SLAC-PUB-5207
March 1990
(I)

AGING OF GASEOUS DETECTORS*

J. VA'VRA
Stanford Linear Accelerator Center, Stanford University,
Stanford, California 94309, U.S.A.

ABSTRACT

This paper makes an overview of developments in the wire chamber aging field since the wire chamber aging workshop held at the Lawrence Berkeley Laboratory, Berkeley, California on January 16–17, 1986.[1] The author discusses new techniques to analyze the gas impurities and the wire aging products, wire "nonaging" in clean systems, wire aging in systems containing various impurities, various examples of problems which can "prime" surfaces prior to the occurrence of the aging, and some recent aging experience with the "SSC micro-straw tubes."

1. Introduction

Fear that the gaseous detectors would not survive the large doses expected at future hadron colliders2 has lead to the support of this type of research. Wire aging has a multidimensional character and therefore it is difficult to come up with a simple recipe explaining all of its aspects. Progress in the theoretical understanding of wire aging during the past 4-5 years has been slow. Instead we have seen-the development of a practical cookbook, full of various recipes "what to do and what to avoid."

Table 1 shows in a simplified form our qualitative understanding of the major variables effecting wire aging as of the end of the LBL workshop1 in 1986. One should say that at that time the results were sketchy and frequently one had to guess what might be the correct interpretation. Many of the 1986 conclusions are still correct in 1990, although some limits are not exactly known. For instance, water is known to help, but the limit at which it starts working is not yet known.

We do not have a precise quantitative model available to explain wire aging. Instead we try to create simple minded models with some unique signatures. A molecular dissociation energy, electron affinity, an ability of a given element to create nonconducting oxides, an inability of certain oxygen containing molecules to form polymers, an avalanche charge density, or a gas flow could be considered as examples of such signatures. It is not clear what signature is the most important, perhaps all contribute at some level.

Lets discuss the *dissociation energy*. An example of a simple minded naive qualitative model of polymerization was presented.3 This model was based on the fact that the dissociation energies of typical molecules are much lower than the ionization energies. Since it is necessary to reach the ionization energies in order to produce a given charge in the avalanche, it was

* **Work supported by Department of Energy contract DE–AC03–76SF00515**

Invited talk presented at the Vth International Conference on Instrumentation for Colliding Beam Physics, Novosibirsk, USSR, March 15–21, 1990

Table 1
Variable Important for Good Aging Results

1. High purity of a system and gases.
2. Addition of H20, alcohols, methylal, and other oxygen-containing molecules.
3. High gas flow.
4. Avoid silicone contamination (oil, raw G-10, etc.).
5. Avoid soft glues (one part RTV, urethane, etc.).
6. Avoid some halogen impurities (Freon-11, etc.).
7. DME works, but worry about its solvent capabilities.
8. Avoid glow discharges.

argued that the avalanche produces even larger population of molecular fragments as is typical in plasma chemistry. These molecular fragments are then either carried away by a gas flow, or attach to electrode surfaces due to their charge or dipole moment. As more fragments attach one may create long macroscopic chains responsible for the detector degradation. Some molecular fragments might chemically react with the anode or cathode material creating insulating oxides or thin insulating films (see discussion later), thus distorting the original electrostatic field. Table 2 shows an expanded list of typical ionization and dissociation energies taken from Ref. 3 The dissociation energy is not a unique number and it is related to a specific reaction. We list the lowest values. If this model is be valid, addition of fragile molecules like a vinyl chloride C_2H_3Cl or a vinyl fluoride C_2H_3F would be expected to worsen the aging rate. Matheson Co. warns that both vinyls can polymerize on their own in a bottle!! Similarly, the addition of TMAE (tetrakis [dimethyamino] ethylene) and its fragile impurities, or undoubtedly many impurities from outgasing of various materials would also make the aging worse. On the other hand, CF_4 or CO_2 molecules would be examples of more resilient molecules. Where is the threshold as one goes from 1 eV to 7 eV of dissociation energy?

Another example of aging signature is the *electron affinity,* i.e., the ability of the gas to create negatively charged ions?4 Such ions would then drift toward the anode and "prime" the surface. Halogens like F, Cl, or Br have the largest electron affinity and therefore one would expect molecules like Freon-11 ($CFCl_3$) to cause a lot of aging problems.

Finally we would like to mention the *"oxygen signature."* As was pointed out in Ref. 3, plasma chemists know empirically that most organic compounds with oxygen containing groups such as –COOH, CO-, -OCO-, -OH, -0-, -C = 0 are generally more reluctant to form a polymer.6 As we

Table 2
(Taken mostly from Ref. 5, except as noted)

Molecule	Lowest Dissociation Energy	Ionization Energy
Ar	–	15.8 eV
Xe		12.1
H_2 (Ref. 6)	4.5 eV	15.6
N_2 (Ref. 6)	9.7	15.5
02 (Ref. 6)	5.1	12.5
Ethanol -	4.0 (OH + C_2H_5)	10.5
Isopropanol	4.0 (OH + C_3H_7)	9.98
C_2H_6	3.8 (CH3 + CH3)	11.5
H_2O Vapor	5.2 (H + OH)	12.6
Methylal		10.0
CO_2	5.2 (0 + CO)	13.8
i-C_4H_{10}	3.7 (CH_3+C_3H_7)	10.6
CH_4	4.5 (CH3 + H)	12.6
CF_4	5.7 (CF3 + F)	
CF_2Cl_2 (Ref. 7)	3.2 (CF_2 + Cl_2)	12.3
CH_3Cl (Ref. 7)	3.7 (CH3 + Cl)	11.3
C_2H_3Cl (Ref. 6)	1.1 (C_2H_2 + HCl)	9.996
C_2H_3F (Ref. 6)	0.8 (CH_2 + HF)	io.37
Freon-11 or FCC13	3.2 (CCl_2 + Cl)	11.77
Freon-12 or Cl_2CF_2	3.3 (CF_2Cl + Cl)	12.31
Freon-13 or CF_3Br	3.1 (CF3 + Br)	11.89
Freon-22 or $CHClF_2$	4.5 (CF_2Cl + H)	12.45
TMAE or $C_2[(CH_3)_2N]_4$ (Ref. 8)	>2.7 (CH3 +. . .)	5.9
NH3	4.8 (NH_2 + H)	10.2

know water, alcohols, ethers and methylal belong to this group. Similarly it was pointed out3 that a plasma polymerization of methane in a presence of oxygen generally terminates with stable molecules like CO_2, CO and H_2O.[10]

