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The Mark III Vertex Chamber *

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Abstract

The design and construction of the new MarkIII vertex chamber is described. Initial tests with cosmic rays prove the ability of track reconstruction and yield triplet resolutions below 50 μm at 3 atm using argon/ethane (50:50).

We have also performed studies using a prototype of a pressurised wire vertex chamber with 8 mm diameter straw geometry. We obtain 35 μm spatial resolution using dimethyl ether (DME) at 1 atm and 30 μm using argon/ethane (50/50 mixture) at 4 atm. Preliminary studies indicate the DME to adversely affect such materials as aluminised Mylar and Delrin.

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Chamber Design and Construction

A vertex chamber has been designed for use in the Mark III experiment. The chamber will be positioned inside the current main drift chamber and will be used to trigger data collection, to aid in vertex reconstruction, and to improve the momentum resolution.

The vertex chamber consists of 640 thin-walled aluminised Mylar* straws, each having a sense wire along its axis. The ends of the straws are fixed to 2.54 cm thick aluminum endplates, separated by 84 cm and epoxied to the beam pipe. The straws are arranged in 12 layers at radii ranging from 5.4 cm to 13.0 cm. The chamber sits in a carbon fibre pressure vessel, sealed with a second set of endplates, allowing operation at pressures of up to 4 atm.

The central 40 cm of the beam pipe is composed of 1.27 mm thick beryllium, plated on the inside with a 16 μm thick layer of nickel and covered on the outside with a 25.4 μm titanium foil. The remainder of the beam pipe encompassed by the vertex chamber is made of 0.32 cm thick aluminum.

Figure 1 shows the arrangement of the straws at one of the endplates. The first four *axial* layers each contain 40 straws parallel to the beam pipe axis. The *stereo* layers, 5 through 8, contain 40 straws placed at angles ranging from 3.002° to 3.563° with respect to the beam pipe. The outer four are again *axial* layers containing eighty straws each. The 0.422 cm diameter holes in the inner endplate which serve to position the straws have been placed to an accuracy of ± 50 μm for the axial layers and ± 125 μm for the stereo layers.

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* Mylar is a registered trademark of E. I. Du Pont de Nemours & Co. (Inc.). We have used type A Mylar.

The aluminised Mylar straws are 8 mm in outer diameter and the walls are roughly 100 μm thick. The straws are constructed from sheets of 25 μm and 50 μm thick Mylar coated electrolytically on one side with 0.25 – 0.30 μm aluminum. The sheets are cut into narrow strips, wound helically and laminated together. A Delrin† feedthrough is held in place at each end of the straw by an aluminum collar, glued to the straw using a silver-loaded epoxy. The feedthrough passes snugly through the endplate hole and is secured on the back side with an aluminum nut.

The straws are tensioned at 500 grams by preparing the straws 0.6 mm shorter than the distance between the two endplates and stretching them during installation until they touch the endplates. The straw ground is thus electrically connected to the endplate and beam pipe assembly.

The chamber sense wires are 50 μm diameter gold-plated tungsten tensioned at 275 g. They are held in place by crimping stainless steel pins (inner diameter 115 μm), which have been press-fitted into the Delrin feedthroughs. Signals from one end of the sense wire are read out along the same coaxial cable as supplies the high voltage. The cables, which connect directly to the back of the inner endplates, pass through the outer endplates where a 1 cm thick layer of Stycast 2850 FT/24 LV epoxy provides a pressure-tight seal. The pins at the other end of the sense wires are shielded with 5 cm long brass collars which, along with the uninterrupted coaxial readout cables reduce the crosstalk considerably.

The chamber signals are amplified by a factor of about 80 using fast (500

† Delrin is a registered trademark of E. I. Du Pont de Nemours & Co. (Inc.). We have used Delrin 500.

