Computer Physics
Communications

Effects of materials on aging rates in wire chambers operated with DME

R.Openshaw*, R.Henderson

Presented by: R.Henderson

TRIUMF, 4004 Wesbrook Mall, Vancouver, BC, Canada V6T 2A3

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Abstract

The effects of various materials on aging rates of wire chambers filled with dimethylether gas (DME) were investigated. Silicone compounds and urethane polymers were observed to dramatically increase aging damage in test chambers. All other materials tested did not appear to significantly affect the measured damage rates.

Keywords: DME; aging; wire chambers; silicone; urethane

1. Introduction

The TWIST (TRIUMF E614) drift chambers [1] are expected to make precise and efficient position measurements of both the polarized surface muons, which stop at a target in the middle of the detector stack, and the resulting decay electrons, which spiral out in the 2 Tesla magnetic field. Dimethylether (DME) was chosen as the chamber gas due to its small Lorentz angle, high primary ionization, low Z, and wide efficiency plateau. Because of concerns that DME may age chambers and attack materials, materials and devices proposed for use in the drift chambers and gas system were subjected to laboratory aging tests. These include various epoxies, adhesives, sealants, elastomers, plastics, valves, and other devices. The goal was to identify and exclude materials that cause chamber aging as well as materials that DME degraded.

Single-wire chambers (SWCs) were used to measure aging damage. As shown in Fig. 1, two adjacent independent SWCs were milled from a single piece of 1.2 cm thick aluminum. The active volume of each SWC was 1.2 x 1.2 x 20 cm, with a

* Corresponding author. Tel.: 604-222-1047; fax: 604-222-1074; e-mail: openshaw@triumf.ca.

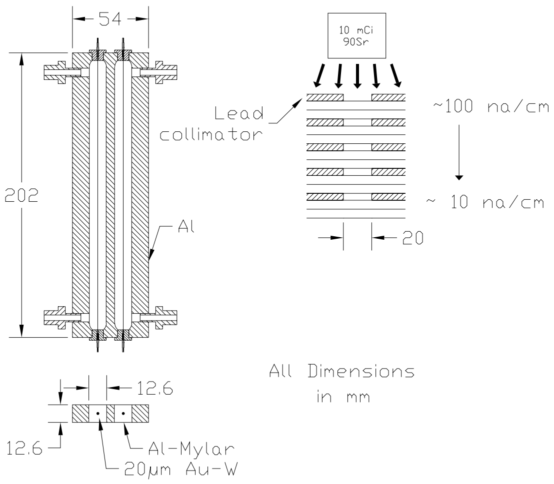

Figure 1 Aging test chambers and test stack

central 20 µm gold plated tungsten anode wire and aluminized Mylar top and bottom cathode foils. Five pairs of SWCs were placed in a stack separated by 6 mm thick lead collimators and illuminated by a single 10 mCi ^{90}Sr source. Only the central 2 cm of each SWC was directly exposed to the source. Typical aging current densities ranged from approximately 100 nA/cm-wire at the top of a stack to 10 nA/cm-wire at the bottom. We used low current densities because our previous work with argon/ethane mixtures [2] indicated that tests at high-current densities yielded much lower damage rates than more realistic low-current density tests.

For each test stack, the gas and all of the gas-delivery system except the final distribution flowmeters and the last 2 meters of polyethylene tubing were shared by all 10 SWCs. Materials exposed to the gas in the shared gas handling equipment included brass, copper, nickel, zinc, stainless steel, glass, Buna-N, Teflon, and natural rubber. The construction materials of the SWCs included aluminum, gold, tungsten, delrin, aluminized Mylar, and Araldite 106/953 epoxy.

Materials being tested were placed inside copper canisters that were inserted in the input gas lines approximately 40 cm from the SWC input ports. Devices being tested such as valves, flowmeters, etc., were inserted at similar locations. Silicone rubbers, epoxies, and other formulations were typically allowed to cure in air for a week before being inserted in the gas stream. A few reference SWCs in each stack had no test materials, and one of these had voltage applied only during ^{55}Fe scans.

