2

This is an informal report intended primarily for internal or limited external distribution. (The opinions and conclusions stated are those of the author and may or may not be those of the laboratory.) ~~This report is not to be given additional external distribution or cited in external documents without the consent of the author or LLL Technical Information Department.~~

UCID - 16349

LAWRENCE LIVERMORE LABORATORY

University of California/Livermore, California

RECENT DEVELOPMENTS CONCERNING BANDPASS DETECTORS

Jerry L. Gaines

September 11, 1973

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

RECENT DEVELOPMENTS CONCERNING BANDPASS DETECTORS

Jerry L. Gaines

I. Introduction

This report discusses several problems which have been encountered since UOPE 71-19 "The XRBPD, A New Bandpass Detector", a report describing the bandpass detector, was distributed. These problems have been discovered as a result of more extensive use in actual field experiments which, although not identical, were similar in many respects. The improvements made to solve these problems as well as some recent developments are also described.

II. Background

Up to the present date, 21 bandpass detectors have been fielded, excluding backups, since they were introduced in late 1971. Of this number, there have been four detectors which have failed to operate as designed. Three of the four detectors failed prior to the experiment and were accessible for replacement. The fourth detector failed prior to the experiment but was not accessible for replacement.

All of the failures were similar in that the obvious symptom was a failure to hold the bias voltages for which the detector was designed. Of the three detectors that failed and were replaced, only one failed because of a faulty vacuum. The other two detectors had arced internally, creating leakage paths across the insulators. The first detector to fail was designed to hold -5KV on the front bias plate and +5KV on the rear bias plate. It began to arc periodically and although it would hold approximately 4KV plus and minus, it was replaced. It was found upon disassembly to have been arcing from the front plate across an insulator to the center plate. The second detector to fail was designed

to operate at plus and minus 6KV. Prior to the experiment it also began to arc. Since this detector was not accessible, the bias voltages were reduced to approximately 4KV plus and minus, where the detector appeared fairly stable with only an occasional arc. To insure elimination of any arcing, the bias voltages were reduced to plus and minus 1KV for the experiment. The next detector to fail also was designed to hold -6KV on the front plate and +6KV on the back plate. It began to arc prior to the experiment and although a corrective procedure to be described later was at first successful, the detector later began to arc again and it was replaced. Upon disassembly, one of the insulators between the front plate and the center plate was discovered to have fractured. Signs of arcing across this insulator were present.

The last detector to fail, initially showed signs of occasional arcing which was corrected using the procedure referred to previously. This detector also was designed to employ plus and minus 6KV. Approximately one month later, this detector failed again and would not hold any voltage. It was replaced and upon checking, the vacuum was found to have leaked up to approximately 150 microns from the seal off pressure of $\sim 10^{-8}$ Torr. Subsequent tests indicated the initiation of a glow discharge at approximately this pressure when the bias was applied.

During the months following the first detector failure, efforts were made to try to improve the high voltage capability of the detectors. In Figure 1 is shown the exploded view of a detector like the first one to fail. Figures 2 and 5 show how the plates were mounted to the four mounting pins. Tests made in the laboratory indicated that there were two areas where arcing generally began. One was between the front plate and the window structure, and the other was from the edges of the small holes in the plates where the mounting pins with quartz sleeves passed through.

The attempts to correct the first problem consisted of lengthening the mounting pins so that the front plate could be moved further away from the window assembly and smoothing any rough edges which might be present. To try and correct the second problem, we reduced the number of mounting pins to three and tried to insure that the sharp burrs were removed from the small mounting holes in the plates. This was not an easy task since the mounting hole passed through three pieces of metal sandwiched together. Mechanical polishing as well as chemical etching were used.

These efforts appeared to be successful since the detectors incorporating these changes would high pot in the lab to 8KV and would operate during an eight hour test period at plus and minus 5KV without any signs of arcing. However, due to an experimental requirement for more linear current, it was necessary to operate many of the next detectors at plus and minus 6KV bias. Tests in the lab indicated that this was not unreasonable. However, the last three failures on three different experiments incorporated the changes mentioned above. Since these experiments had been scheduled for execution within a short time span, all the detectors were alike.

The procedure which was used to try and correct the arcing problems was to raise first the negative bias to approximately 9KV and let it arc to try and burn off the sharp edges. Next, the negative bias was turned off and the positive bias turned on and the same procedure used. Following this, the detector would usually hold plus and minus 6KV. If this failed, the next procedure was to raise both the plus and minus high voltage up to approximately 9KV and try to burn off any sharp edges or leakage paths. If both methods failed, the detector was replaced if possible.

