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# **Beam Profile Monitors Used in the Fermilab Fixed Target Beamlines**

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# BEAM PROFILE MONITORS USED IN THE FERMILAB FIXED TARGET BEAMLINES

by

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## ABSTRACT

A description of the Segmented Wire Ion Chambers, typically known as SWICs, is given. These devices have been used at Fermilab since 1972 to monitor the particle beam profiles of the various beamlines. Many modifications and improvements have been made since that time. SWICs are presently used to display beam profiles at intensities from  $10^6$  to over  $10^{13}$  particles/sec.

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## I. INTRODUCTION

After the proton beam is extracted from the Tevatron ring it is transported through Switchyard to form the primary and secondary beams required to operate the Fixed Target Experiments. The Research Division is responsible for transporting these beams from the end of Switchyard to the various experimental halls. The devices that have been used extensively to monitor the position and profile of the beams are SWICs and in low intensity beamlines PWCs (proportional wire chamber) [1]. SWICs, also referred to as chambers, are reasonably rugged and reliable. A complete system is expensive and requires maintenance. During the 1991-1992 fixed target run there was a total of 127 gain SWICs and 22 PWCs divided among the various beamlines. Only PWC's information as it compares to SWICs will be discussed here.

## II. DEFINITIONS

- GAIN SWIC:** A chamber in which the high-voltage plane is made using 25 microns (1 mil) Au-plated W wires, spaced 2 mm apart, and wound at 45 degrees. The signal planes (X and Y) are made using 100 micron (4 mil) Ni wire for "F" chamber and 150 micron (6 mil) for "D" type chamber (fig. 1). Gains up to  $10^5$  [2] can be achieved at 4000 Volts.
- NO-GAIN SWIC:** Previously used only in high intensity beamlines; currently this type of SWIC is only used in Switchyard. A chamber in which the high voltage plane is made using 150 micron diameter Ni wires, spaced 2 mm apart, and the signal planes are made using 100 or 150 micron diameter Ni wire.
- VACUUM SWIC:** A removable chamber located in a mechanical assembly that allows for beamline vacuum continuity. For complete assembly drawings refer to 6018-ME-43360 (fig. 2) for the bayonet type and 6018-ME-42243 (fig. 3) for the box type.
- AIR SWIC:** A chamber installed in a beamline vacuum break e.g., upstream of a target. FNAL drawing 60014-ME-76406 (fig. 4) shows a complete assembly.
- "D" CHAMBER:** A chamber in which the outside dimensions are  $7 \frac{3}{4}$ " x  $7 \frac{3}{4}$ " x  $\frac{3}{4}$ " and the space between planes is  $\frac{1}{4}$ ". The signal planes can be fabricated for 0.25 mm, 0.5 mm, 1.0 mm, and 2.0 mm spacing and are called D.25-G, D.5-G, D1-G, and D2-G respectively for gain SWICs.
- "F" CHAMBER:** A chamber in which the outside dimensions are  $9 \frac{3}{4}$ " x  $9 \frac{3}{4}$ " x  $\frac{3}{4}$ " and the space between planes is  $\frac{1}{4}$ ". The signal planes are wound for 1 mm spacing but 2 mm and 3 mm spacing can be achieved by

soldering sets of 2 or 3 wires together. These chambers are called F1-G, F2-G and F3-G respectively for gain SWICs.

BEAM PWCs: The X and Y sense planes have 128 sense wires spaced 1 mm apart. Beam PWCs are presently only used in low intensity secondary beamlines.

During the 1992 fixed target run the Research Division decided to use gain SWICs for the following reasons:

1. Tests indicated that the same gain chamber could be used in high and low intensity beamlines:
  - A. The Meson West primary beamline where a proton beam of an energy of 800 GeV and of an intensity of  $6 \times 10^{12}$  proton per spill (23 seconds) was displayed at a bias voltage of 400 Volts.
  - B. The Meson West secondary beamline where a pion beam of 100 GeV of  $10^8$  particles/sec was displayed at a voltage of 2600 Volts.
2. Minimize the number of parts needed.
3. Possibility of source testing the SWIC, therefore verifying that the chamber is hooked up properly.