The SWCs were aged at a nominal gas gain of 50,000 for 3 to 6 months, to total accumulated charges ranging from 0.1 to 1.8 C/cm-wire. Once a week, the ^{90}Sr source would be removed and the gas changed to Argon/Ethane (50:50) to provide more precise pulse height spectra. A 1 mCi ^{55}Fe X-ray source collimated to 1 mm was then used to measure the average pulse height at the center of the irradiated region and at locations 4 cm upstream and 5.5 cm downstream of the center for each SWC. Three or four SWCs would also be selected for detailed pulse height profiles, measurement of pulse height at 1 cm intervals along the anode wire. The gas was then changed back to DME and the ^{90}Sr source reinstalled for further aging. Damage rates were estimated for each SWC, and the profiles provided a detailed record of the changes.

2. Results

It is estimated that the TWIST drift chambers will accumulate less than 0.1 C/cm-wire of charge. Consequently, many of the tests were terminated at low accumulated charges of a few hundred mC/cm. Table I lists all the tests performed, along with descriptions of the materials tested, typical aging current density, estimated damage rates, and the accumulated charge at which the estimated damage rates were calculated. Some aging tests were continued beyond the accumulated charge listed in Table 1. However, damage saturation effects would artificially reduce the estimated average damage rate if the calculation were to be done at that point.

The design constraints of the TWIST drift chambers required soft flexible gas seals between each module gas box and its outermost cathode frames. Much of our testing involved trying to find a suitable material to make this seal. Three different types of silicone rubber were tested, including both 1-part and 2-part formulations. Fig. 2 shows a set of pulse height profiles for E35, a 1-part silicone rubber sample, and is typical of the results obtained. Significant loss of pulse height in the irradiated area is evident after only 0.034 C/cm of accumulated

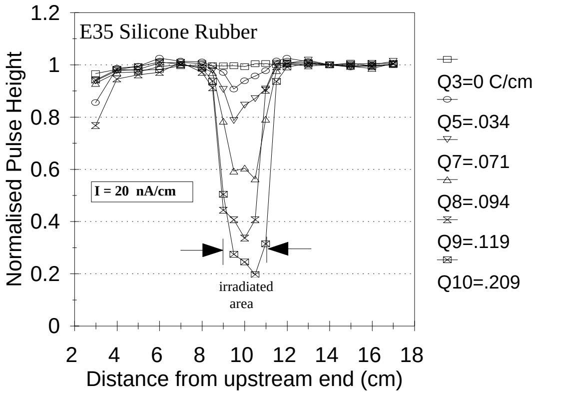

Figure 2 Aging damage due to a silicone rubber sample

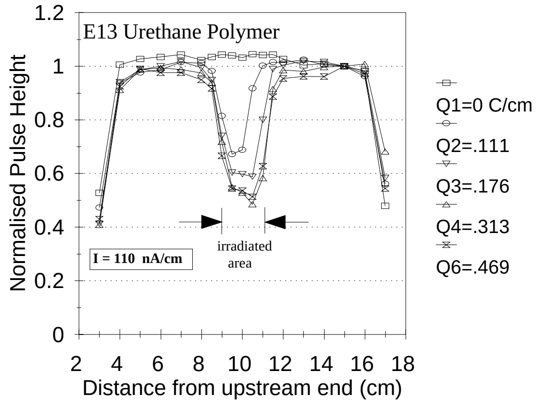

Figure 3 Aging damage due to urethane rubber sample

t has fallen ur tests of l to several thousand %/C/cm. Other authors [3] have also reported accelerated aging with silicone compounds.

The two urethane rubber formulations tested demonstrated unacceptably high damage rates. Aging in argon/ethane due to a urethane adhesive has previously been reported [4]. Interestingly, E13 (Fig. 3) showed initial fast damage, but about 50 days after the urethane polymer was mixed, the damage rate slowed markedly. There is almost no change in the pulse height profile between Q4 = 0.313 C/cm and Q6 = 0.469 C/cm. This may indicate the depletion of some volatile damage-causing component in this urethane rubber. Our requirement for a soft, flexible gas seal was finally satisfied by a latex rubber formulation. In two separate tests, we saw no evidence of damage with this material up to an accumulated charge of 0.288 C/cm. Fig. 4 shows the pulse height profiles for one of these tests. This latex polymer was used extensively in the construction of the TWIST drift chambers.

