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**Shipboard Test of the Forward Scattering Meter:
Preliminary Results
(July 1987)**

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A shipboard test of the Forward Scattering Meter (FSM) was conducted aboard the POINT SUR during a cruise off the California coast from July 6 to July 17. This report discusses the performance of the FSM during this period, problems which were encountered in the operation of the FSM, and steps which need to be taken to solve the data problems. Power outages revealed a need for solenoid-driven doors over the transmitter and receiver windows. Strong winds into either window would overcome the flow of clean purging air from the single pump and therefore two pumps should be used, one for the transmitter window and one for the receiver window. A method of monitoring the background level is needed and a telescoping cylindrical sleeve is suggested. 24-hour plots of the FSM data, HSS Visibility-Meter, and Radon concentrations measured during the cruise are given.					
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**SHIPBOARD TEST OF THE FORWARD SCATTERING METER:
PRELIMINARY RESULTS
(JULY 1987)**

INTRODUCTION

The Forward Scattering Meter (FSM) was developed as a prototype by the Naval Research Laboratory because of a Navy operational requirement of the SMOOS program. It is used to measure extinction in the infrared at 10.6 μm and can also be used to indicate the liquid water content of aerosols in clouds, fogs, and hazes.

The extinction at 10.6 μm is important to the Navy to determine the effectiveness of equipment and instrumentation operating at that wavelength such as optically guided missiles and Forward Looking Infrared Radar (FLIR).

The FSM had been tested and calibrated at the Calspan atmospheric test chamber in Buffalo, New York where it was subjected to various fogs and hazes, and the output compared to chamber instruments. The chamber tests demonstrated that the FSM worked as designed, but were unrealistic of how the instrument would perform under adverse conditions.

The FSM was given a shipboard test to determine how it would perform in the marine environment, and to uncover any operational deficiencies that need to be corrected in engineering prototypes.

Manuscript approved March 4, 1988.

SHIPBOARD TEST

The POINT SUR is a research vessel owned by the National Science Foundation and operated by Moss Landing Marine Laboratories. It is based in Moss Landing 20 miles north of Monterey, California and is used extensively by the Naval PostGraduate School. Its overall length is 135 ft, and it has a beam of 32 ft. It has a maneuvering speed of 0 to 10 knots, can sustain 11.5 knots, and has a cruising range of 5600 nmi. The POINT SUR carries nine crewmen and is capable of carrying twelve scientists for a normal cruise duration of 21 days.

Several groups were aboard the POINT SUR, including scientists from the Naval PostGraduate School, the Naval Research Laboratory, and the National Center for Atmospheric Research.

The FSM was mounted on the railing above the pilot house, with the open area of the sensor aligned perpendicularly to the centerline of the ship (Fig. 1). The electronics enclosure was mounted on the roof of the pilot house, and coaxial cable was used to connect the FSM to the data acquisition unit located in the wet lab of the POINT SUR. A Tektronix 4052 Graphic system was used to store data and to provide real-time plots of the FSM output. The output was monitored 24 hours a day for the duration of the cruise.

The cruise began on July 6, 1987. The POINT SUR left Moss Landing at noon and headed toward San Nicolas Island, which lies approximately 300 miles south

of Moss Landing. The majority of the cruise was spent sailing between San Nicolas Island and Santa Rosa Island (Fig. 2). The POINT SUR spent 12 days at sea; it headed back to port on July 16 and arrived at Moss Landing at noon on July 17.

Many meteorological observations were made aboard the POINT SUR, including radiosonde data every 4 hours, aerosol size distributions, radon concentrations, SODAR measurements, wind speed, wind direction, and air and sea surface temperature.

Following is an overview of the weather observed aboard the POINT SUR during the cruise.

July 6: The day started out hazy with poor visibility. Occasional white caps were observed. Visibility improved later that day.

July 7: The morning began with heavily overcast skies and white caps. Skies were brighter later in the day.

July 8: Skies were cloudy and overcast with a moderate swell causing the ship to pitch. The wind speed began to increase. The sun shone through clouds in late afternoon.

July 9: The day started out cloudy and overcast. Seas were calm with light winds. The skies were clear in late afternoon except for high thin clouds.

July 10: The morning began cloudy with a heavy haze. By noon the clouds were thinning out and skies got brighter. The sea was glassy.

July 11: This day was cloudy, with calm seas, light winds, and very good visibility.

July 12: There was 100% cloud cover and good visibility in the morning. By 2:00 p.m. winds had increased to 8 knots and cloud cover dropped to 80%. By 3:00 p.m. the winds were still increasing and cloud cover had dropped to 5%. Occasional white caps were observed. Cloud cover had increased to 50% by 9:00 p.m. that night.

July 13: Winds had increased to 17 knots. The skies were overcast with denser clouds than the previous day. Swells intensified as the wind speed increased to 20 knots. By 8:00 p.m. the winds had decreased to 17 knots.

July 14: The morning was cloudy and overcast with winds out of the northwest at 11 knots. Cloud tops were measured at 55 m. By noon droplets could be felt on skin. Visibility was poor. Fewer white caps were observed. By 4:00 p.m. the skies had cleared except for thin clouds and haze. By 6:00 p.m. there were no clouds. By 7:00 p.m. there was 100% cloud cover. At 9:00 p.m. the following was observed:

Wind Speed	21	knots
Dew Point	12.1	°C
Temperature	13.7	°C
Barometer	1010.3	mb.

July 15: The morning was overcast with poor visibility and winds at 8 knots. Fine mist could be felt on skin. At 10:00 a.m. the following was observed:

Wind Speed	8	knots
Dew Point	11.7	°C
Temperature	13.3	°C
Barometer	1012.3	mb

Cloud base at approximately 80 m.

At 1:40 p.m. mist could still be felt.

July 16: Winds had dropped to 6 knots.

July 17: The POINT SUR returned to port at Moss Landing.

RESULTS

The POINT SUR cruise was very helpful in evaluating the performance of the FSM in the maritime environment. During the cruise several problems severely affected the operation of the FSM. The following is a description of the problems and of the steps that need to be taken to resolve them.

The FSM utilizes a clean air purging system to keep the transmitter and receiver lenses free from airborne contaminants such as dust, smoke, and sea spray. Any type of lens contamination would cause changes in the background level, which would give an erroneous output. During the cruise we encountered several unexpected power outages that caused the purge system to fail and in turn caused the lenses to become contaminated. To correct this problem there should be a solenoid-driven door mounted over the transmitter and receiver windows (Fig. 3). It could automatically close during power or air pump failures. The second problem encountered also involved the clean air purging system. If the wind blew in the direction of either window (transmitter or receiver), clean air flowing through that window would reverse flow thus causing lens contamination. In the present design only one air pump is used, which is the cause of this problem. Two pumps should be used; one for the transmitter and one for the receiver. Another finding during the cruise was in regard to the background level. On a clear day with good visibility the FSM output is an indication of the background level, but it would be desirable during periods of poor visibility or when lens contamination is suspected to be able to check the background level to ensure accurate measurements are being

made. A means of doing this would be to use a telescoping cylindrical sleeve that could manually or mechanically be put in place to isolate the path of the laser beam from the atmosphere (Fig. 4). The FSM output could then be monitored for a specified amount of time and compared to previous background measurements to ensure the background had not changed. If in fact the background had changed, the FSM could still be used without having to clean the lens by simply subtracting the new background level from the FSM output signal.

With the incorporation of these simple design changes it is believed that the FSM will be an accurate and reliable means of obtaining extinction in the infrared at $10.6 \mu\text{m}$ aboard ship.

The shipboard test was run concurrently with the FIRE experiment at San Nicolas Island, in which NRL flew an FSM aboard their $19,000 \text{ ft}^3$ aerostat. Data from several flights will be compared to data from the POINT SUR.

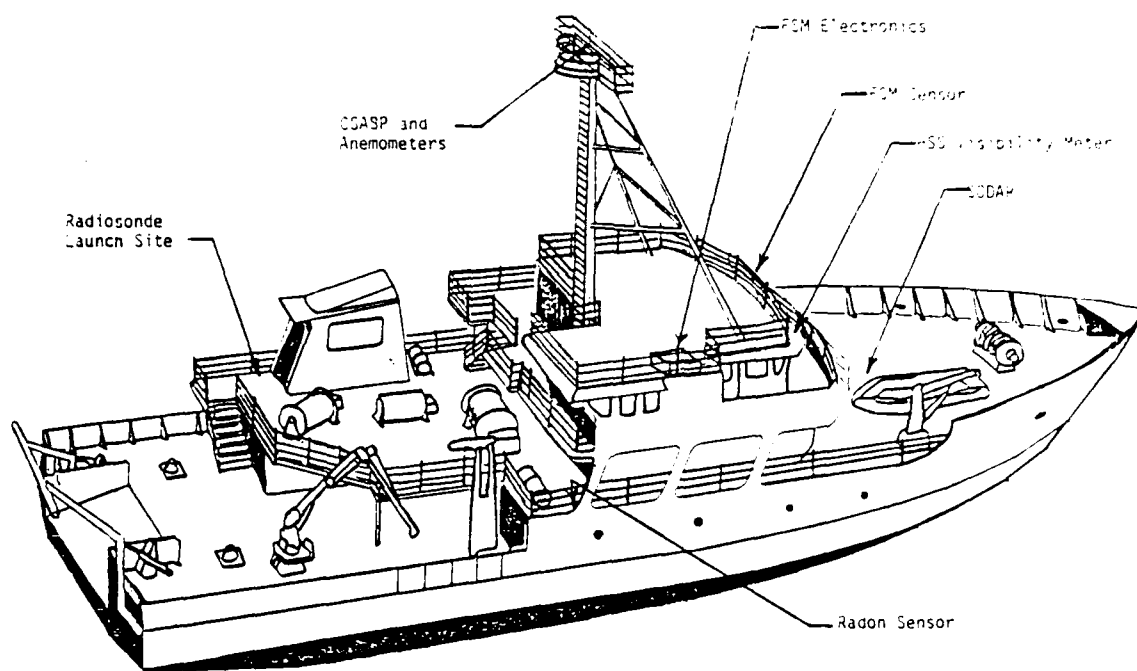
ACKNOWLEDGEMENTS

We thank Ted Czuba of NAVAIR for his support in the development and testing of the Forward Scattering Meter as part of the SMOOS project (Project No. 63207N PDW106-8-058C-6X0514). We thank Stuart Gathman of NRL for his help during the cruise. We thank Dr. Ken Davidson of the Naval Postgraduate School for his cooperation during the cruise. We also thank the captain and crew of the POINT SUR.

