days in which snow was officially observed at least once during the day. The column named 'BLSN/DRSN Days' is the number of days in which blowing or drifting snow was reported through normal surface observations but no falling snow was reported. The column labeled 'Mixed Precip' is the number of days with mixed rain/snow reports but no reports of just snow. It is seen from Table 2 that the sites with the most snow events and wet window signals are nearest the coast. The site with the fewest snow event days, Fairbanks, had the lowest reported temperature minima. This is attributed to its inland location. The characteristics at these sites were statistically comparable to the five-year average shown in Table 1, especially in terms of blowing snow.

Table 4 lists events where there were significant wet window signals snow on the VS associated with snow and blowing where the peak loss was at least 10%. Figs. 5-6 illustrate a sample of these window signal characteristics. All three sites with events listed in Table 4 are on the Alaskan coast. In Table 4, the column labeled σ /km' is the inferred σ in km^{-1} near the peak window signals. The remaining columns derive from official surface observation or METAR reports at the sites. The present weather was snow (SN), snow showers (SHSN), blowing snow (BLSN) and/or mist (BR). One of the events had rain (RA) mixing with snow. Note that the temperature was near the freezing mark except for one event. Also, the sustained wind speeds were at least 20 knots except for one event. There was a wide range of wind angles indicating that information on the wind direction may be evident in the data.

In Fig. 5, the wet signal peaked at 0410 GMT during an event at Cold Bay on December 24, 1997. There were sharp baseline variations in both transmitter and receiver window signals between 0200-0400 GMT. After the end of the wet receiver window signal peak, the baseline was markedly reduced from before.

Meanwhile, the baseline of the transmitter window signal increased steadily from 0210-1140 GMT. The visibility sensor stopped reporting after 1320 GMT for some unknown reason. The visibility sensor resumed reporting at about 0030 GMT, December 25, 1997. The weather was reported at 0150 GMT as light mixed rain and snow showers with a visibility of 1 mile. The wind blew at 38 knots with a gust of 45 knots from a 280^o wind direction. The temperature was 34^{o}F. After the window signal events started, the wind direction changed to 270^o, with wind speeds and peak gusts decreasing to 26 knots and 35 knots, respectively, by 0350 GMT. Meanwhile, the temperature fell to 30^{o}F. The visibility remained at 1 mile and the precipitation was all snow after 0250 GMT.

In the April 10, 1998 event at Nome shown in Fig. 6, the wet window signal on the receiver head occurred very late during the snow event. The value of σ was about 6 km^{-1} when the window signal peaked at 0445 GMT. The baseline window signal was declining for a few hours just before the start of the wet window signal starting at about 0430 GMT. Unfortunately, no official weather observation data were available while the window signal was elevated. Official observation at 0350 GMT shows the wind direction of 110^o with speed of 33 knots and gust of 39 knots. The visibility was ½ mile with light snow and blowing snow reported. The temperature was about 31^{o}F. The weather observation at 0559 GMT was similar except that the visibility improved to 1 mile.

4.4 ALS Window Signals

Window signal variations from blowing snow were more frequent on the ALS because the ALS is required to point six degrees above the horizon. Examples of significant wet window signals are shown in Figs. 2 and 7. All of the example events also resulted in changes in the baseline window signal. Weather conditions for the events described below are summarized in Table 3.

The event closest to a clogging case was the event of November 27, 1997 at Cold Bay as shown in Figure 2. More details are discussed above in Section 4.1.

Figure 7 shows a broad window signal spike near 0220 GMT just after the peak of a brief σ event at Bethel that happened on November 27, 1997. The baseline window signal increased from about 0.5 to 4% loss from about 0225-1200 GMT and for several hours after the σ event was essentially over. The weather was blowing snow with a one-mile visibility and a temperature of 9^{o}F. The wind direction was 360^o and blew at a speed of 15 knots with a 25 knots peak gust.

5. CONCLUSIONS

Data were gathered and processed from five Alaskan RVR sites in search of instances of VS and/or ALS clogging from blowing snow. No major clogging instances were found even though some events had very high wind speeds. Several cases where wet window signals on the ALS and VS due to blowing snow were detected. Other cases of window signal baseline changes were also found. These cases involved gradual buildup over several hours or days. In a few cases, the window signal exceeded the hard alarm limit and failed the sensor. In these cases, the sensor remained failed or failed intermittently for days or weeks until the window(s) were cleaned. Overall, especially considering the severity of the winter weather at these sites, the new generation RVR systems performed remarkably well.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

