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# USE OF A HIGH DENSITY LEAD GLASS TUBING PROJECTION CHAMBER IN POSITRON EMISSION TOMOGRAPHY AND IN HIGH ENERGY PHYSICS *

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## Abstract

We describe the principle of operation of a high density Projection Chamber, in which the converter/radiator and drift field shaping structures are combined in the form of high density (5-6 $g/cm^3$) lead glass tubing. The main applications of this type of detector to Medical Physics (Positron Emission Tomography) and High Energy Physics (Electromagnetic Calorimetry) are discussed.

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## 1. Introduction

The detection of high energy photons in a gas filled medium is limited by the density and the absorption properties of the gas. Honeycomb arrays of lead glass tubing were originally developed at the Lawrence Berkeley Laboratory[1] to enhance the absorption and detection of photons with gas counters.

In Positron Emission Tomography it is necessary to detect the two (511 keV, back to back) annihilation photons in two opposing detectors with high spatial resolution to reconstruct the $\beta^+$ emitter radioisotope distribution. A schematic drawing of a MWPC/converter is shown in fig. 1.

The converter is made of lead glass capillaries fused to form honeycomb matrices. In order to have a high efficiency, a high surface to volume ratio is necessary. Therefore, typical dimensions for the tubes are 0.5-2.0 mm inner diameter, 50-200 μm wall thickness, 1-2 cm drift space. The lead glass matrices are treated in a $H_2$ reduction process to form a uniform resistive layer[2] on the walls of each tube. The Compton or photoelectron produced by the photon interacting within the converter has a finite range which depends on its energy. If it reaches the gas region within the tube, a number of primary ionization electrons are produced. A voltage difference applied between the ends of the tubes drifts these primary electrons along the electric field lines within the tube towards the chamber avalanche region.

Various size capillaries of different diameter and wall thickness have been tried. Our best results have been obtained with a matrix of lead-glass tubing with 0.48 mm inner diameter, 0.06 mm wall thickness (80% PbO, density 6.2 $g/cm^3$) which gives a measured efficiency of 6.5% for a 1 cm thick converter[3]. The experimental efficiency measurements for the various converter types agree very well with the Monte Carlo predictions[4].

We are also investigating the possibility of using this type of converter in High Energy Physics and particularly as

an electromagnetic calorimeter[5]. The proposed drift collection calorimeter (see fig. 2) is a method of achieving fine granularity in gas sampling which minimizes the number of readout channels. The z-coordinate (along the longitudinal direction of the shower) is directly read from the anode wire; the y-coordinate can be obtained by means of delay lines parallel to the anode wires or by charge division method. The third coordinate is given by the drift time of the electrons within the tubes to the anode plane.

## 2. Contruction of the lead-glass matrices

The described PET and HEP applications are both dependent on the use of fused, reduced lead-glass tubes for their success. There are essentially six phases to the construction of the finished project, which are described in detail in reference (6):

i) Cutting of the tubes and their stacking in a mold. The tubes of small diameter (ranging between 0.5 and 1 mm, and wall thickness 50 to 100 μm) used in PET applications were lined up side by side, set flush at one end, ticked with a carborandum blade and the cut lengths were placed in a mold. The bigger diameter tubes (5-10 mm as for calorimetry application) were simply cut to size individually on a lathe. The mold was made of graphite to avoid attachment and to match the expansion coefficient of the glass.

ii) Fusing of the glass The temperature of the oven was slowly raised (over a period of 36 hrs) until the softening point of the glass was reached. A space was left between the mold and its lid to allow for compression of the tubes. A closed lid indicates that the glass has sagged. To avoid a visual inspection of the mold, an electrical sensor has been developed that announces the closure of the lid (see fig. 3), i.e. the end of the fusing process. An annealing and a cooling processes are then performed.

iii) Slicing of the fused glass. The tubes were cut with a diamond saw (400 mm diameter, 2 mm thick with a very fine grit ) rotating at high speed ( ~3000 r/min); no polishing of the glass was made.

