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SOLENOIDAL DETECTOR NOTES

STUDY OF SENSE WIRE STABILITY AND SUPPORT IN STRAW TUBE DETECTOR ELEMENTS

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Study of Sense Wire Stability and Support in Straw Tube Detector Elements

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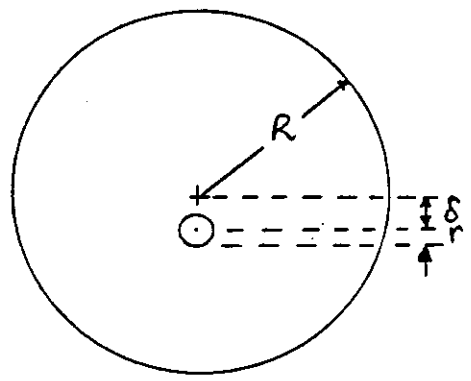
I. Electrostatic Stability of Straw Tubes

The straw tube design for the central tracking chamber in a solenoidal detector at the SSC calls for 4 mm diameter detector elements. The sense wire would be operated at 2 - 2.3 kV to achieve gas gains which give suitable signal pulses. The ideal case in which the sense wire is exactly centered within a perfectly cylindrical cathode is elctrostatically stable. Practically, however, the sense wire will not be exactly centered due to positioning error and gravitational sag and the straw tube cathode will be neither perfectly cylindrical nor perfectly straight. Therefore it is important to determine the conditions under which an operational straw tube detector element will perform satisfactorily. The electrostatic force due to offset of the sense wire in the straw tube is given by:

$$F_E = \frac{2\pi\epsilon_o V^2 \delta}{R^2 (ln(R/r))^2}$$



where V is the sense wire potential, δ is the offset of the sense wire from the center of the straw tube, R is the radius of the straw tube cathode and r is the radius of the sense wire.

We have constructed a straw tube model of stainless steel tubing which is held in alignment by a 3/4 inch square steel "backbone" and machined mounting brackets. The tubing has an inner diameter of 3.9 mm. The steel tube is placed in a horizontal orientation. A manifold on one end allows gas flow to purge air from the tube to eliminate molecular ionization currents which occur with oxygen and nitrogen at potentials in excess of 2 kV. We

have used CH_4, CO_2 and CF_4 as stable gases.

We find that the longest cell that is stable above 2.5 kV with a 25 μm sense wire centered in the tube under 50 grams tension is one meter. The tensile strength of 25 μm diameter tungsten wire is 150 - 200 grams so the applied tension to the wire should be kept below 100 grams. Keeping the wire tension to a minimum will also reduce the mechanical load on the detector assembly.

Using a one meter long tube, we have conducted a series of tests to determine the effect of a position offset of the wire in the tube on the maximum voltage the cell can sustain before breakdown. A sense wire is positioned in the tube so as to be centered vertically. The horizontal position of the sense wire with respect to the center of the tube is adjustable. The distance from the center of the tube to the position of the sense wire is measured by means of a travelling microscope to an accuracy of better than 20 μm. The wire position was adjusted relative to the center of the tube and the potential on the wire was then increased until breakdown occured in the cell.

Figure 1 shows the maximum stable operating voltage that a one meter long cell filled with CH_4 can sustain when the sense wire is displaced from the center of the cathode for two different wire tensions of 50 and 100 grams. *These tests show that wire offsets of up to 100 μm will not compromise cell operation.*

One can predict the motion of the sense wire under increasing electric potential. This has been studied by drilling a hole in the middle of the steel tube to observe the position of the sense wire with a travelling microscope as the wire potential is raised. The arrangement is depicted in Figure 2.