REFERENCES

Jeffrey E. James and H. Gerber, "Design and Operation of the Forward Scattering Meter", NRL Report 8996, 1986.

"Instruction Manual for the VR-301 Visibility Meter", HSS-M-004, 1983, HSS, Inc.



Location of Meteorological Instrumentation
Aboard the Point Sur

Fig. 1

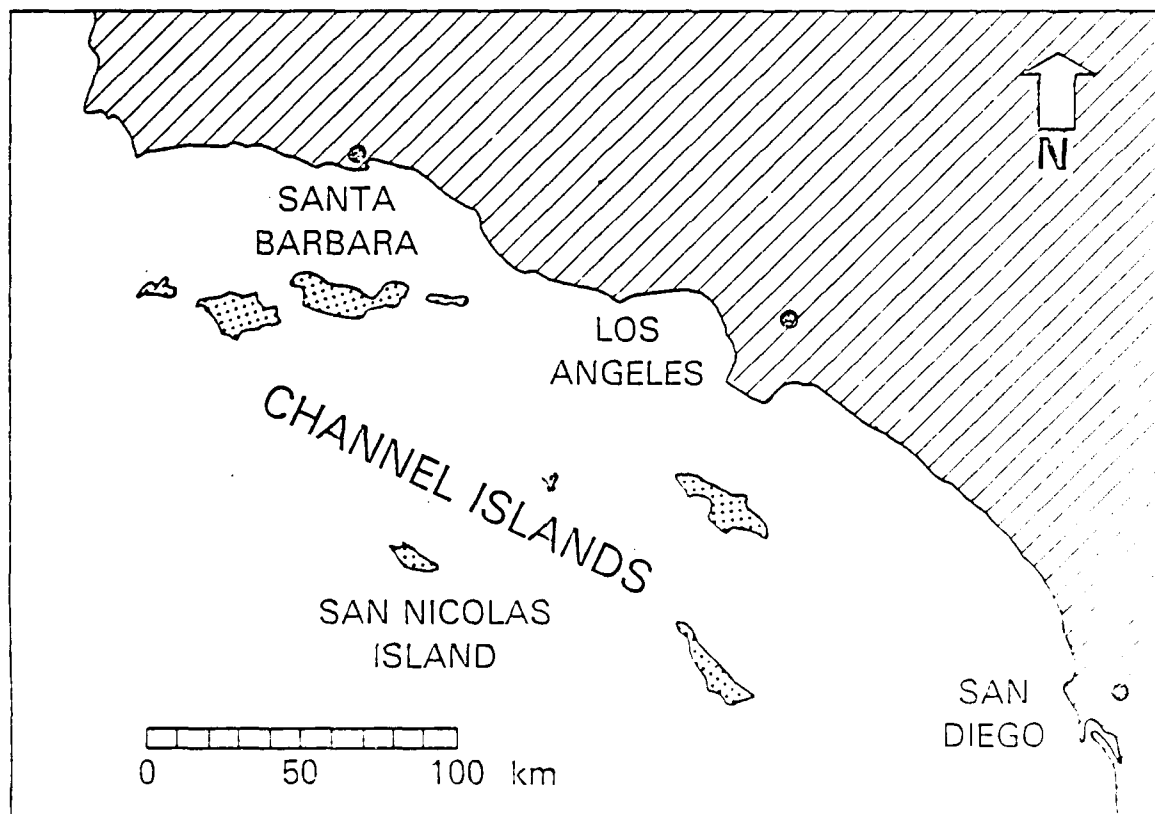


Fig. 2

A Means of Keeping Lenses
Free from Contaminants
During Power Outages

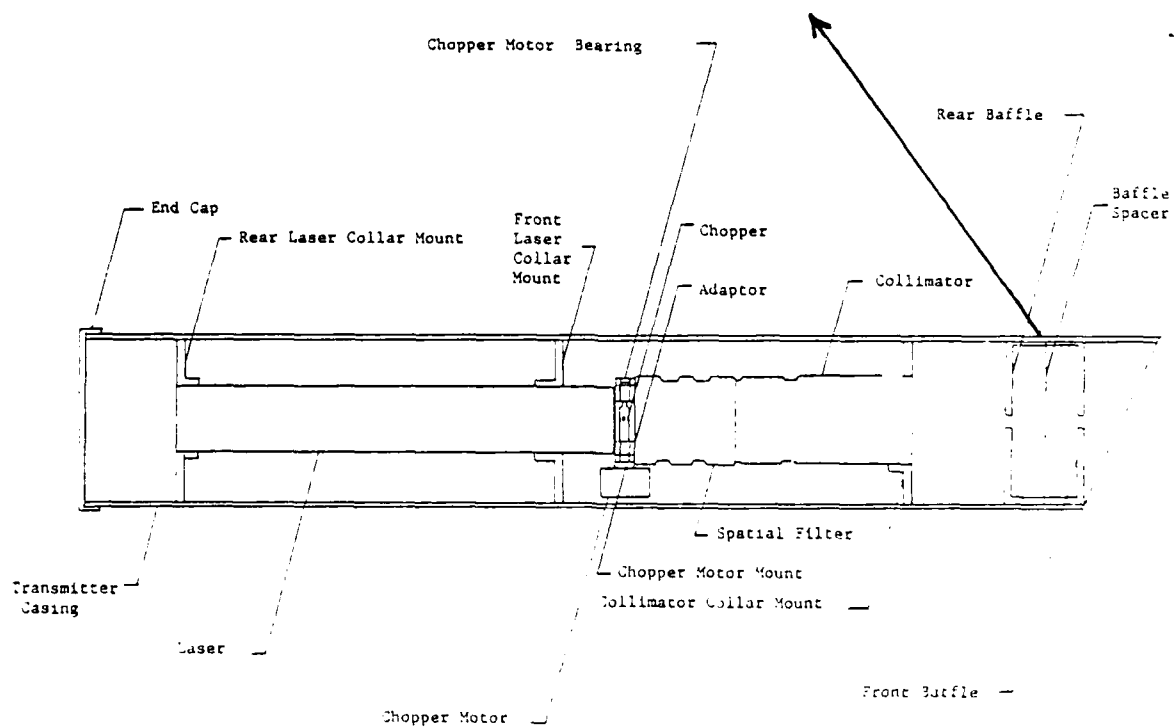
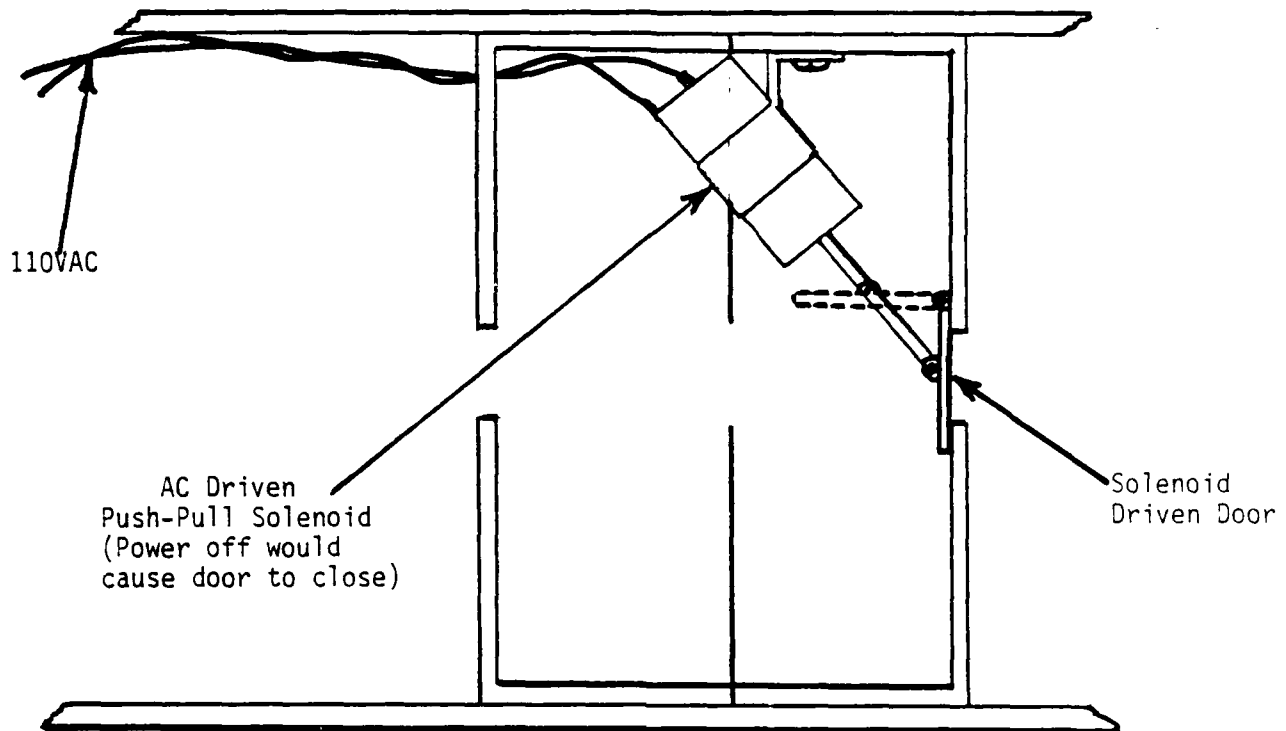