iv) Cleaning of the glass and HCl treatment. First, the glass was ultrasonic cleaned with deionized water, acetone and again deionized water. Then it was soaked for few minutes in a 0.1 molar HCl solution to produce a protective $SiO_2$ layer on the surface. This silica layer was then hardened by putting the glass for 8 hrs inside a oven at 140°C.

v) The $H_2$ reduction treatment. The glass to be treated was placed at the bottom of the oven, which was sealed and evacuated. The temperature of the oven was slowly raised until the desired temperature was reached. The $H_2$ was then allowed to flow at low rate for a period of some hours.

vi) Production of the conductive layer at the ends of the tubes. A conductive layer was produced by applying silver epoxy with a rubber roller, following a method not unlike that of a printing press. Very thin layer of silver epoxy was transferred to the surface of the glass, to produce a resistance across the surface of 50-200 Ω depending upon the tube diameter.

Two types of glass tubes have been treated: the Nuclear Pacific Hi-D glass, as originally used at Lawrence Berkeley Laboratory[1], and the Schott RS-520 glass. Table I shows the main properties of the latter, that is going to be used for both applications (fig. 4 ).

TABLE 1

Physical properties of the Schott RS-520 Glass

| | |
|---|---|
| PbO Composition (by weight) | 71% |
| Density | 5.18 $g/cm^3$ |
| Annealing temperature | 423°C |
| Thermal expansion coefficient | $8.1 \times 10^{-6}$/°C |

We have investigated the resistivity of this specific glass versus the temperature of the $H_2$ treatment (fig. 5) and versus the duration of the $H_2$ treatment at a fixed temeprature (fig.6). As a result, we decided to treat the glass in $H_2$ at 360° for 6 hours which gives a glass resistivity of $\sim 10^{11}$ $\Omega/\square$ , adequate for both applications.

## 3. The applications

### 3.1 -The HISPET Project

Based on the use of MWPC equipped with this type of converter, a HIgh Spatial resolution Positron Emission Tomograph has been designed. It will consist of six modules arranged so as to form the lateral surface of a hexagonal prism. Each module of HISPET will have two MWPC and two 1 cm thick converter planes (tubing diameters: 0.48 and 0.60 mm ID and OD, respectively), see figure 7. HISPET will be capable of imaging three-dimensional distributions of a positron emitting radioisotope within a typical volume of 3 litres. It will have a volume sensitivity of $\sim$ 100000 c/s per 0.1 $\mu$ Ci/ml, a signal to noise (true to accidental coincidences) ratio of 3:1 and an intrinsic spatial resolution of less than 4.5 mm (FWHM) [7].

A first prototype has been built, which consists of two 50x50 $cm^2$ MWPC, each equipped with a 2 cm thick lead glass converter. A fast data taking system based on CAMAC/FASTBUS modules is now under installation.

### 3.2- The CALTUB Project

We have designed a drift collection calorimeter prototype, with lead glass tubes of 40 cm drift length and a total longitudinal dimension of $\sim 20$ $X_0$ which fully contains the electromagnetic shower of incident particles of energy up to 10 GeV.

The main characteristics of the prototype are listed in table 2

TABLE 2

Physical characteristics of the calorimeter prototype

| | |
|---|---|
| Glass used | Schott RS-520 |
| Tubing diameter (ID/OD) | 5/7 mm |
| Radiation length | 1.66 cm |
| Drift length | 40 cm |
| Longitudinal dimension (in radiation lengths) | $\sim 20\ X_o$ |
| Actual longitudinal dimension | 75 cm |
| Transverse dimension | 30 cm |
| Total weight | $\sim$200 kg |

The full prototype will be made by assemblying several modules of 10x14x40 $cm^3$ (see fig. 8). A detailed Monte Carlo study[5] has shown than an energy resolution ( $\sigma/E$ ) of $17\%/\sqrt{E}$ is expected with the calorimeter working in proportional sampling mode. The first experimental test have been successfully performed [8] in the laboratory with radioactive sources and at CERN with m.i.p., and the prototype is now under construction.