Efforts to develop a detector with better high voltage characteristics were continuing throughout this period and the mounting arrangement shown in figures 3 and 6 was developed just prior to the first of the last three failures. Detectors employing this design were used to replace the two detectors that failed and were accessible. This design eliminated the mounting holes in the plates, one of the major sources of rough edges that caused arcs. The path length along the quartz insulators from one plate to another plate was also greatly increased using this design over that shown in figures 2 and 5. The mounting pins were long enough to insure adequate separation of the front plate from the entrance window assembly. These detectors were capable of high potting to 10KV and would hold 8.5KV for test periods of four hours without any arcing. A total of six of these type detectors have been used in field experiments without any evidence of high voltage problems.

Another problem which arose with the bandpass detectors involved the response to radiation. Since the detector is relatively insensitive in the pass band region, $\sim 10^{-23}$ coulombs/kev and very insensitive outside the pass band region, 10^{-24} to $< 10^{-26}$ coulombs/kev, it is very difficult to calibrate accurately. The response is governed partially by the thickness of the platings on the first two foils as described in UOPE 70-6 by J. Lindsey and, therefore, each detector although very similar, must be individually calibrated since the plating thicknesses can vary slightly. Although it was not too difficult to calibrate the detector within the passband, it was much more difficult outside the pass band because with the radiation flux levels available, the currents often were in the 10^{-15} to 10^{-17} ampere range. In addition, any small spectral contaminants that fell within the pass band region became large effects since the sensitivity was much higher in this region. Until these problems were properly appreciated, it was not possible to get an accurate calibration outside the passband region. We now use an unfolding code to minimize these problems. We still have problems, however, when the sensitivity goes negative since the code is presently not capable of handling positive and negative sensitivities together.

III. New Developments

Efforts to improve the pass band detector in all respects has been a continuing effort. The high voltage capability has been further improved by the foil mounting method shown in figures 4 and 7. There are six mounting pins, three of which support the front and rear bias plates and three of which support the center or signal plate. There are no insulators contacting both the signal plate and bias plates. Arcs can still occur from signal plate to bias plate but no leakage path between them can develop. These detectors have been able to withstand high potting for short periods of time greater than plus and minus 12KV and will hold 10KV for much longer. At 8KV they have not arced at all during eight hour test periods. Even when they do arc, they do not seem to get any worse, and usually they get better. However, we need to gain more experience with this design to establish a good upper high voltage limit. Each detector is slightly different depending on the smoothness of the internal surfaces.

It is felt that we are probably at the high voltage limit with the present design and plate separation.

The limiting current from this detector can be approximated using the relation¹

$$i = \frac{\sqrt{2}}{9\pi} \left(\frac{e}{m}\right)^{\frac{1}{2}} \frac{V^{\frac{3}{2}}}{X} \text{ A K} \quad (1)$$

where

i = maximum linear current from the detector

e/m = ratio of charge to mass of an electron

V = voltage applied between adjacent plates

¹ I. Langmuir and K. T. Compton, "Electrical Discharges in Gases", Rev. Mod. Phys. 32, April 1931, p. 191.

X = plate separation (.3175 cm)

A = area of beam incident on plates

K = ratio of net current from center plate to the maximum current between the plates (usually about .67).

This relationship can be simplified to:

$$i = 2.334 \times 10^{-6} A V^{\frac{3}{2}} X^{-2} K \quad (2)$$

Figure 8 is a graph showing the approximate maximum linear current obtainable from a bandpass detector as a function of bias voltage and radiation beam diameter incident on the detector plates. From this graph, it is obvious that if more linear current is required and there is a high voltage upper limit, then a larger radiation beam diameter is indicated.

Efforts to improve the response of the 5-7 kev and 9-11 kev detectors have essentially stopped. We have not succeeded in improving the ratio of the sensitivity in the pass band to the sensitivity outside the pass band. We can, however, adjust the thicknesses so that the detector does not have a negative sensitivity anywhere if desired. We try to adjust the thicknesses of the plating so that with the prefilter in place, the detectors' sensitivity at its lowest point is as close to zero as possible. In the past, this point has been determined to actually be negative in some cases. The normal plating thicknesses for the various detectors are as follows. For the 5-7 kev detector, the front foil of 1 mil Be has 1.5×10^{-5} gm/cm² of iron plated on the side toward the middle foil. The middle Be foil has 4×10^{-5} gm/cm² of Ti plated on the side facing toward the back plate which has no plating on it. The 9-11 kev detector has 1.15×10^{-5} gm/cm² Ge on the first foil and 1.75×10^{-5} gm/cm² Cu on the middle foil. The 7-9 kev detectors use 2.85×10^{-5} gm/cm² Cu and 5×10^{-5} gm/cm² Fe.

