A three channel rocket borne auroral photometer

Harris, F. R.; Bradley, D. T.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/21276350
Report (National Research Council of Canada. Radio and Electrical Engineering Division : ERB), 1973-03

ERB - 874

UNCLASSIFIED

NATIONAL RESEARCH COUNCIL OF CANADA

RADIO AND ELECTRICAL ENGINEERING DIVISION

A THREE CHANNEL ROCKET BORNE AURORAL PHOTOMETER

F. R. HARRIS AND D. T. BRADLEY

OTTAWA

JANUARY 1973

ABSTRACT

This report describes a photometric payload for sounding rockets. The instrument is intended for auroral research at visible wavelengths. Design specifications, circuitry, laboratory tests and data from one flight are presented.

CONTENTS

Page

INTRODUCTION 1

SPECIFICATIONS 1

2.1 Scientific 1
2.2 Technical 2
2.3 Size 3
2.4 Cost 3

PROBLEMS ENCOUNTERED 3

DESIGN 5

4.1 The Housing 5
4.2 The Optical Assemblies 5
4.3 Circuit Design 5

TESTS 7

5.1 Environmental 7
5.2 Thermal 7
5.3 Frequency Response 7
5.4 Vacuum Operation 7
5.5 Long term Stability 7
5.6 In-Flight Test 8

References 9

FIGURES

1. Block schematic of one photometer channel.
2. Circuit diagram of one photometer channel.
3. Thermal drift of the low gain circuit shown in Figure 5.
4. Frequency response of the circuit in Figure 5 for (a)$R_2 = 10^8$ ohms and (b)$R_2 = 10^9$ ohms.
5. In-flight data acquired by the photometer package for one rotation of the rocket about its spin axis.

PLATES

1. Front view of the photometer housing.
2. Rear view of the photometer housing.
3. Interior view of the photometer housing.

A THREE CHANNEL ROCKET BORNE AURORAL PHOTOMETER

- F. R. Harris and D. T. Bradley -

1. INTRODUCTION

A useful parameter in the study of auroral excitation mechanisms is the vertical distribution of auroral luminosity. To acquire the necessary data from the ground one has to employ two station photometry with narrow (less than one degree) field of view functions. In doing so problems are encountered with synchronization, instrument sensitivity, field of view misalignment and non-linear atmospheric extinction of the auroral spectrum. These problems can be overcome with in-situ measurements.

In 1970 a decision was made to begin a continuing program of auroral photometry using rocket borne photometers. The purpose of the program is to study excitation mechanisms in auroras classified as types b and c (Vallance Jones, 1971), and the program forms an extension of the ground based study of auroral emissions published by Harris et al (1970).

This report is devoted to a discussion of the instrument constructed for the project from the design stage through to its final form, the problems encountered and how they were overcome.

2. SPECIFICATIONS

2.1 Scientific

Three components of the auroral spectrum are of interest in this project; the N_2^+1NG (0, 0) band at 3914 Å, the atomic oxygen line at 5577 Å and the portion of the $N_2$1PG band system between 6465 Å and 6855 Å. Three photometer channels are therefore incorporated into the unit. The field of view function selected for each is circular with a 2^o width and all are parallel. The necessary sensitivities and dynamic ranges are based on the data published by Harris et al (1970) and additional unpublished data on the N_2^+1NG (0,0) band. Two sensitivities are provided for each channel, one being twice the other, and the amplifiers are linear for ease of data analysis. The dynamic ranges of each, based on the photon sensitivity in units of kilorayleighs per volt output (Chamberlain, 1961), are listed in Table 1. These figures are calculated using a telemetry dynamic range of 0 to + 5 volts. The desired frequency response of the amplifiers is constant gain ± 1 db over the frequency range of DC to 150 Hz in order to faithfully reproduce all signal functions arising as a result of auroral temporal variations, rocket motion, rocket spin, and

Data Channel	Sensitivity (kR/v)	Dynamic Range (kR)
3914 Å x 1	20	0 - 100
3914 Å x 2	10	0 - 50
5577 Å x 1	40	0 - 200
5577 Å x 2	20	0 - 100
N_2 1 PG x 1	40	0 - 200
N_2 1 PG x 2	20	0 - 100

Table 1.