The rate of wire aging is usually expressed in terms of gain loss rate $R = -1.0/G*(dG/dQ)$ in %/C/cm. Throughout the text we consider a good aging rate when $R<10$, moderate when $10< R<30$ and rapid for $R>30$. The R is usually determined by measuring the anode current as a function of collected charge. Typically, the Fe55 source pulse height spectrum is measured from time to time. However, this may not be a complete picture of aging the singles rate with a single electron threshold also should be measured to determine how the aging affects the chamber resolution.

2. Examples of Methods Used to Analyze the Wire Aging Products and Other Impurities in the Gas Systems

Wire aging research has added a number of new techniques to the analysis of the wire aging molecular products in recent years. Certainly, the definition of the *word "clean" has changed considerably since* 2986 in our field. We mention three techniques here, the GC-MS, FTIR and ESCA techniques:

a. **The** GC-MS **technique** stands for the gas chromatography combined with a mass spectrometer analysis. The principle of this method is the separation of the individual gas molecules in the chromatographic column in time, and a subsequent measurement of their m/Z ratio.

b. **The FTIR technique** stands for Fourier Transform Infrared Analysis. It is based on the fact that molecular bonds vibrate at characteristic frequencies when exposed to infrared radiation. This is the least destructive technique of all, however it can be only used for the transparent samples.

c. **The ESCA technique** stands for the electron spectroscopy for chemical analysis. This method uses 1.487 keV X-rays which strike the sample, and the energy of liberated electrons is measured by a magnetic analysis in vacuum.

Figure 1 shows a beautiful analysis of the avalanche products performed by Kadyk and Wise using the GC-MS technique.11 In this experiment a test tube chamber operated with 50% Ar + 50% C_2H_6 gas without any additives, and no wire aging was observed up to a level of 2 C/cm at this operating point (see discussion later). The GC-MS analyzer was connected directly to the wire chamber. However, in order to enhance the sample size it was necessary to cryotrap the avalanche byproducts for a while. The cryotrap could be cooled to any predetermined temperature (> -186 deg C) by liquid nitrogen, and heated by an electric current, all under computer control. The sample was then heated and transfered to the column and analyzed by ion trap mass spectrometer. Only heavier molecules were captured. The considerable complexity of molecular fragments produced by the avalanche is very impressive. Nevertheless, the CC pattern **was** reproducible and responded differently to different gases. Although many molecules were identified, the original radical formation in the avalanche could not be observed, only the terminal molecular configurations, (i.e., a situation somewhat similar to a microwave background left from the big bang!) This study will allow testing of some wire aging models and provide an insight for what is going on in the avalanche.

Figure 2 shows what is perhaps a more direct practical use of the GC-MS technique, again in the same experiment.11 This figure shows an analysis of the outgasing products from various tubings used in the high energy physics gas systems. We find what the semiconductor industry knew long time ago, that electro-polished stainless steel tubing is the only way to deliver the clean