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Figure Captions

1. Schematic drawing of a MWPC equipped with delay line readout and a single layer of lead glass tube converter.
2. Principle of the drift collection calorimeter with lead glass tubes.
3. Graphite mold with its sensors: a 5x5 $cm^2$ prototype for the calorimeter is inside the mold.
4. Prototypes of lead glass matrices for PET and HEP projects
5. Resistance of a 10 cm (5 mm ID) tube vs. temperature of the $H_2$ treatment.
6. Resistance of a 10 cm (5 mm ID) tube vs. time of the $H_2$ treatment.
7. Schematic drawing of HISPET: only three modules are shown.
8. A final module (10x14x40 $cm^3$) of the electromagnetic calorimeter, before being polished and $H_2$ treated.

Fig. 1

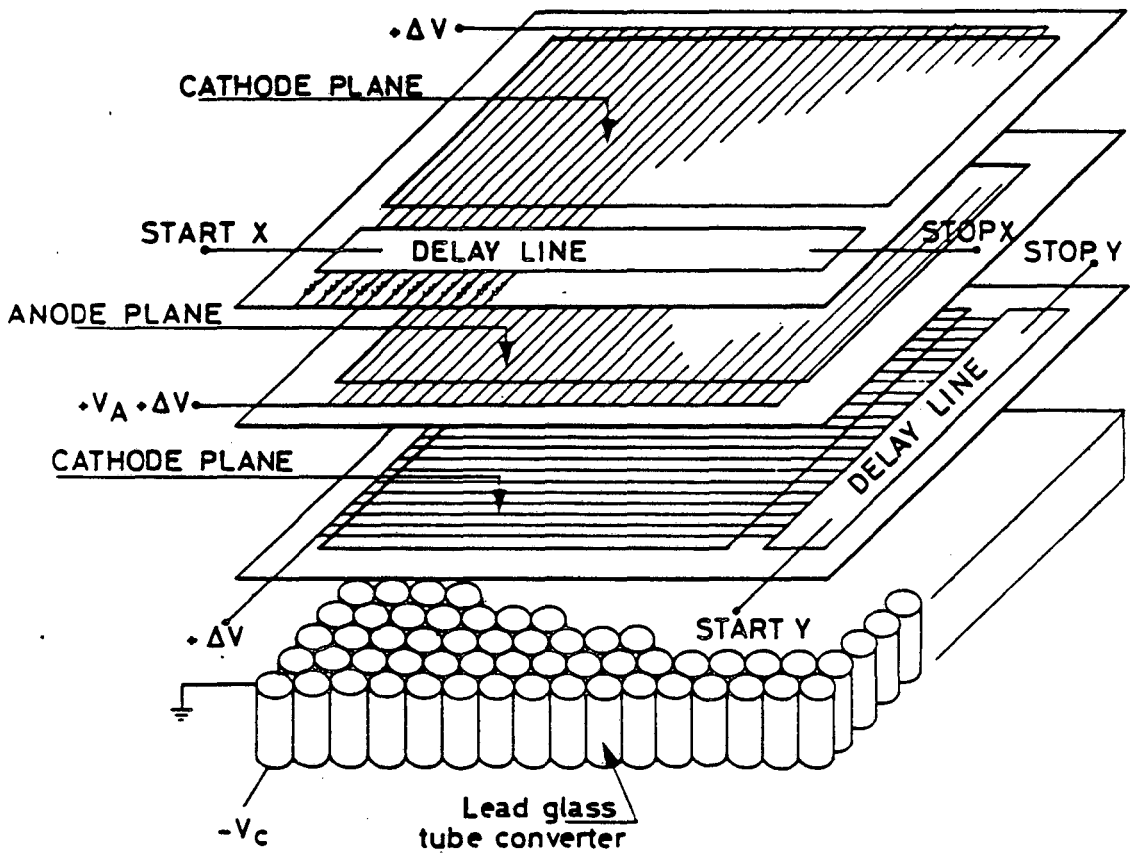
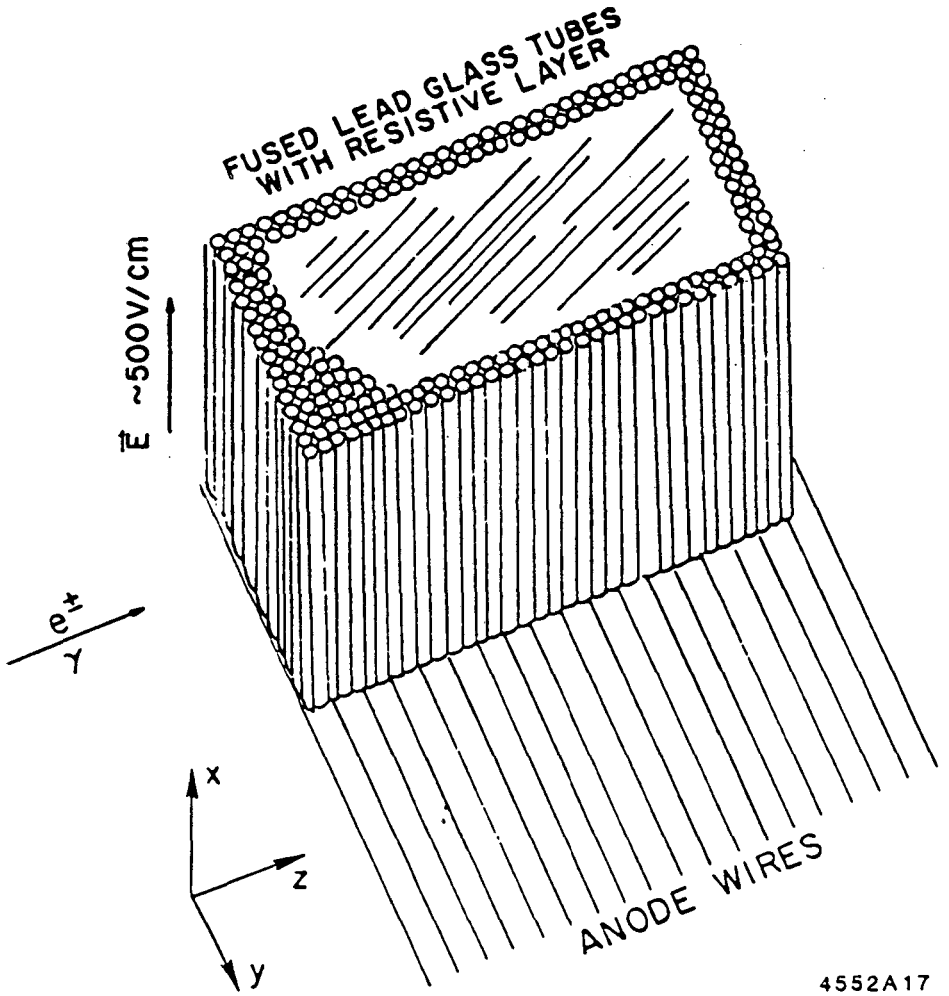