Sensitivities and dynamic ranges of the three photometer channels

size of the auroral form. Under certain conditions explained in section 5. 3 it was not possible to make the gain variation less than $\pm$ 1 db. Each photometer is intended to look out the side of the rocket in order to provide data as a function of height.

2. 2 Technical

Because of the nature of the experiment a high reliability factor had to be designed into the instrument. For this reason 3 high voltage power supplies are incorporated. In the event that one fails, two data channels will still be operational. In addition adequate safety margins were allowed for in selecting the voltage and dissipation ratings of the components.

An additional essential characteristic is ease of operation, i. e. , final adjustments are made in the field and must be accomplished quickly with a minimum of equipment. The number of operations here then was minimized. Two adjustments per photometer were acceptable; balance of the input circuit and high voltage adjustment to set the sensitivity. Furthermore, once the payload is sealed and on the launch pad it becomes virtually inaccessible, so stability of the final adjustments to the low gain channel to within $\pm$ 0. 25 volt over periods of time up to one week and over a temperature range of + 40°F to + 100°F is critical.

The final and very important point is that the instrument must operate in a vacuum. It was decided initially to pot the high voltage circuits. Later this decision was changed for the reasons discussed in section 3.

2.3 Size

The package is compatible with the Black Brant series of rockets, types V and III, manufactured by Bristol Aerospace Limited. Vertical size is not critical here but horizontal cross section is. The horizontal cross section of the type III rocket is a 9-in. diameter circle and that of the type V is larger. The design horizontal cross section then is set at 6.875 inch square radiused to 9.0 inches.

2.4 Cost

Because the program is continuing, i.e., vertical emission profiles are required from a number of auroras in different height ranges, cost was a factor given careful consideration. The heart of a photometer is the photomultiplier tube, an inherently expensive device for an expendable instrument and three are required for each rocket. A survey of available compatible units was carried out and cost versus performance for each was evaluated. It was decided to use two types manufactured by RCA. One is a 1P21, sensitive in the short wavelength portion of the spectrum, and the other a 4526, sensitive in the red. These tubes have side cathodes, compatible with short photometer lengths, are rugged and relatively inexpensive. All other components are not items of major cost and need not be considered here.

3. PROBLEMS ENCOUNTERED

As stated in section 2.2 the initial plan was to pot or encapsulate the high voltage circuits to eliminate problems arising from gaseous discharge while operating at low pressures. This was the only area where a serious difficulty was encountered. The compounds tried were Silastic RTV Type A, Eccofoam Type FP and epoxy. Silastic RTV and foam contain air pockets which lead to high voltage tracking on the circuit boards and subsequent component failures during low pressure operation. These compounds were discarded for all but packing purposes. Epoxy proved to be more suitable but still not adequate. With epoxy potting no visible signs of discharge were detected in the circuitry; however, there was still interference on the signals at low pressure. This was finally traced to a discharge from the photomultiplier tube envelopes. To eliminate this problem complete potting of the tubes would be required. This was obviously impossible so a new course of action was decided upon. The entire photometer housing was sealed at one atmosphere pressure. This solution was satisfactory.