Vacuum SWICs can be source tested by inserting a Strontium source through a 1/4" copper tube which goes through the mechanical assembly to end at a 45 degree angle at the beginning of the anti-vacuum box, between a Kapton window and a titanium window. The electrons penetrate the Kapton window and ionize the ArCO<sub>2</sub> gas inside the SWIC chamber.

### III. PRINCIPLE OF OPERATION

The center plane of a SWIC is hooked up to a positive high voltage power supply. When a beam of charged particles ionize the gas inside a chamber primary electrons and positive ions are produced. The electrons, attracted by the positive wires, produce secondary electrons as they approach the bias wires. The gas multiplication that results is a function of the diameter of the wires and the electric field strength. These electrons in turn give rise to positive ions which migrate toward the signal wires. A set of 27 twisted pair cables take the positive signals from the SWIC, located in a beamline enclosure, to the input channels of a scanner located in a service building.

### IV. CHAMBER CONSTRUCTION

Since F. Hornstra [3] and M. Atac generated the first set of guidelines in 1972 for assembling SWIC chambers, the Research Division made many modifications. FNAL

drawing 2259-ME-173170 (Fig. 1) shows how a standard D type Gain SWIC is presently built.

To minimize the gas flow through the chamber, typically set to 10 ml/min, the chamber planes are epoxied together making the chamber a sealed unit (except for two ports for gas flow). This procedure makes the chamber very difficult to repair if a wire breaks. One can reduce the possibility of a failure due to high voltage by limiting the current at the high voltage power supply.

## V. MECHANICAL ASSEMBLY

In order to allow for beamline vacuum continuity and to reduce the amount of material in the beam, most of the Research Division SWICs are vacuum SWICs. The SWIC chamber is placed inside what has historically been called an anti-vacuum chamber that can be moved in or out of the beam. Depending on space requirements one can use a bayonet assembly, which has a flange to flange distance of 6", or a box assembly which has a flange to flange distance of 12 inches.

Air SWICs are installed in a beamline vacuum break, typically in front of a target station. The minimum space requirement is about 3". Air SWICs can also be source tested by placing a Sr<sup>90</sup> source in front of one of the kapton windows.

## VI. BEAMLINE INSTALLATION

SWIC output is typically displayed as 2 traces: the lower trace represents the horizontal beam profile and the upper trace represents the vertical beam profile (Fig. 6). By convention, a motion of the upper trace to the right indicates that the beam moves up and a motion of the lower trace to the right indicates that the beam moves east. Because a SWIC can be installed in different ways due to space constraints we had to devise a way to satisfy these requirements. The solution was found in terminating the SWIC wires into a 50 pins connector with the first and last pins grounded and the remaining 48 wires dedicated to signal wires. In such a scheme one can reverse the direction of a beam profile by reversing the 50 pin connector as it plugs into the SWIC adapter board (Fig. 5).

## VII. MATERIAL IN THE BEAM

The amount of material in the beam depends on the type of SWIC used. In the case of a vacuum SWIC the Ti windows separate the beamline vacuum from the ArCO<sub>2</sub> gas inside the anti-vacuum chamber and therefore the SWIC chamber. The Kapton windows have been added to protect the wires during the source test operation. In the case of an air SWIC, besides the Kapton windows, one has to account for a beamline window in front of the chamber and the amount of air between the two. A typical 6" OD beam pipe has a Ti window about 10 mil thick.

