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Aging in large CDF tracking chambers

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Abstract

The experience of the Collider Detector at Fermilab (CDF) with aging in the large axial drift chamber responsible for tracking in the central region is presented. Premature aging in the Run 1 chamber was observed after only 0.02 C/cm. After cleaning much of the gas system and making modifications to reduce aerosols from the alcohol bubbler, the observed aging rate fell dramatically in test chambers. Considerable effort has been made to better understand the factors that affect aging since the replacement chamber for Run 2 will accumulate about 1.0 C/cm. Current test chambers using the full CDF gas system show aging rates of less than 5%/C/cm.

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1. Introduction

Collider Detector at Fermilab (CDF) is a large magnetic detector built to study 2 TeV PbarP collisions at the Fermilab Collider. At its center is a large cylindrical tracking chamber coaxial with the beam. This chamber is inside a large solenoidal magnet with a 1.4 T field.

In Section 2, both versions of the central drift chamber will be described. In Section 3, the aging experience with the Run 1 chamber (CTC) [1] will be detailed. In Section 4, the response to the unexpectedly large aging rate measured in Run 1 will be described. This includes the results from

aging studies in test chambers. In Section 5, the analysis of the deposits on the chamber wires will be discussed. In Section 6, the monitoring for the Run 2 chamber (COT) [2] will be discussed.

2. Chamber specifications

The chamber is roughly 3 m long by 3 m in diameter and filled with a 50/50 mix of argon/ethane with a small admixture of alcohol (roughly 1%) [3] to reduce aging. In the future when the beam crossing time is decreased, a component of CF₄ will be added to the gas in order to increase the electron drift velocity. The sense wires are 40 μm gold-plated tungsten.

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1 The Run 1 chamber (CTC) had over 6000 sense
 2 wires distributed over 9 superlayers (5 axial and 4
 3 stereo) in a jet cell configuration. The drift distance
 4 was about 5 cm, the cathode was a wire plane, and
 5 there were potential wires between sense wires to
 6 shape the electric field. The potential and cathode
 7 wires were $\geq 140 \mu\text{m}$ 304 stainless steel. Ethanol
 8 was the additive.

9 The Run 2 chamber (COT) has over 30,000
 10 sense wires distributed over 8 superlayers (4 axial
 11 and 4 stereo). The drift distance is about 1 cm and
 12 the cathodes are 35 nm of gold, vapor-deposited
 13 on a mylar sheet. Both the sense and potential
 14 wires are $40 \mu\text{m}$ gold-plated tungsten. Isopropanol
 15 is the additive.

17 3. Aging experience with the CTC

19 Prior to Run 1, tests on prototype chambers
 20 indicated aging rates of $< 10\%/C/cm$ using gas
 21 from the CDF gas system. Near the end of Run 1
 22 (early 1995), much larger aging effects were
 23 noticed in the CTC. This large rate started in
 24 early 1994 coinciding with two unrelated occur-
 25 rences: (1) There was a change in ethane supply.
 26 The ethane came from a new well that had a much
 27 larger component of ethylene than the previous
 28 source. (2) There was a significant increase in the
 29 interaction rate (luminosity) seen by the chamber.

31 Before the change of ethane supply, the effect of
 32 ethylene on the aging rate was measured in test
 33 chambers. Without an admixture of alcohol it was
 34 about $80\%/C/cm$ and with alcohol it was about
 35 $5\%/C/cm$. The lower aging rate with alcohol was
 36 obtained with either ethanol or isopropanol.

37 The aging rate in the CTC was measured using
 38 the physics data by monitoring the average width
 39 of the discriminated pulses from the chamber.
 40 Longer pulses correspond to larger pulse height
 41 and higher gain. By quantifying this relationship,
 42 the gain of the chamber could be determined as a
 43 function of time. Fig. 1 shows the average width of
 44 pulses associated with good tracks and the
 45 corresponding gain for wires in the innermost
 46 superlayer as a function of integrated luminosity.