To see if filters could remove silicone contaminants from the gas stream, we diverted part of the gas through a filter containing BASF R3-11 activated copper and 3 angstrom molecular sieves in test E36 after passing over the silicone rubber sample. The resulting damage rate of 31 %/C/cm compares favorably with 447 %/C/cm in the unfiltered E35.

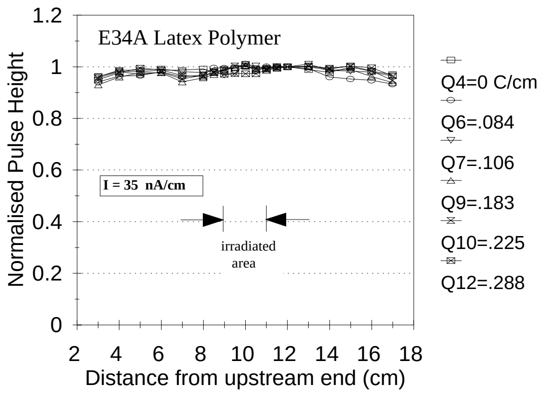

Figure 4 Latex polymer sample, very little damage observed

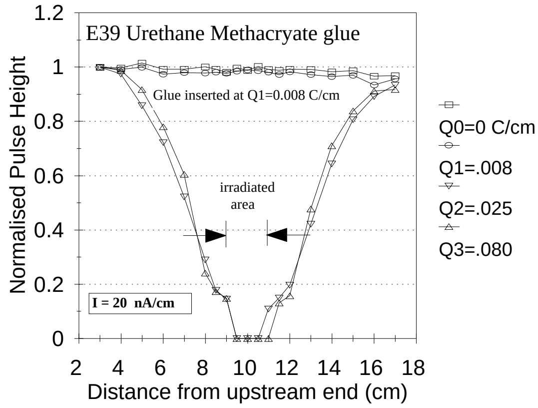

Figure 5 Extreme damage from urethane methacrylate glue

In E31 we saw high damage rates due to a plug valve that used a silicone-based lubricant. This result and the tests with Kapton tape (E17), which uses a silicone-based adhesive, demonstrate the need to be vigilant for silicone compounds which are used in many products and can show up in unexpected places.

Fast-curing, UV-activated urethane methacrylate glues were suggested to speed up the stringing of the wire planes. Two different formulations were tested, showing extremely high damage rates of 2900 %/C/cm and 5600 %/C/cm. In test E39, the SWC was aged to Q1 = 8 mC/cm with an empty inline copper canister with no evidence of damage. The urethane methacrylate sample was then inserted. As shown in Figure 5, the resulting damage was extreme and spread far beyond the irradiated area to both upstream and downstream ends of the wire.

We tested an assortment of different connectors, tubing, O-rings, and epoxies. Most of these tests showed results consistent with zero damage. The 20 cm length of Teflon bellows tested in E30B caused an immediate 15% decrease in average pulse height. The pulse height completely recovered when the Teflon was removed, indicating that the pulse height change was not due to aging. Others have previously noticed this effect [5]. An electronegative outgassing contaminant is suspected. The two tests of Buna-N O-rings showed damage rates of 14 %/C/cm and 43 %/C/cm. These rates were considered low enough for our purposes, given that we expect less than 0.1 C/cm total accumulated charge during the TWIST experiment.

Many of the gas-handling components proposed for the TWIST gas system were also used in the common section of the aging test gas system. Since many of the aging tests resulted in no damage, these devices were deemed suitable for use with DME. We also did explicit tests of various tubing, valves, mass flowmeters, and a water and oxygen filter as listed in Table I. Except for the previously discussed silicone-lubricated plug valve, all of these devices caused negligible damage rates. These included an inexpensive Honeywell mass flowmeter (AWM3100V), in which the DME was exposed to silicon, silicon nitride, gold, aluminum oxide, epoxy, and polyetherimide. The TWIST gas system contains 56 of these devices, one at the input of each of the 56