+ΔV
CATHODE PLANE
START X
DELAY LINE
STOP X
STOP Y
ANODE PLANE
+V_A +ΔV
CATHODE PLANE
DELAY LINE
+ΔV
START Y
-V_c
Lead glass
tube converter

Fig. 2


FUSED LEAD GLASS TUBES
WITH RESISTIVE LAYER
~500V/cm
e±
γ
x
z
y
ANODE WIRES
4552A17

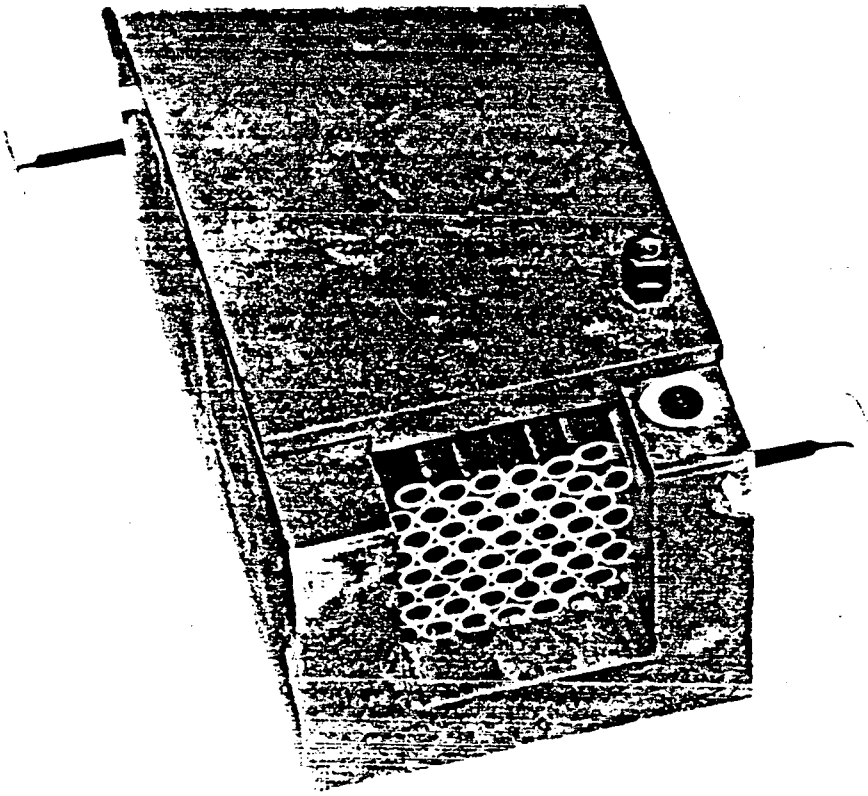


Fig. 3

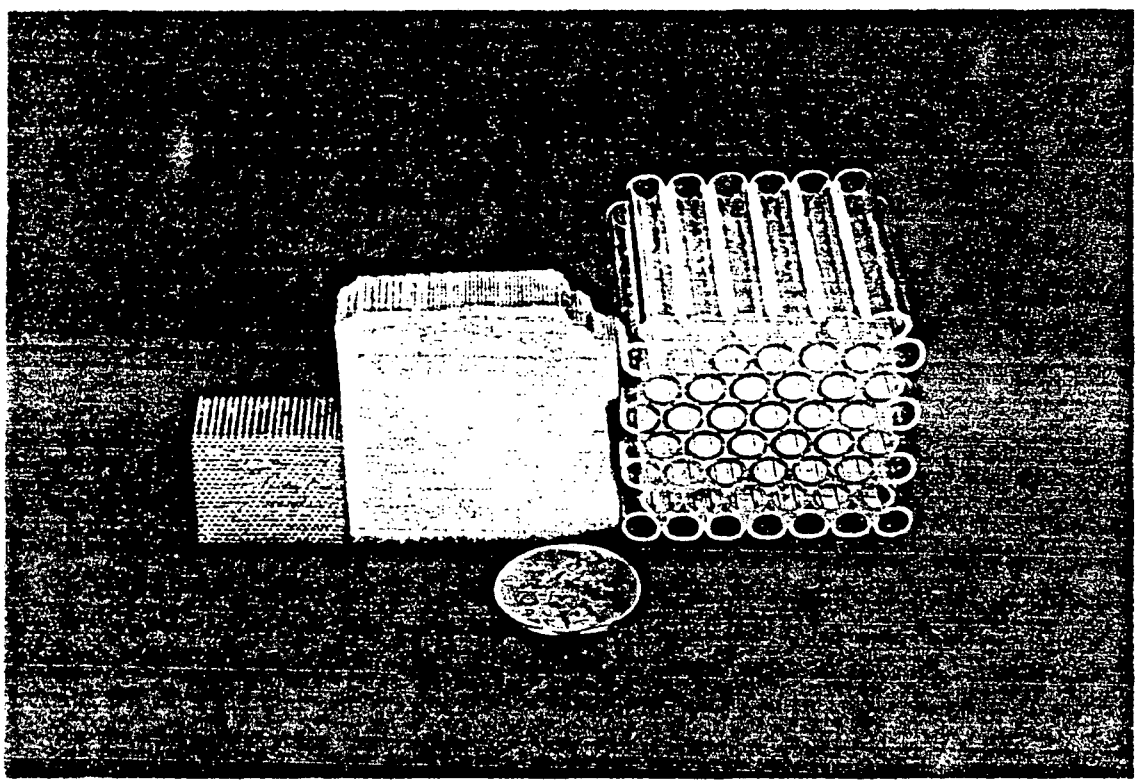


Fig. 4

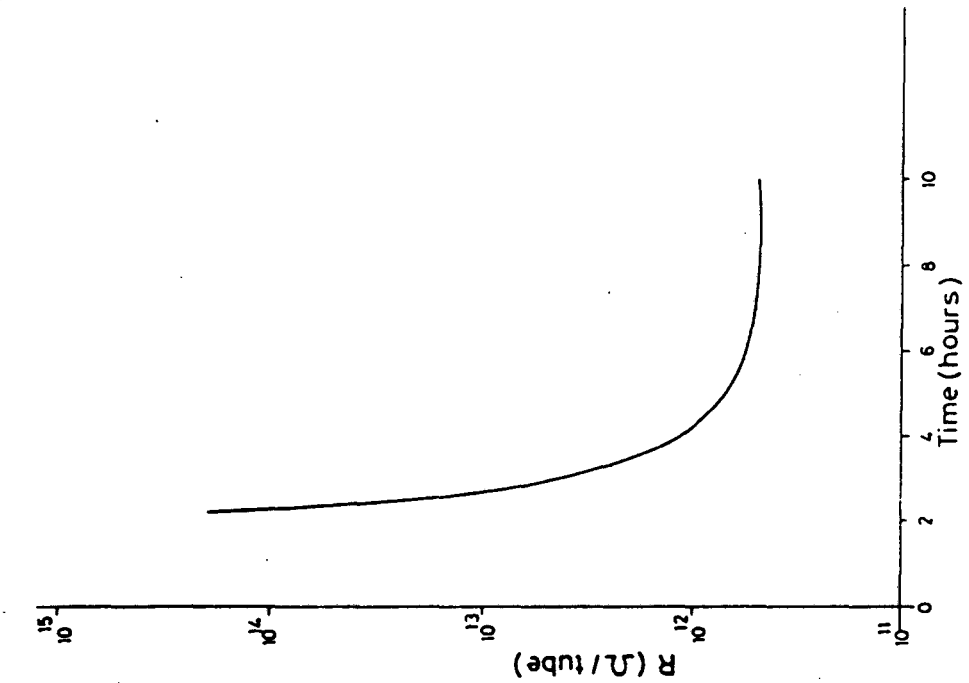

R (Ω / tube)
$10^{15}$
$10^{14}$
$10^{13}$
$10^{12}$
$10^{11}$
0
2
4
6
8
10
Time (hours)