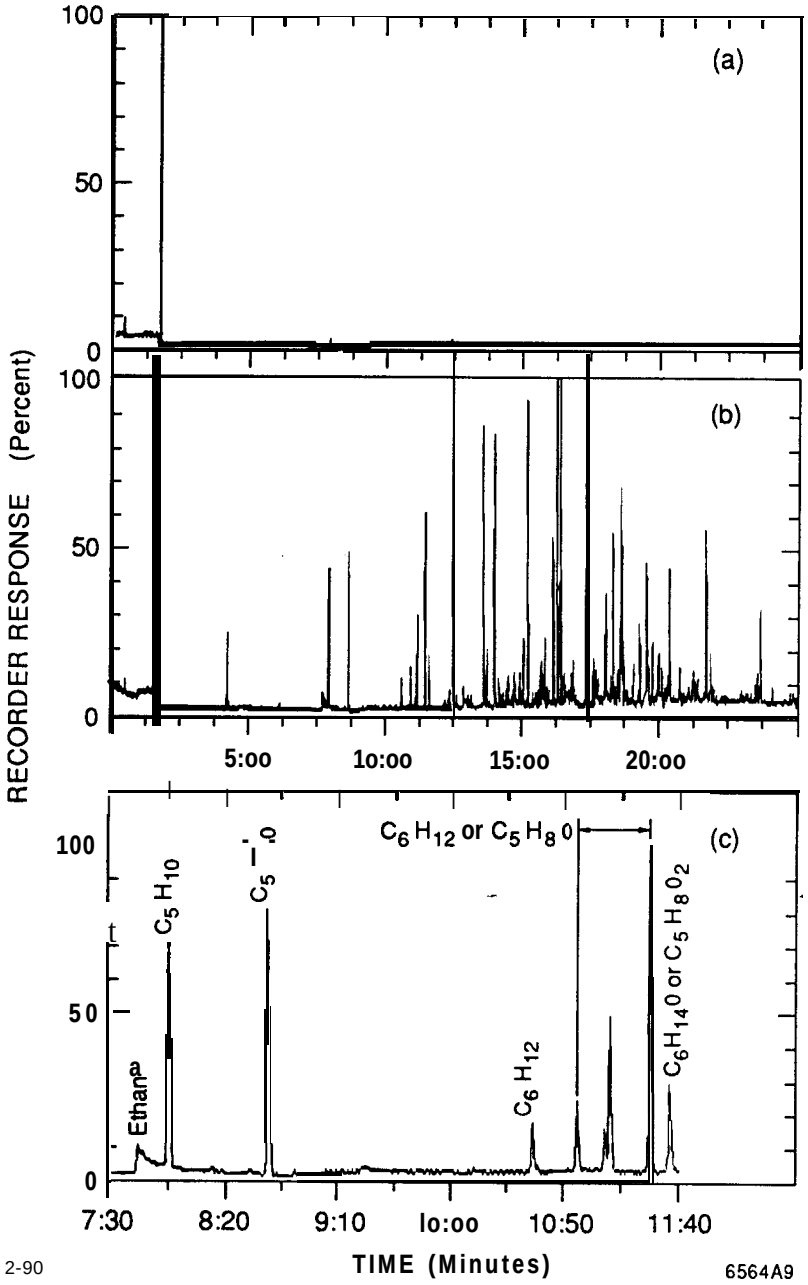

Figure 1: GC-MS **analysis of avalanche products in 50% Ar + 50% ethane: (a) high voltage off, no source; (b) high voltage on, Fe55 source on; (c) some peaks identified.3**

gas. Nylon gas tubing can be safely used in the last flexible connection to the chamber. This was known at the time of LBL workshop,[1,3] but certainly not at the quantitative level of Fig. 2.

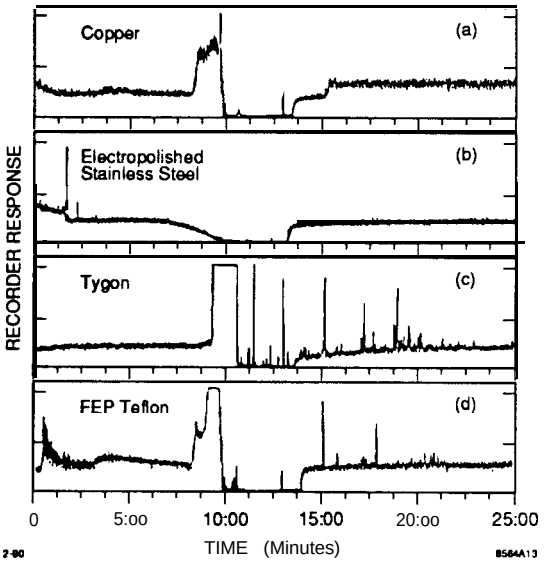

Figure 2: GC-MS analysis of impurities coming from typical gas tubing.3

Figure 3 shows a GC-MS analysis of TMAE $\{C_2[(CH_3)_2N]_4\}$ purity for various cleaning procedures as performed by the CRID group.12 Typical TMAE impurities were identified. It is another example of a very practical and useful relative analysis. In this **case** attaining long electron lifetime **was** the primary motivation to perform this kind of analysis. During the wire aging experiment13 the CRID experiment used TMAE purity corresponding to Fig. 3(b). At present the CRID group is using the purity corresponding to Fig. 3(c). Incidentally, Woody[14] also performed TMAE wire aging experiments mentioned later in the paper, and his TMAE purity probably corresponded to Fig. 3(c), judging from a description of his TMAE cleaning method.15

The FTIR and the ESCA analysis performed on the TMAE wire aging products.13 Both measurements were carried out by a commercial company,[16] and therefore it was necessary to exposed the samples to air which further confused the analysis. Both techniques could identify only specific molecular bonds leaving a gross ambiguity in interpreting results. This is rather typical if the two techniques are used without a help of the GS technique.

3. Examples of Wire *"Nonaging"* in Clean Systems

Several examples in 1986 LBL workshop did not show any sign of wire aging, provided that they used high purity gases without any bad impurities like oils, avoided gas tubing materials like PVC or tygon, avoided soft glues like one-part RTV, and used no greases or silicone oil bubblers.[1,3] This conclusion appears to be confirmed in 1990. Note that in this particular group of