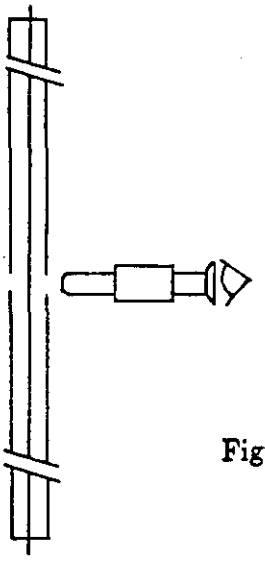


Figure 2

The sense wire was positioned off center by a known amount (δ). The sense wire potential was increased and the deflection of the midpoint of the wire (d) from its initial position was measured. This deflection can be calculated and is related to the potential on the wire to good approximation by the expressions

$$d = \frac{L^2 F_E}{8T}$$

$$d = \frac{2\pi\epsilon_o V^2 L^2(\delta + d/2)}{R^2(ln(R/r))^2}$$

For a one meter long wire the displacement is given by

$$d = \frac{\delta(\frac{V}{V_o})^2}{(1-\frac{1}{2}(\frac{V}{V_o})^2)}$$

where $V_o = 2700\sqrt{\frac{T}{50}}$

with T the wire tension in grams and
V the applied potential in volts

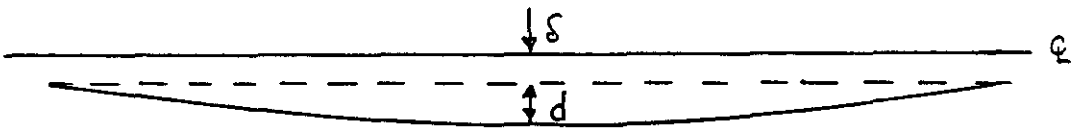


Figure 3 shows measurements of the wire deflection versus sense wire potential for tensions of 50 and 100 grams. The lower set of data in each case is with an initial offset of 100 μm and the upper set of data is for an initial offset of 200 μm. The solid curves are predictions from the formula for the wire deflection. The open circle data points are for initial offset in one direction while the closed circle data points are for initial offset in the opposite direction. The discrepancies between the data are indicative of some nonlinearity of the tube. The measurements agree quite well with the predictions of the above calculations.

