MODIFIED ELECTRON SPECTROMETER FOR MEDIUM ENERGY

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Abstract: Electron Spectrometer for Medium Energy (ESM) aboard the S-310JA-1 rocket worked successfully, but the experimental results showed that several points should be revised. We have improved these points and designed a modified ESM. The modified ESM will be launched with the S-310JA-5 and 6 rockets.

1. Introduction

The S-310JA-1 rocket which carried an Electron Spectrometer for Medium Energy (ESM) was launched from Syowa Station at 12:45 LT on February 13, 1976. The ESM was designed for a flux measurement of electrons precipitating into the polar region. The compactly designed instrument consists of a magnetic analyzer with a permanent magnet, a secondary electron multiplier (CEM), and the associated electronics. The ESM is covered with double meshes which make evacuation quick and prevent a high voltage electrical breakdown. The inner mesh was biased to -20 V in order to retard thermal electrons. The ESM successfully worked in the S-310JA-1 rocket experiment, but the experimental results revealed that several points should be revised further.

These points are as follows;

1) energy resolution
2) reliable protection against the electrical breakdown
3) noise reduction
4) leakage of electric and magnetic fields.

In this paper we discuss these points and show the corresponding measures.

2. Improvement and Modification of the Instrument

2.1. Energy resolution

A higher energy resolution has been achieved with a new magnetic deflector in which a deflection angle is improved from 90° to 180°. A sharper focussing is realized by the new ESM. Fig. 1 shows a comparison of energy resolving

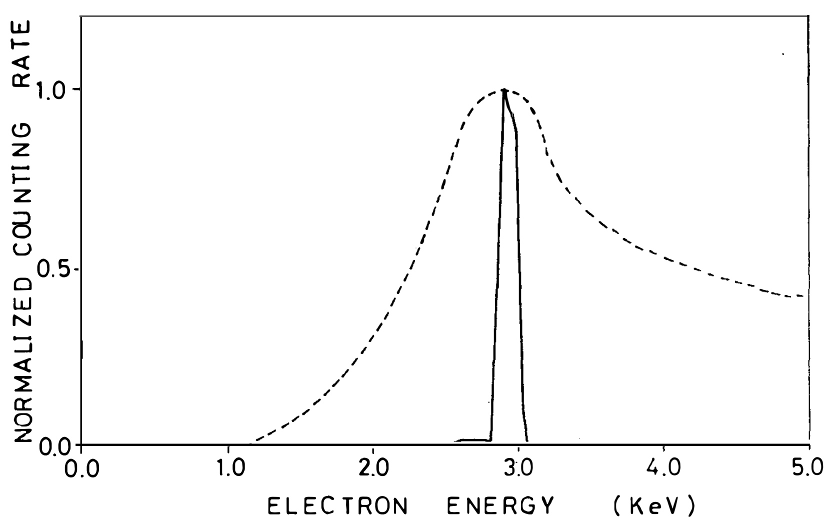

Fig. 1. The over-all energy response for both the new (indicated by solid line) and the old (dashed line) ESM's.

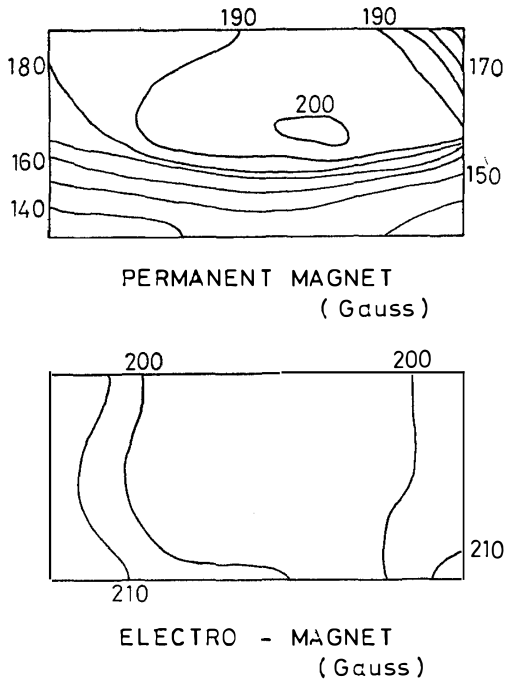

Fig. 2. Distribution of magnetic field by an electro-magnet and a permanent magnet. It shows that a better distribution can be obtained by the electro-magnet than by the permanent magnet.

capability between the new and old ESM's. The solid and dashed lines indicate energy-resolution curves for the new and old ESM's, respectively. The full width half maximum ($\Delta E/E$) has been improved up to 1/20. An electro-magnet is used for energy scanning. The electro-magnet has an advantage of better uniformity of the magnetic field compared with a conventional permanent magnet. A comparison of the uniformity of magnetic field strength for both electro and permanent magnets is shown in Fig. 2.