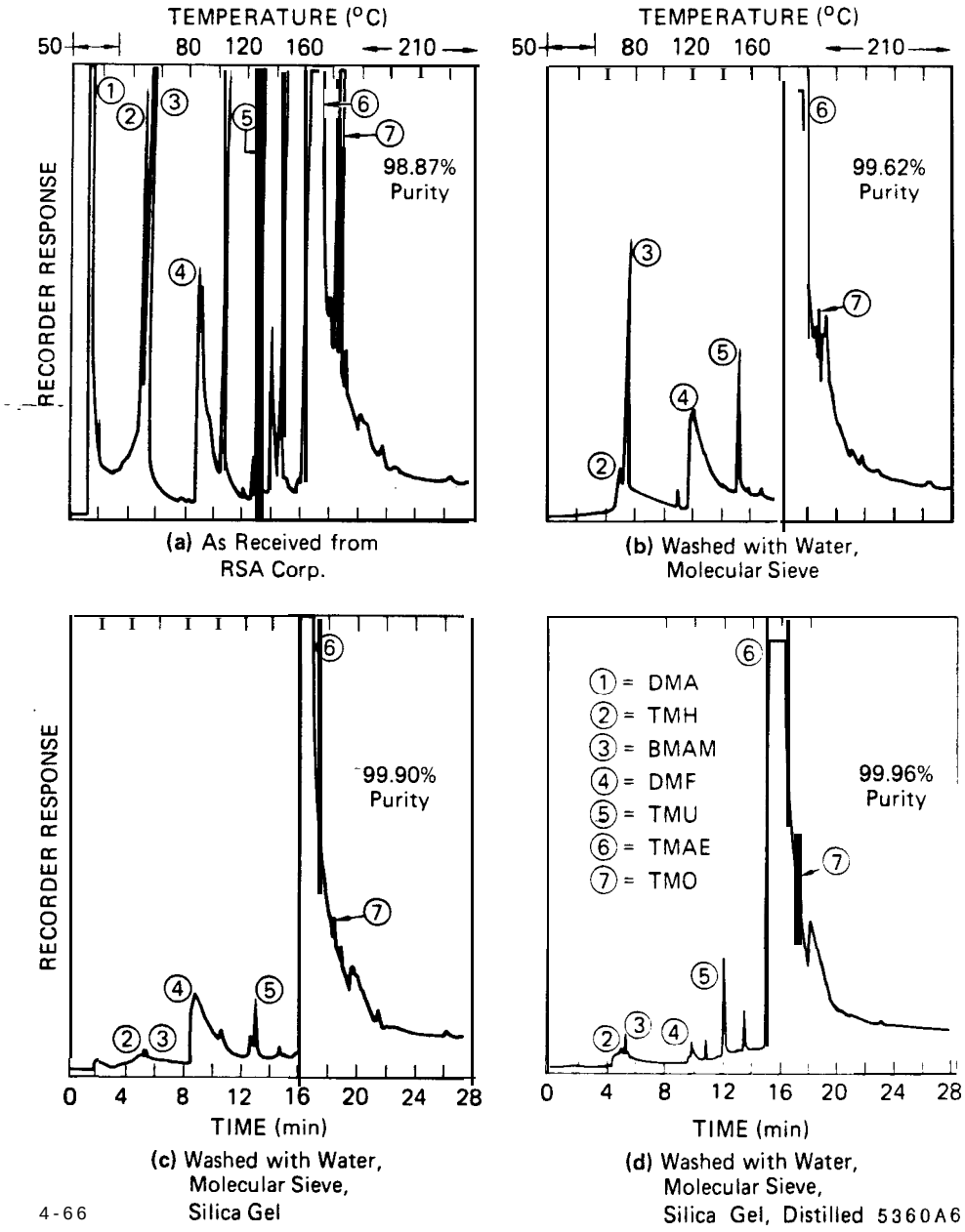

Figure 3: GC-MS analysis of various stages of TMAE purity as a function of various cleaning methods.

tests no special additives like water, alcohols, etc. were added. However, water and oxygen were a natural contamination (few to tens of ppm) in most of the tests in this section!

Openshaw et al.17 saw negligible aging up to about 8 C/cm in a fast flowing gas 80% CF_4 + 20% C_4H_{10} without any additive. They were the first group

to show that the CF_4 might be a good candidate for "nonaging" fast gas useful for high intensity machines. Kadyk et al., confirmed their results.4 He4 also saw little aging up to 2 C/cm collected charge with 50% Ar + 50% C_2H_6 (Ref. 18) with no additives and gold-plated anode wire. Similarly he obtained good results with 89% Ar + 10% CO_2 + 1% CH_4 (so-called HRS gas), when he used the gold-plated anode wires.

Jibaly and Majewski et al.[19]measured negligible wire aging up to about 1 C/cm in DME (dimethyl ether) in a tube chamber with stainless steel and gold-plated wires. These results were obtained with so called purified DME which had less than 1 ppb of Freon-11, only slight trace of Freon-12 and other impurities also negligible. Similar results were obtained in the multidrift chamber[20] with large number of cathode wires. In this case the chamber lived up to about 0.5 C/cm; i.e., somewhat less than the single ideal test tube. Kadyk et al.4 also obtained excellent aging results with DME, although his specification on a level of Freon-11 **was** not as stringent (to specify "less than 1 ppm" was sufficient with Matheson Co. gas).

We have to exercise a great care in choice of materials, if the DME gas is to be used. The DME is considered to be a solvent by the gas companies,21 and as a result it helps to release impurities from a number of plastic materials typically used in the wire chamber construction. There are very few plastic materials which do not expand and swell in presence of DME.[19] According to Jibaly and Majewski et al.,[19] examples of good materials for DME use are brass, stainless steel, polyethylene, polypropylene, Torr-Seal epoxy and Nylon 11 (Rilsan). Examples of moderately good materials (some swell, but no problem with chamber operation) were Delrin, Mylar, and perhaps Kapton. Examples of bad materials were Macor, Teflon, Viton, Stesalit glass epoxy, polyurethane and various rubbers. Kadyk et al.4 also avoided all materials like Viton, Kel-F, Tefzel, Teflon which happen to be typically used in all pressure regulators, needle valves and safety shutoff systems. He had to invent his own stainless steel needle valve. Only stainless steel and copper (oven-fired) were in -contact with gas. After all precautions were carefully implemented, he obtained good aging results with all kinds of anode wires, including Stableohm and Nicotin.22

Even large experiments have observed no aging recently. According to Zarubin,[23] there was no aging observed in the UA1 central detector which used 40% Ar + 60% C_2H_6 and reached 1 C/cm,[24] and similarly there was no aging in the drift tubes of the SIGMA detector at Serpuchov, which ran CH_4 gas and reached 4.1 C/cm.

4. Examples of "Rapid" Wire Aging

Figure 4 shows a rapid aging in a mixture of 1% NH_3 + (50% Ar + 50% C_2H_6), and even worse rate in 50% Ar + 40% CF_4 + 10% O_2.[25] This is a puzzle because for instance the CF_4 molecule is difficult to dissociate (see

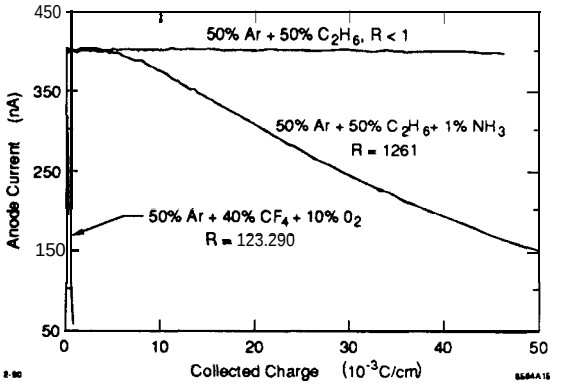

Figure 4: An example of surprisingly rapid aging.25

Table 2) and shows no aging if mixed C_4H_{10}.[17] Probably, excited argon under certain operating regimes is readily dissociating either CF_4 or NH3 molecules.