On the latest detectors to be built, the 3 mil beryllium entrance windows were replaced with 5 mil beryllium to give added reliability although we have not had any 3 mil Be windows leak in field use. The 3 mil Be windows will rupture if the Be window is subjected to atmospheric pressure on the inside and vacuum on the outside while the first test with the 5 mil window indicated that it can survive those conditions. Either window thickness can be supplied depending on the experimental requirements.

Figures 9 and 10 show a 5-7 kev detector which was specially built to be inserted into a line of sight experiment. The detector has conflat flanges on both ends and thus can become an integral part of the line of sight vacuum system. The entrance window is a standard 1" diameter assembly using 5 mil beryllium and the exit window is a 1.75" diameter, 10 mil Be assembly which is normally used as the entrance window on the 9-11 kev detectors. The foil mounting pins were removed from the latter window assembly for this special case. The internal structure is identical to that shown in figures 4 and 7 and the detectors' operating characteristics are identical to the normal 5-7 kev detectors. Only the outside configuration has been changed.

A change has been made to the standard field test procedure for checking out the bandpass detector after it has been installed, as was described in UOPE 73-1. The change is to reduce the voltage to half value when conducting these tests. This eliminates any possibility of the detector being over voltaged due to surges or charging effects. Another feature which should be employed when using these detectors is to install a large value bleeder resistor in the signal line to prevent it from building up a charge. There are changes which have proven to be of value from past experience with these detectors.

A new detector, in the fact that it has a different bandpass region, has also been developed. This detector has a pass band from 17 to 20 kev. The foil plating materials are molybdenum on the front foil and yttrium on the second foil. A 2 mil molybdenum prefilter is used with this detector. The response with and without the prefilter is shown in figure 11.

IV. CONCLUSIONS

Although several problems have been encountered in past usage of these detectors, this is not uncommon with most new type detectors. We have attempted to solve these problems as they occurred and to anticipate them before they happened. The development has been a continuing effort. The latest designs appear at present to solve the problems that have been encountered. Efforts to further improve these detectors as well as developing ways to more effectively use them will continue as long as there is any interest in them. Many of the fabrication techniques can be applied to other detectors which have had similar problems with high voltage. This detector can also be used as a gamma insensitive XRD with minor modifications. The front and rear plates are left unplated and the center foil is plated with a fairly thick coating of a material chosen according to the energy range desired. Two of these type detectors have been used on an experiment with good results. (COL 73-153 by J. Lindsey.)

It is hoped that we can continue to work closely with those conducting field experiments where bandpass detectors are used in order to continue to incorporate improvements which are suggested or indicated from field experience. The suggestions made by the experimenters in the past and their patience when problems have arisen has been appreciated. We encourage inquiries on problems where we can be of help such as special design modifications to the detectors or discussions concerning the use of or data obtained from the bandpass detectors.

JLG:cp

Distribution:

C. Anderson, L-45
T. Boster, L-45
H. Catron, L-8
C. Curry, L-154
W. Dickinson, L-41
P. Ebert, L-525
B. Faraudo, L-49
H. Francis, L-8
J. Gaines, L-525
L. Germain, L-7
V. Gregory, L-525
R. Guerra, L-777
R. Hanson, L-525
T. Harper, L-45
A. Jorgensen, L-48
H. Kornblum, L-45
R. Kuckuck, L-525
G. Leipelt, L-525
J. Lindsey, L-525
H. Mallett, L-45
L. Richards, L-45
F. Seward, L-46
J. Shearer, L-18
W. Slivinsky, L-525
W. Tindall, L-156
G. Tirsell, L-8
A. Toor, L-46
J. Watson, L-45
J. Wobser, L-777
E. Woodward, L-46
TID File, L-9 (5 copies)
External Distribution:

Brent Davis, EG&G, L.V., D-81
P. A. Hawkins, EG&G, L.V., D-91
G. Allen, EG&G, L.V., D-81

NOTICE

"This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately-owned rights."

Exploded View, Bandpass Detector

Figure 2, Initial Foil Mounting Arrangement

Figure 3, Improved Foil Mounting Arrangement

Figure 4, Latest Foil Mounting Arrangement

Initial Foil Mounting Arrangement

Improved Foil Mounting Arrangement

Latest Foil Mounting Arrangement

EUGENE DIETZEN CO.
MADE IN U.S.A.

LINEAR CURRENT IN AMPERES

BIAS VOLTAGE IN KILOVOLTS

Figure 9

-16-

UCID 16349

Entrance Window of Special Detector

Figure 10

-17-

UCID 16349

Exit Window of Special Detector