2.2. *Improvement of protection against electrical breakdown*

Under insufficient evacuation, we have a danger of electrical breakdown of high voltage in the instrument (PAUL and BURROWBRIDGE, 1970; TIMOTHY, 1973). The old ESM had an open structure with double meshes and application of the high voltage was delayed, for safety, up to 186 sec. The rocket reached the apex of its trajectory (215.6 km) at 230 sec after launch, therefore, data from means of the ESM were little obtained in the ascending-leg. In order to avoid a dead-time caused by an over-estimation of evacuation time, it is necessary to examine the efficiency of exhaustion from the interior of the instrument, especially from an analyzer and a CEM. It would be a good idea to build a simple vacuum meter in the instrument in order to determine an optimum time of the high voltage application. For rocket experiment, a Schulz gauge shown in Fig. 3 may be suitable. It is supported with a frame for resistance against vibration. The grid made with a mesh works as an air hole. It can provide accurate pressure (10%)

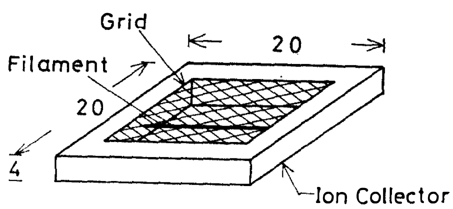

Fig. 3. A Schulz gauge designed for rocket experiments. It is supported with a frame for resistance againist vibration. The grid made with a mesh works as an air hole.
Sensitivity; 1.0 Torr^{-1}, Emission current; 20 μA,
Filament; Thoria-coated Iridium.

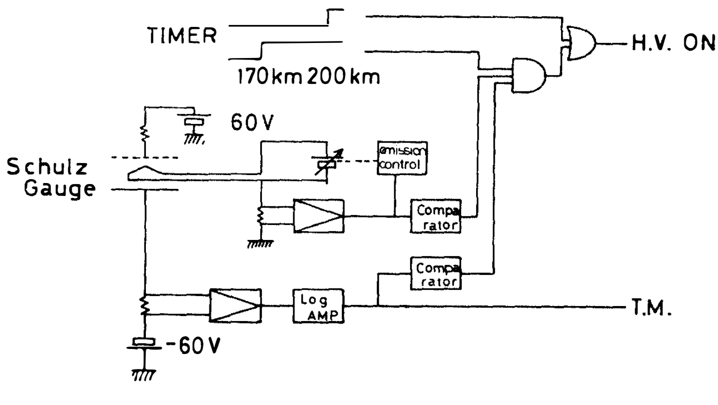

Fig. 4. A block diagram of the Schulz gauge.

and quick response (about 1 msec) over the range of 1 to 10^{-5} Torr. The vacuum meter circuit is shown in Fig. 4. It starts to work after the opening of nose cone of the rocket. The high voltage is turned on either if an AND condition is satisfied or if a fail safe timing pulse (200 km timing signal in the figure) is imposed. The AND input are; 1) a preset altitude signal (170 km timing signal in the figure), 2) an output signal of the Schulz gauge showing a safe pressure, and 3) a monitor signal of filament current of the Schulz gauge.

2.3. *Noise reduction*

Noises are generated mainly by photoelectrons which are produced by solar ultra-violet rays incoming through the double meshes. These noises were the cause of the spin modulation of the counting rate on the data of the old ESM. Effective methods for noise reduction are as follows: First, a complete shield on the analyzer is effective to prevent photoelectrons from penetrating into the entrance of the CEM. Second, application of -40 V to the entrance of the CEM is effective to retard the low energy photoelectrons. Third, coating of platinum black on the inside surface of the collimator and the analyzer is effective in absorbing the scattered ultra-violet rays.

An experiment to clarify an effect of ultra-violet radiation on the instrument was performed. Ultra-violet rays were radiated onto the ESM from various directions with a deuterium lamp (Fig. 5). The result of the experiment shown in Fig. 6 indicates that the above-mentioned revisions are very effective in eliminating the noise caused by ultra-violet rays.