## VACUUM SWIC

$\lambda_i=0.23\%$  interaction length  
(2) 3 mil Ti windows  
(2) 3 mil kapton windows  
1.25" ArCO<sub>2</sub> gas  
 $1 \times 10^{-6}$ " of AuW  
 $2 \times 10^{-6}$ " of Ni

## AIR SWIC

$\lambda_i=0.2\%$  interaction length  
(2) 3 mil kapton windows  
0.75" ArCO<sub>2</sub> gas  
 $1 \times 10^{-6}$ " of AuW  
 $2 \times 10^{-6}$ " of Ni

## BEAM PWC

$\lambda_{rad}=0.007$  radiation lengths  
(4) 0.5 mil Al foils  
0.75" ArCO<sub>2</sub> gas  
 $2 \times 10^{-6}$ " of W

## VIII. SWIC ALIGNMENT

Every SWIC chamber has two 3/8" precision pins that are at a specific distance from the center wires of the chamber:

- A. In the case of a bayonet vacuum SWIC the alignment is done by referencing the chamber alignment marks to fiducial reference surfaces (fig. 2). A typical uncertainty at position L1 (chamber in the beam) is  $\pm 5$  mil. As soon as the L1 limit has been reached a 24 Volts DC brake is switched ON therefore reducing the uncertainty around the switch. The system depends on the reliability of the limit switch and care is taken to ensure that the switch is electrically and mechanically sound.
- B. In the case of a box vacuum SWIC the alignment is done by referencing the chamber alignment marks to the top and side of the vacuum box. The uncertainty of position at L1 for the box SWIC is less than  $\pm 5$  mil.
- C. In the case of an air SWIC the alignment is done by referencing the chamber alignment marks to fiducial reference surfaces on the mounting plate (fig. 4) The uncertainty is typically less than  $\pm 3$  mil.

## IX. ELECTRONICS

At the time of this writing the electronics consists of a Scanner and associated CAMAC interface modules (032 Data Transfer Module and 096 Timing Module). Fig. 5 shows a complete electrical hookup.

The scanner is a Z80 microprocessor based originally designed by Carl Wegner and Jim Simonton.

The operation of the scanner is specified in Fermilab TM-868A [4]

The SWIC Scanner is a 96 channel, charge integration device that is capable of carrying out the following functions:

1. Sample the ninety-six analog inputs for a programmable time interval
2. Digitize the analog sampled data and store in local memory
3. Subtract the background noise from the stored chamber data
4. Carry out calculations ( Sigma and mean) on the stored data
5. Display the results on a video monitor
6. Transmit the stored data.

## X. DISCUSSION

In primary beamlines most of the SWICs are of the type D1-G and D2-G . A few chambers of the type D0.5-G and D0.25-G are located in front of target stations. There are special cases in which 3 beams are seen on a single SWIC. These are located at the upstream end of the Proton and Meson areas and in secondary beamlines. Fig. 6 shows three beams vertically split at the end of switchyard. Fig. 7 shows the vertical and horizontal separation of the same three beams after the Lambertson magnets located at the beginning of the Proton Area.

In secondary beamlines a SWIC or a PWC is selected depending on the intensity requirements. Even though a SWIC can be "pushed" to display rates around  $10^5$  p/sec the noise level at these rates is sizable. So a decision was made to use SWICs for rates greater than  $10^7$  particles per slow spill (about 500 KHz since the spill was about 23 seconds long), and a PWC for rates below 500 KHz.

## XI. CONCLUSIONS

The gain SWICs have operated well within the intensity range indicated. The Research Division has already started making plans for future electronic upgrades, and for further SWIC tests to be performed when beam becomes available.