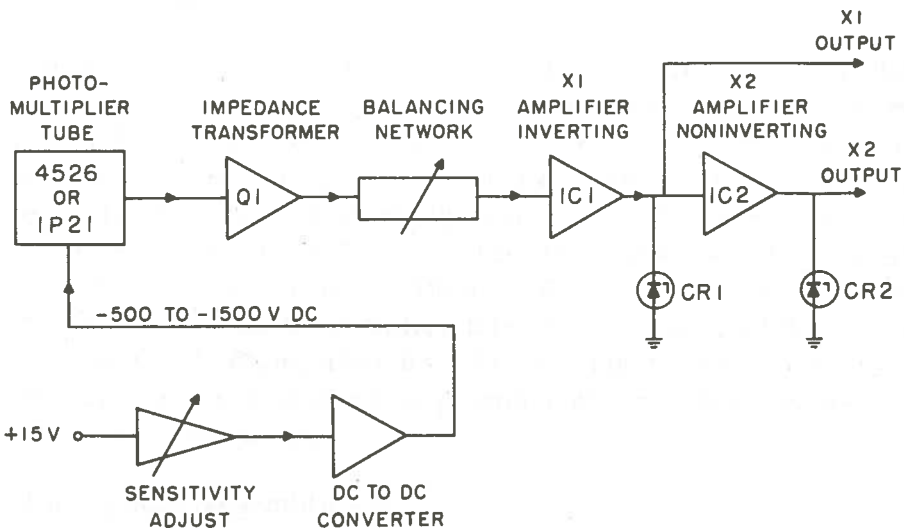

Figure 1.

Block schematic of one photometer channel

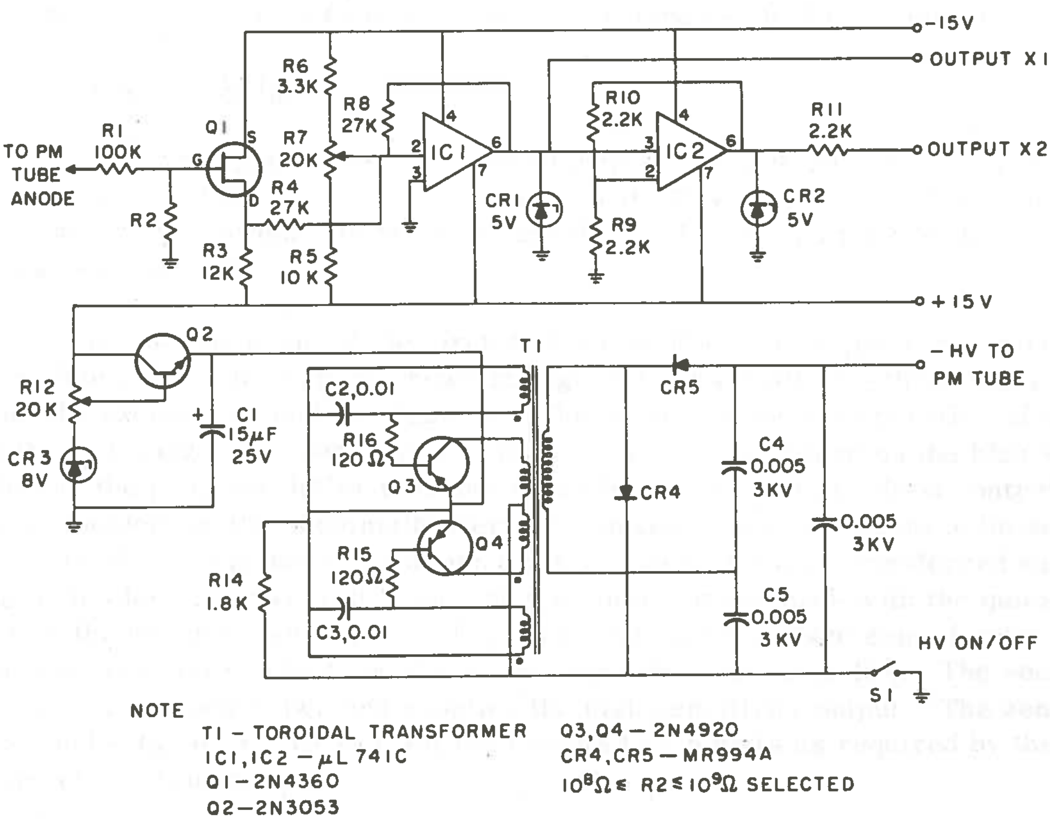

Figure 2.