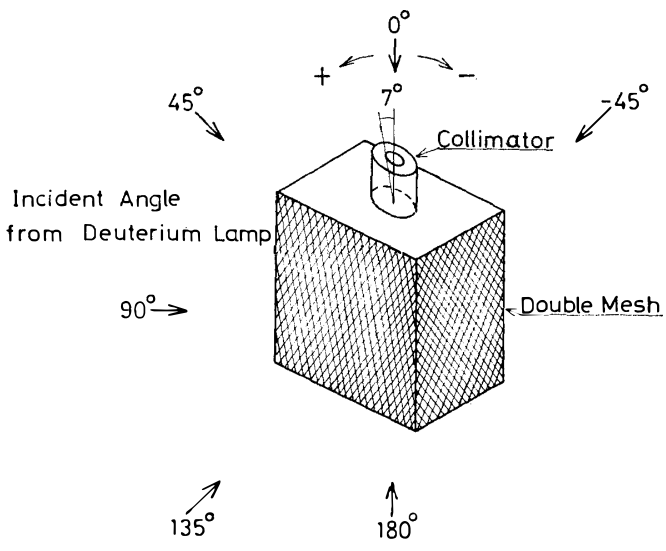

Fig. 5. An illustration of an experiment to clarify an effect of ultra-violet radiations on the instrument from all directions with a deuterium lamp.

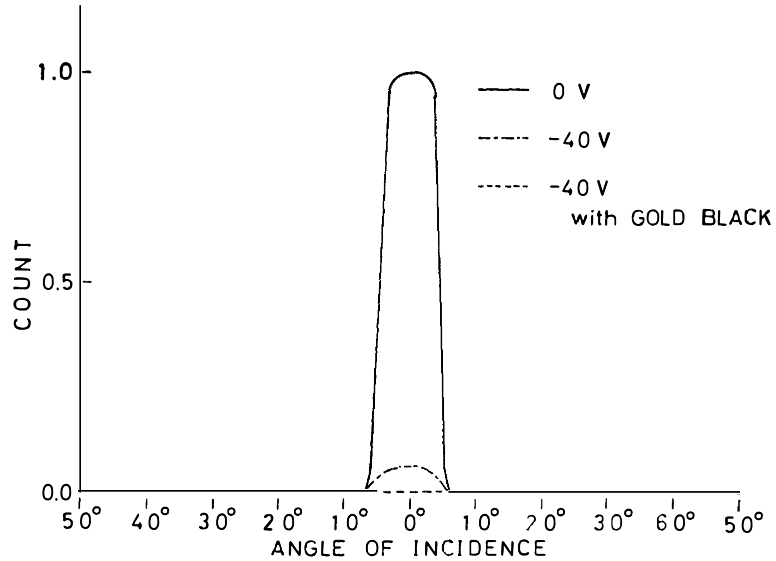

Fig. 6. A result of the ultra-violet experiment. A complete shield on the analyzer, application of the retarding potential to the entrance of the CEM, and platinum blackening of the analyzer can reduce the noise caused by ultra-violet rays.

2.4. *Leakage of electric and magnetic fields*

Leakage of the electric and magnetic fields from the high voltage 3 kV applied to the CEM and the electro-magnet used for energy analysis may disturb not only the surrounding plasma but also other physical instruments on board the same rocket. Therefore, the following examination has been made for the new ESM.

Leakage of the electric field was examined in an experiment sketched in Fig. 7. A floating potential and the Langmuir curve of the outer mesh, and the Langmuir curve of a probe in the vicinity of the instrument were monitored in

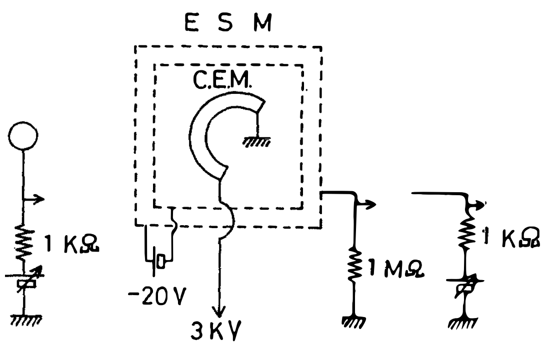

Fig. 7. A experimental setup to examine a leakage of electric field. No change of a floating potential and the Langmuir curve was observed when the high voltage was switched on and off.

a plasma with $N_e \simeq 10^4$/cc and $T_e \simeq 1500$ K. No change of the potential and the Langmuir curve was observed when the high voltage was switched on and off, showing a sufficient shield effect of the double meshes adopted in the new ESM.

Leakage of the magnetic field was examined with a gauss meter. A magnetic field comparable to the Earth's field was observed at 1 cm apart from the electro-magnet of 300 gauss gap field. The leakage field, however, is reduced to a sufficiently low level which cannot be measured by the gauss meter when the electro-magnet was enclosed with a μ-metal.