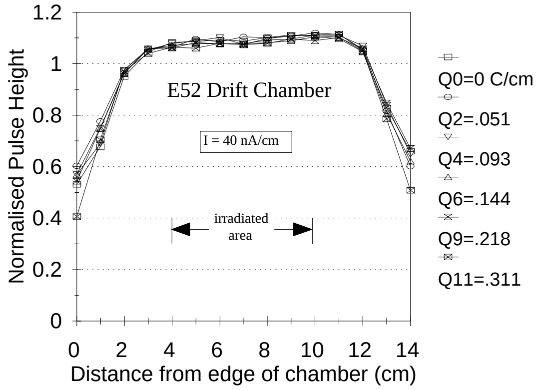

Figure 6 No aging damage observed in TWIST drift chamber

...re was no ...arate tests. ... SWC that was aged with no extra materials inserted in the gas stream. These were meant to establish a baseline level of damage rates. Three of these "no material" tests (E3, E20, E30A) showed negligible damage, while another three tests (E27, E37, E47) resulted in moderate damage rates ranging from 100 %/C/cm to 300 %/C/cm. It may be significant that the three SWCs with negligible damage were aged at higher current densities of 90 nA/cm to 160 nA/cm, while those with moderate damage had low current densities of 10 nA/cm to 22 nA/cm. However, this cannot be the whole explanation since several of the other tests on materials were aged at similar low-current densities and resulted in no observable damage. The damage rates seen in (E27, E37, E47) may be caused by some parameter that we were not controlling or observing, possibly contaminants accidentally introduced during construction. These results illustrate some of the uncertainties and frustrations inherent in aging studies. It is extremely difficult to control all the variables that can affect the results. For this reason, it is important to perform multiple tests under different conditions before attempting to draw any conclusions.

Aging tests were also performed on the first TWIST production drift-chamber module. This module was constructed with materials that passed our screening aging tests. To enhance the effects of any outgassing from chamber materials, a 40 cm^2

circular area at the edge of the active area was irradiated at a 60 nA/cm rate. The set of pulse height profiles of the first active wire at the edge of the drift chamber is shown in Fig. 6. It demonstrates that there was no evidence of any aging damage in the irradiated area to a total accumulated charge of 0.311 C/cm-wire. The roll-off in pulse heights seen at both ends of the wire in Fig. 6 is due to edge effects near the point where the wire meets the anode frame.

At the end of each set of tests, we inspected and conducted rudimentary physical tests of materials and devices, which had been exposed to the DME gas stream. We saw very little evidence of any changes that could be attributed to exposure to DME. We did observe that a conductive epoxy (Tracon VA-2902) was not as hard as unexposed samples. We also observed some discoloration of the inside surface of the zinc body of a pressure regulator. This regulator had accidentally been exposed to liquid DME. A similar regulator in series in the same gas line that was not exposed to the liquid phase did not display any discoloration.

3. Conclusions

It seems clear that silicone compounds in contact with the gas stream should be rigorously avoided. Silicone compounds are found in many lubricants, adhesives and rubbers, and their presence may not necessarily be noted in the documentation. If there is any question whether some material or device might incorporate silicone compounds, it should be subjected to aging tests.

All four urethane polymers tested showed significant aging damage. While the number of tests is too few to allow us to make any general statement about urethane compounds, it does indicate considerable caution. Researchers should probably conduct aging tests of any urethane compounds before using them in any place where they would be exposed to DME.

From an aging perspective, DME appears to be reasonably tolerant to most materials we tested. Of the materials tested, most resulted in damage rates of less than 10 %/C/cm, and many of these were consistent with zero observable damage.

The purpose of this aging study was to test materials and devices proposed for use in the TWIST drift chambers. Some damaging materials were discovered and acceptable alternatives found. This, plus the successful aging test on the first production module, gives us some confidence that this experiment will take data for an extended period without significant aging effects.

References

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FIGURE CAPTIONS

Figure 1 Aging test chambers and test stack
Figure 2 Aging damage due to a silicone rubber sample
Figure 3 Aging damage due to a urethane rubber sample
Figure 4 Latex Polymer sample, very little damage observed
Figure 5 Extreme damage from urethane methacrylate glue
Figure 6 No aging damage observed in TWIST chamber