Fig. 6

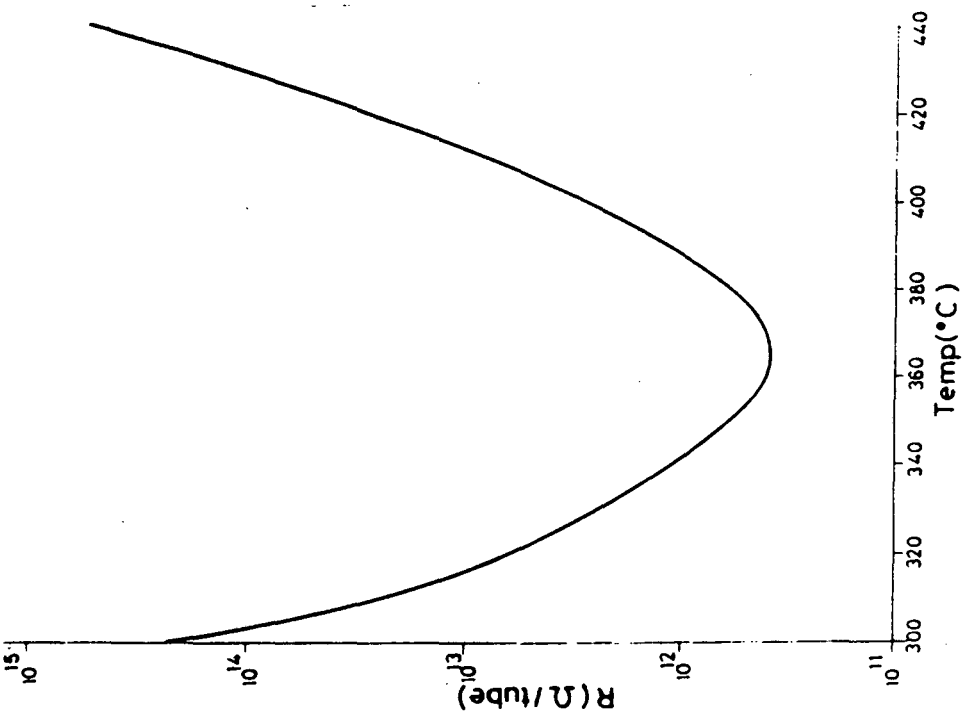

R (Ω / tube)
$10^{15}$
$10^{14}$
$10^{13}$
$10^{12}$
$10^{11}$
300
320
340
360
380
400
420
440
Temp(°C)