47 Fig. 2 compares the average loss of gain for each
 superlayer relative to the current drawn. The

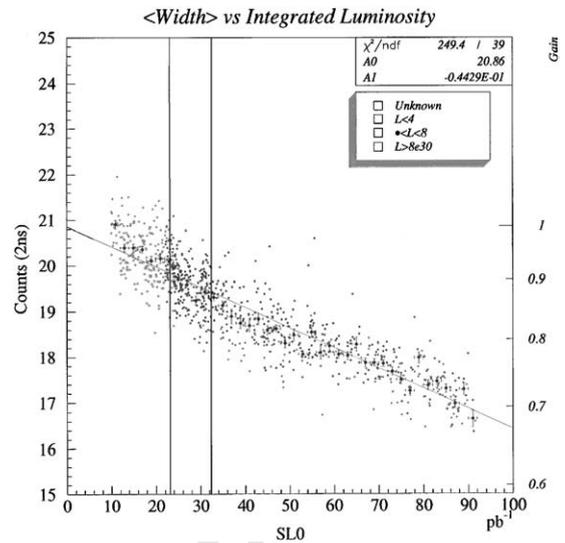


Fig. 1. Pulse width and gain vs. integrated luminosity.

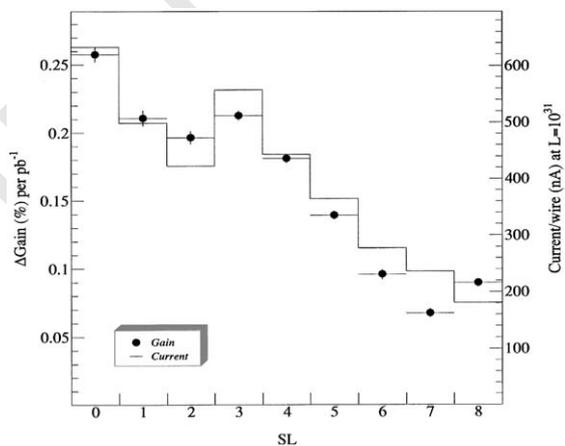


Fig. 2. Average gain loss and current per superlayer.

correlation between the two is quite good. The
 gain loss observed corresponds to about $1000\%/C/cm$
 or $200\%/fb^{-1}$ of integrated luminosity.

4. Response to the measured CTC aging rate

During March–April 1995 parts of the gas
 system were cleaned. The mineral oil inlet pressure
 valve was replaced by a mechanical valve. The
 alcohol bubbler was cleaned and refilled. The
 alcohol and bubbler looked clean to the eye, but

traces of silicon and glycol were found in the evaporated residue using Fourier Transform Infrared Spectroscopy (FTIR). The molecular sieve absorber for the ethane was found to be contaminated with vacuum pump oil; it was cleaned and precautions were taken to prevent a reoccurrence. Gas monitor chambers were inserted into the CTC gas system in strategic places to measure changes in aging rates. ^{90}Sr sources were used to produce aging in these chambers and ^{55}Fe sources were used to measure the change in gain.

The chronology of the subsequent events is summarized as follows:

- *April*: The aging rate was measured directly after the alcohol bubbler to be $\sim 100,000\%/C/cm$.
- *April–May*: After cleaning many valves, the aging rate still was $\sim 100,000\%/C/cm$.
- *May–June*: Aging measured at the CTC input (50 meters from the bubbler) was $\sim 15,000\%/C/cm$.
- *July*: It is suspected that aerosols from the alcohol bubbler are contributing to the large aging rates. A filter canister with a single copper wool pad is placed after the bubbler. Aging before the copper wool was $\sim 100,000\%/C/cm$ and $\sim 50,000\%/C/cm$ after the copper wool.
- *August*: A second copper wool pad was added to the filter canister and it was heated to $\sim 50^\circ\text{C}$. The aging rates were $(17,000 \pm 4000)\%/C/cm$ directly after the filter canister; $(3000 \pm 2000)\%/C/cm$ at the CTC input; and $(400 \pm 200)\%/C/cm$ at the CTC exhaust.
- *November–February*: A second heated filter canister with two copper wool pads was added after the alcohol bubbler. In order to reduce turbulence in the bubbler, 80% of the argon/ethane flow was bypassed and the alcohol temperature was increased by the amount necessary to maintain the same alcohol content in the total flow. The aging rates were now measured to be $(50 \pm 30)\%/C/cm$ directly after the two filter canisters; $(10 \pm 30)\%/C/cm$ at the CTC input; and $(80 \pm 20)\%/C/cm$ at the CTC exhaust.

