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THE JOHNS HOPKINS UNIVERSITY

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DEPARTMENT OF PHYSICS

SPECIAL REPORT

NASA/MSC Contract NAS 9-11528

Task I. Principal Investigator Services

CROSS CALIBRATION OF JHU TEST EQUIPMENT WITH GSFC VACUUM OPTICAL BENCH

Submitted by
Wm. G. Fastie
Principal Investigator

September 12, 1972

Baltimore, Maryland 21218

THE JOHNS HOPKINS UNIVERSITY
DEPARTMENT OF PHYSICS
HOMEWOOD CAMPUS
BALTIMORE, MARYLAND 21218

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To: Distribution

From: Wm. G. Fastie, Principal Investigator

Subject: Special Report on the Cross Calibration of JHU Test Equipment with GSFC Vacuum Optical Bench. NASA/MSC Contract NAS 9-11528. Task I - Principal Investigator Services Apollo 17 Ultraviolet Spectrometer Experiment (S169).

We submit herewith a special Principal Investigator's report which describes the result of the cross calibration experiment performed under the referenced contract in cooperation with Goddard Space Flight Center.

Wm G Fastie

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TEST REPORT

CROSS CALIBRATION TEST AT
GODDARD SPACE FLIGHT CENTER

Submitted by
Wm. G. Fastie, Principal Investigator

I. Introduction

The purpose of the test described below was to confirm the validity of the absolute calibrations which have been performed with the Apollo 17 Ultraviolet Spectrometer (UVS) in the calibration test equipment (CTE) which has been constructed in this laboratory for that purpose. To accomplish this the prototype UV spectrometer SN/01 was retrofitted by the Applied Physics Laboratory to be substantially identical to the qualification unit and to the two flight units. It was renamed the cross calibration unit (CCU). The instrument was first calibrated in the JHU calibration test equipment (CTE), then installed in the vacuum optical bench (VOB) at Goddard Space Flight Center and calibrated. The following day a second CTE calibration was conducted which provided substantially the same calibration values as were obtained on the first CTE calibration, and showed remarkably close agreement with the VOB calibration values at two of the wavelengths which were studied. The VOB results at the third wavelength (1216 A) indicate the CTE calibration at 1216 A is 15% too low. This apparent discrepancy is discussed in Section V and represents a very important result of the cross calibration effort.

II. Comparison of Calibration Methods

In the CTE an F/80 beam of photons of any desired wavelength is imaged at the UVS entrance slit, the image being much smaller than the slit width. The number of photons in the beam is determined by directing the beam to a calibrated reference photomultiplier tube. The beam can be directed to any part of the entrance slit and the UVS can be tilted in a vertical and horizontal axis so that the calibrated beam can be directed to any point on the grating. By averaging the signal obtained over the full length of the slit and over the full area of the grating, the sensitivity of the instrument when illuminated by an extended uniform monochromatic source can be determined.

In the VOB a parallel beam of monochromatic radiation fills the complete entrance slit. By tilting the UVS in two axes this beam can be directed to any area on the grating and by obtaining the average signal over the grating area the sensitivity of the instrument can also be calculated. In the VOB a calibrated reference photomultiplier tube was provided which could be placed in the beam to measure the flux impinging on the UVS slit and scanned over a larger area to measure the uniformity of the VOB beam. The VOB also included another reference photomultiplier tube which had been independently calibrated in our laboratory. During reference tube beam scans the VOB reference tube and the JHU reference tube were moved successively across the same area of the beam so that a large amount of data was acquired to determine the relative sensitivity of the two reference tubes.

The JHU tube which was used in the VOB and the JHU tube which was used in the CTE were calibrated with the use of a photodiode which had been absolutely calibrated by the National Bureau of Standards. The method employed was to place both the photodiode and the reference tube in the CTE so that the monochromator beam could be switched back and forth between the NBS calibrated photodiode and the reference tubes. The face of the JHU reference tube employed in the VOB was carefully "mapped" at three wavelengths so that its average sensitivity to the extended VOB beam could be determined. This mapping was carried out immediately following the VOB calibration and provided a correction factor to be applied to the VOB data. The VOB reference tube on the other hand was calibrated by GSFC in a separate photomultiplier tube calibration equipment which uses another NBS calibrated photodiode as a standard.

Thus there are two separate comparisons which were studied: the absolute calibration of the reference tubes, and the absolute calibration of the Apollo 17 UVS.

III. Reference Tube Comparison

The VOB provided a beam scan readout in flux values (photons/ cm^2/sec) for the JHU reference tube and for the GSFC reference tube. An average value of the flux read by each tube as it scanned the area of the beam in which the UVS was located gave the comparison shown in Table I.