## XII. ACKNOWLEDGMENTS

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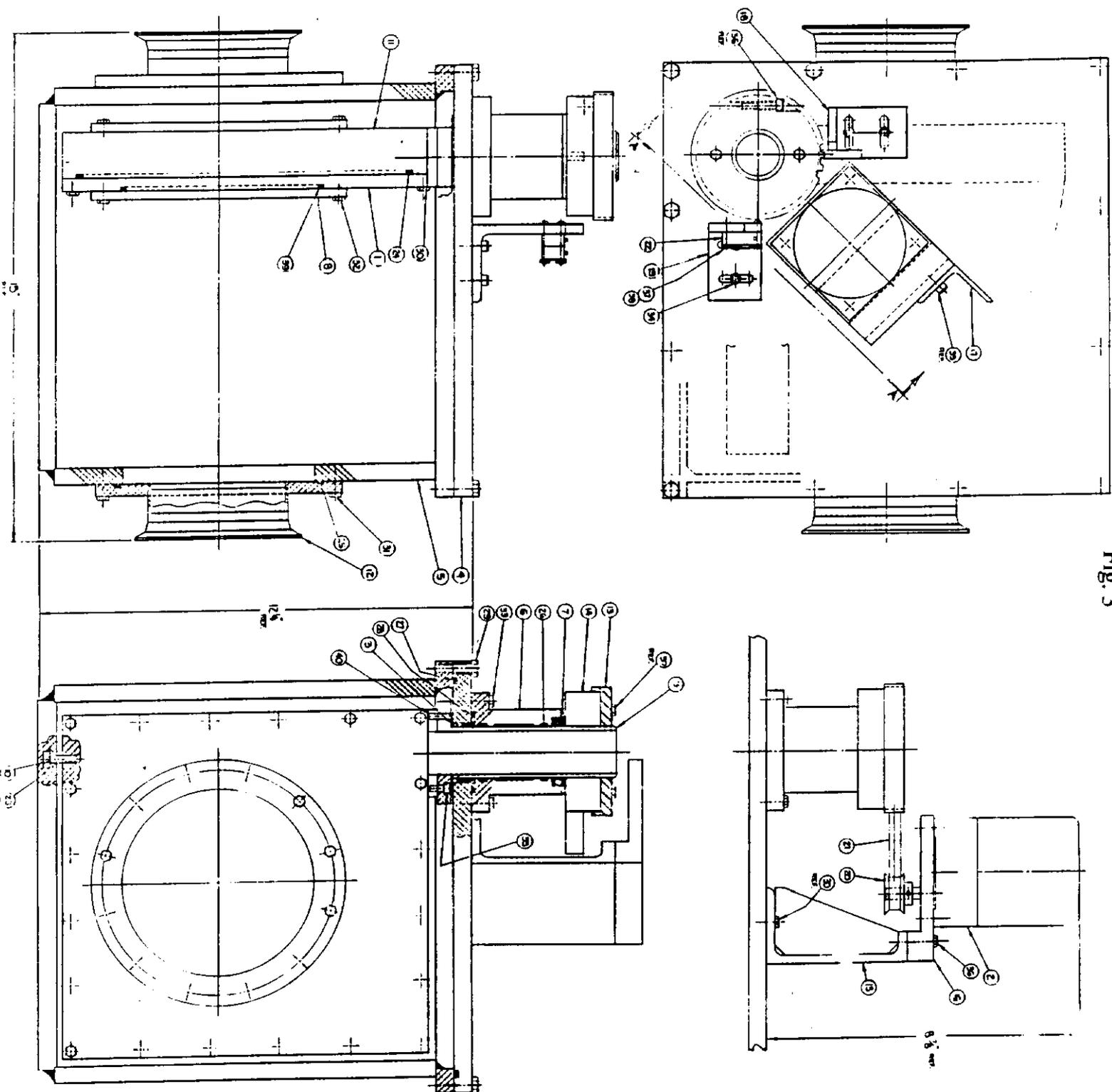
## XIII. REFERENCES

1. H. Fenker: "A STANDARD BEAM PWC FOR FERMILAB". FNAL TM-1179
2. M. Haldeman, SWIC Chamber Specifications, 1974
3. F. Hornstra, FNAL Internal Memo, 1973
4. W. Higgins, "User's Manual for Microprocessor Based Swic Scanner" FNAL TM-868A