In addition, bench test aging measurements were made to determine the effects of several contaminants for the standard CTC gas. These tests were all carried out without alcohol in order to enhance the effects of the contaminants. In general, the aging rate due to most contaminants was found to be reduced by about an order of magnitude by the addition of alcohol.

Fig. 3 summarizes these bench test measurements. The “Old CDF Gas” points used ethane from the original vendor. The “1800 ppm Ethylene Test Gas” was a special test gas which was prepared with 1800 ppm of ethylene; other identified impurities were measured to be less than 200 ppm. The “New CDF Gas (unprocessed)” was from a batch of ethane from the new vendor that had not been processed with hydrogen to reduce the ethylene content. This gas had approximately 1400 ppm ethylene, 600 ppm propane, and 1100 ppm propylene. The “New CDF Gas” was actual gas used by CDF from the new vendor that had been “processed” to remove the ethylene.

In general, the gas from the new vendor showed larger aging rates than the set of measurements for the old gas. There was little difference between the new gas and the unprocessed gas. The most striking feature of this figure is that the lowest aging rate was obtained using a cold trap. Because

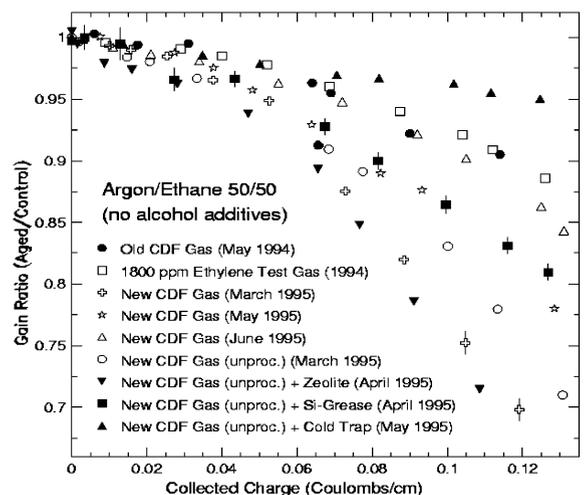


Fig. 3. Summary of the effect of contaminants on aging in bench tests using argon/ethane with no alcohol admixture.

of this, a cold trap was added to the gas system for Run 2.

5. Analysis of aged wires

To help interpret the aging results, sample wires were scanned using electron microscopes. Energy and Wave Dispersive Spectroscopy (EDS and WDS) gave a spatial resolution of a few nanometers and good automated elemental spectroscopy. Additional FTIR gave the capability of measuring molecular bonds.

Wires from bench test chambers without alcohol (used for the aging measurements shown in Fig. 3) had deposits dominated by silicon and oxygen in the form of amorphous silicon oxide. Pictures of a wire aged with the unprocessed gas from the new vendor showed a landscape of thin fibers that resembles a dense, burnt-out forest as shown in Fig. 4. These pictures are consistent with the chemically active nature of silicon.

A wire from a gas monitor chamber inserted into the CTC gas flow just after the bubbler (before measures to reduce aerosols were implemented) had a smoother film-like polymer coating. The coating was mostly long-chain hydrocarbon polymers with only traces of silicone and O–H bonds. A lower magnification picture of this wire is shown in Fig. 5 which had aged at a rate of about 100,000%/C/cm.