Fig. 3

A Means of Obtaining
a Background Level During
Periods of Poor Visibility

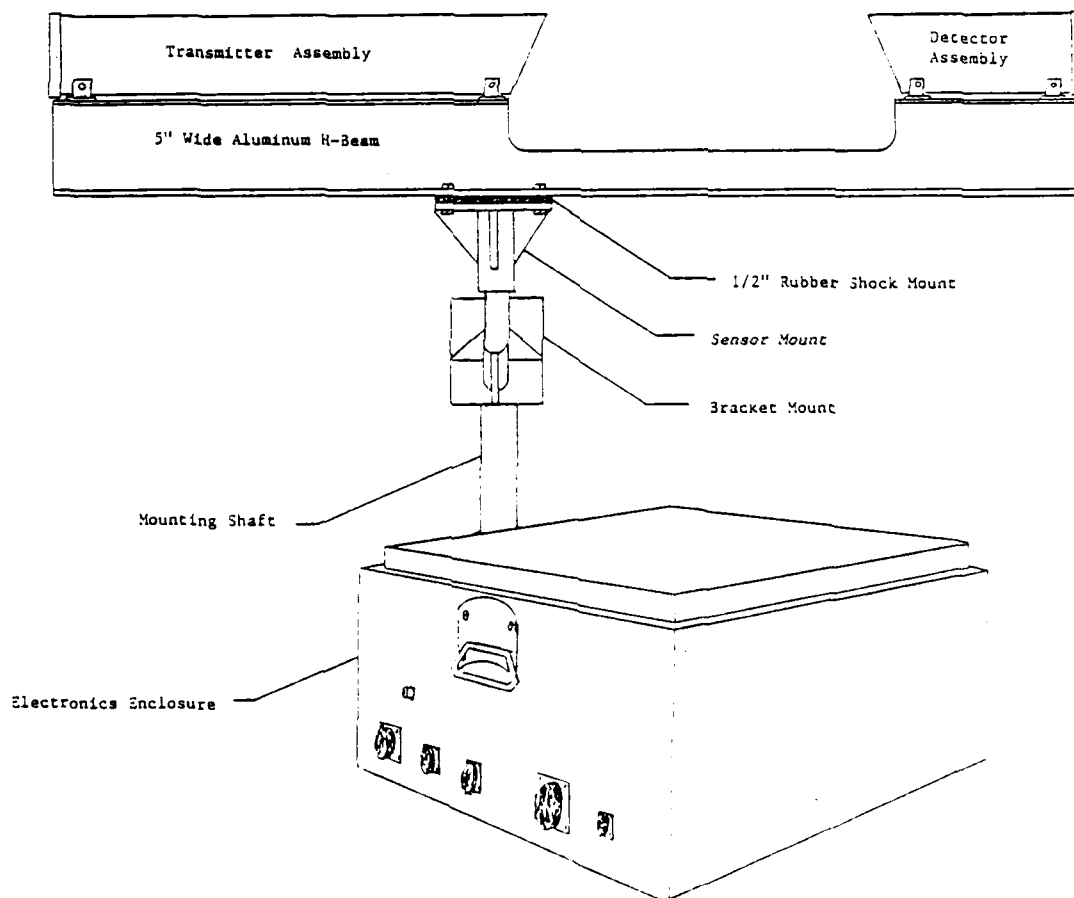
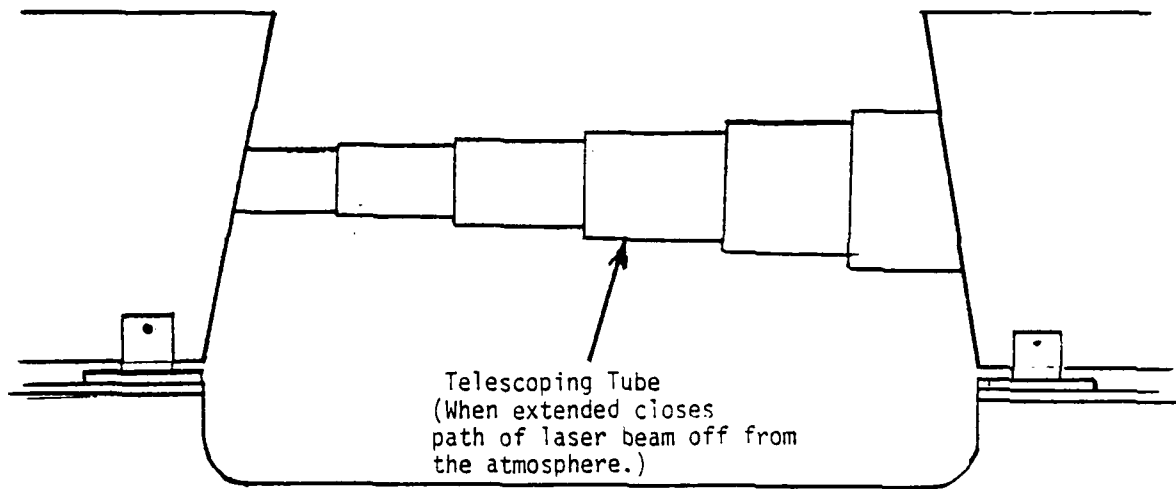


Fig. 4

APPENDIX A

PLOTS OF FSM AND HSS VERSUS TIME

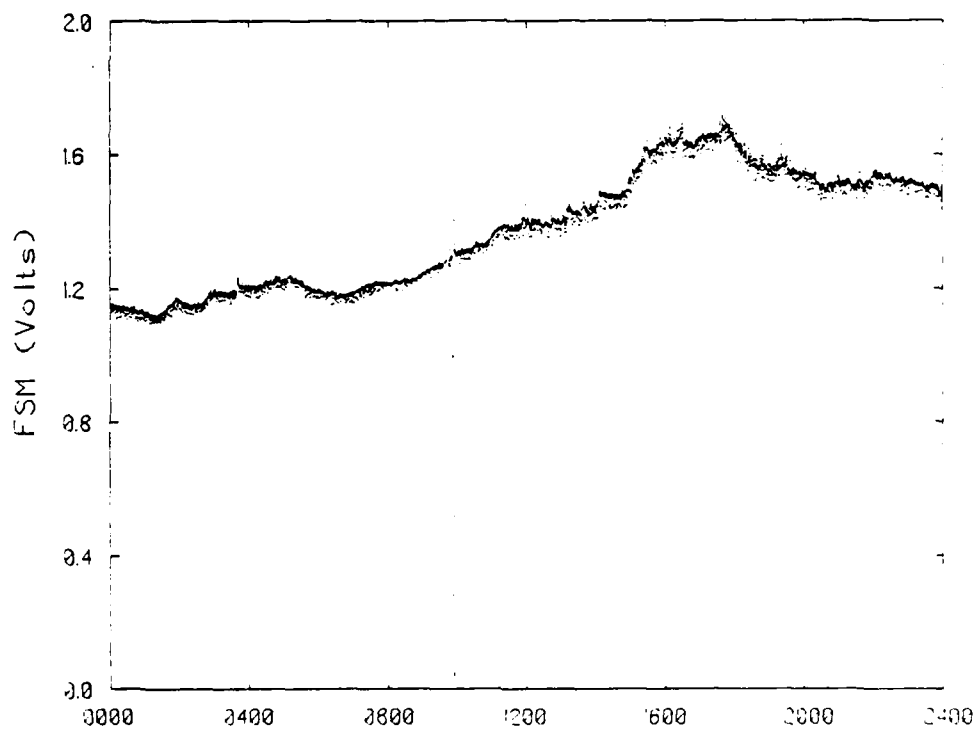
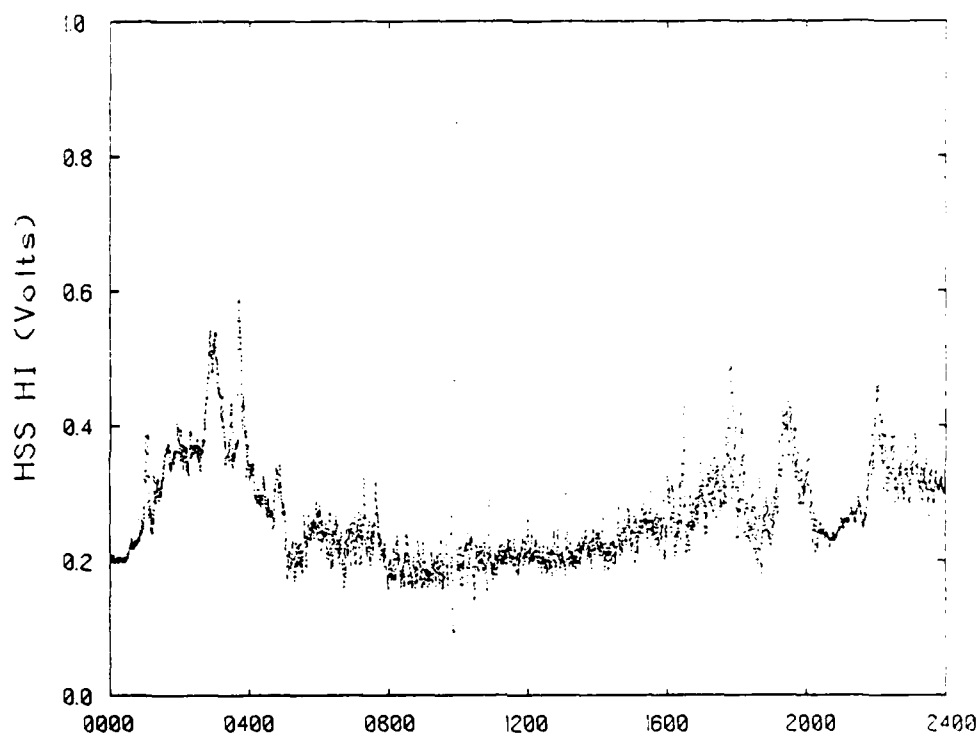
Table A1 contains observations regarding the operation of the FSM and the HSS. Figures A1 to A12 are plots of the output voltages of the two instruments. The signals have not been converted to engineering units because the meteorological data taken aboard the POINT SUR was not available at this writing. For information on the conversion of these signals see their respective manuals whose titles are listed in the reference section of this report.