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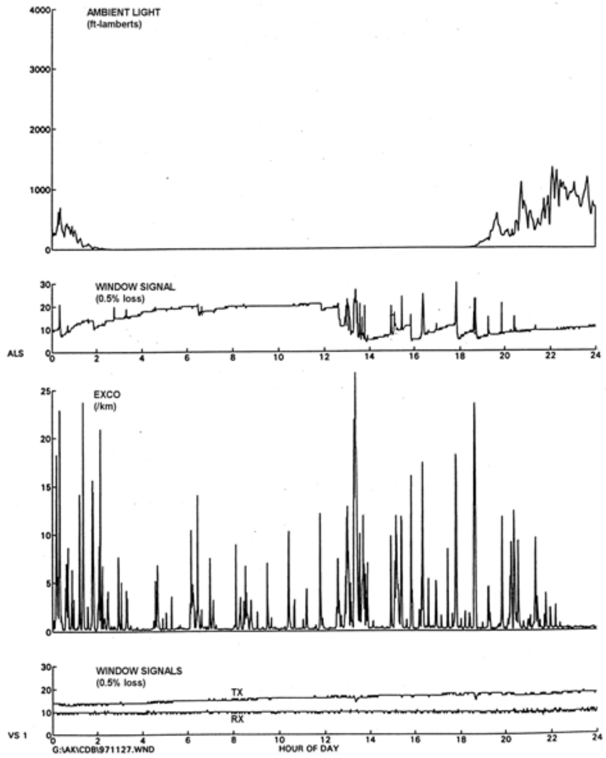