At the same time, wires in a test chamber at the CTC input (50 m downstream from the alcohol bubbler) developed a coating that was dark to the naked eye. They had been aged at a rate of about 15,000%/C/cm with a total gain drop of 50–60%. Electron microscope spectroscopy measured mostly carbon, some oxygen, sodium, and a little silicon. FTIR analysis picked up a long aliphatic hydrocarbon polymer (at least 10 carbon atoms long), a likely mixture of a free organic acid (possibly oleic acid or stearic acid) and an organic-acid salt, and silicone. Under magnification the coating appeared smooth with occasional nodules as shown in Fig. 6.

Sample sense wires from the CTC itself had a similar appearance to Fig. 6, but with a lower density of nodules. A sample near the west

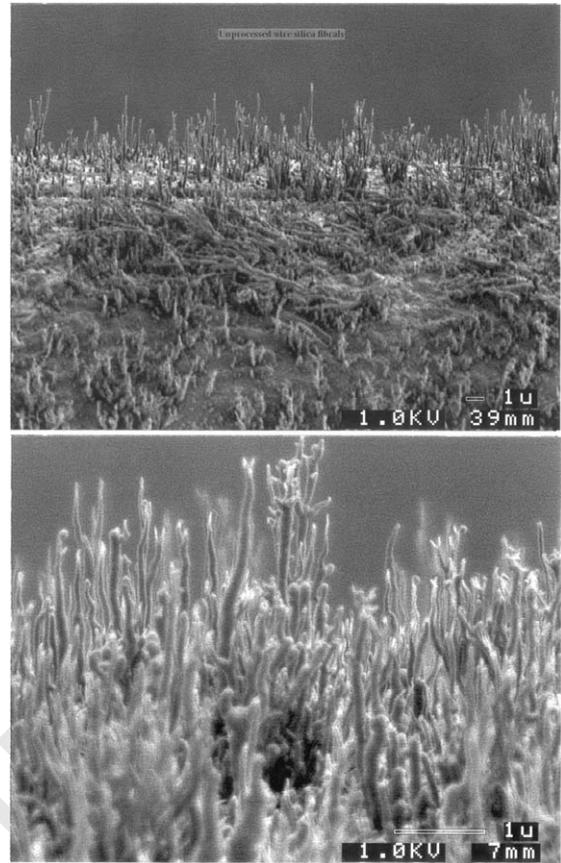


Fig. 4. Pictures of silicon growths on a wire aged to 30% gain loss in unprocessed gas from the new vendor. The lower picture is with higher magnification.

endplate (gas input) had elemental percentages of 23% carbon, 8% oxygen, and 1.2% silicon (with the rest being gold and tungsten from the wire). A sample near the east endplate (gas output) had 20% carbon, 15% oxygen, and 3% silicon. This is in contrast to the wires from the bench test chambers without alcohol that had mostly silicon and oxygen.

6. Gas monitoring for Run 2

For Run 2 an integrated luminosity of 15fb^{-1} is expected corresponding to about 1.0C/cm of accumulated charge in the worst case. Therefore, several steps have been taken to ensure that the

time. In general, the effects of temperature and pressure cancel out in the ratio of the currents. However, the ionization rates are large enough such that a correction must be made because the variation in space charge effects as a function of gain is different for the two planes. Fig. 8 shows how the current ratio I_1/I_4 varies as a function of I_4 (i.e. gain) due to space charge effects. Variations in I_4 were obtained by making small changes to the high voltage.

Fig. 9 shows the results of one aging study. The horizontal axis is time in hours. The top curve is the temperature in degrees Celsius. The second curve is the pressure in torr. The third curve is the current I_4 in plane 4 which reflects the gain of the chamber. The gain is proportional to the temperature and the inverse of the pressure and changes by about 25%. The fourth curve is the ratio I_1/I_4 ; its variation is of order 2%. The bottom curve is I_1/I_4 corrected for the space charge dependence on gain using the quadratic fit to the central region shown in Fig. 8. It is a measure of aging and varies by less than 1%. The approximations in the space charge correction cause some structure; the two larger glitches are coincident with large temperature excursions.