Table A1 - Observations Regarding the Operation of FSM and HSS

Date	Time	Background FSM (V)	Background HSS (V)	Calibration Check	Comments
7/05	0954			X	FSM background high because of contaminated lens and pinhole misalignment during shipping.
7/05	1500-2400	1.47			
7/05	0000-2400		.09		
7/06	1210			X	HSS not operating from 1200 to 2400. Noise on FSM signal from 1210 to 2400.
7/06	0000-2400	1.50			
7/06	0000-1200		.09		
7/07	1401			X	From 0800 to 1300 the FSM was serviced. The lens was replaced and pinhole was adjusted.
7/07	0000-0800	1.50			
7/07	1404-2400	.55			
7/07	0800-2400		.04		
7/08	0840			X	The chopper motor jammed at 2200, and several power outages occurred between 1910 and 2100. FSM data are suspicious on this day because of several problems.
7/08	0000-2400	N/A			
7/08	0000-2400		.08V		
7/09	1013			X	Noise on FSM signal from 1330 to 2100. FSM suffered a background shift between 0000 and 0200. At 1941 a Coast guard cutter stopped by ship. Exhaust blew across FSM and HSS.
7/09	0200-2400	0.681			
7/09	0000-2400		.09		
7/10	1021			X	FSM output was erratic between 0935 and 0947. Data acquisition stopped from 1230-1413.
7/10	0000-2400	0.681			
7/10	0000-2400		.09		
7/11	1011			X	
7/11	0000-2400	0.681			
7/11	0000-2400		.09		
7/12	1115			X	Data acquisition stopped between 0847 and 0941.
7/12	0000-2400	0.681			
7/12	0000-2400		.09		

Date	Time	Background FSM	Background HSS	Calibration Check	Comments
7/13	1219			X	FSM chopper jammed at 2000.
7/13	0000-2400	0.681			
7/13	0000-2400		.13		
7/14	1202			X	Change in weather at about 1800. Change in FSM signal is believed to be real.
7/14	0000-2400	0.681			
7/14	0000-2400		.08		
7/15	1230			X	FSM suffered background shift at about 1044.
7/15	0000-1044	0.681			Changed lens in FSM at 1557. Background dropped to 0.21V.
7/15	0000-2400		.09		
7/15	1557-2400	0.21			
7/16	1021			X	Equipment turned off at 1600.
7/16	0000-1600	0.235			
7/16	0000-1600		.09		

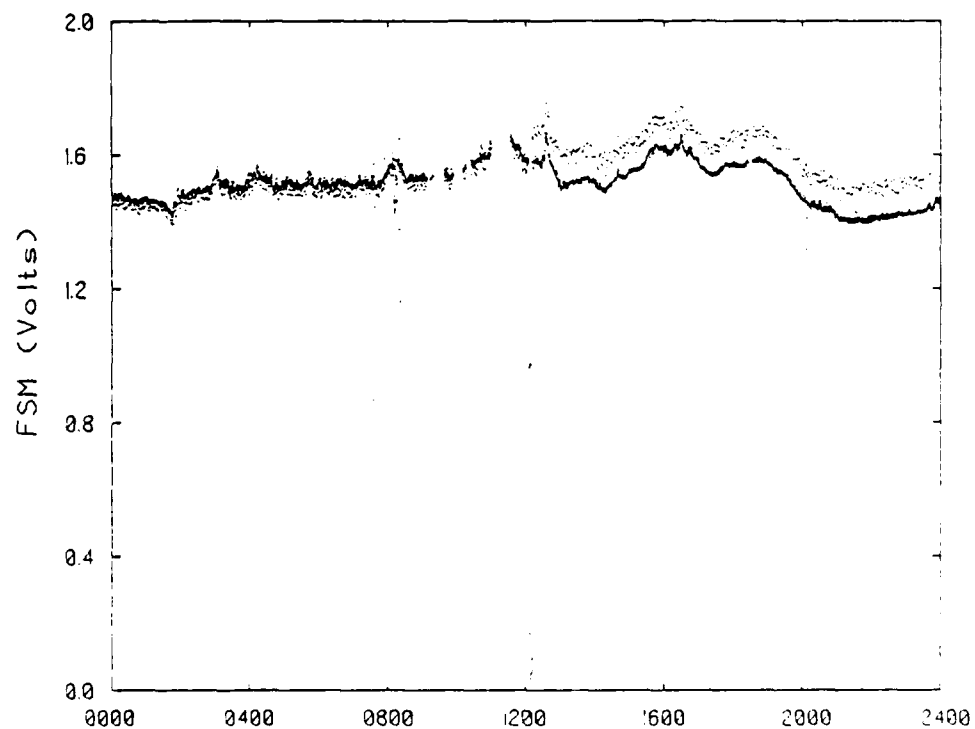
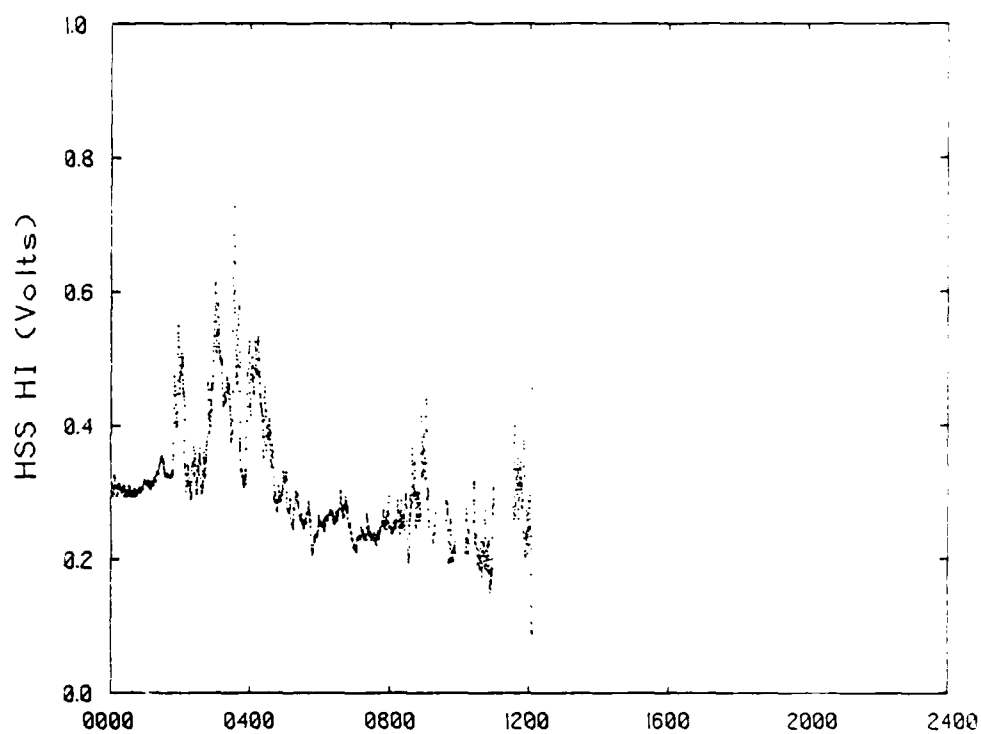
Point Sur Cruise 1987