For some applications the vapor of TMAE is added to a carrier gas, resulting in UV-sensitivity within the detector. Table 2 shows that TMAE is a rather fragile molecule and it was not very surprising to find a faster rate of aging than usual. The author has done tests with 7 μm carbon anodes and CH_4,C_2H_6 and C_4H_{10} carrier gases in the CRID detector geometry.13 Many parameters were tuned, namely wire diameter, gas, gain, rate, gas flow, temperature, etc. Figure 5 shows an example of aging using C_4H_{10} + TMAE (27 deg C bubbler giving about 0.5 Torr vapor pressure) at 1 atm, and a rate of aging of 0.6 mC/cm for 50% gain drop was found. Visual inspection supports a theory that the anode wire is coated by a thin transparent nonconducting film, which is responsible for gain loss. After exposing the wire to air, the film deposits react with air and form droplets. The droplets, if left on the wires for a year, get very viscous, bringing up the question of how long one can wait before cleaning has to be attempted. These droplets can be easily washed away by ethanol,26 if the procedure is applied promptly. However, a new technique of cleaning of the deposits was found. By sending a small 10–11 mA current through the resistive carbon wire, the deposits can be evaporated by reaching a temperature of about 380 deg C. Figure 5(c) shows that the wire regains its full efficiency. The main advantage of this technique is that one does not have to open the chamber to air, which is a troublesome point for these types of chambers. One should say that the CRID detectors were designed so that the wire heating can be performed without a necessity to remove the detectors.

Woody has investigated the aging in BaF_2-TMAE calorimeter.14 Here the expectation is confirmed that the wire aging in this geometry would be less severe than in the CRID detectors. This is because a substantial part of the

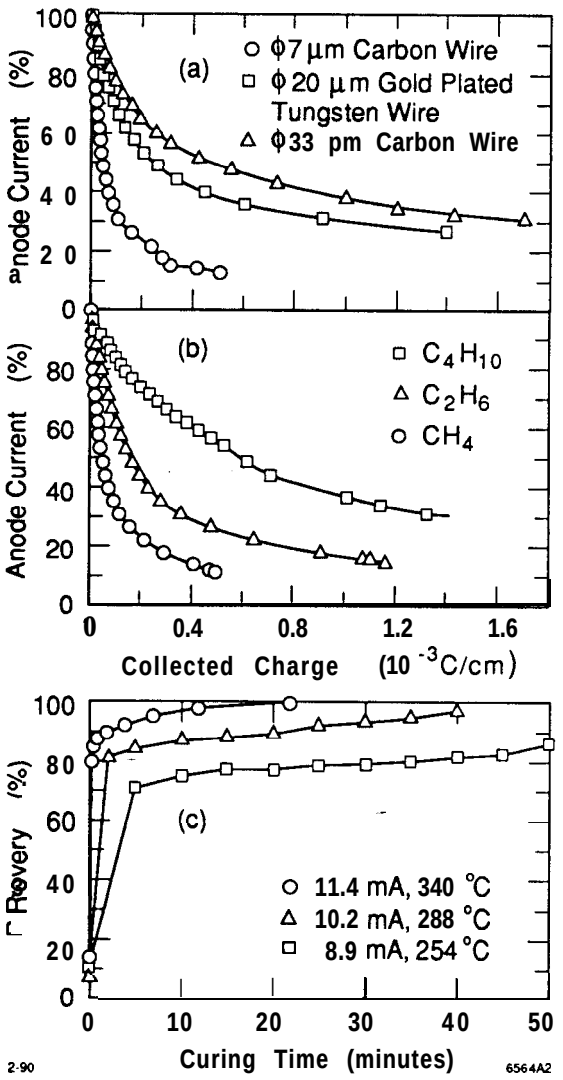

Figure 5: An example of rapid aging in TMAE gas: (a) 1 atm, carrier gas CH_4, starting current 220 nA, TMAE (27 deg 0,100 cc/min gas flow; (b) 1 atm, 7 μm carbon wire, TMAE (27 deg C); (c) wire efficiency recovery as a function of current in 7 μm carbon wire, CH_4 + TMAE (27 deg C).[13]

gas gain takes place in a parallel plate avalanche mode, and hence the avalanche is spread over a much larger region than just around the thin anode wire; also, the low pressure helps to reduce the charge density. Nevertheless, the substantial aging was still observed. A 50% gain drop was observed after about 7 mC/cm in C_4H_{10} + TMAE (20 deg C bubbler) at 10 Torr of pressure. It is interesting to note that pumping on these deposits for 15 hours restored the gain to 80% of its initial value, and pumping for five days restored the gain to 96%. Figure 6 shows that the gas flow also influenced the rate of aging, and

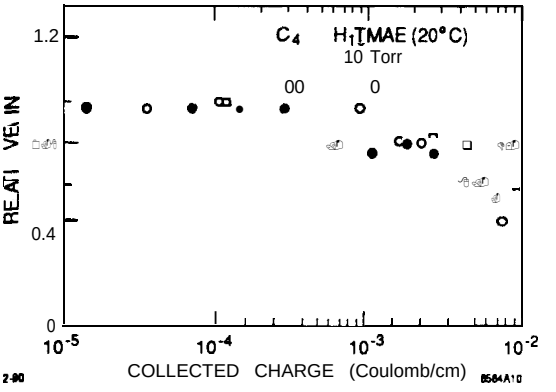

Figure 6: An example of rapid aging in TMAE at low pressure: (a) open points, multistep gain mode; (b) solid points, anode wire and multistep gain mode; (c) squares, as in (b) but higher gas flow of 200 cc/min.[14]

that in the parallel plate mode one obtains less aging than in a mode where the anode wire runs at higher relative proportion of the gain. The deposits were very similar in appearance to those observed in Ref. 13. For completeness, one should say that Woody's TMAE was cleaned according to the procedure on Fig. 3(c).[15] The CRID wire aging[13] was done with TMAE purity corresponding to Fig. 3(b). Woody's test used UV lamp to induce the aging, rather than Fe^{55} in the CRID case.