Circuit diagram of one photometer channel

4. DESIGN

4.1 The Housing

Front, rear and interior view of the housing are shown in Plates 1,2 and 3 respectively. Plate 1 shows the optical assemblies which are from left to right N_2 1 PG, 5577 Å and 3914 Å. The upper and lower rows of binding head screws, above the optical assemblies, seal the ports for the balance and sensitivity adjustments respectively. Plate 2 shows the exterior cable harness and the DA15P connector that mates with the cable connecting the experiment to the payload battery, telemetry and switching circuits. Plate 3 shows the three compartments, each containing an inverted photomultiplier tube at the rear, a high voltage power supply board on the left and an amplifier board on the right. The housing was sealed with the use of silver and soft solders on permanently mounted components and rubber O-rings on removable parts.

4.2 The Optical Assemblies

Each of the three optical assemblies, except for filters, are identical. Each assembly consists basically of 4 components; a filter to select the spectral window, a plano-convex lens of focal length 3.9 inches to focus the light on a field stop, a field stop to determine the field of view and a sealed barrel which acts as a housing and mates with the main body. The field stop position is adjustable so as to enable correction for minor variations in lens focal lengths and for chromatic aberration.

4.3 Circuit Design

The three photometers combined require a regulated power supply capable of supplying + 15 volts ± 0.1 volt at 160 ma and -15 volts ± 0.1 volt at 60 ma. The reason for the current difference is that the + 15 volt supply feeds the high voltage power supplies.

A block diagram of the circuit of one photometer is given in Figure 1 and a complete circuit diagram is shown in Figure 2. Basically the three units are identical with the exception noted on Figure 2. The theory behind the operation of the circuit is the following. The sensitivity of the system is determined by the high voltage applied to the photomultiplier tube and is set by the sensitivity adjust control R12. Light incident on the photomultiplier tube causes a negative signal to be delivered to the gate of the impedance transformer, Q_1. This signal is transferred with a voltage gain close to unity to IC_1 operating in an inverting mode with the quiescent point set by the balance control, R7. IC_1 operating with a voltage gain of unity supplies the low sensitivity output and the second amplification stage IC_2. The second stage has a voltage gain of two and supplies the high sensitivity output. The zener diodes CR_1 and CR_2 serve only to limit the outputs to + 5 volts as required by the rocket telemetry circuits.

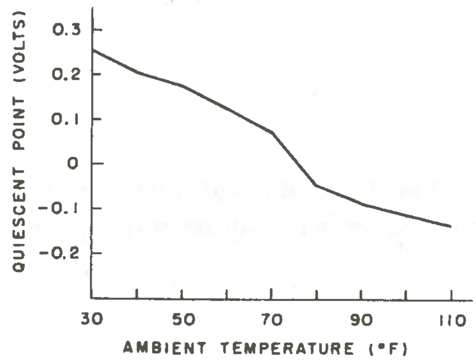

Figure 3
Thermal drift of the low gain circuit shown in Figure 2

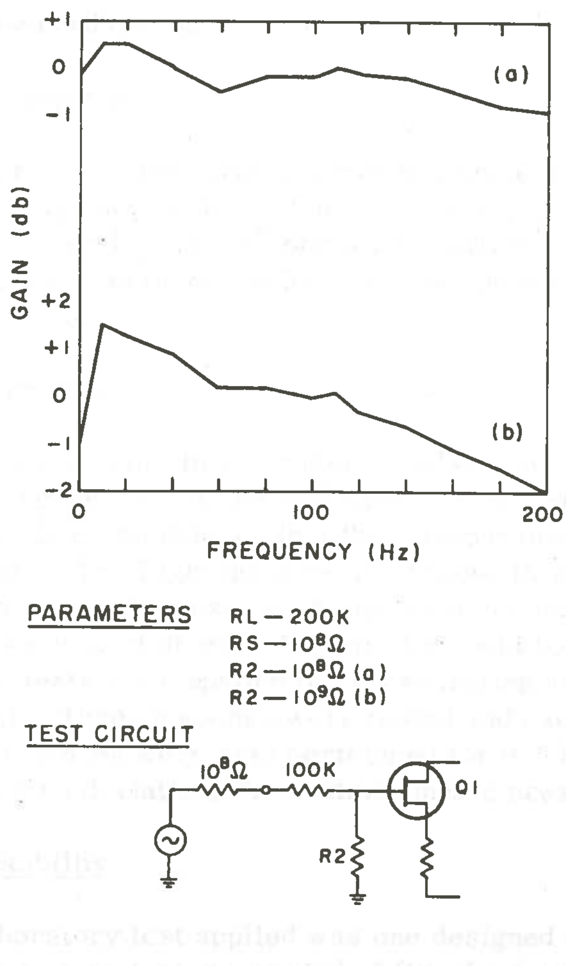

Figure 4
Frequency response of the circuit in Figure 2 for
(a)R_2 = 10^8 ohms and (b)R_2 = 10^9 ohms