July 5th 1987

Fig. A1

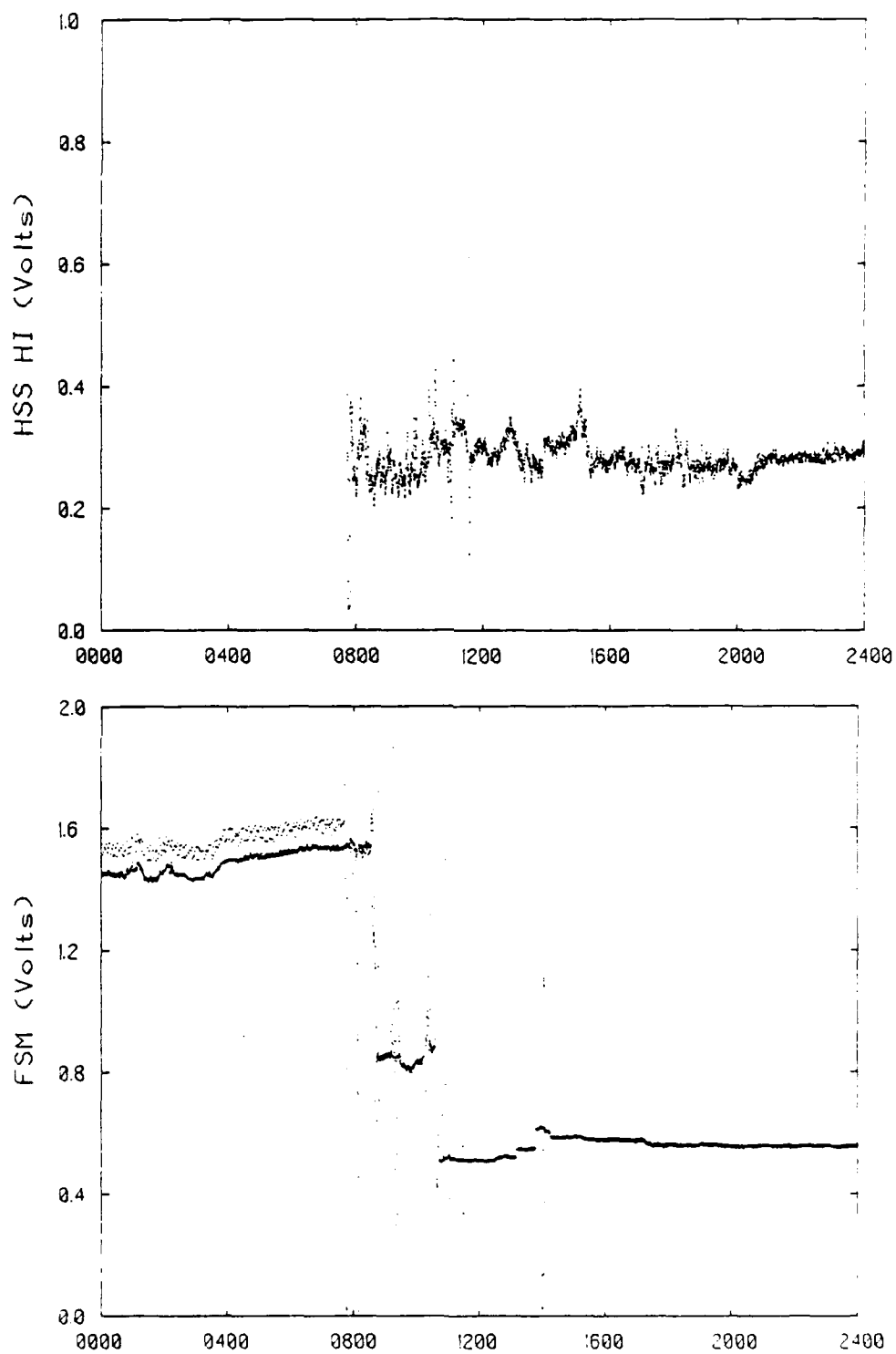
Point Sur Cruise 1987



July 6th 1987

Fig. A2

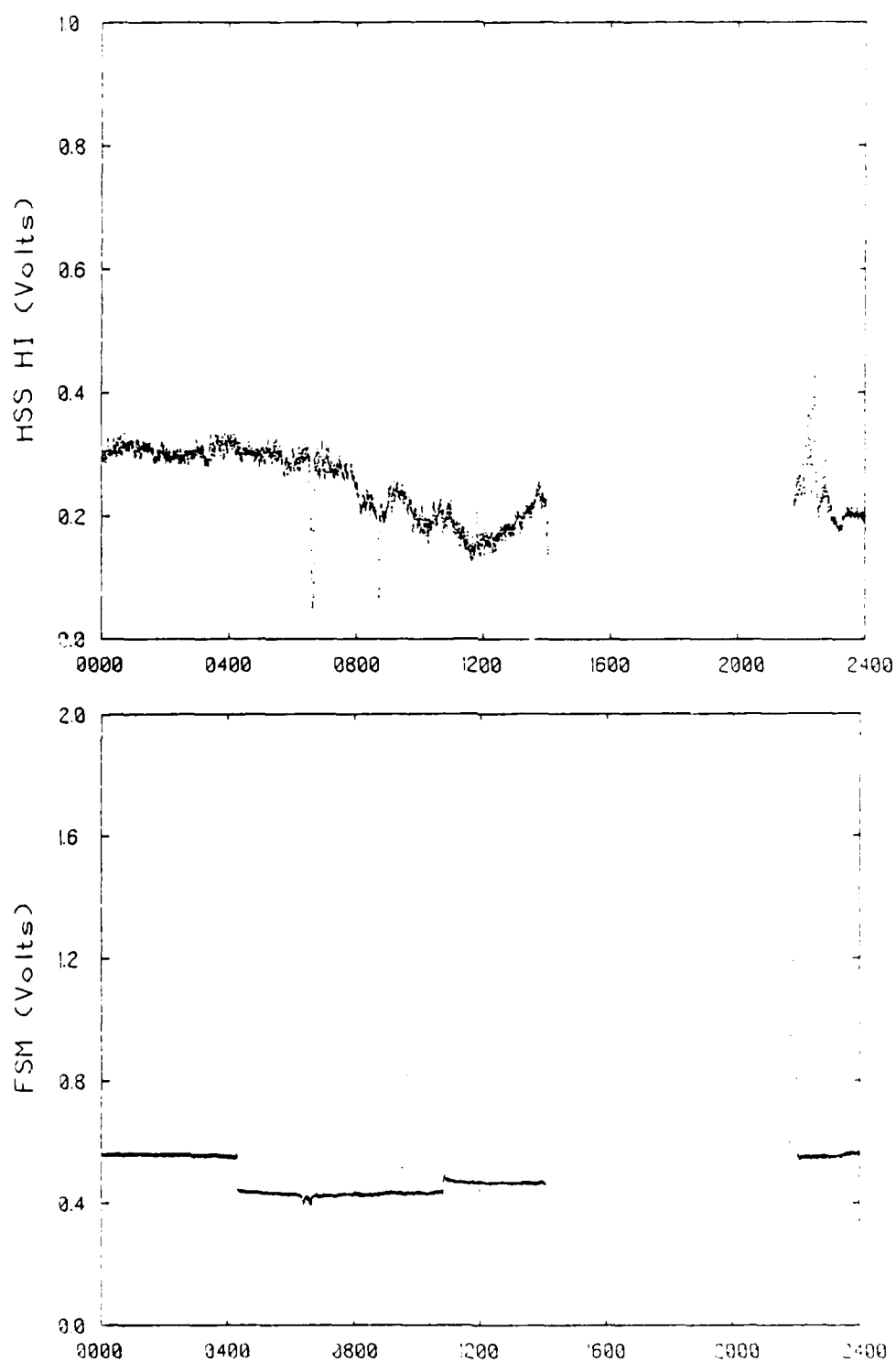
Point Sur Cruise 1987



July 7th 1987

Fig. A3

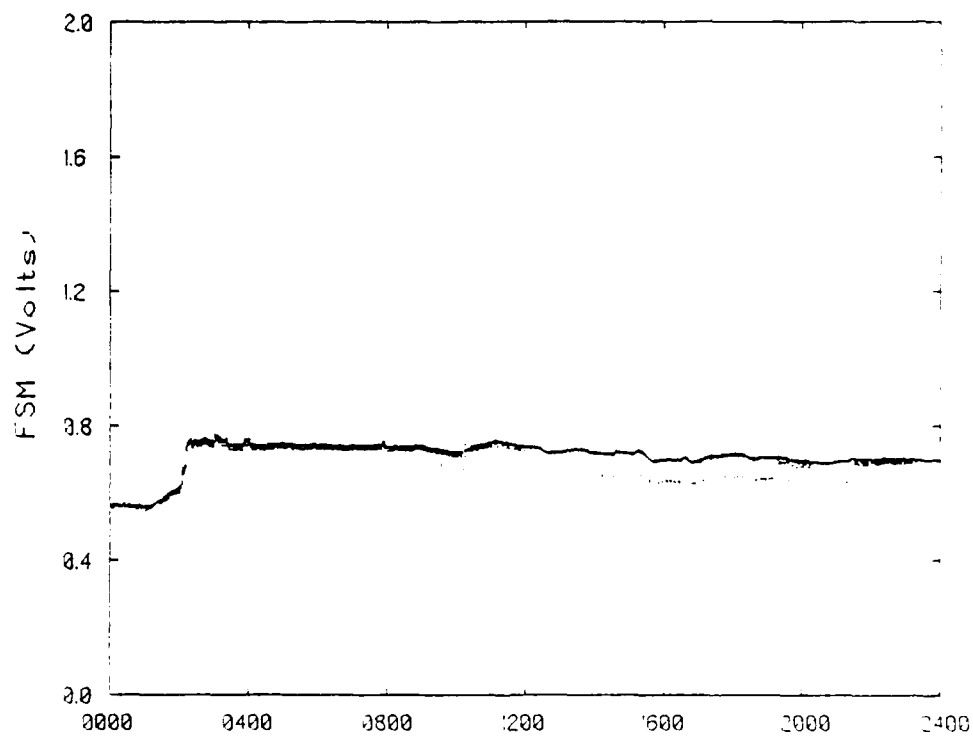
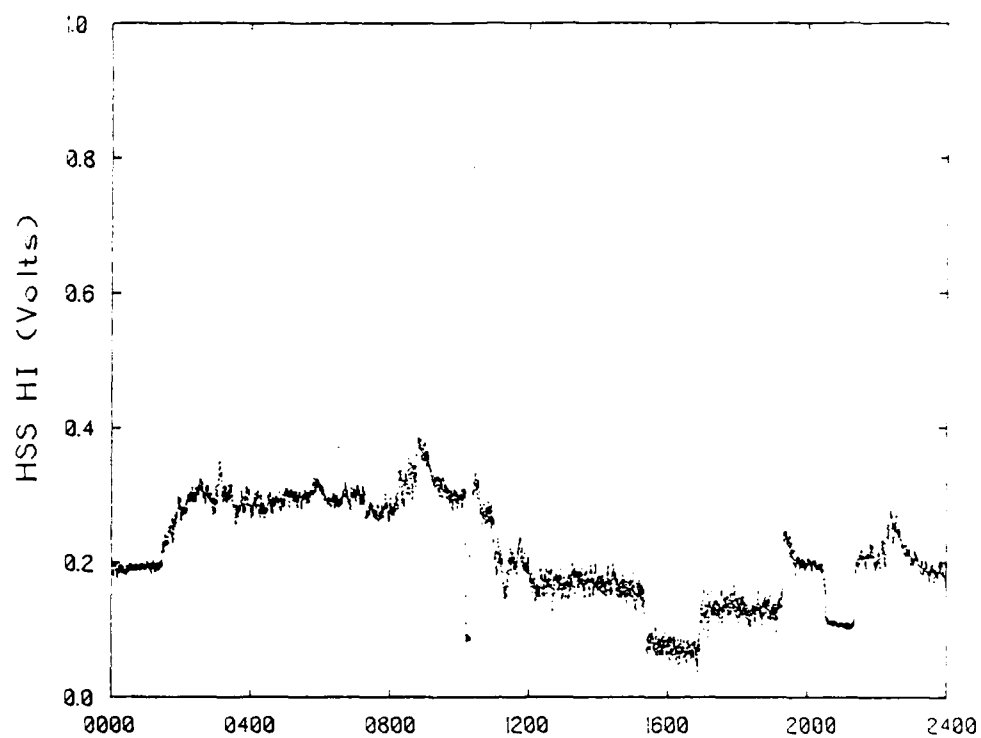
Point Sur Cruise 1987