TMAE can be decomposed thermally rather easily at temperatures above 100-200 deg. C. Waring and Berard[27] observed condensable products in TMAE thermal decomposition, similar in appearance to the wire-aged products observed in Ref. 13. It is not unreasonable to speculate that the avalanche process could have a similar heating effect to that of directly heating the gas. Waring and Berard suggested to admix NO gas to the TMAE to inhibit the thermal decomposition.

5. Examples of Problems which will "Prime" Surfaces for Aging

A number of effects can "prime" surfaces so that subsequent aging can occur very rapidly. Lets give a few examples: Atac has found28 that if aluminum or nickel is present in the anode wire material, certain gases containing oxygen in their molecules induce oxidation of these elements in the presence of avalanches, producing oxides sufficiently nonconducting that the original electric field is sufficiently modified to cause gain loss. Copper oxides are semiconducting and do not suffer from this problem. As a result alloys like Nicotin or Stableohm[22] must be used with caution. For instance,

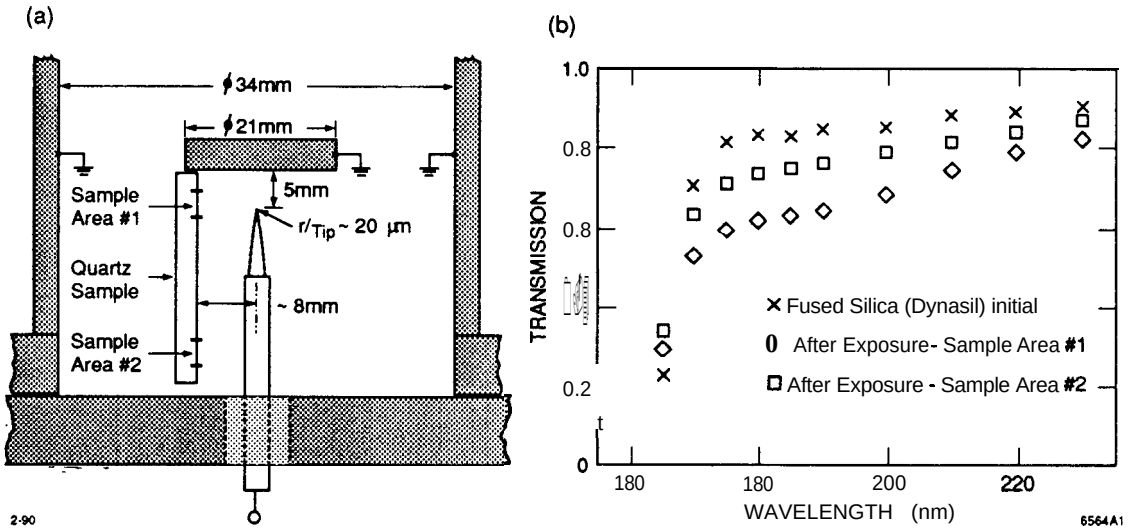

Figure 7: An example of polluting surfaces by a corona in C_5F_{12}: (a) a corona test setup; (b) a loss of transparency in the quartz sample due to deposits.29

Kadyk et al.[4] found that Stableohm wire shows moderate aging in HRS gas (89% Ar + 10% co_2 + 1% CH_4), while no aging was observed with the gold-plated wire.

Quality of plating also should not be taken for granted. This is especially sensitive for aluminum surfaces. For instance, in case of CRID detector nickel plated aluminum cathodes, we found initially a number of surface contamination problems due to "insufficiently" clean plating baths.

Similarly, a number of people are using epoxy glues to hold the anode wires. The wet epoxy is usually cured at slightly elevated temperature. This can cause a "plating" of wires with the epoxy volatile components.

Corona can occur due to mistakes, procedures like reversing voltages and allowing a large current, or because of a finite number of defects in a very large system of field electrodes. This may not be caught if the instrumentation is not adequate or if the chamber runs at large current due to large background. Figure 7(a) shows a test geometry performed for CRID high voltage system.29 The test cell had a piece of quartz near the source of corona and the test used C_5F_{12} gas, which is used as a gaseous Cherenkov photon radiator in the CRID/RICH detectors. The typical corona current was a few μA and the total accumulated charge was about 15 C. Figure 7(b) indicates a loss in UV transmission due to the corona pollution deposits. The ESCA analysis revealed a fluorocarbon deposits totally obscuring the Si peak of quartz, indicating that the layer was at least 100 A° thick. This example proves that the corona functions as a chimney which will pollute nearby surfaces and contribute to the Malter effect.

Oil bubblers were suspect to cause aging a long time ago and an extremely efficient silicon deposition on the wires has been reported.[1,3] Recently Kadyk et al.4 has compared a silicone diffusion oil (Dow 704), a

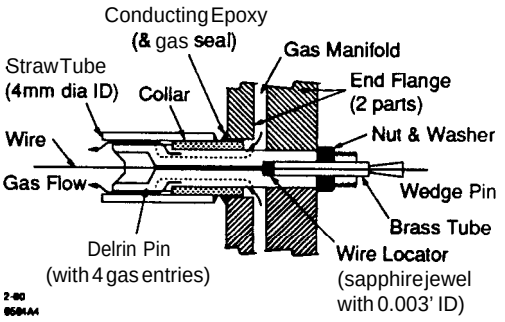

Figure 8: Pin design for 4 mm diameter straw tube which allows a gas flow.33

mineral oil (Squibb), and a mechanical pump oil (Duo-Seal). For each test, the 50% Ar + 50% C_2H_6 was bubbled through the oil and then was fed into the test chamber. Only in the case of the silicone oil was any significant aging observed (R -50). The estimated concentration of oil in the gas was only about 18 ppb!!!