Currently, gas monitor chambers are located after the alcohol bubbler, at the COT input, and at the COT exhaust. After taking into account systematic uncertainties, the measured aging rate has always been $<5\%/C/cm$. This will be an

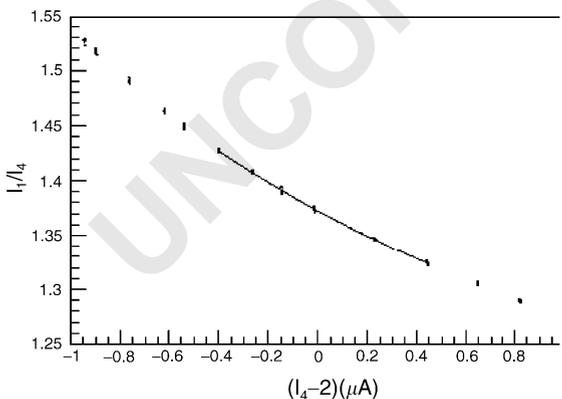


Fig. 8. The current ratio between wire planes giving a measure of the space charge correction.

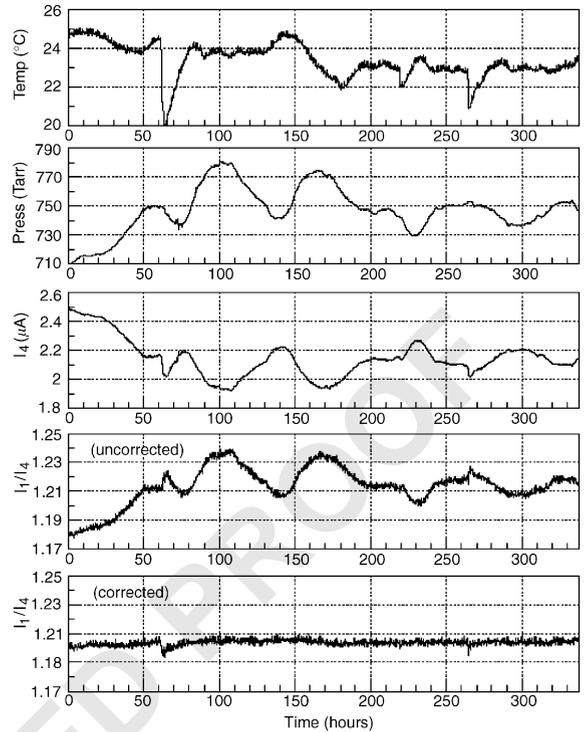


Fig. 9. Curves from a typical aging study. The corrected ratio of currents in the bottom curve reflects the aging rate.

acceptable aging rate for Run 2 if it can be maintained.

7. Conclusions

Near the end of Run 1, an unexpectedly large aging rate in the CTC of $1000\%/C/cm$ was observed using the physics data. Gas monitor chambers were inserted at important points in the gas system and they also exhibited large aging rates. The reasons for this accelerated aging are not completely understood; however, cleaning parts of the gas system and implementing procedures to reduce aerosols from the alcohol bubbler restored the aging rate to the expected levels in the gas monitor chambers. The nature of the deposits on the wires of the gas monitor chambers and on wires from the CTC itself was different from the deposits on wires aged without an alcohol bubbler.

1 For Run 2, the gas system for the COT is
2 cleaner, a cold trap and activated charcoal filters
3 have been added, and the procedures for reducing
4 aerosols from the alcohol bubbler have been
5 retained. New multilayer gas monitor chambers
6 have been built which measure aging by looking at
7 the ratio of currents in the different layers. To
8 date, the aging in these chambers is $<5\%/C/cm$
9 after including systematic uncertainties. This
10 should allow the COT to operate for the full
11 15 fb^{-1} of integrated luminosity expected in Run 2.

Acknowledgements

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Run 2.

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