July 3th 1987

Fig. A4

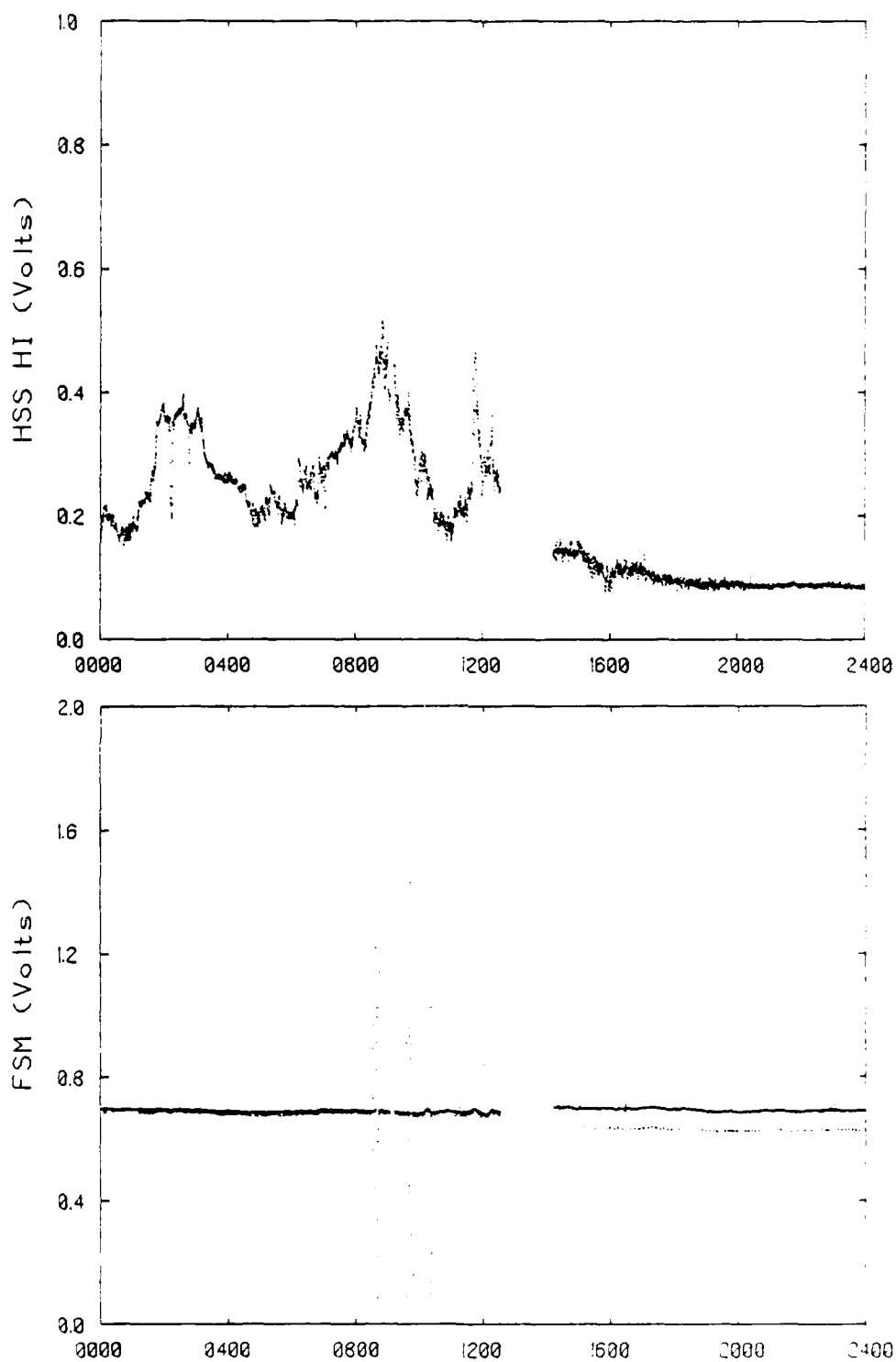
Point Sur Cruise 1987



July 9th 1987

Fig. A5

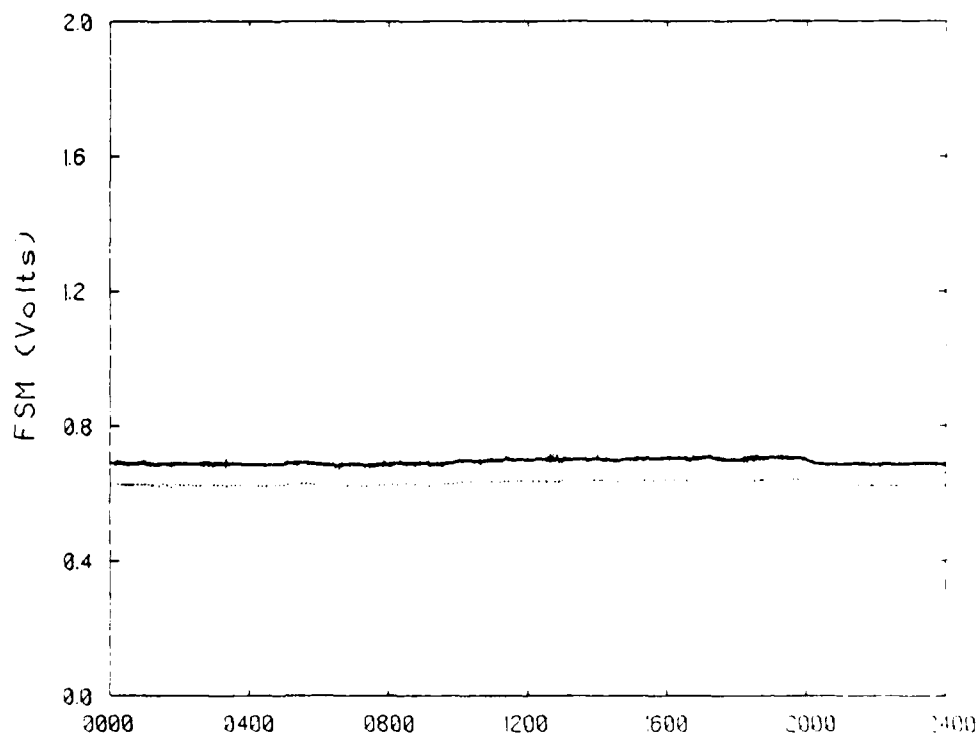
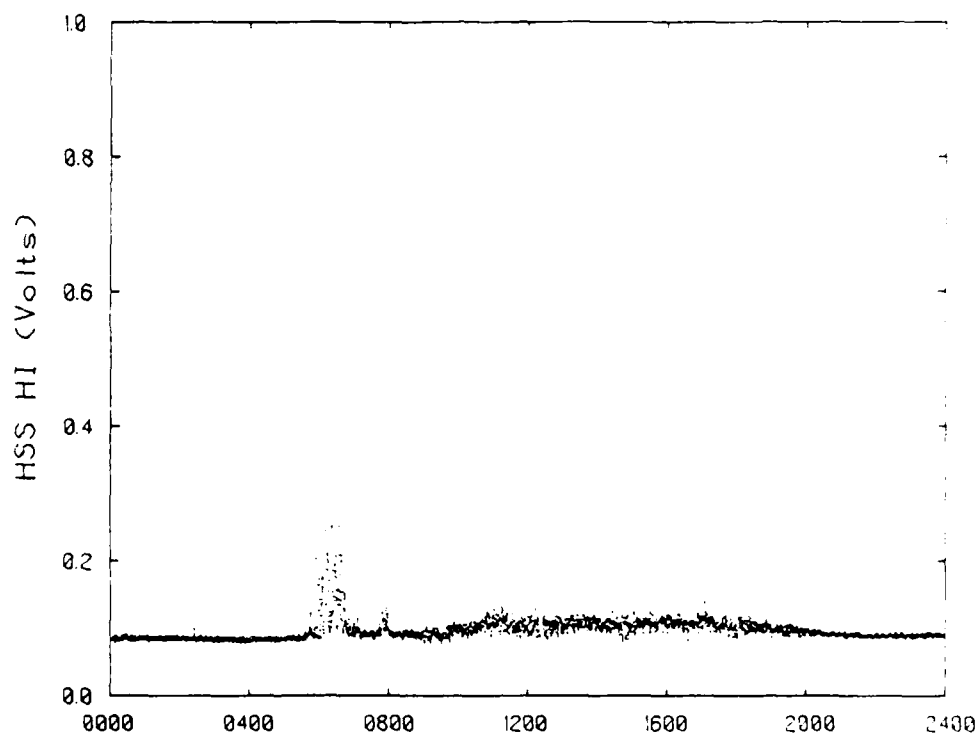
Point Sur Cruise 1987