MHz) Avantek MSA-0135-22 RF amplifiers. The discrimination of the signals is achieved by use of fast (400 MHz) LeCroy MVL-407 chips. The minimal charge required to pass the preamp/discriminator stage is 6 fC at 5 ns width. The signals then are independently supplied to our trigger logic and to time-to-amplitude converters (TAC-II, SLAC-135-589) to provide a drift-time measurement with an accuracy of σ_t below 500 ps.

Prototype Tests

A prototype of the vertex chamber was used to study various gases and gas pressures, sense wire diameters, and operating conditions. The construction of the straws in the prototype was identical to that used in the vertex chamber. However, the geometrical arrangement of the straws was different. Cosmic ray data from two sets of triplets staggered by approximately ± 100 μm were used to calculate the resolution σ by fitting a Gaussian to the distribution,

$$\delta = (d(t_1) + d(t_3))/2 - d(t_2),$$

where t_i is the drift time for straw i, and $d(t_i)$ is the drift distance corresponding to the time t_i. For saturated gases such as argon/ethane, we assumed a constant drift velocity v_{drift} of 50 μm/ns at these high voltages. For dimethyl ether (DME), which exhibits a non-linear time-to-distance relationship, we have derived *d(t)* by starting with the parametrization given in Bari *et al.* (CERN EP/86-56), and then iteratively determined the final *d(t)* -relation from the data set itself.

Figure 2 shows the single tube resolution, σ_{tube}, obtained with the prototype assembly under different operating conditions. Assuming the three tubes in a triplet contribute equally to the resolution, $\sigma_{tube} = \sqrt{2/3}\ \sigma$. The data include tracks at all radial and longitudinal positions. No corrections have been applied as a function of the longitudinal position of the track. We obtain 30 μm spatial resolution for argon/ethane at 4 atm and 35 μm resolution at 1 atm using DME. The addition of small percentages of water (0.2% and 0.3%) to the argon/ethane mixture did not show any change of the resolution. The optimum resolution obtained with DME remains fairly constant over a broad range of operating voltages, in contrast with the argon/ethane result, which is quite sensitive to the voltage. In addition, the use of DME allowed to operate the prototype chamber at a very high gain of up to 10^8.

Initial Tests with the Vertex Chamber

The construction of the chamber nears completion and initial tests with cosmic rays are used to determine the chamber performance. After each sublayer is completed, the chamber is placed in a steel pressure can, filled with argon/ethane (50:50) and operated at 3 atm. The event trigger and the time reference are both provided by a coincidence of scintillation counters, mounted above and below the chamber. Figure 3 shows the reconstruction of a cosmic ray track with the first inner four layers connected. The radii of the darkened circles indicated in the figure correspond to the drift distances, as determined from the measured times, assuming a constant drift velocity of 50 μm /ns. Combining measured drift distances (d_i) from staggered tubes results in a triplet resolution of better than

50 μm (see method above) for a pressure of 3 atm at 3.9 kV. The triplet-expression δ, used to derive this number is depicted in figure 4.

Materials Studies

A study was undertaken to evaluate the potential effects on the straws of pressurised air, DME, argon/ethane (50/50 mixture) and argon/ethane (50:50) with a small (0.2%) percentage of water. One meter long samples of the straws, half with feedthroughs and half without, and 20 cm x 3 m x 25 μm sheets of aluminised Mylar were placed in pressurised containers. Control samples were left exposed to the ambient temperature and pressure in our clean room.

The straws weighed between 3 and 6 g, depending upon whether they contained Delrin feedthroughs, and the aluminised Mylar sheets weighed about 18 g. The accuracy of the measurement was 0.01 g. The lengths of the Mylar and of those straws containing feedthroughs were measured to an accuracy of 0.25 mm.

The samples were removed from the containers after one month and were measured. The results are shown in Figure 5. The relative weights of the samples exposed to DME increased by approximately 10^{-2} and the relative lengths increased by about 10^{-3}. No significant change was observed for the samples in other gases. It was also noticed that the Delrin feedthroughs exposed to DME swelled and the sheets exposed to DME exhibited a strong tendency to curl along their lengths.