5. TESTS

5.1 Environmental

Vibration and acceleration tests as outlined in Bristol Aerospace report 69538 were applied to the photometers. There were no noticeable aftereffects.

5.2 Thermal

As stated in the technical specifications adequate thermal stability over the temperature range of + 40°F. to + 100°F. is required. Adequate stability is here defined as a shift of the zero signal output voltage of the low gain channel by no more than 10% of the maximum output, or 0.5 volt. The measured drift over this temperature range, as shown in Figure 3, is 0.36 volt increasing linearly as the temperature decreased from + 100°F. In addition a gain change of 1% was acceptable. No gain change was observed during the tests.

5.3 Frequency Response

Response curves for the circuit drawn in Figure 2 are shown in Figure 4 for the two values of R_2 used in the instrument. The gain is constant within 1 db and 2.4 db in the cases of 10^8 and 10^9 ohms respectively over the frequency range of dc to 150 Hz. In the case of 10^9 ohms it was not possible to remain within the desired limits of ± 1 db.

5.4 Vacuum Operation

Tests of the instrument in a vacuum chamber have shown that discharge problems are first encountered in the one kilovolt range at pressures around 350 mm Hg. It is imperative, therefore, that the internal pressure does not drop this low during flight. The flight duration is at most 15 minutes. The test criterion was therefore set well in excess of this requirement. For a housing to be acceptable a pressure loss of at most 100 mm Hg could be tolerated over a 24-hour period. These tests were applied by pressurizing the housing to one atmosphere above ambient. Three housings were tested and each was satisfactory. Vacuum tests at 0.1 mm Hg were also performed for 0.5 hr with high voltage applied. There were no deviations from atmospheric pressure operation.

5.5. Long Term Stability

The final laboratory test applied was one designed to examine the stability of the quiescent point output over a period of five days under conditions similar to those encountered during holds on the launch pad. The test consisted of switching the instrument on for 7 hours and off for 17 with no input at an ambient temperature of + 70°F. The result of the test of one channel is given in Table 2. The total drift of the quiescent point from its initial value of + 0.080 volt was 0.030 volt. This drift is negligible compared with that encountered due to the thermal effects discussed in section 5.2.

Day	Quiescent Point (volts)
1	+ .080
2	+ .095
3	+ .100
4	+ .110
5	+ .100

Table 2. Results of a 5 day stability test of the low gain channel

5.6 <u>In-Flight Test</u>

In January 1972, a prototype of the photometer package was flown satisfactorily on board the Black Brant vehicle AAF-VB-33. The data received were of good quality. A 2-second segment of the data obtained during the flight from one photometer channel, corresponding to one rotation of the rocket, is shown in Figure 5. The signal is virtually noise free and the auroral luminosity profile measured by the rotating photometer can be clearly seen.

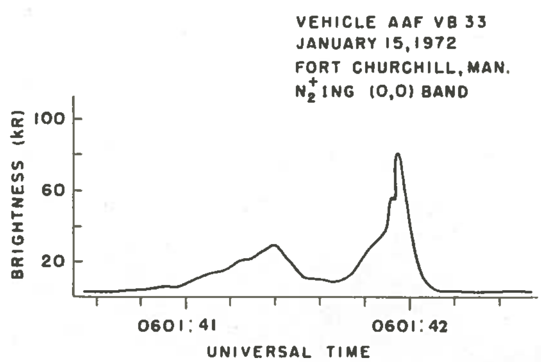

Figure 5
In-flight data acquired by the photometer package for one rotation of the rocket about its spin axis

References

Bristol Aerospace Limited, Engineering Report 69538. "Environmental Specifications for Black Brant Payloads and Instrumentation".