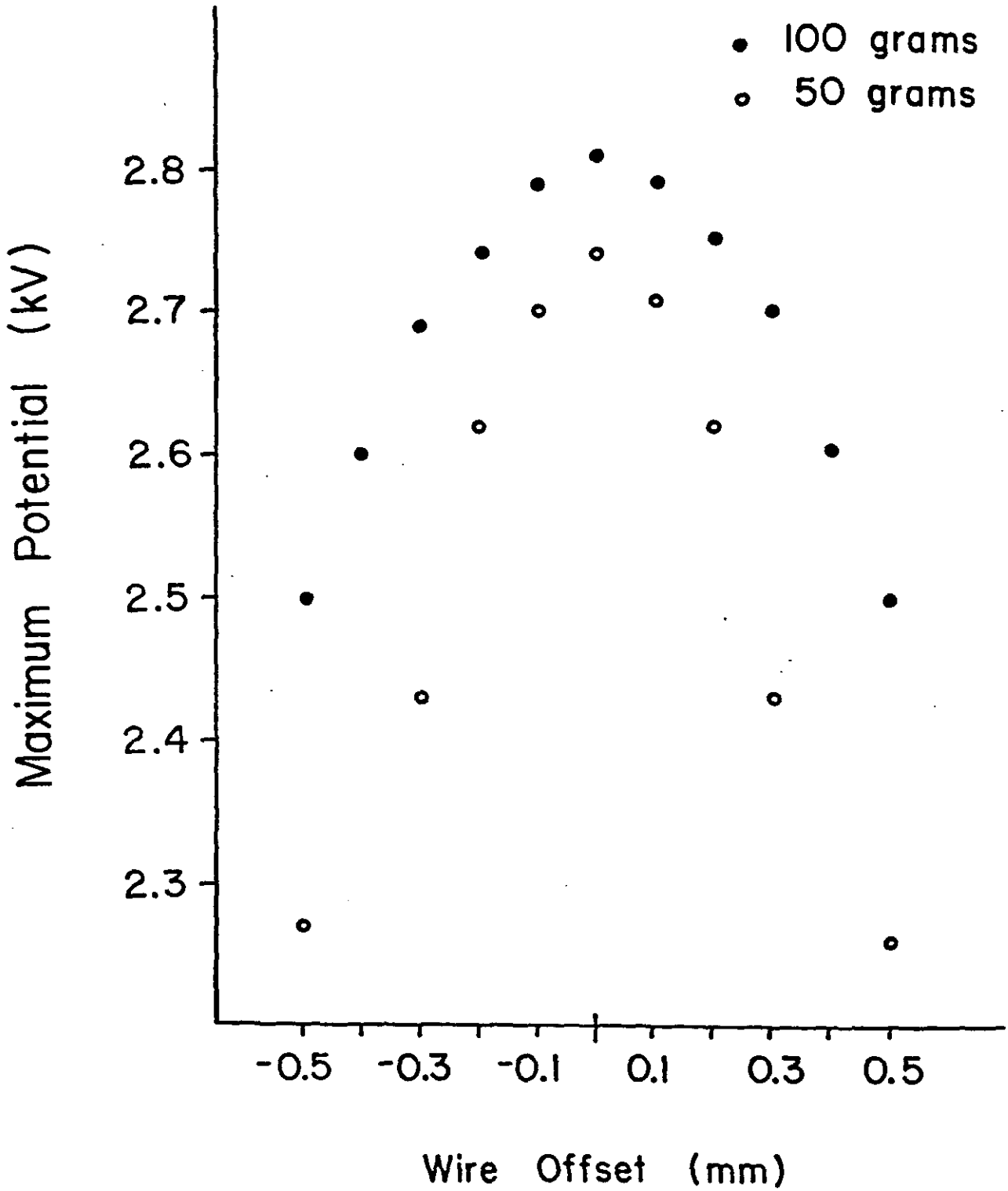
With 50 grams wire tension the amount of deflection of the wire from its initial position can exceed 100 μm at potentials at which the straw tubes are expected to be operated. In order to optimize spatial measurement resolution such wire deflections must be minimized. Therefore, it will probably be necessary to use greater wire tension or support the wire at distance intervals of less than one meter.