Table 1 Summary of DME aging tests

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Exp #	Description	Current Density (nA/cm)	Accumulated Charge (C/cm)	Damage Rate (%/C/cm)	Estimated Error (%/C/cm)
SILICONE COMPOUNDS					
E5	silicone rubber, epoxy, connector	48	0.044	**886%**	68%
E6	silicone rubber, Dow Corning 3110	41	0.127	**1043%**	43%
E11	silicone rubber, Silguard 170	40	0.016	**5000%**	250%
E36	silicone rubber, filtered thru R3-11 + 3A sieve	20	0.229	**31%**	9%
E26	silicone rubber, GE RTV162	25	0.114	**211%**	61%
E10	silicone rubber, GE RTV162	65	0.054	**704%**	33%
E25	silicone rubber, GE RTV162	35	0.110	**182%**	36%
E35	silicone rubber, GE RTV162	20	0.094	**447%**	21%
E43	silicone rubber, GE RTV162	30	0.036	**1333%**	83%
E22	Kapton straw/tape (little exposed silicone adhesive)	75	0.265	**8%**	8%
E17	Kapton tape, (silicone adhesive)	43	0.068	**456%**	29%
E31	plug valve, Swagelok B-4P4T (silicone lubricant)	60	0.034	**1176%**	88%
URETHANE AND LATEX POLYMERS					
E13	urethane polymer, Devcon Flexane	110	0.111	**315%**	27%
E12	urethane polymer, 2 part	40	0.100	**70%**	30%
E39	urethane (meth)acrylate glue, Dymax 9-911	20	0.017	**5588%**	588%
E40	urethane (meth)acrylate glue, Dymax X-306-96-A	20	0.027	**2895%**	105%
E34A	latex polymer, de-ammoniated, TechForm TC530	35	0.288	**0%**	7%
E24	latex polymer, de-ammoniated, TechForm TC530	39	0.177	**0%**	11%
PLASTICS					
E45B	black PE tube	35	0.116	**0%**	9%
E34B	latex tube	35	0.318	**0%**	6%
E33B	neoprene bellows	35	0.305	**3%**	3%
E33A	lo density PE	35	0.276	**4%**	4%
E30B	Teflon bellows	90	1.313	**0%**	2%
E23	polyethylene straw, low density	37	0.163	**25%**	12%
E44	Buna N	27	0.276	**43%**	7%
E14	Buna-N	110	0.354	**14%**	6%
E16	polyester connector, Samtec SSM-108-01-S-S	90	0.132	**227%**	23%
E21	polyester connector, Samtec SSM-108-01-S-S	62	0.275	**11%**	7%
E8	polyester connector, Samtec SSM-108-01-S-S	115	0.563	**5%**	2%
EPOXIES					
E7	epoxy, Devcon 2-ton	115	0.563	**4%**	2%
E15	epoxy, Devcon 2-ton	100	0.322	**19%**	6%
E9	epoxy, conductive, Tracon VA-2902	98	0.477	**4%**	4%
E18	epoxy, Bicron BC600	48	0.153	**13%**	7%
GAS HANDLING EQUIPMENT					
E28	mass flowmeter, Honeywell AWM2100V	11	0.052	**0%**	77%
E2	mass flowmeter, Honeywell AWM2100V	200	1.789	**7%**	1%
E38	mass flowmeter, Honeywell AWM2100V	10	0.177	**6%**	11%
E46	mass flowmeter, Honeywell AWM3100V	37	0.406	**0%**	5%
E45A	ball valve, Parker 6Z-B6LJ-BP	35	0.263	**0%**	11%
E32	ball valve, Parker 6Z-B6LJ-BP	60	1.146	**5%**	2%
E48	needle valve, Parker 4Z-H3A-BN-TC	22	0.247	**4%**	4%
E4	BASF R3-11 + sieve filter	185	1.660	**1%**	1%

Exp #	Description	Current Density (nA/cm)	Accumulated Charge (C/cm)	Damage Rate (%/C/cm)	Estimated Error (%/C/cm)
NO MATERIALS (CONTROLS)					
E3	no materials	160	1.406	**6%**	1%
E20	no materials	113	0.506	**0%**	4%
E30A	no materials	90	0.666	**3%**	2%
E47	no materials	22	0.247	**291%**	40%
E27	no materials	11	0.049	**163%**	82%
E37	no materials	10	0.185	**119%**	11%
COMPLETE DRIFT CHAMBER MODULE					
E51	drift chamber, U-plane, wire# 40	60	0.400	**0%**	10%
E52	drift chamber, V-plane, wire# 1	40	0.311	**3%**	6%
E53	drift chamber, V-plane, wire# 7	40	0.311	**0%**	10%