Chamberlain, J.W. 1961, "Physics of the Aurora and Airglow", Academic Press, New York.

Harris, F.R., Peterson, R.N. and Bradley, D.T. 1970, Can. J. Phys. 48, 2283.

Vallance Jones, A. 1971, Space Sci. Revs. 11, 776.

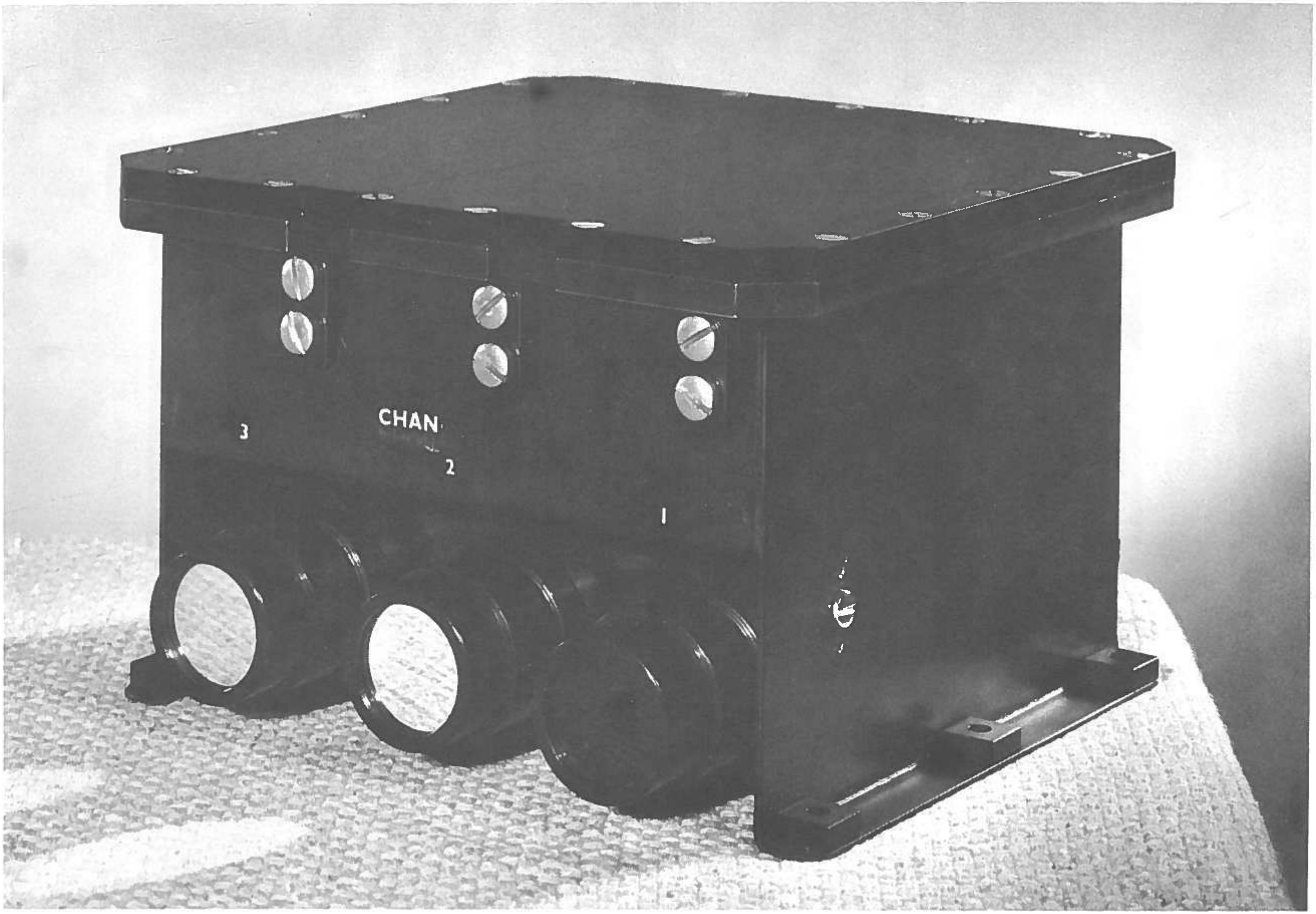

Plate 1
Front view of the photometer housing