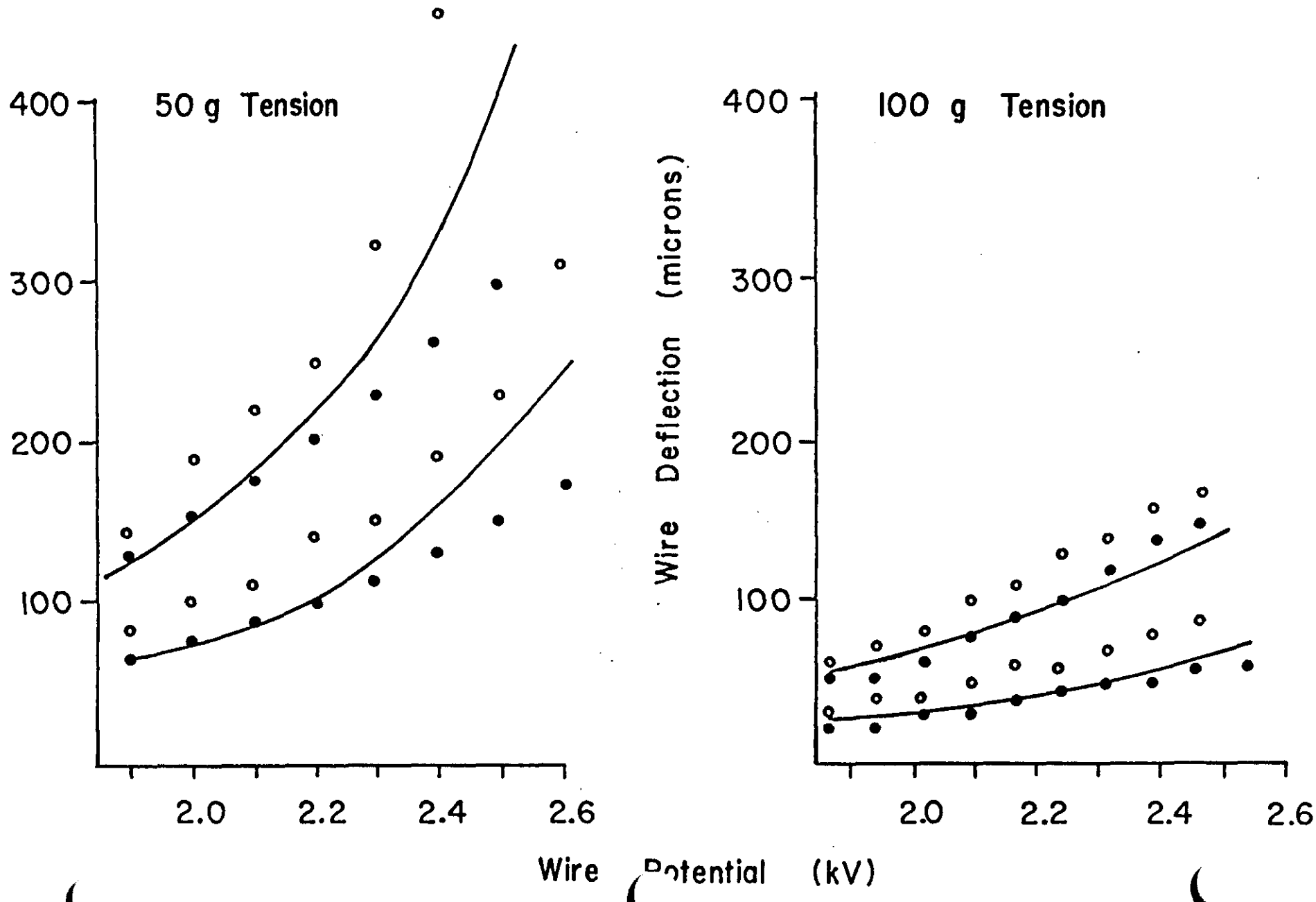
II. Sense Wire Support

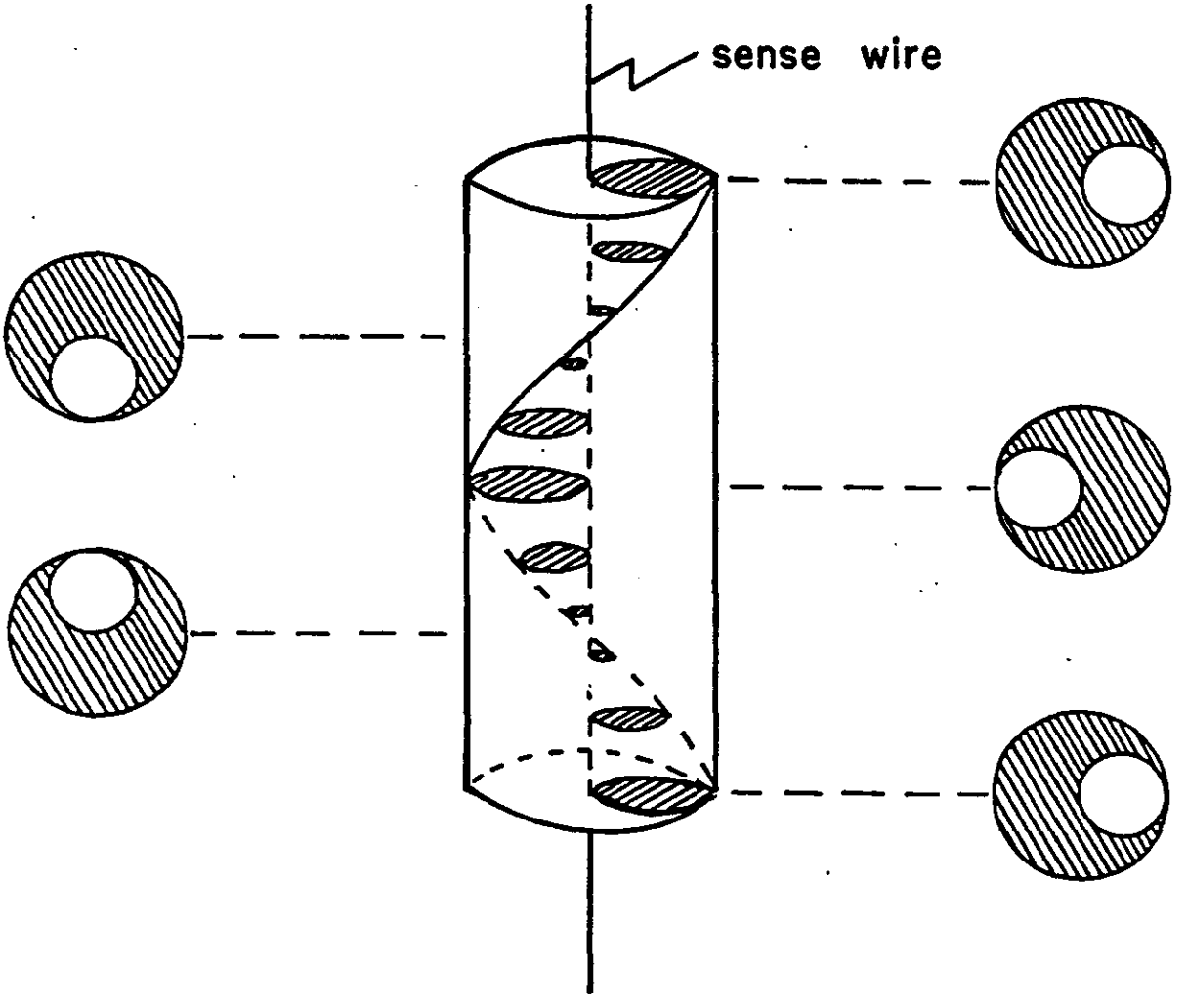
To achieve adequate geometric acceptance for charged tracks the SSC central tracking chamber will have to be six meters long at an outer radius of 1.7 meters. Some designs call for a gap in the middle of the chamber in which case straw tube cells may be about three meters long. In either case it will be necessary to provide centering support for the sense wires in the straw tubes at about one meter intervals to ensure electrostatic stability.

