SDC-91-00093

SDC
SOLENOIDAL DETECTOR NOTES

EFFECTS OF CATHODE AND WALL MATERIALS AND WATER VAPOR ON STRAW TUBE AGING

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ABSTRACT

Nine short straw tubes with different cathode and wall materials have been used for accelerated aging tests and high-voltage breakdown tests. The gases used were argon/ethane (50/50) and CF_4/isobutane (80/20). The effect of adding water vapor in each type of test has been investigated. All but one of the tubes performed well in aging and HV breakdown tests, and water vapor was found to be effective in suppressing discharges during aging tests, but had no noticeable effect in the HV breakdown tests.

1. Introduction

Nine straw tube prototypes about 15 cm long by 4 mm diameter have been used for accelerated aging tests and high-voltage breakdown tests, as a function of several variables: HV or gain, principal gas mixture (two types), water vapor to quench discharges, and current densities. The tube wall materials are Mylar, Kapton, polycarbonate, and aluminum, and cathode materials are aluminum, copper, nickel, and gold. The anode wire was 38 μm diameter gold-plated tungsten, except for one tube which used a carbon fiber of 33 μm diameter. The gases were: (1)argon/ethane (50/50), and (2)CF_4/Isobutane(80/20). The latter has properties that appear very attractive for use in high radiation environments, such as at an SSC experiment.[1] Aging studies of this gas mixture and of related gases will be reported in an accompanying paper. The parameters used to measure aging are: (1)the

*This work was supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Division of High Energy Physics, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

[1] Use of Straw Tubes In High-Radiation Environments, J. Kadyk et al., NIM A300(1991)511.

current drawn by the straw tube vs. the charge transfered; (2)gain uniformity using pulse-height analysis; (3)spontaneous breakdown during aging tests; (4) measurement of the high voltage necessary to induce breakdown of the tube by deliberately raising the voltage.

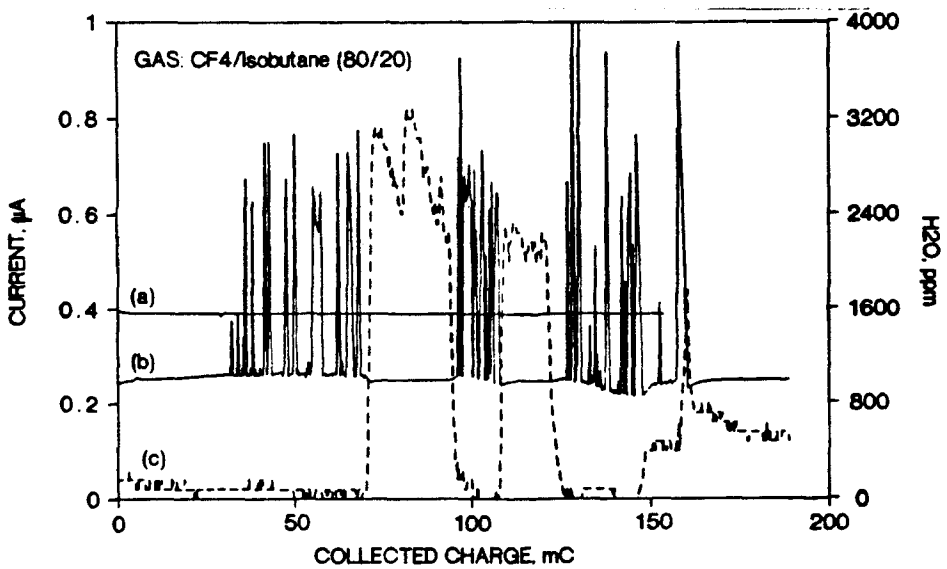

Fig. 1. Two examples of aging tests (see Table 1): (a)gold-plated Al tube, and (b) Mylar tube. The latter went into discharge mode after 0.1 C/cm, and subsequently recovered when H_2O was added, as shown by the graph (c). As can be seen, the cycle of removing and adding H_2O vapor was repeated with similar results.