Finally, we would like to mention another problem with TMAE-laden gases. Since TMAE is very reactive with oxygen one has to be careful with accidental opening or leaks of such detectors. If that occurs, various chemical like TMO, DMF and TMU are produced, which cause surface breakdown because the surface resistivity can drop by many orders of magnitude on the G-10 surface.30 It is necessary to design such detectors very conservatively.

6. Solutions When Things are About to Go Wrong

Water and some alcohols were recognized for some time as good additives to prevent aging or to keep sick chambers alive.13 In fact, water and oxygen contamination are always present at some level (few to tens ppm). For example, Atac[28] has been using argon-ethane-ethyl alcohol mixture with gold-plated wires successfully up to 2 C/cm. However, Juricic and Kadyk[31] found that this technique doesn't work on certain resistive wires like Stablohm. A substitute was found in isopropyl alcohol28 which does appear to inhibit aging even on the resistive wire. Kadyk et al.4 confirmed that 0.7% isopropanol added to 50% Ar + 50% C_2H_6 gas mixture causes no aging with resistive Stablohm-800 wire. Venuti et al.32 also found recently that the dark currents can be stopped if water or isopropanol is added to 92% CO_2 + 8% C_2H_6 gas.

7. Example of Wire Aging in the "SSC Micro-straw Tubes"

Kadyk and Va'vra[33] are presently investigating the aging in so called "micro-straw" tubes which might be candidates for some SSC tracking detectors. A novel feature of these tubes is that the diameter is only 4 mm. Since it is well known that it is necessary to have an efficient gas flow through the tube[1,3] it was necessary to design a feedthrough to allow this. Figure 8 shows our design of this pin. It assumes that the end flange has a gas manifold to

allow the gas to flow into the tube. We have constructed a number of tubes with the following aims:

a. Study of previously damaged tube by a corona. The tube is a classical straw tube made of aluminized Mylar bonded with polyethylene. The anode wire is 38 μm diameter gold-plated tungsten.
b Study of various cathode materials (Au, Cu, Ni, Al) and gases.
c. Study of the avalanche thermal effects with with carbon wires.
d. Tracking resolution studies and their correlation with the rate and aging problems.

So far we have completed only the first test. The glow discharge damaged tube would not take a large current. A classic Malter effect occured already at 60 nA/cm. This was occuring in 80% CF_4 + 20% C_4H_{10}, 90%CF_4 + 10% DME and 50% Ar + 50% C_2H_6 gases. After adding 500–1000 ppm of water to -any of these gases we could run more than 400 nA/cm using the Fe^{55} source. The gas tubing was made of electropolished stainless steel. We then switched to nylon tubing (without adding water) which is known to outgas water, and the tube could also take the large current without any breakdown. We then switched back to the s.s. tubing without water, and indeed we obtained the breakdown again. After switching back to nylon tubing, the high current capability resumed.

Figure 9 shows the aging result with this chamber. The gas saw the following materials during this particular test: aluminum, Mylar and polyethylene as a part of the straw tube, DP-190 glue, brass, Delrin, gold-plated tungsten wire and aluminum in the end plate.

How water works is still being questioned. One theory is that water makes the cathode deposits slightly conducting thus removing a positive charge from the cathode surface which is a precursor of the Malter effect. Another theory is described qualitatively on Fig. 10. If hard U.V. photons from carbon excitations34 are responsible for a photoionization of cathode, then the water absorption is correctly placed to absorb them. (Photons from hydrogen and oxygen excitations are easily absorbed because they occur at lower wave lengths.) However, even 1000 ppm of water uniformly distributed throughout the gas of 4 mm diameter tube is not enough to absorb them. On the other hand, we could explain it, if there is a larger concentration of water around the anode wire due to water molecular dipole moment. The limit on minimum necessary amount of water to prevent the Malter effect is not yet known. One should mention that this type of straw tube was found to be extremely photosensitive to fluorescent lights in the room and this sensitivity increased after the glow discharge (this was already mentioned by other people; see Refs. 1 and 3).

8. Tables of Various Experimental Results

We refer to tables presented elsewhere describing various recent aging results.[3,4,35]

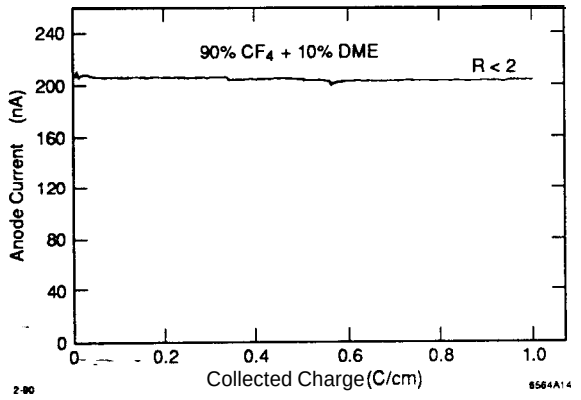

Figure 9: Wire aging in the 4 mm diameter micro-straw tube. The tube was "preaged" by a glow discharge. The subsequent Malter effect was stopped by water, in this case coming from a section of 10 ft-long nylon tubing.

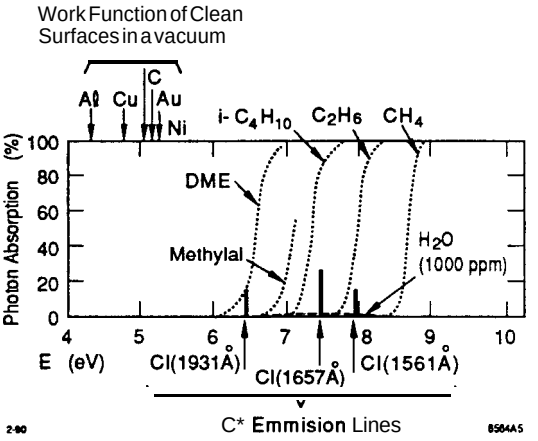

Figure 10: Photon absorption in 2 mm of various gases at 1 atm, 1000 ppm water absorption if distributed uniformly in 2 mm space, work function of various metals and carbon emission lines thought to be responsible for photosensitivity of the cathode.