Fig. 2 – ALS Window Signal Case at Cold Bay Occurring on November 27, 1997

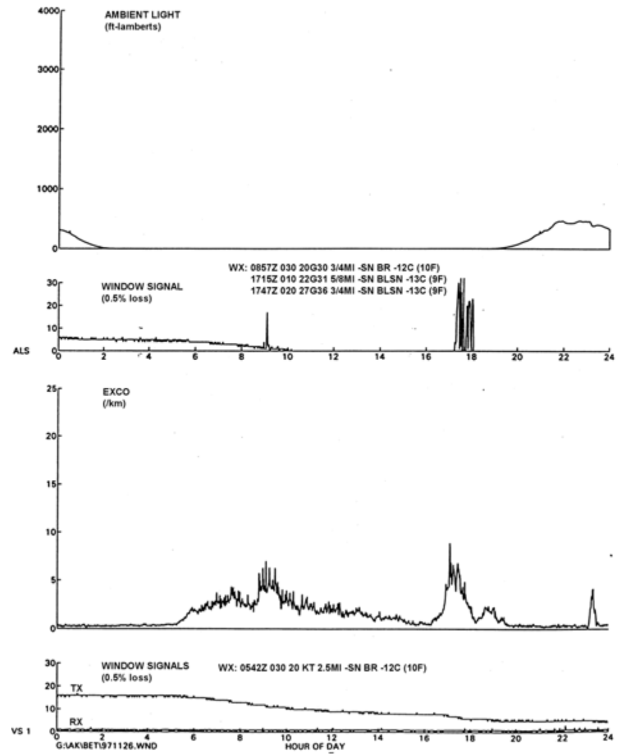

Fig. 4 – VS Window Signal Baseline Change

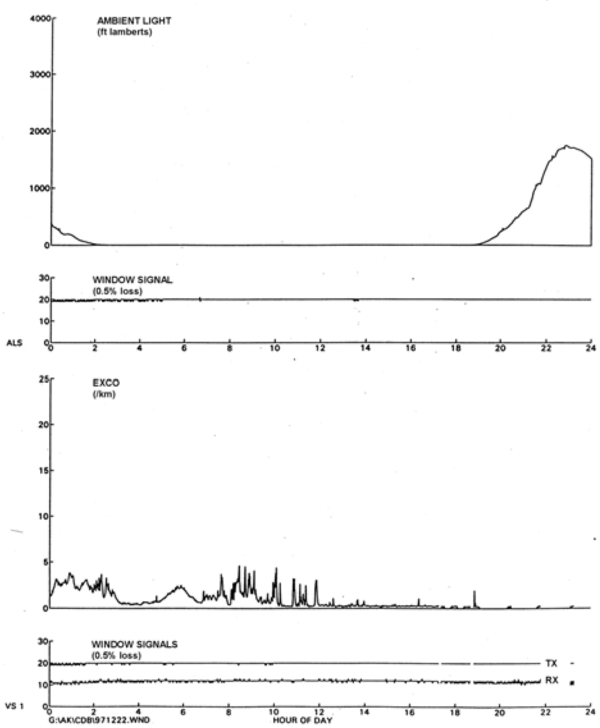

Fig. 3 – Sample VS Failure

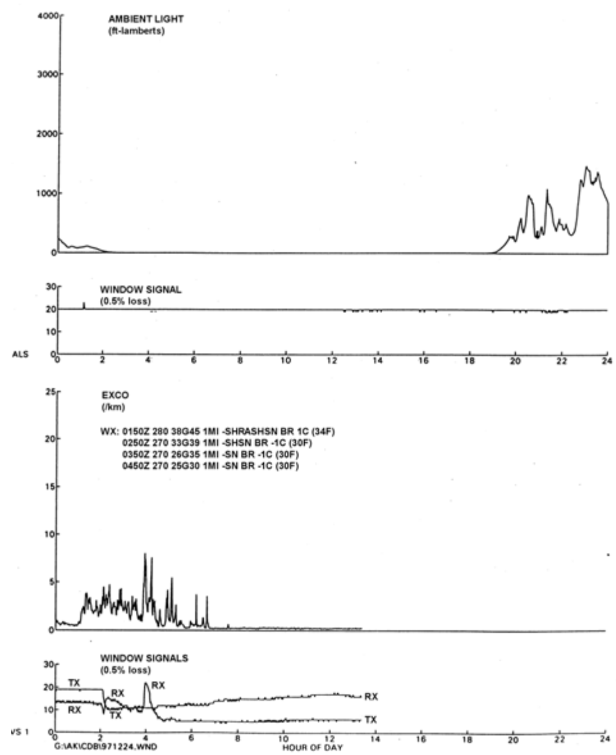

Fig. 5 – VS Wet Window Signal Case at Cold Bay Occurring on December 24, 1997

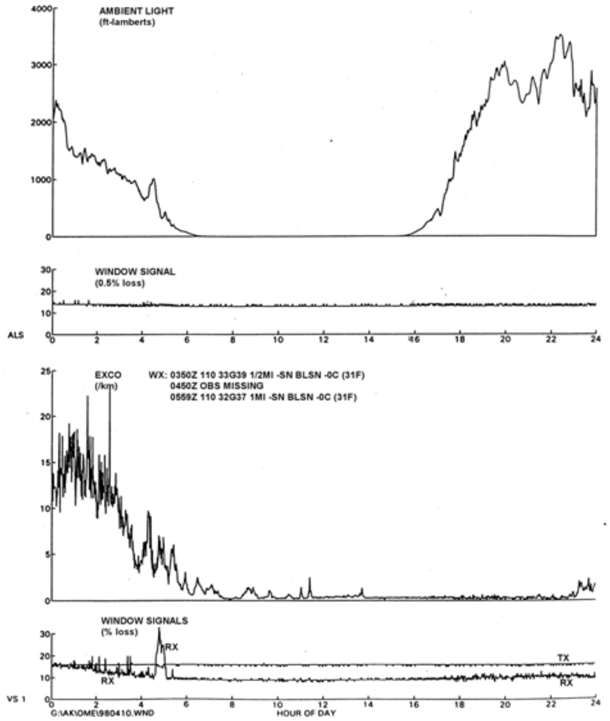

Fig. 6 – VS Window Signal Case at Nome Occurring on April 10, 1998

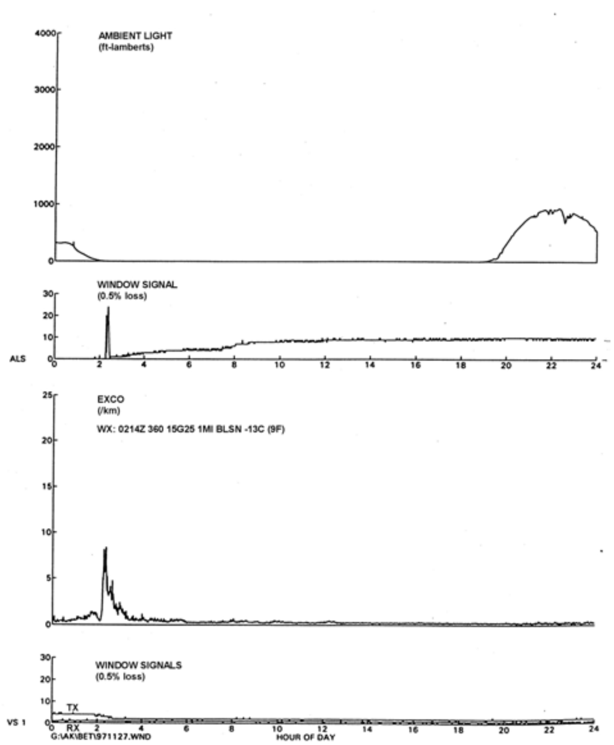

Fig. 7 – ALS Wet Window Signal Case at Bethel Occurring on November 27, 1997