TABLE I

VOB Reference Tube Comparison

λ	Measured Rel. Sens. (JHU/GSFC)	Mapping Factor	Corrected Rel. Sens.	Observed Rel. Sens. (VOB)	% Difference
1216	1.356	.85	1.152	1.294	+11.6
1463	.976	.96	.935	1.01	+ 6.7
1608	.611	1.01	.610	.549	-10.5

The difference between the two reference tubes as determined above can be explained by the ± 6% accuracy limit for each of the NBS photodiode calibrations, but this explanation is unlikely and the differences are most likely to be accumulated measurement errors or systematic errors associated with the calibration equipment. Further studies will be made to resolve the differences if possible, but the ± 12% variation between the two photomultiplier tube calibrations may be as good as can be achieved. As described below this source of error can be cancelled out in the comparison of the UVS sensitivities.

IV. Absolute Calibration of Apollo 17 UVS

The comparison between the CTE and VOB shown below is based on data obtained from both facilities from the central 25% of the grating area. In order to remove the effect of the disparity in the calibration of the reference photomultiplier tubes, the VOB beam flux values have been modified to correct for the disparity. This means that we are assuming that the disparity is due only to systematic errors in the reference tube calibration equipment and not in the NBS calibration of the photodiodes. Since the JHU tube in the VOB and the JHU tube in the CTE were calibrated in the same facility by identical techniques, using the same NBS standard, the correction which we have applied to the VOB data should largely remove the error introduced by the reference tubes, no matter what the source of that error is.

The method of determining the UVS absolute sensitivity from CTE measurements is described in the CTE Calibration Procedure Documents DRD-JHU-700, DRD-JHU-800 and DRD-JHU-1000. In summary, the method involves measuring the ratio of the average number of photoelectron counts per second (C_T) to the number of photons passing through the entrance slit per second, where the average number of photoelectron counts is determined for all points on the entrance slit and for all points on the grating. This ratio is the product of the average quantum efficiency over the utilized portion of the photocathode and the average transmission over the full field of view. According to the sensitivity equation

$$S\,(\mathrm{pe/sec/Ray}) = \frac{10^4}{4\pi}\,\frac{A_s A_g}{F^2}\,QT \qquad (1)$$

With the values $A_s = 1.14\ \mathrm{cm}^2$ (slit area), $A_g = 10^4\ \mathrm{cm}^2$ (grating area), and $F = 50$ cm (focal length) we obtain

$$S\,(\text{pe/sec/Ray}) = 3770\ QT \qquad (2)$$

In the VOB the entire entrance slit is illuminated by a known photon flux. This flux must be multiplied by the slit area to determine the number of photons passing through the entrance slit. The product QT is given by

$$QT = \frac{C_T\ (\text{number of photoelectrons/sec})}{A_s\ X\ \text{Flux}} \qquad (3)$$

The sensitivity is determined by substituting the value obtained by Eq. (3) in Eq. (2). Table II is a summary of the calibration data.

TABLE II

Absolute Calibration of UVS

Wavelength (AU)	Sensitivity VOB*	VOB†	CTE**	% Difference	Scan Rate
1216	52.1	45.9	38.8	+15	1.7 A/sec
1463	37.2	34.4	36.0	- 4.5	1.56 A/sec
1608	14.6	16.3	15.6	+ 4.3	7.41 A/sec

*As determined with GSFC reference tube
†Normalized to JHU reference tube
**Avg. of Test UVS-800-9 and UVS-700-11

The rate at which the UVS scans the spectrum is fast enough that the true peak value cannot be measured. In addition, slight nonmonochromaticity in the VOB beam broadens the spectral feature. We have avoided the errors introduced by these two factors by integrating the total signal obtained during the UVS scan of a spectral feature and multiplying this number by the spectral scan rate in A/sec. The spectral scan rate at each calibration wavelength is shown in the last column of Table II. The product Σ counts X Spectral Scan Rate gives the peak value which would be produced by a monochromatic beam with a UVS spectral slit width of 10 A.

V. Analysis of Results

Table II shows that at 1463 and 1608 A the two facilities provide calibrations that are in very good agreement. At 1216 A the VOB calibration gives a value which is 16% higher than that obtained in the CTE. This difference is perhaps within the experimental limit. However, on the basis of other evidence, which is discussed below, we believe that the VOB value is the more nearly correct one.