9. Conclusions

a. The understanding of wire aging is still on a very superficial level.

b. We believe that future high-intensity high-energy physics experiments will be instrumented much better to certify their gas purity. They will probably use the GC-MS analysis to identify the gas impurities in the relative sense. There will be the "CRID" or "RICH" -type material selection, only this time to prevent the wire aging.

c. We should worry about chemical reactivity of various components and perform systematic study. For instance, to build a very large tracking detector system based on the use of DME gas is a considerable material challenge problem somewhat, comparable to the use of TMAE in the CRID-RICH detectors.

d. We will probably make a number of mistakes causing glow discharges and other errors which will "prime" surfaces for aging. As a result we will probably have to end up using additives like water or isopropyl alcohol to prolong the chamber lifetime. Some people prefer to start with them right from the beginning. Water is already a natural contaminant in most of the experiments.

e. TMAE aging is faster than in usual gases.

f. Table 1 is still valid, but more precise measurements are needed.

10. Acknowledgments

I would like to thank J. Kadyk for providing me with some of his results and many discussions about the aging topics.

11. References

1. *Proceedings* of *the Workshop on Radiation Damage,* J. Kadyk, editor, Lawrence Berkeley Laboratory, January 16, 1986.
2. *Proceedings* of *the Workshop on Radiation Effects at the SSC,* M. G. D. Gilchriese, editor, Lawrence Berkeley Laboratory, June 1988; SSC Report SSC-SR-1035.
3. J. Va'vra, *Nucl. Instr. Methods,* A252 (1986) 547; and review article in Ref. 1, p. 263.
4. J. Kadyk, J. Wise, D. Hess, and M. Williams, to be published in *IEEE Trans. Nucl. Sci., NS-37,* 1990.
5. *Handbook* of *Chemistry and Physics,* published by The Chemical Rubber Co., Cleveland, OH.
6. H. Yasuda, *Plasma Polymerization,* (Academic Press, New York, 1985, p. 74.)
7. See Ref. 10, p. 116.
8. R. T. Rewick, SRI, Menlo Park, CA, private communication.
9. See Ref. 6, p. 113.
10. H. V. Boenig, *Plasma Science and Technology,* (Cornell University, Ithaca, NY, 1982, p. 280.)
11. J. Wise, J. Kadyk, D. Hess, and M. Williams, to be published in *IEEE Trans.Nucl.Sci., NS-37,* 1990.
12. R. T. Rewick, T. Weber, M. Cavalli-Sforza, M. L. Schumacher, and S. Shapiro, SLAC-PUB-4115 .
13. J. Va'vra, *IEEE Trans. Nucl. Sci.,* NS-35; 1988; SLAC-PUB-4116, 1986; CRID Memo #36, 1988; and Ref. 2, p. 191.
14. C. Woody, *IEEE Trans. Nucl.* Sci., NS-35 (1987); and Ref. 2, p. 207.
15. C. Woody, private communication.
16. Analysis performed for author by SSL Co., Mountain View, CA 94043.
17. R. Henderson et al., *IEEE Trans. Nucl. Sci., NS-35,* 1988; R Openshaw et al., *ibid, NS-36,* 1989.
18. This test used Matheson HP-grade argon (99.995% min. purity) and CP-grade ethane (99.0% min. purity).
19. M. Jibaly, S. Majewski, P. Chrusch, R. Wojcik, F. Sauli, and J. Gaudaen, *IEEE Trans. Nucl. Sci.,* Vol. *NS-36,* 1989; *Nucl. Instr. Methods,* A273 (1989) 161.
20. R. Bouclier, G. Charpak, G. A. Erskine, B. Guerard, J. C. Santiard, and F. Sauli, *Nucl.Instr. Methods,* A265 (1988) 78.
21. *Matheson Gas Data Book,* East Rutherford, NJ (a Div. of Will Ross, Milwaukee, WI)
22. Stableohm 800 consists of 75% nickel, 20% chromium, and 5% (aluminum + copper) and is made by California Fine Wire Co., U.S.A; Nicotin wire consists of 40% cobalt, 20% chromium, 16% nickel, 13% iron, and 11% molybdenum and is made by Microfil, Switzerland.
23. A. H. Zarubin, *Nucl. Instr. Methods,* A283 (1989) 409.
24. S. P. Beingesner et al., *Nucl. Instr. Methods,* A257 (1987) 552.

25. J. Kadyk, private communication.
26. Similar droplets were seen by D. Anderson; he could wash them easily with alcohol.
27. C. Waring and R. Berard, *J. Phys. Chem., 80* (1976) 1025;
This paper mentioned in P. Coyle, *CRID Note #48,* 1988, unpublished.
28. M. Atac, *IEEE Trans. Nucl. Sci., NS-34,* 1 (1987) 476;
Wire Chamber Aging and Wire Material, Proceedings of a workshop for the INFN Eloisatron Project, September 21, 1986, Erice, Sicily, Italy (Plenum Press, New York, 1988).
29. J. Va'vra, *CRID Note #38,* unpublished.
30. J. Va'vra, *CRID Note #37,* January 1988, unpublished; SLAC-PUB-4432, -1987.
31. I. Juricic and J. Kadyk, Ref. 1, pp. 141-151.
32. J. Venuti et al., *IEEE Trans. Nucl. Sci.,* **Vol.** 36, **No.1,** (1989) 595.
33. J. Kadyk and J. Va'vra, to be published.
34. H. D. Morgan and J. E. Mentall, *J. Chem. Phys.,* Vol. 60, No. 12, 1974.
35. J. Kadyk and J. Va'vra, Ref. 2, p. 159.