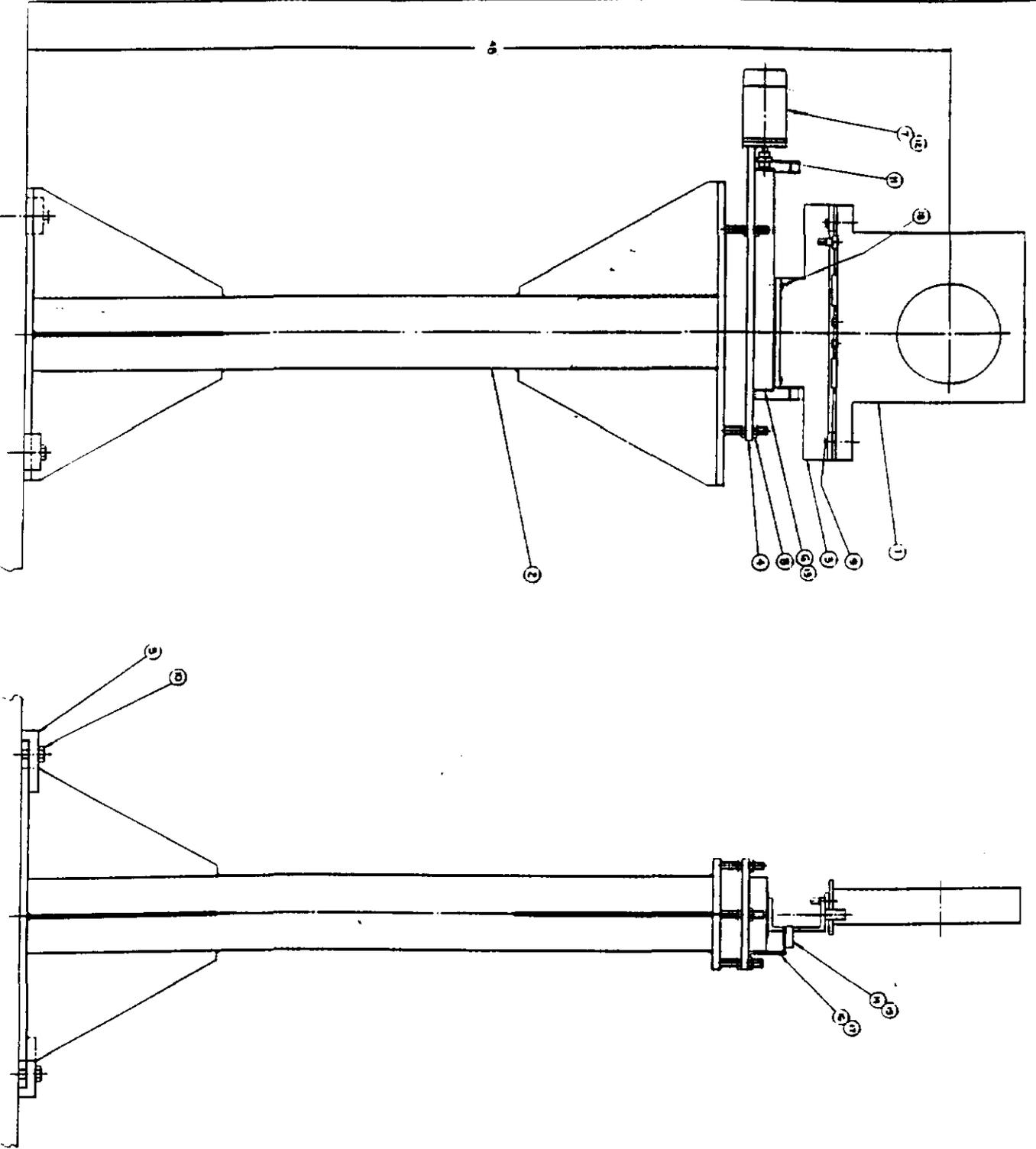
Fig. 3



NO.	DESCRIPTION	QTY.	UNIT
1	SCREW	1	PC
2	SCREW	1	PC
3	SCREW	1	PC
4	SCREW	1	PC
5	SCREW	1	PC
6	SCREW	1	PC
7	SCREW	1	PC
8	SCREW	1	PC
9	SCREW	1	PC
10	SCREW	1	PC
11	SCREW	1	PC
12	SCREW	1	PC
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23	SCREW	1	PC
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25	SCREW	1	PC
26	SCREW	1	PC
27	SCREW	1	PC
28	SCREW	1	PC
29	SCREW	1	PC
30	SCREW	1	PC
31	SCREW	1	PC
32	SCREW	1	PC
33	SCREW	1	PC
34	SCREW	1	PC
35	SCREW	1	PC
36	SCREW	1	PC