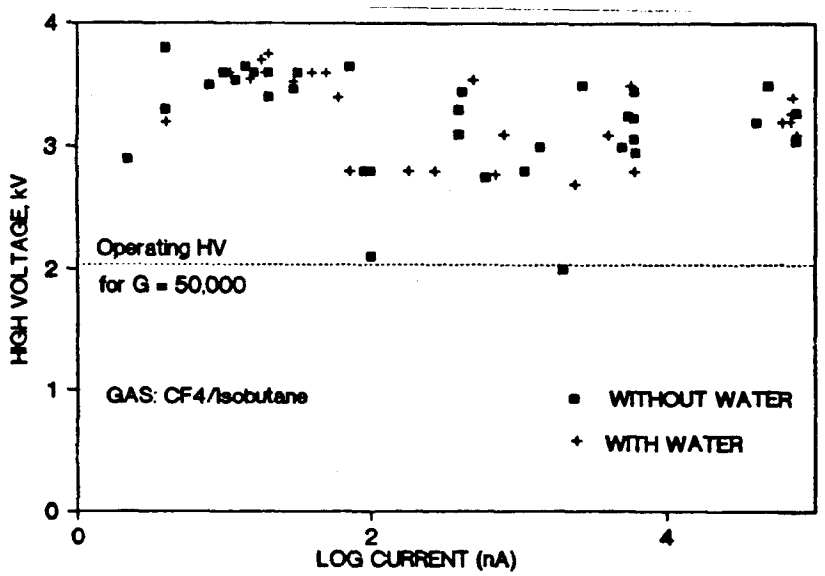

Fig. 2. High voltage breakdown tests on nine straw tubes, using CF_4/isobutane gas. Plotted are the HV and current when breakdown occurred, with and without H_2O vapor. The tests were performed at three radiation levels:a)no source, b)200μCi, and c)2mCi sources.

During an aging test, the current is induced by exposure to a relatively intense Fe^{55} source, which results in an avalanche region of about 3 mm along the wire. Measurements of the current vs. charge are shown in Fig. 1, with examples of a small aging rate (a), and tube discharges (b). Breakdown resulting in large current "spikes" is typically a result of cathode surface coating by a thin insultating layer. Measurements of deliberately induced HV breakdown are summarized in Fig. 2. HV tests were done with and without the addition of water vapor at the level of 3000-6000 ppm; previous reports[2] have indicated that breakdown and other aging effects can be suppressed by the addition of similar amounts of water into the gas. We have used a permeation device to control the amount of water vapor injected into the gas stream and also have monitors to measure continuously the amount of water vapor and oxygen.

2. Result from Accelerated Aging Tests

Table 1 summarizes the results from accelerated aging tests. The fractional gain decrease is parameterized by:

$$R = -(1/G)dG/dQ, \ \%/(C/cm), \tag{1}$$

where G is the tube gain, assumed to be proportional to current, and Q is the linear charge transfer in coulombs. The total charge accumulated during each test is given, as are the wall and cathode materials of each tube. General parameters applying to all the tests, unless otherwise noted, are: 1) G is near 50,000; 2) the wire is gold-plated tungsten of 38μm diameter; 3) the current density is about 0.6 - 1.2 μA/cm. Under "Comments" are found other relevant observations or departures from these general parameters.

Under the most extreme conditions anticipated for use in SSC experiments, wire chambers might be expected to sustain a current of about one μA per meter.[3] Assuming this current over a period of "five years", or 5×10^7 sec, then the total charge transfer during the lifetime of the experiment is 10nA/cm x 5×10^7 sec = 0.5 coulombs/cm. The tube should not lose gain more than, say, 10%, requiring $R < 20\%/(C/cm)$. This then sets the scale by which the results in Table 1 can be measured, assuming that accelerated aging tests can be scaled to lower radiation intensities. The general picture is that nearly all results are compatible with the required performance.The one test which has resulted in poor performance is that of the tube with a polycarbonate wall.[4] There is some evidence that the aluminum cathode film does not adhere well to the wall in this case.[5]

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[2] Wire Chamber Aging, J. Kadyk, NIM **A300**(1991), p. 448 and references 24-29.

[3] See, for example, p. 25 of Radiation Effects At The SSC, SR-1035, SSC Central Design Group, M.G.D. Gilchriese, Editor, June 1988.