Conclusions

Good spatial resolution from a prototype wire vertex chamber has been obtained at 1 atm using dimethyl ether and at 4 atm using argon/ethane (50:50). Our results prove the ease of use of DME. However, they also indicate that DME adversely affects at least two common drift chamber materials, Mylar and Delrin. Further studies must be performed to ascertain the extent of the effects on these and other drift chamber materials.

Cosmic ray tracks have been successfully reconstructed using the vertex chamber. We have reliably operated the chamber with argon/ethane at 3 atm and preliminary studies indicate a triplet resolution of about 50 μm.

Figure Captions

Figure 1. Cross section of the vertex chamber at the interaction point. The inner four and last four layers have straws parallel to, the middle four layers have straws at small angles relative to the beam pipe axis. The radial distances vary from 5.4 cm to 13.0 cm.

Figure 2. The single tube resolution obtained using a prototype for a) argon/ethane (50:50) at various pressures as a function of the voltage on the sense wire, and b) DME at 1 atm as a function of the voltage.

Figure 3. Reconstruction of a cosmic ray track through the vertex chamber, after the first inner four layers are completed. The radii of the full circles correspond to the measured drift distance in the particular straw.

Figure 4. The triplet-expression δ for staggered straws in the the first sublayer of the vertex chamber in units of 10 μm , measured at 3 atm and 3.9 kV.

Figure 5. Relative changes in weight and length of samples of aluminised Mylar straws and sheets after exposure to various gases. a) Changes in the relative weight (ΔW/W). b) Changes in the relative length (ΔL/L).