Fig. 5

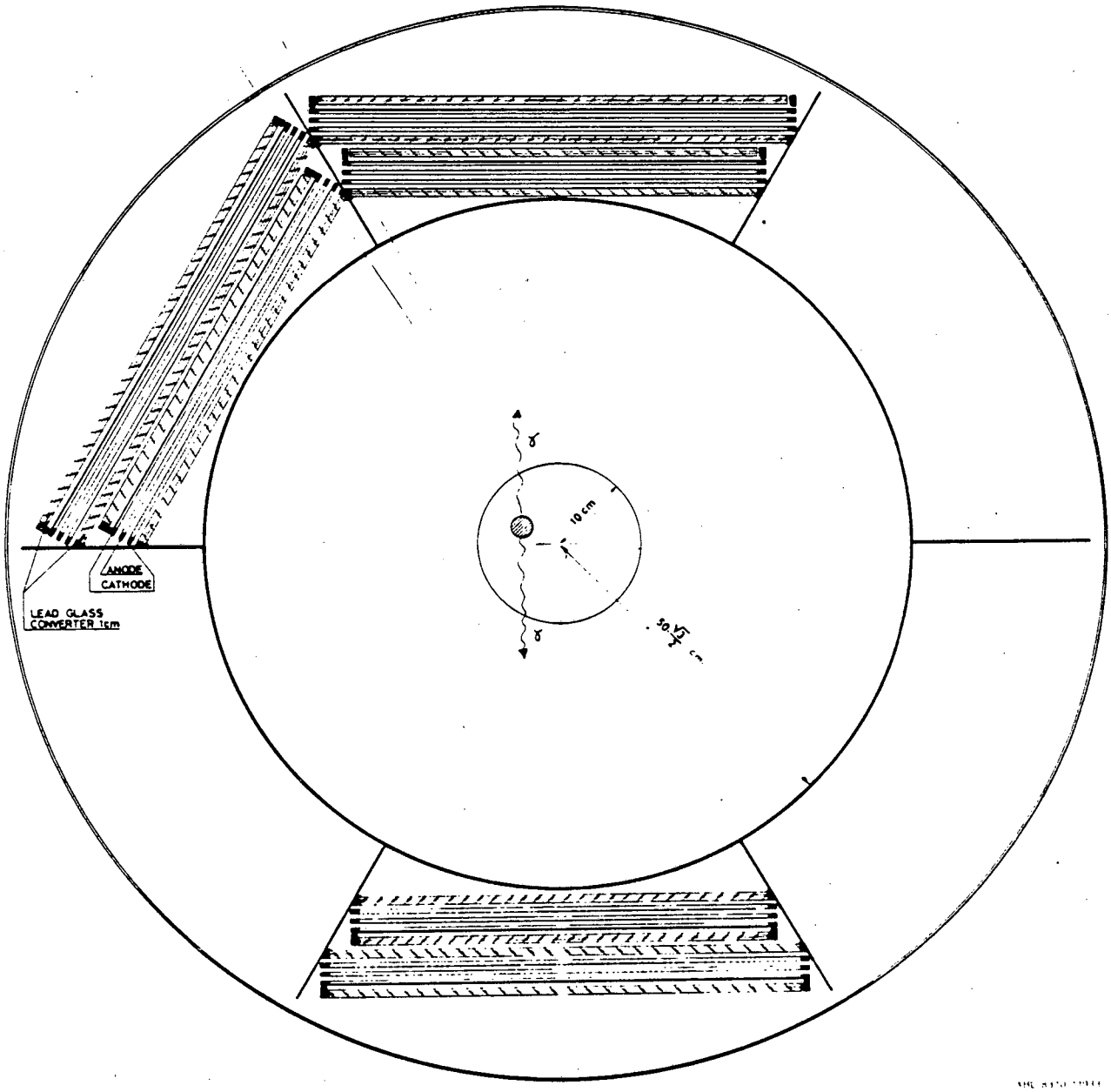



Fig. 7

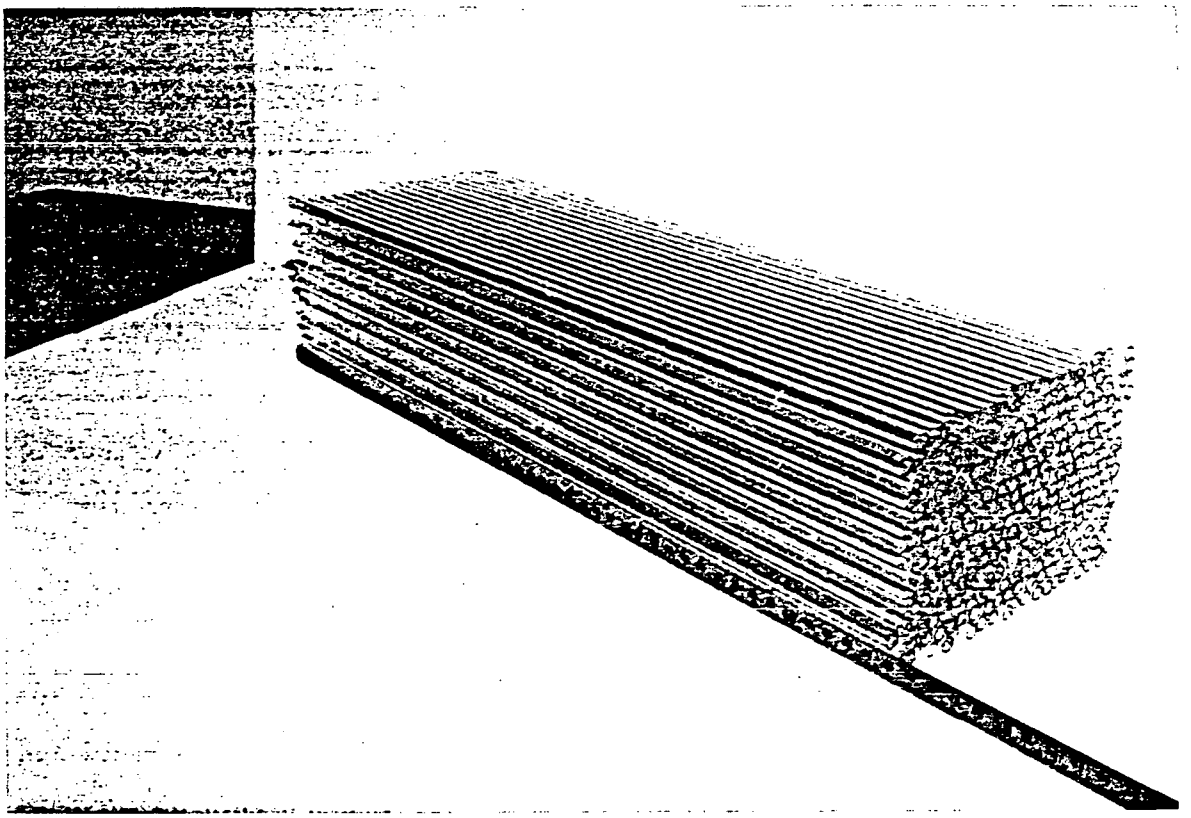


Fig. 8

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