[4] Private communication with B. Dolgoshein at the Pisa Instrumentation Conference, Elba, May 1991; he has said that he used similar tubes successfully.

[5] Private communication with D. Rust of University of Indiana, which supplied much of the tubing we used to fabricate the test counters.

sufficient amounts of water vapor. In the case of the polycarbonate tube, which underwent both rapid decrease of gain and breakdown, between 4000 and 5000 ppm of H_2O were needed to suppress the discharges; in the case of a Mylar/Al tube, a smaller amount, <1000ppm, seemed to suffice (see Fig. 1).

Table 1. Accelerated Aging Test Results

Gas	Gain Loss, R (%/(C/cm))	Linear Charge Transfer (C/cm)	Materials: Wall/Cathode	Comments
Ar/Eth. (50/50)	5	1.2	Mylar/Al	33μm carbon fiber anode
"	3	0.5	Al/Al	
"	8	0.6	Al/Ni	
"	5	0.6	Al/Cu	
"	12	0.2	Al/Au	
"	8	0.4	Mylar/Al	2 discharges, then recovery
CF_4/Iso butane (80/20)	3	0.5	Mylar/Al	Discharges quenched by H_2O (Fig. 1)
"	6	1.0	Kapton/Al	gain=1.5×10^5
"	200	0.06	polycarbonate/ Al	Rapid gain loss and discharges; gain=1.5×10^5
"	<1	0.5	Al/Au	Very stable, Sr^{90} (Fig. 1)
"	2	0.2	Al/Ni	Sr^{90}
"	10	0.2	Al/Cu	Sr^{90}
"	9	0.1	polycarbonate/ Al	gain=1.5×10^5
"	4	0.4	Kapton.Al	gain=1.5×10^5
"	9	0.2	Mylar/Al	gain=1.5×10^5
+1000 ppm H_2O	5	0.4	Mylar/Al	Same as above, with H_2O added.

3. High Voltage Test Results

The capability of a straw tube to reach a level of high voltage momentarily does not appear to be correlated with its integrity over a longer time period, or its history of aging. The nine straw tubes were tested at three different radiation levels, both with and without addition of water vapor. Each tube was tested to find its maximum voltage before discharge (1)without a source, (2)with a 200μCi source, and (3)with a 2mCi source. For each of these, tests were done with a low (about 200ppm) and high (3000-6000ppm) water content.

Figure 2 summarizes the HV tests: each test is represented by a point having the HV at breakdown plotted on the vertical axis, and $\log_{10}(I_b)$ on the horizontal axis, where I_b is the current at breakdown. Two points lying near 2.0 kV are from the tests of a damaged Mylar tube that subsequently recovered to about 3.0 kV when water vapor was added. The remainder of the points cluster in the neighborhood of 3.0 - 3.6 kV, where there is no apparent effect of the water vapor! It is of interest that a typical breakdown HV far exceeds the operating voltage for our standard gain of 50,000 (2050 kV), and yet some of the same tubes that breakdown at 3.0 kV or more will enter the discharge mode operating at only 2050 volts during aging tests. It becomes clear that the momentary HV breakdown test has only limited utility in identifying damaged tubes.

4. Outgassing From Gas Tubing

Since it is confirmed that water vapor is influential in suppressing discharges during aging runs, it is interesting to measure the "natural" outgassing which occurs from tubing commonly used for gas plumbing. The results of Table 2 were obtained by flowing argon/ethane (50/50) at a rate of 20 cc/min through a 3m length of the tubing; the gas was pre-filtered to remove the H_2O and O_2 in the supply gas:

Table 2. Outgassing From Gas Tubing

Tubing	H_2O Content, ppm	O_2 Content, ppm
0.25" Nylon	3000	10
0.25" polyethylene	300	70
0.125" copper	4	2

5. Summary

Using CF_4/isobutane(80/20) and argon/ethane (50/50), the potential influence of cathode and wall materials on straw tube performance have been studied. All of the tubes performed well in aging tests except the one with polycarbonate wall. Water vapor added to the gas suppressed discharges occurring during aging runs, but did not significantly affect the HV at which a deliberate breakdown was induced. The HV test was found to have little usefulness in identifying damaged tubes. All tubes but one were compatible with anticipated running in an extended SSC experiment.