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AN IMPROVED KANNE TRITIUM MONITORING SYSTEM

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ABSTRACT

A Kanne chamber has been redesigned to reduce its sensitivity to such contaminants as tritium water vapor and tritiated oil. The high voltage electrode has been replaced by a wire cylinder and the collection electrode has been reduced in diameter. The sensitivity to contamination of the chamber has been reduced by about a factor of 40. The design allows for decontamination of the chamber in place. The improved electronics used is also discussed.

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Introduction

The Kanne chamber has been used for over two decades to monitor radioactive gases. The advantage of this chamber is the high sensitivity due to its large active volume. A conventional 51.5 liter Kanne chamber, as described by Hoy,[1] is shown in Fig. 1. It consists of three concentric cylinders, with the inner and outer cylinders at ground potential while the intermediate cylinder is operated at about 200 V. The region between the outer and intermediate cylinder serves as an ion trap. The inner region (shown dotted) is the ion chamber, with the inner cylinder acting as the collector electrode.

Under normal operating conditions, using filtered air, contamination is not a major problem. However, when exposed to high concentrations of some radioactive gases such as HTO, or contamination with tritiated oil, there tends to be a buildup of activity which greatly reduces the sensitivity of the chamber at low tritium concentrations. This residual activity can often be removed by several hours of air purging. Heat has been successfully used for decontamination and so has disassembly and cleaning. Occasionally, chambers must be permanently removed from service due to contamination.

The standard techniques for measuring the signal from the Kanne chamber have changed little in the last 20 years. The current is typically measured with an electrometer with a logarithmic scale to cover the current range of 10^{-13} to 10^{-7} A. A strip chart recorder with a six decade range is used to record the output. In order to determine the amount of tritium that has passed through the chamber, the area under the logarithmic trace must be integrated by hand. This can be very time-consuming and introduces inaccuracies, particularly when a great excursion (spike) is experienced. Another drawback of this system is that there is no means of zeroing the electrometer to subtract a constant background.

Under ideal conditions, concentrations of 5×10^{-6} $\mu Ci/cm^3$ can be measured[1] with this system. This is the occupational concentration guide (CG) limit of tritium water vapor in air in the U.S.A.[2]

In order to improve the sensitivity of the Kanne chamber to tritium and to improve the ease of determining the total amount of tritium passing through the system, we have redesigned both the chamber and the electronics.

Chamber Design

In order to reduce the problem of contamination and improve the ability to decontaminate our chamber, we designed the improved Kanne chamber shown in Fig. 2. The objective was to reduce the sensitive area, that is, the surface area whose contamination will contribute to the background of the chamber. The high voltage cylinder of the conventional Kanne was replaced by a wire cylinder 78.7 cm long and 30.5 cm in diameter, made of forty-five 0.2 mm diameter nichrome wires running parallel to the center electrode. The wires are spaced every 10.7 mm. The conventional 76 mm diameter central collector electrode was replaced with a 6.4 mm diameter aluminum rod with a sensitive length of 77.2 cm. Figure 3 shows a detail drawing of the intake end of this chamber. The wires are stretched between ninety ceramic pieces on two inner support rings. These rings are connected to outer support rings by six short rods. The outer support rings are themselves supported by eight connecting rods fastened to the exhaust end of the chamber. All rings and rods are held at ground potential. A photograph of the high voltage assembly and center electrode is shown in Fig. 4.

The maximum energy of a tritium beta is 18 keV with a mean energy of 5.6 keV. Thus, the betas have a maximum range in air of about 7 mm under standard conditions, with the mean range a little over 1 mm. At Los Alamos, New Mexico, U.S.A., where the pressure is only about 70% of an atmosphere, the maximum range is about 10 mm. For this reason, all surfaces outside of the high voltage cylinder (i.e., connecting rods and chamber wall) are greater than 1 cm from the wires. Since the support rings are grounded, the majority, if not all, of the ionization due to their contamination will terminate in the ring. Thus, this contamination will not contribute to the signal. The supported end of the collector electrode is shielded to prevent detection of contamination from the support rings or the chamber end. The sensitive

area of the improved Kanne is less than 266 cm^2 while the sensitive area of a conventional Kanne chamber is about 1.1×10^4 cm^2. This is a reduction in sensitive area by a factor of 40.