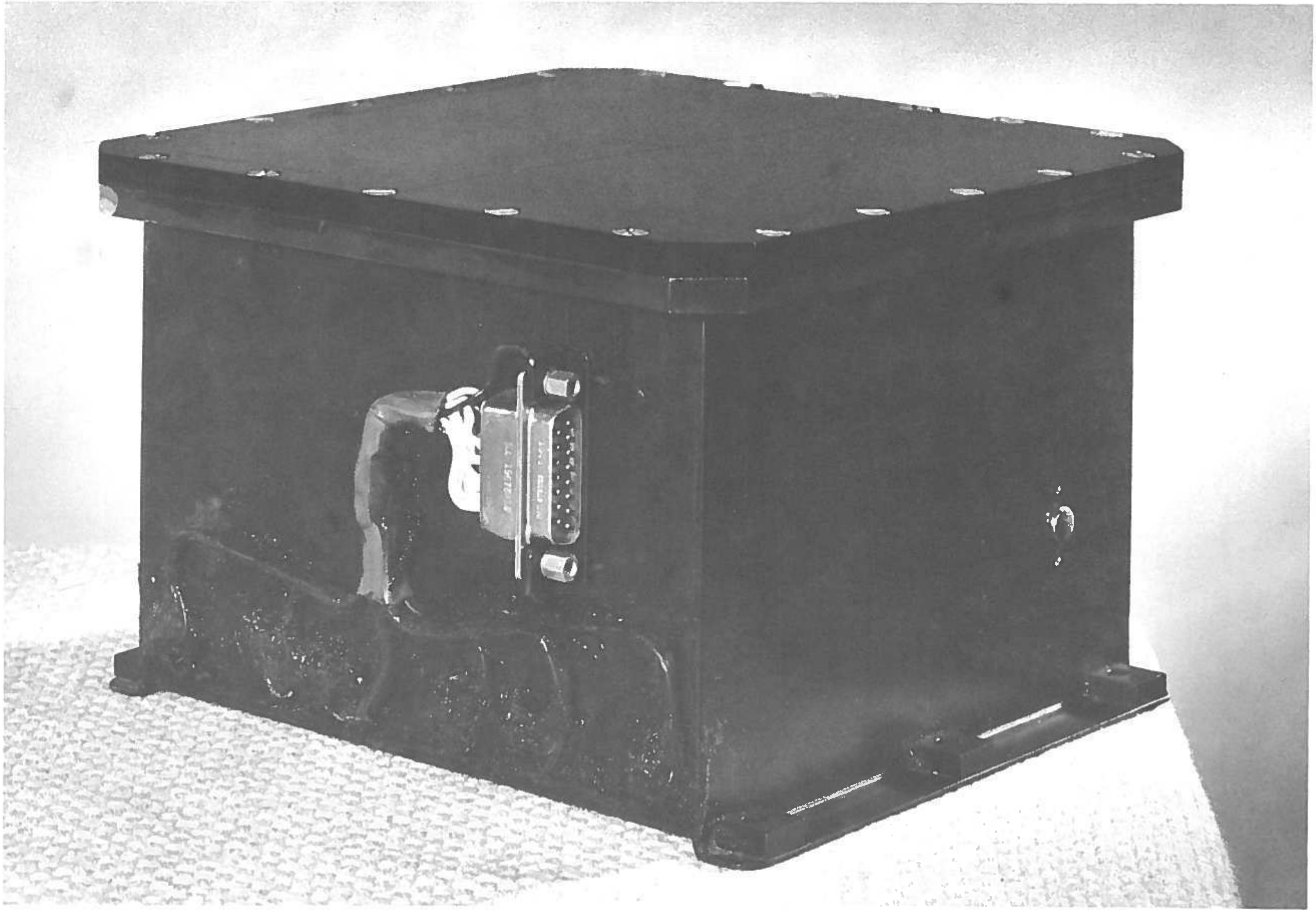

Plate 2
Rear view of the photometer housing

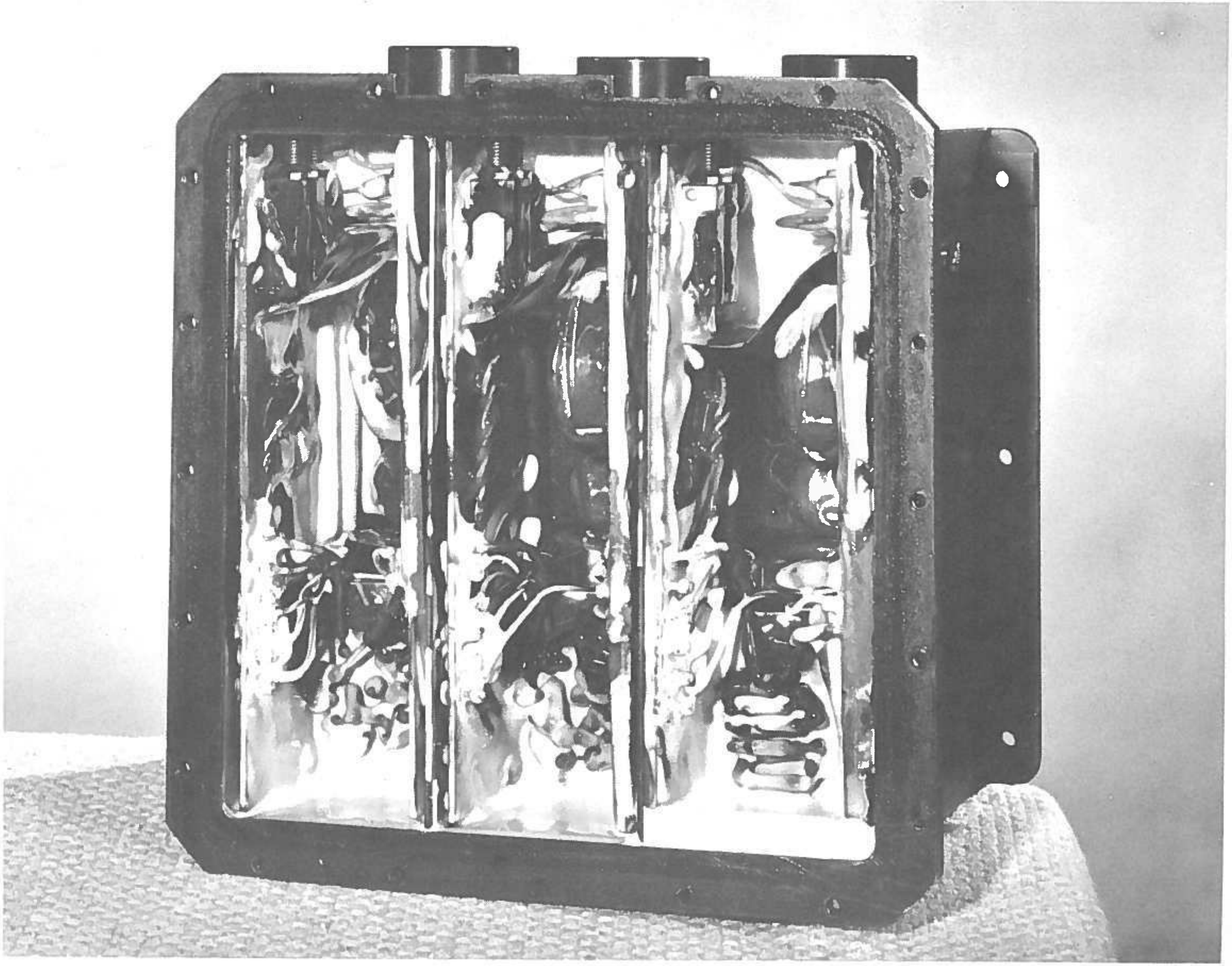

Plate 3
Interior view of the photometer housing