July 10th 1987

Fig. A6

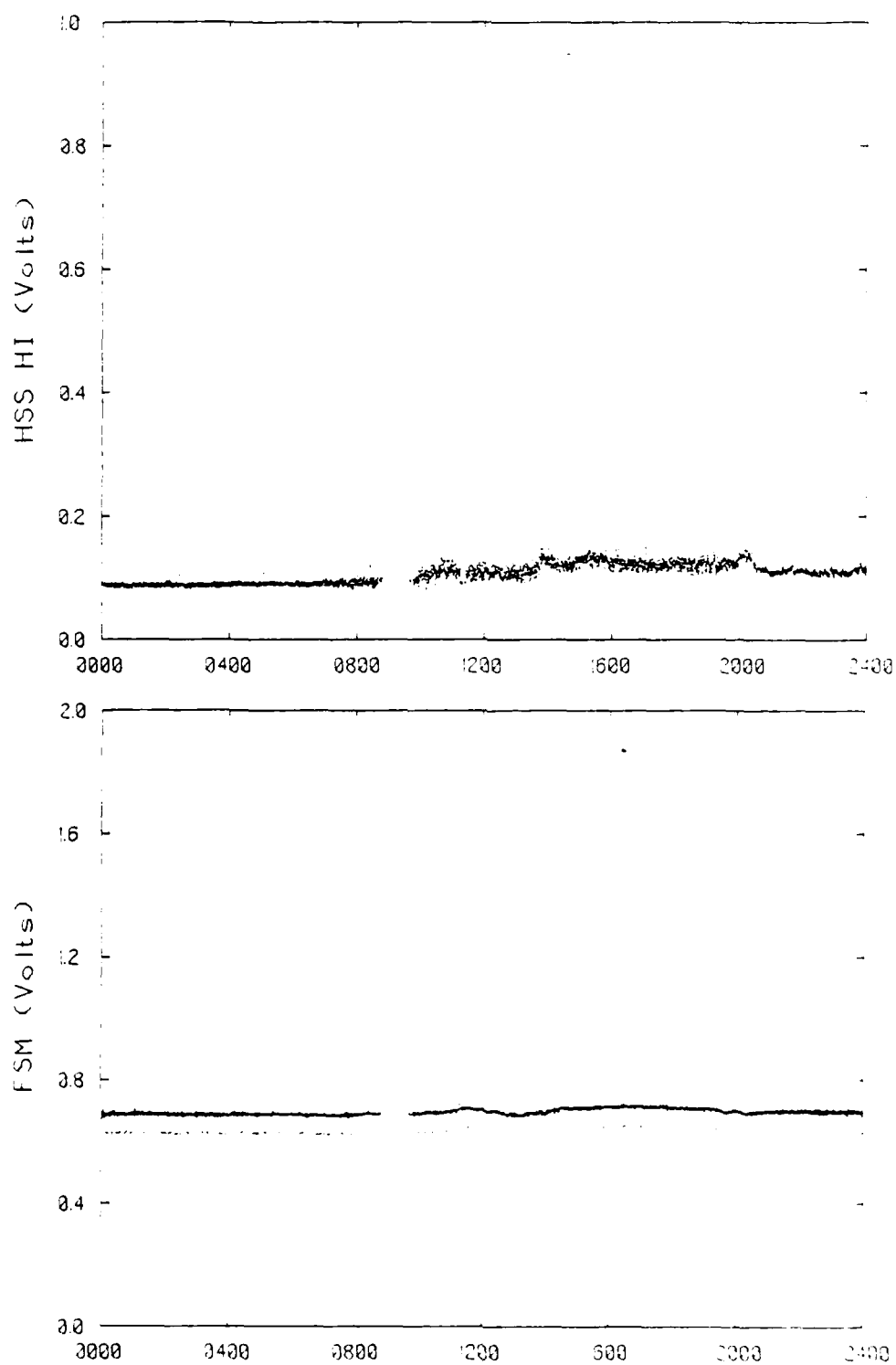
Point Sur Cruise 1987



Julv 11th 1987

Fig. A7

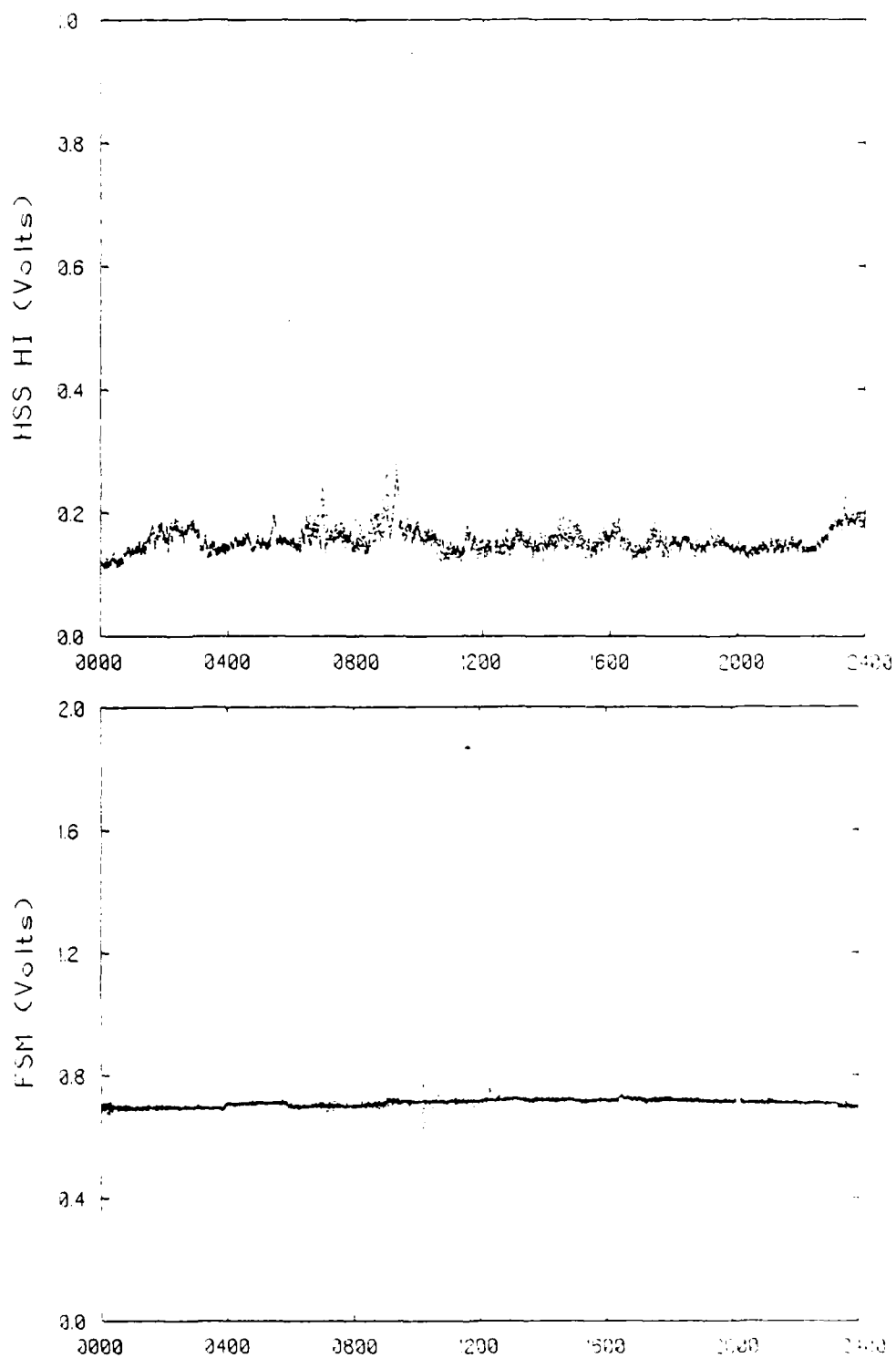
Point Sur Cruise 1987



July 12th 1987

Fig. A8

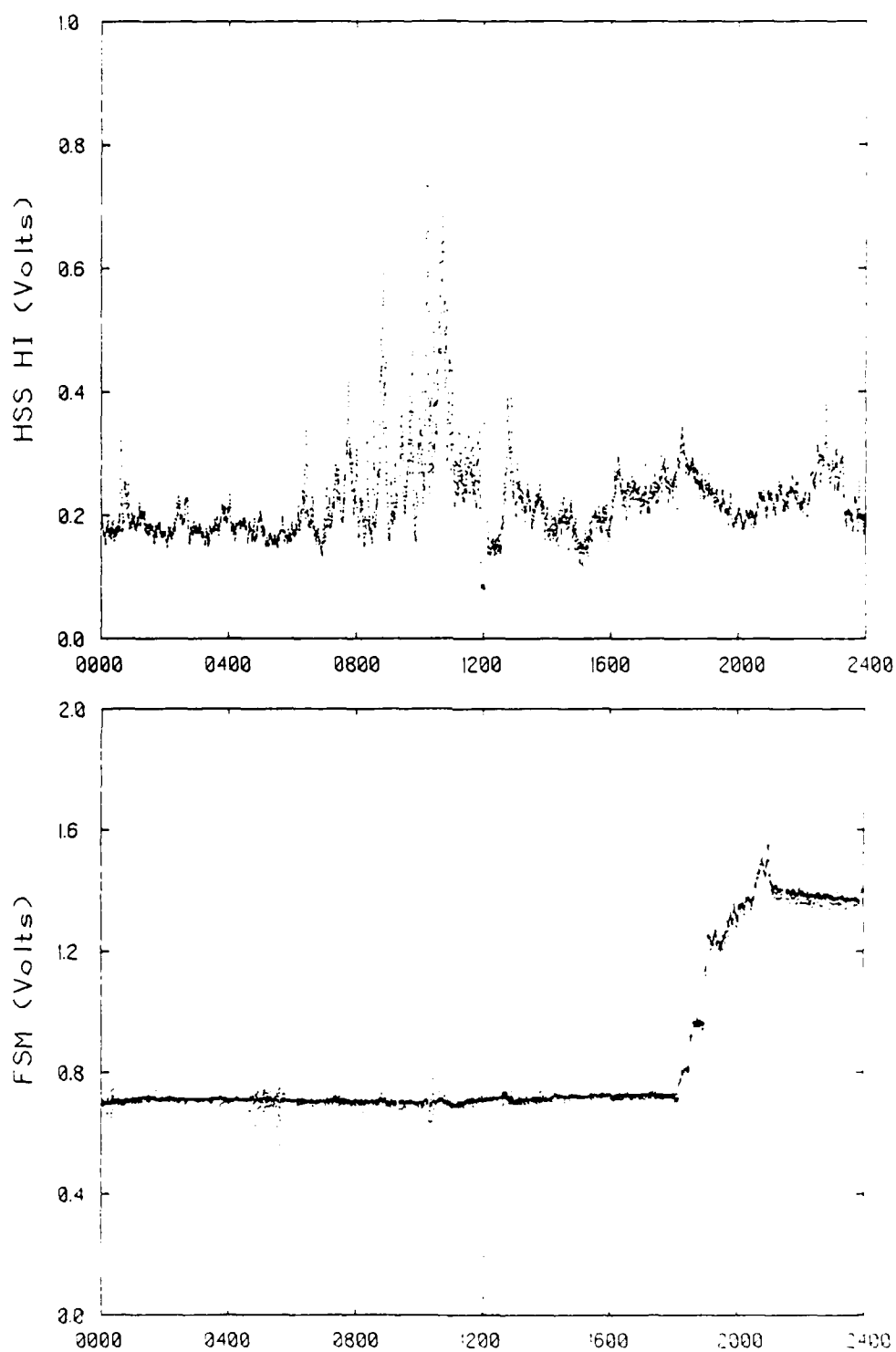
Point Sur Cruise '987



July 13th 1987

Fig. A9

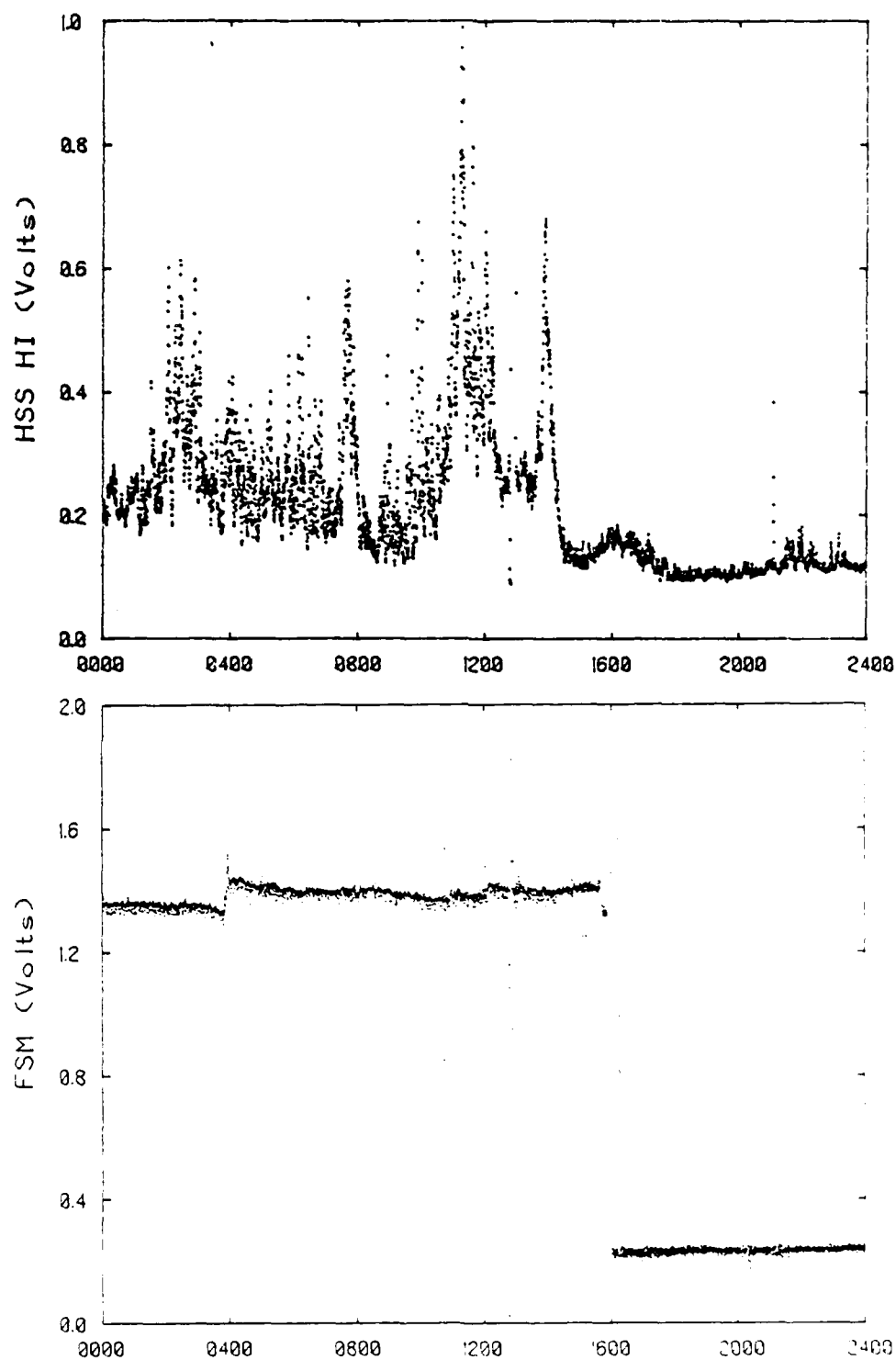
Point Sur Cruise '987



July 14th 1987

Fig. A10

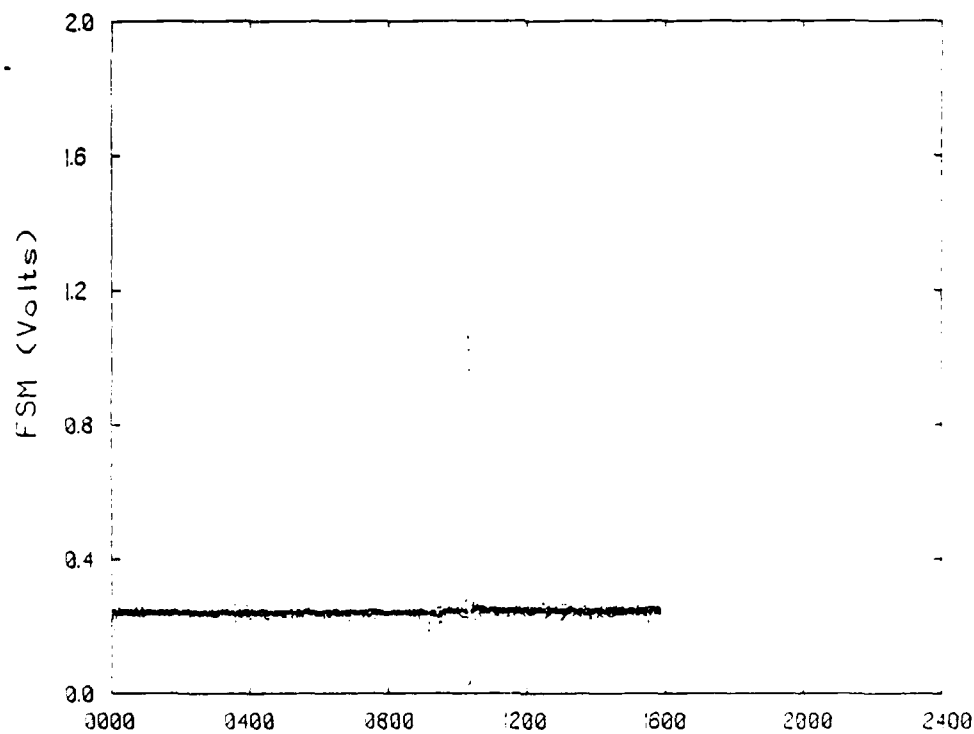
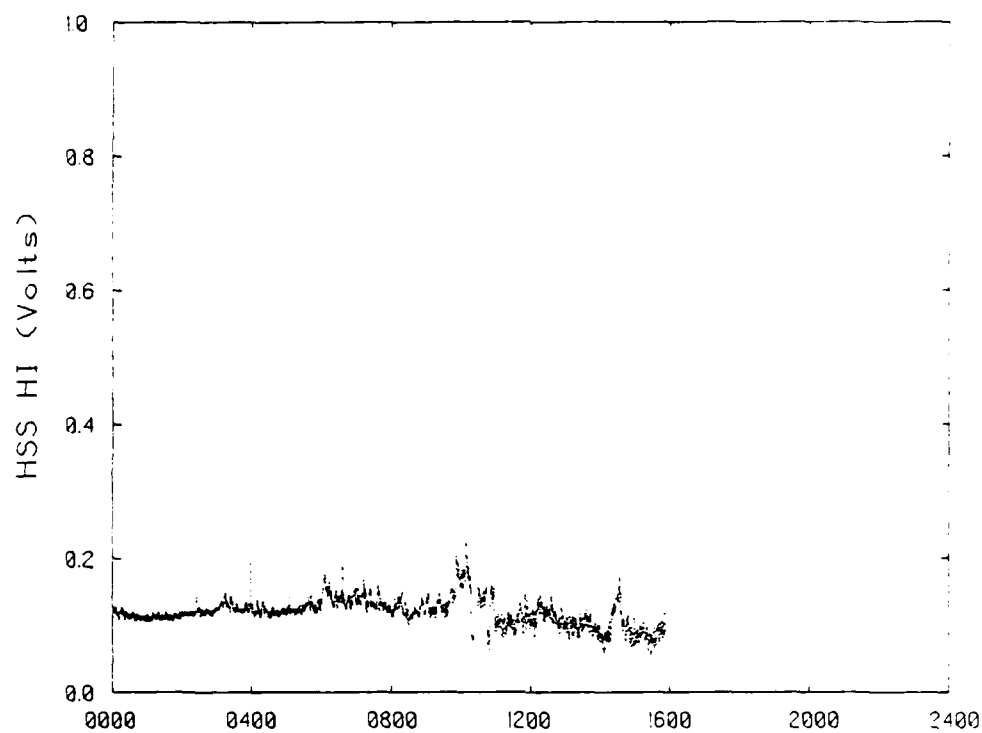
Point Sur Cruise 1987



July 15th 1987

Fig. A11

Point Sur Cruise 1987



July 16th 1987

Fig. A12

APPENDIX B

PLOTS OF RADON CONCENTRATIONS VERSUS TIME

RADON MEASUREMENTS TAKEN ABOARD THE POINT SUR

(July 1987)

Radon concentrations were measured at 80-min intervals during the period July 6 through July 16 by semiautomatic instrumentation aboard the POINT SUR. Twenty-minute air samples were collected automatically on filter paper that was normally changed once each day. This method limits the frequency of sampling but since each sample is analyzed by computer taking into account residual activity from the previous sample, a built-in assurance of accurate measurements is obtained since unusual noise or other false data will show up as improper decay rates for the radioactivity on the sample.

Throughout most of the cruise there was a continental contribution to the air being sampled. Typical coastal radon concentrations were observed as the ship left Moss Landing on July 6 and by 1800 the ship was in clean maritime air (by Northern Hemisphere standards) of about 3 pCi/cubic meter. The radon increased to the continental value of 90 when the ship went close to shore early on 7 July to pick up scientific personnel and then returned to maritime levels for a few hours.

While the maritime radon concentrations were measured on 8 and 10 July, a small continental contribution to the air (less than about 10 pCi/cubic meter) or moderate contribution (about 10 to 30 pCi/cubic meter) prevailed throughout the cruise. The radon peak on July 7 was the consequence of anchoring off Santa Rosa Island. The strong continental influence on July 9 (with some moderate radon on the 8 and 10 July) and during the three day period of July 13 through 17 has to be a consequence of a substantial contribution of continental air to the air masses in the vicinity of the ship.