EXP. AREA  
 BOX 5-100 1557  
 5013-1-421

Fig. 4



NO.	DESCRIPTION	QTY.	UNIT
1	BASE	1	PC
2	LEG	4	PC
3	LEG HOLDER	4	PC
4	POWER PULLEY FLAT	1	PC
5	BRACKET	1	PC
6	ROTOR	1	PC
7	ROTOR HOLDER	1	PC
8	ROTOR FLANGE	1	PC
9	ROTOR FLANGE NUT	1	PC
10	ROTOR FLANGE WASHER	1	PC
11	ROTOR FLANGE WASHER	1	PC
12	ROTOR FLANGE WASHER	1	PC
13	ROTOR FLANGE WASHER	1	PC
14	ROTOR FLANGE WASHER	1	PC
15	ROTOR FLANGE WASHER	1	PC
16	ROTOR FLANGE WASHER	1	PC
17	ROTOR FLANGE WASHER	1	PC
18	ROTOR FLANGE WASHER	1	PC
19	ROTOR FLANGE WASHER	1	PC
20	ROTOR FLANGE WASHER	1	PC
21	ROTOR FLANGE WASHER	1	PC
22	ROTOR FLANGE WASHER	1	PC

AIR MAIL 31410 1551  
 AIR MAIL 31410 1551  
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Fig. 5