This new design greatly improves the ability of the chamber to be decontaminated, if need be. The high voltage wires can be decontaminated in place by passing a heating current through them. The center electrode is mounted by four external screws and can be easily removed. This electrode can be either replaced or decontaminated with a mild caustic solution. Decontamination can be accomplished in a few minutes without removal of the chamber from the system.

Since this design does not include an internal deionizer, an external deionizer is provided. It consists of 0.8 mm thick stainless steel plates (20) spaced at 3.2 mm centers. Alternate plates are connected to the same high voltage supply as the Kanne chamber, with the remaining plates at ground potential. An external HEPA filter is used to remove dust and oil.

Electrometer Design

A new electrometer, called the Model 39 Electrometer-Chargemeter, is shown in Fig. 5. It has been designed to measure currents as low as 1 fA (10^{-15}A), and to integrate these currents for a measure of accumulated charge. The instrument is intended to be used with ionization transducers having grounded collecting electrode configurations. This instrument is not only useful with Kanne chambers but with tritium monitors having much smaller detection volumes.

The electrometer has 4 decades of range, with a switch to select the current ranges of interest. Logarithmic and linear display of current is furnished in analog format. In the most sensitive configuration, the range is 1 pA (10^{-12}A) full scale, with 0.1 fA (10^{-16}A) detectability. The chargemeter readout is a digital display that covers 10 decades from 10^{-12} C/digit to 10^{-2} C full scale. Readout is with 3 decades of digital indicators and exponent multipliers. Range of charge readout selection is either manual with a selector switch or auto-ranging whereby the 3 most significant digits with non-zero information are displayed along with the exponential multiplier. Both analog and digital data are presented to output connectors for use in data acquisition systems.

The electrometer operational amplifier and its associated high-megohm resistors are housed in a separate temperature-controlled oven, shown on the left in Fig. 5. Input is through a coaxial connector. This configuration allows the shortest distance from the collector of the tritium chamber to the amplifier. There is insignificant variation in gain or instrument zero with changes in ambient temperature. The power and control lines for this assembly are carried in a multiconductor cable, with the output signal on a separate coaxial connector. The circuit design allows a steady-state background of an instrument to be suppressed. Thus, the constant background due to contamination will not contribute to the integrated charge measured by the instrument.

Performance

To calibrate this tritium monitoring system, the improved Kanne was placed in series with a conventional 51.6 liter Kanne chamber in an operating environment. The air passes through the improved chamber before entering the latter. The calibration for the improved chamber was found to be 1.8×10^{7} $\mu Ci/cm^3$ per amp compared to 2×10^{7} $\mu Ci/cm^3$ per amp for the conventional chamber. This implies an effective volume of 56.6 liters for the improved chamber.

The air system in which the two chambers operated was very contaminating. The background of the conventional chamber varied from about 1.4×10^{-12}A to 2.8×10^{-12}A after use for about one month on the system. This corresponds to a background of 2.8×10^{-5} to 5.6×10^{-5} $\mu Ci/cm^3$. When the improved Kanne was introduced, the background in the conventional chamber averaged about 2×10^{-12}A but with less variation. This is probably due to the better filtering of the first chamber. Upon installation of the new tritium monitor, the electrometer was zeroed. After 16 weeks of constant use, the zero still did not require adjustment. With this system, steady-state concentrations of about 1×10^{-7} $\mu Ci/cm^3$ (about 5×10^{-15}A) should be measurable, even under the contaminating environment of the test situation. It was found that when measuring concentrations on the order of 10^{-3} $\mu Ci/cm^3$, the new chamber read slightly lower (~2%) than the conventional Kanne. This is undoubtedly due to the smaller collecting electrode which allows more recombination at high concentrations.

Conclusion

The improved Kanne tritium monitoring system described above should greatly improve the monitoring capability of low concentrations of tritium, particularly in contaminating environments. With the improved electronics, the volume of the monitor can be greatly reduced, while maintaining high sensitivity. Concentrations of 10^{-6} $\mu Ci/cm^3$ may be measured with a 1-liter chamber in a short period of time. The reduction of sensitive surface area is also adaptable to smaller chambers. These smaller instruments will have much faster response time and much less bulk, making them more convenient than Kanne systems. Smaller instruments can also be designed which, besides being less susceptable to contamination, will also be linear over a very large dynamic range. The improved electronics and the idea of reduction of sensitive area opens the avenue to much improved tritium monitoring.