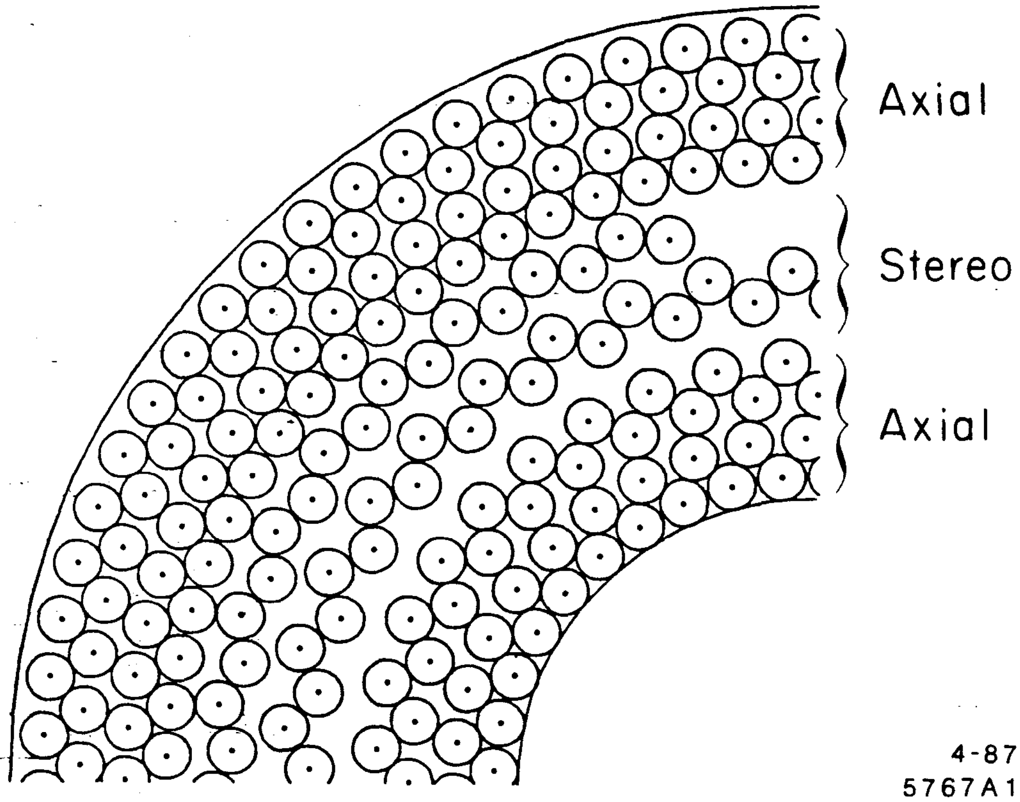
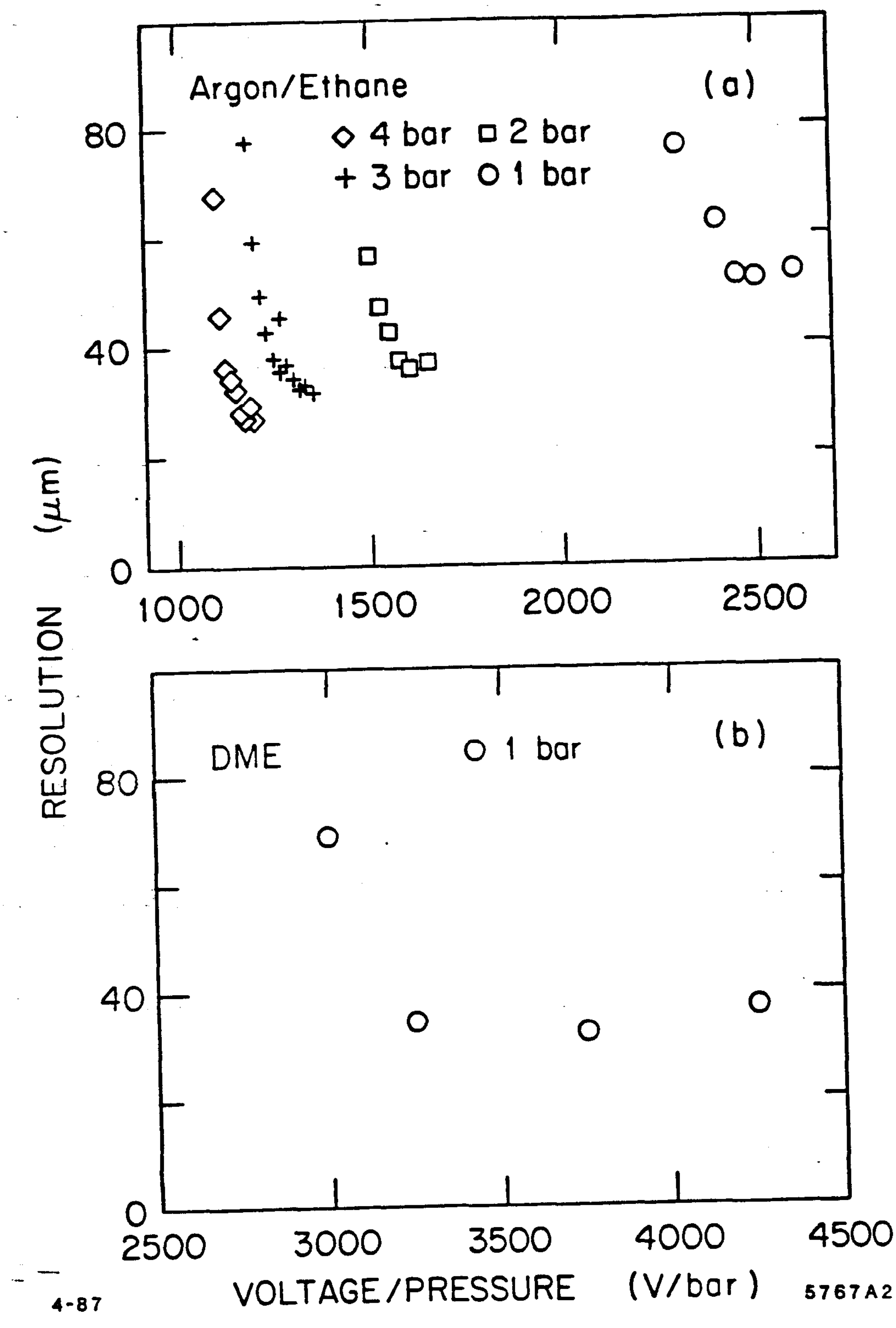