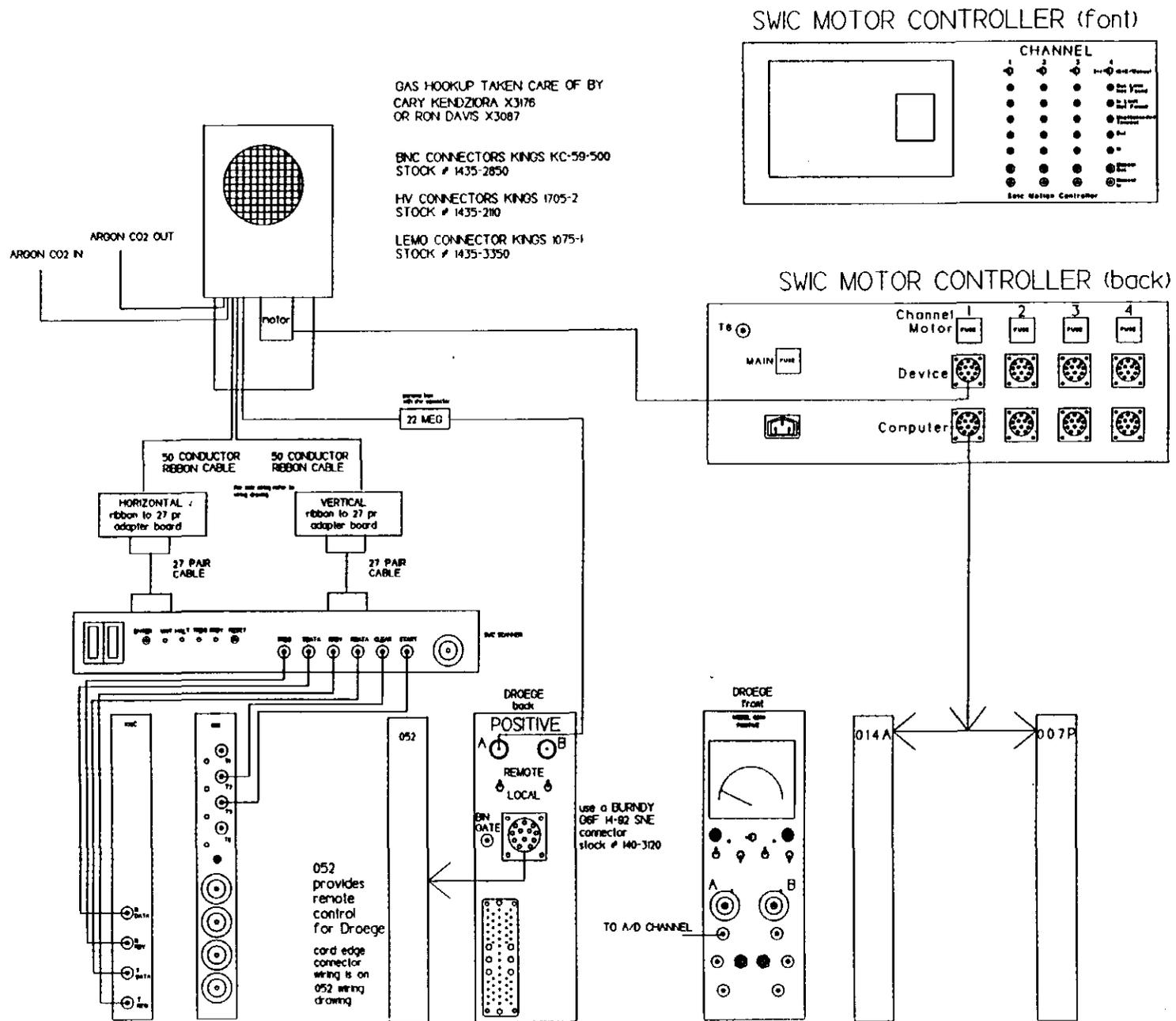


Fig. 6

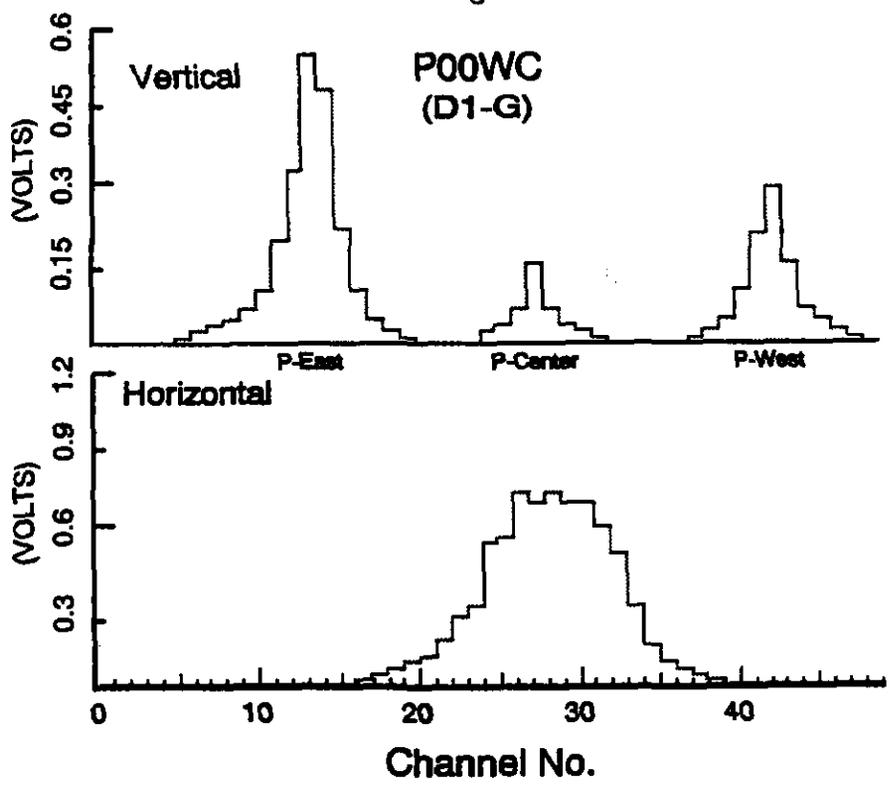


Fig. 7