3. A Design of the New ESM for S-310JA-5 and 6 Rocket Experiments

The configuration of the new ESM is shown in Fig. 8. Two same sensors

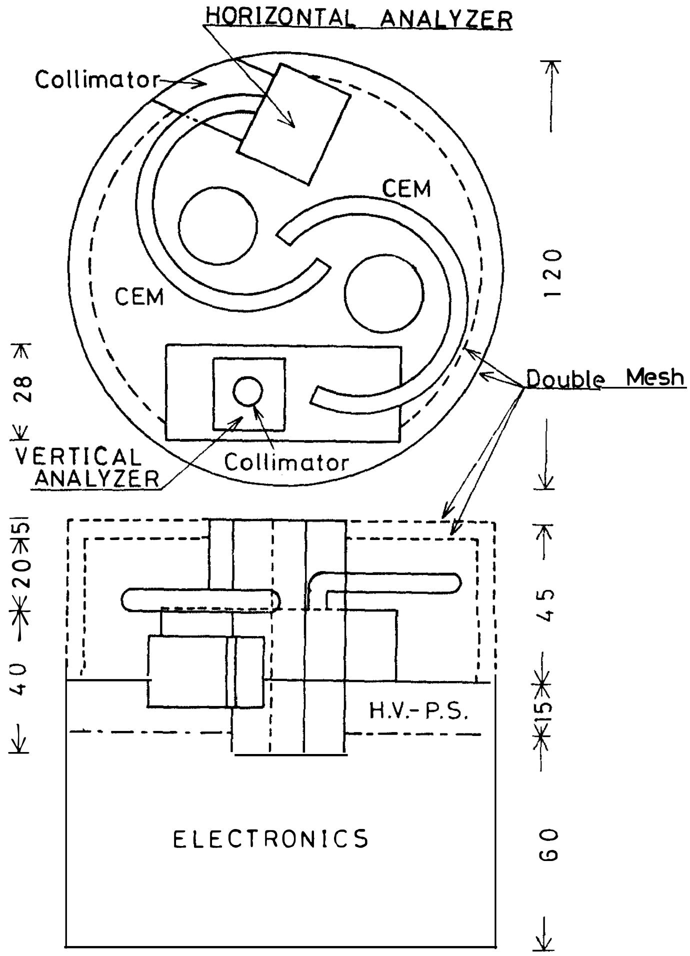

Fig. 8. The configuration of the new ESM which will be aboard the S-310JA-5 and 6 rockets. It has an open structure for the protection from the electrical breakdown. The two same sensors are mounted with two different monitoring directions, parallel and perpendicular to the rocket axis. The size of the new ESM is one-third as small as the old one.

are mounted which are set to monitor electrons from two different directions, parallel and perpendicular to the rocket axis, for the purpose of measuring wider pitch angle distributions. The size of the instrument is $120\phi \times 120$ mm which is much smaller than that of the old ESM. Polarity of the magnetic field is inversed at some interval to check dark counts. The measured energy range is controlled stepwise by the electro-magnet current.

The specifications of the analyzer are as follows:

1)	Energy steps	1, 2, 3, 5, 10 keV
2)	Sweep speed	1 step (energy)/sec
3)	Energy resolution	$\Delta E/E=1/10.33$
4)	Geometrical factor	$G=6.61\times 10^{-5}$ [cm^2·ster]
5)	Maximum measurable flux	1.56×10^9 [/cm^2·ster·sec·keV]
6)	Field of view	10° (circle).

4. Conclusions

Conclusions are summarized as follows:

1) The magnetic analyzer using an electro-magnet has a performance equivalent to the electro-static analyzer (FRANK *et al.*, 1966) and yet is more compact and lighter than that.

2) The open structure with the double meshes is effective for prevention of electrical breakdown. Laboratory simulation for the evacuation prior to the flight gives a rough estimate of the timing of the high voltage application. An on-board vacuum meter is adopted to decide the optimum time of the high voltage application. Further experiments, however, will be necessary to assure the protection. A compact vacuum meter which has a simpler circuit (for example, thermister, etc.) should be developed to make the instrument smaller.

3) A complete shield of the analyzer, application of the retarding potential to the entrance of the CEM, and platinum blackening of the analyzer can reduce the noises caused by ultra-violet rays.

4) Leakages of the electric field and the magnetic field were reduced to sufficiently low levels.

5) The size of the new ESM is one-third as small as that of the old one.

The new ESM has thus been successfully improved in comparison with the old ESM.

Acknowledgments

The authors wish to thank all members of the wintering parties of the 17th and 19th Japanese Antarctic Research Expedition for their efforts in making the launch. They also thank the National Institute of Polar Research for giving them the opportunity to conduct the experiments.

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(*Received May 16, 1978*)