Fig. 1



Argon/Ethane
(a)
◇ 4 bar
□ 2 bar
+ 3 bar
○ 1 bar
80
40
0
1000
1500
2000
2500
RESOLUTION (μm)
DME
○ 1 bar
(b)
80
40
0
2500
3000
3500
4000
4500
VOLTAGE/PRESSURE (V/bar)
4-87
5767A2

Fig. 2

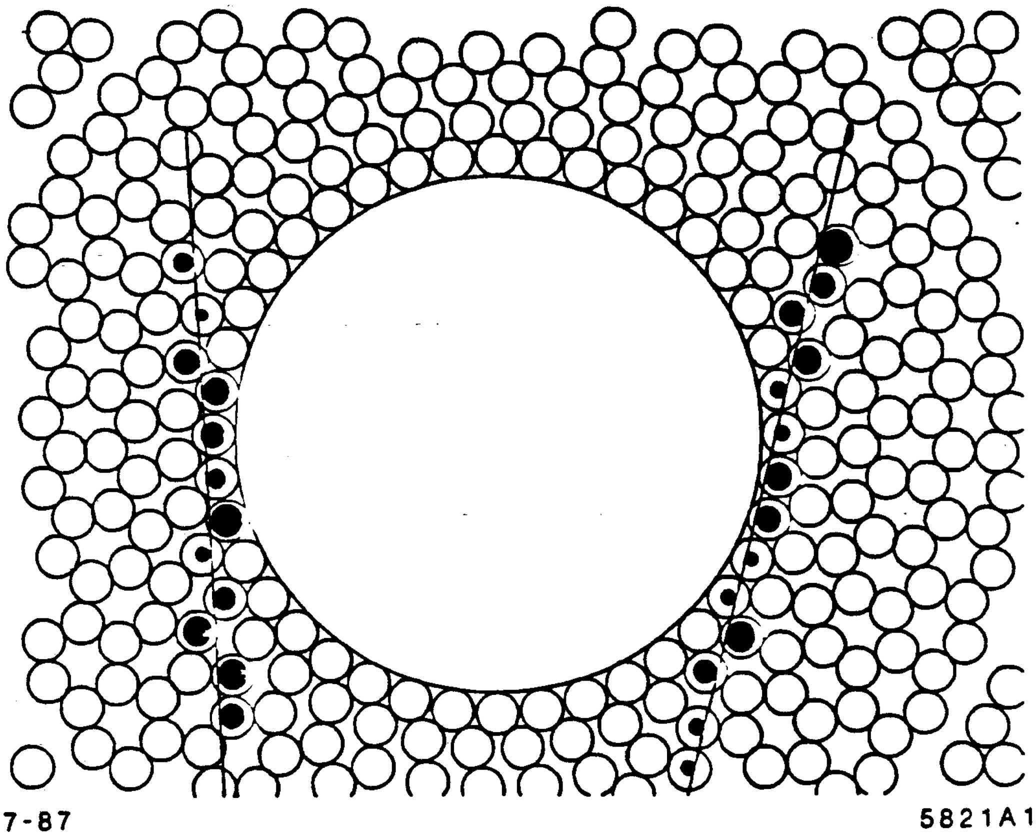


Fig. 3

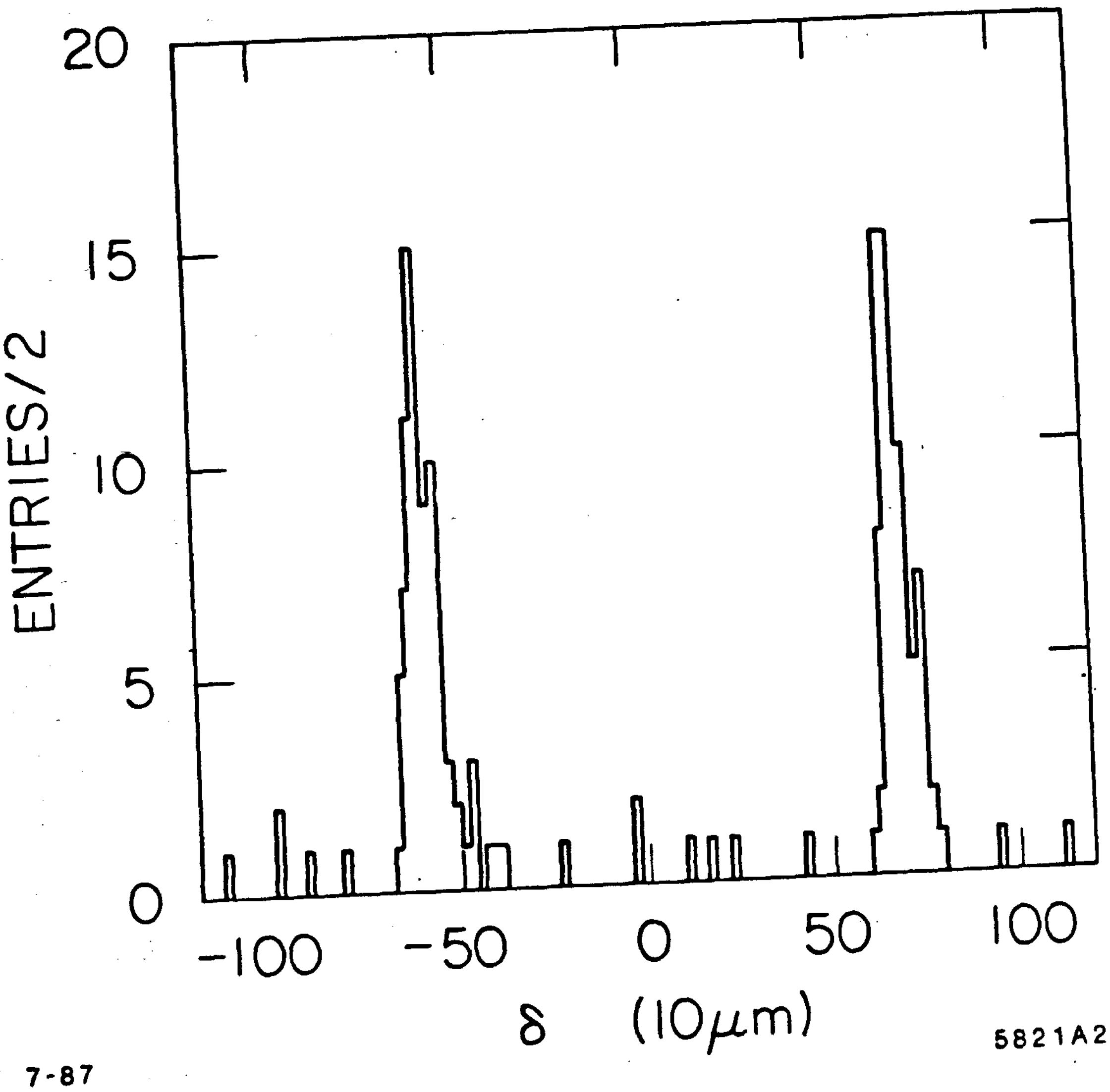
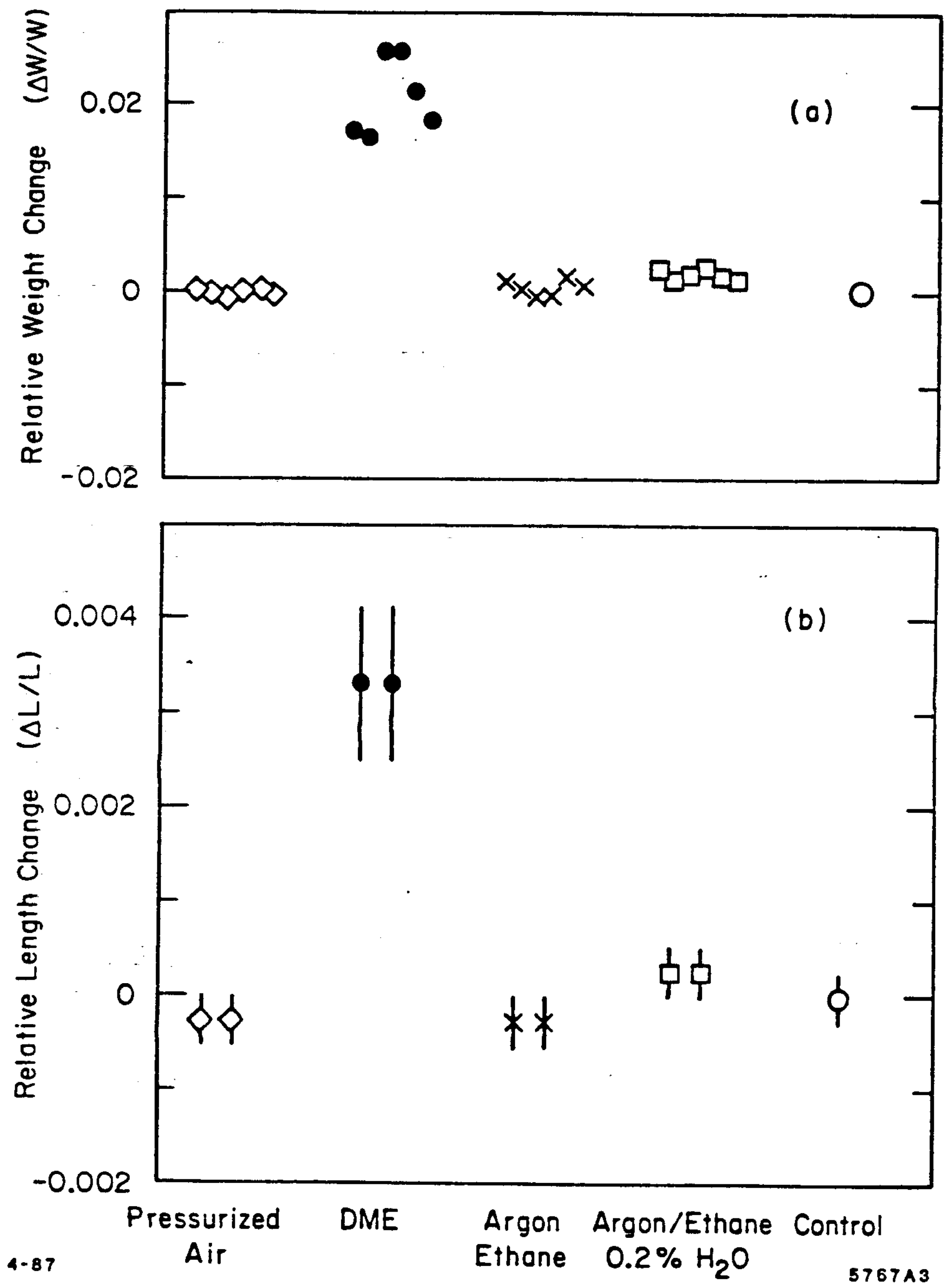


Fig. 4



Relative Weight Change (ΔW/W)
0.02
0
-0.02
(a)
Relative Length Change (ΔL/L)
0.004
0.002
0
-0.002
(b)
Pressurized Air
DME
Argon Ethane
Argon/Ethane 0.2% H2O
Control
4-87
5767A3

Fig. 5