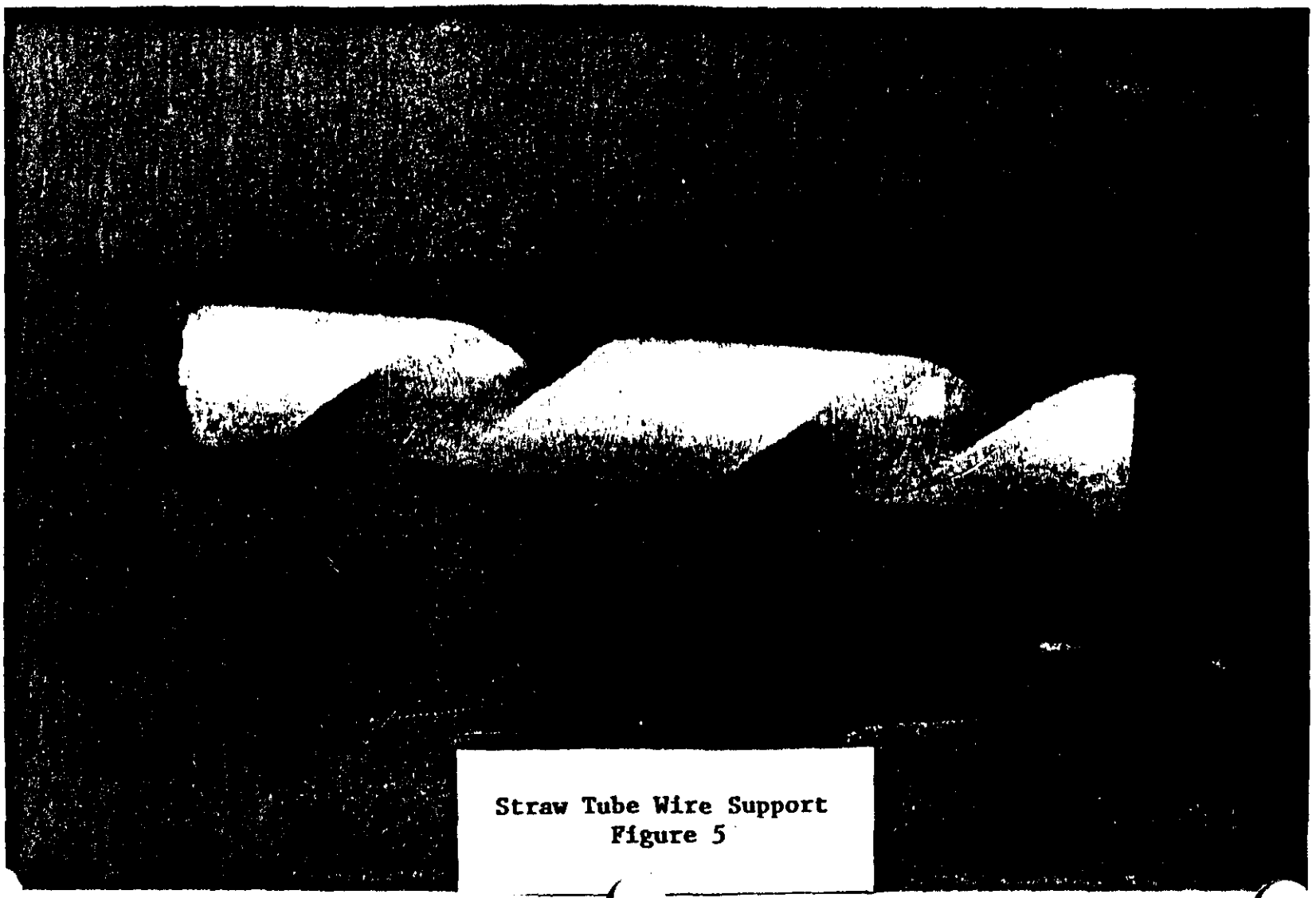
The wire supports must center the wire in the straw tube while at the same time not restricting gas flow through the tube. Our design for the wire support consists of a plastic cylinder with a helical groove which is a cylinder radius deep and makes at least one complete revolution around the cylinder in a length of 1-2 cm. The wire support will provide gravitational support regardless of the orientation of the tube. A schematic drawing of the wire support design with cross section views is shown in Figure 4. Enlargement of a prototype wire support fixture is shown in Figure 5. Production of an injection molding form is in progress and the first molded fixtures should be available for testing within a month.

The wire supports will be attached to the straw tube. The wire will then be threaded through the tube. This has the advantage that if a wire should break during installation in a straw tube, as will likely happen, it will be easy to remove the broken wire and restring the tube. We have used air flow through the tube to draw and guide the sense wire. We are hopeful that this procedure will also work with the wire support pieces in place.


100 grams
50 grams
Maximum Potential (kV)
2.8
2.7
2.6
2.5
2.4
2.3
-0.5
-0.3
-0.1
0.1
0.3
0.5
Wire Offset (mm)


50 g Tension
100 g Tension
400
300
200
100
Wire Deflection (microns)
2.0
2.2
2.4
2.6
Wire Potential (kV)


sense wire



Straw Tube Wire Support
Figure 5