During the CTE testing of all of the Apollo units, we have observed variations in the sensitivity at 1216 A which did not occur at other wavelengths. During a given test, the 1216 A sensitivity increased by as much as 10% from the beginning to the end of the test. For the VOB test, the instrument was held at very low pressure for several days before test data was obtained.

We conclude that these observations indicate that water vapor adsorbed on the optical surfaces (probably on the grating) is responsible for the observed sensitivity variations. Water vapor absorbs much more strongly at 1216 A than at the other wavelengths.

We plan an extended period of evacuation in the CTE (24 hours or more) following the completion of the final calibration of the Flight Unit and the Back-up Flight Unit, followed by a calibration check at 1216 A. In addition during the optical mission simulation test with the cross calibration unit we will be able to study the effect of the trans-lunar coast period on the sensitivity at all wavelengths.

VI. Summary

The cross calibration test in the VOB has confirmed the validity of the CTE data. It has indicated that the sensitivity at 1216 A is higher after extended evacuation, probably due to the slow removal of adsorbed water vapor from the optical surfaces. During the VOB test a cross check of GSFC and JHU reference photomultiplier tubes indicated an error, probably ascribable to differences in measuring techniques. This error is small but should be further investigated.

APOLLO 17 ULTRAVIOLET SPECTROMETER (S169)

Spectral Sensitivity Determinations
(Photoelectrons/sec/Rayleigh)

UVS Description and Purpose of Testing	Test Description and Completion Date		Test Number	Spectral Sensitivity* (Photoelectrons/sec/Rayleigh)		
				1216 A	1463 A	1608 A
Prototype Acceptance Testing	Calibration	1/25/72	UVS 700-1	30	22	8.5
	Optical Verif.	2/3/72	UVS 800-1	35	24	10
	Calibration	2/23/72	UVS 700-2	33	26	9
	Average			33	24	9
	Calculated**			48	34	17
Qualification Unit Acceptance Testing	Calibration	3/1/72	UVS 700-3	76	56	26
	Optical Verif.	3/16/72	UVS 800-2	72	64	26
	Calibration	3/24/72	UVS 700-4	77.3	57.4	27.6
	Average			75.1	59.1	26.5
	Calculated**			89	71	28
Qualification Unit Qual. Testing	Optical Verif.	4/3/72	UVS 800-3	68.2	56	25.2
	Optical Verif.	4/10/72	UVS 800-4	68.1	61	25.3
	Optical Verif.	5/17/72	UVS 800-6	78.1	58.3	27.0
	Optical Verif.	5/31/72	UVS 800-8	76.9	61.0	26.3
	Calibration		UVS 700-			

*Preliminary Calculation. Sensitivity numbers are not final.

**Calculation based on data obtained during evaluation of components employed in each instrument.

5 Sept. 1972

UVS Description and Purpose of Testing	Test Description and Completion Date		Test Number	Spectral Sensitivity* (Photoelectrons/sec/Rayleigh)		
				1216 A	1463 A	1608 A
Flight Unit #1 S/N 03 Acceptance Testing	Calibration	4/24/72	UVS 700-6	63.3	69.4	30.6
	Optical Verif.	5/1/72	UVS 800-5	63.2	69.7	30.3
	Optical Verif.	5/22/72	UVS 800-7	53.2	72.0	27.6
	Calibration	5/25/72	UVS 1000-1	55.1	70.1	29.8
	Average			58.7	70.3	29.5
	Calculated**			94	100	38
Flight Unit #2 S/N 04 Acceptance Testing	Calibration	6/7/72	UVS 700-7	75.0	73.7	28.7
	Calibration	7/25/72	UVS 700-10	66.6	73.8	27.8
	Optical Verif.	7/31/72	UVS 800-10	65.4	71.2	27.8
	Calibration	8/8/72	UVS 1000-2	67.4	68.2	28.4
	Average			68.6	71.7	28.2
	Calculated**			93	89	32
Cross Cal. Unit CCU-1 1st VOB Cross Check	Calibration	7/5/72	UVS 700-8	39.2	35.7	15.6
	Optical Verif.	7/27/72	UVS 800-9	37.0	36.2	15.2
	VOB Check		VOB 900-1	45.7	34.4	16.3
	Calibration		UVS 700-11	40.6	35.9	16.1
Flight Unit S/N 04 Final Calibration	Calibration		UVS 1000-			
Back-up Flight Unit S/N 03 Final Calibration	Calibration		UVS 1000-			
After KSC Integration						

*Preliminary Calculation. Sensitivity numbers are not final.
**Calculation based on data obtained during evaluation of components employed in each instrument.

5 Sept. 1972