References

1. Hoy, J. E., Health Physics 6 (1961) 203

2. U. S. D. O. E. Manual Chapter #0524, Standards for Radiation Protection, April, 1977

Figure Captions

Figure 1 - Conventional 51.6 liter Kanne Chamber

Figure 2 - Improved Kanne Chamber

Figure 3 - Detail of the Improved Kanne Chamber

Figure 4 - Photograph of High Voltage Assembly and Center Electrode

Figure 5 - Model 39 Electrometer-Chargemeter. The temperature-controlled oven containing the amplifier is on the left.

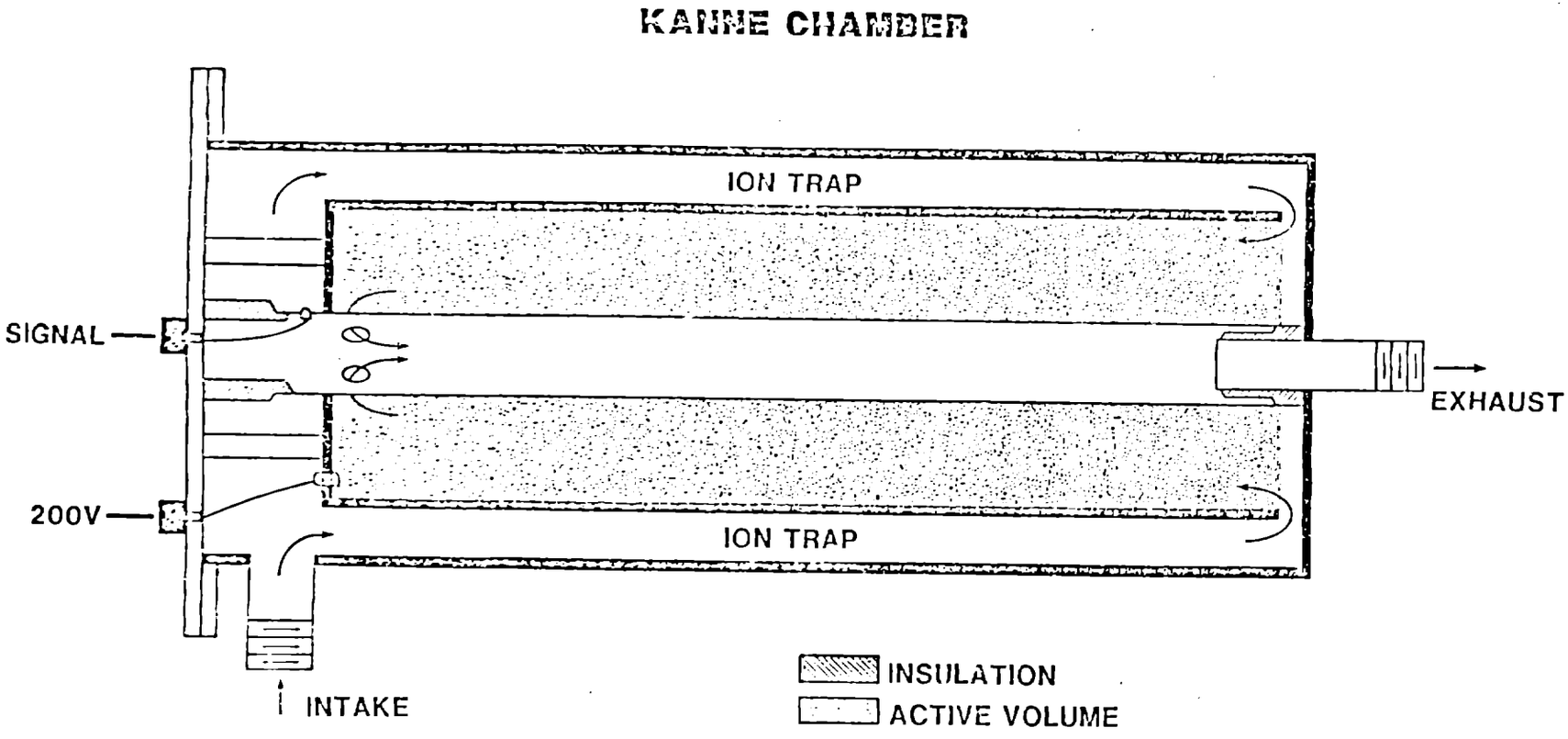
KANNE CHAMBER
ION TRAP
SIGNAL
EXHAUST
200V
ION TRAP
INTAKE
INSULATION
ACTIVE VOLUME

FIGURE 1

IMPROVED KANNE CHAMBER

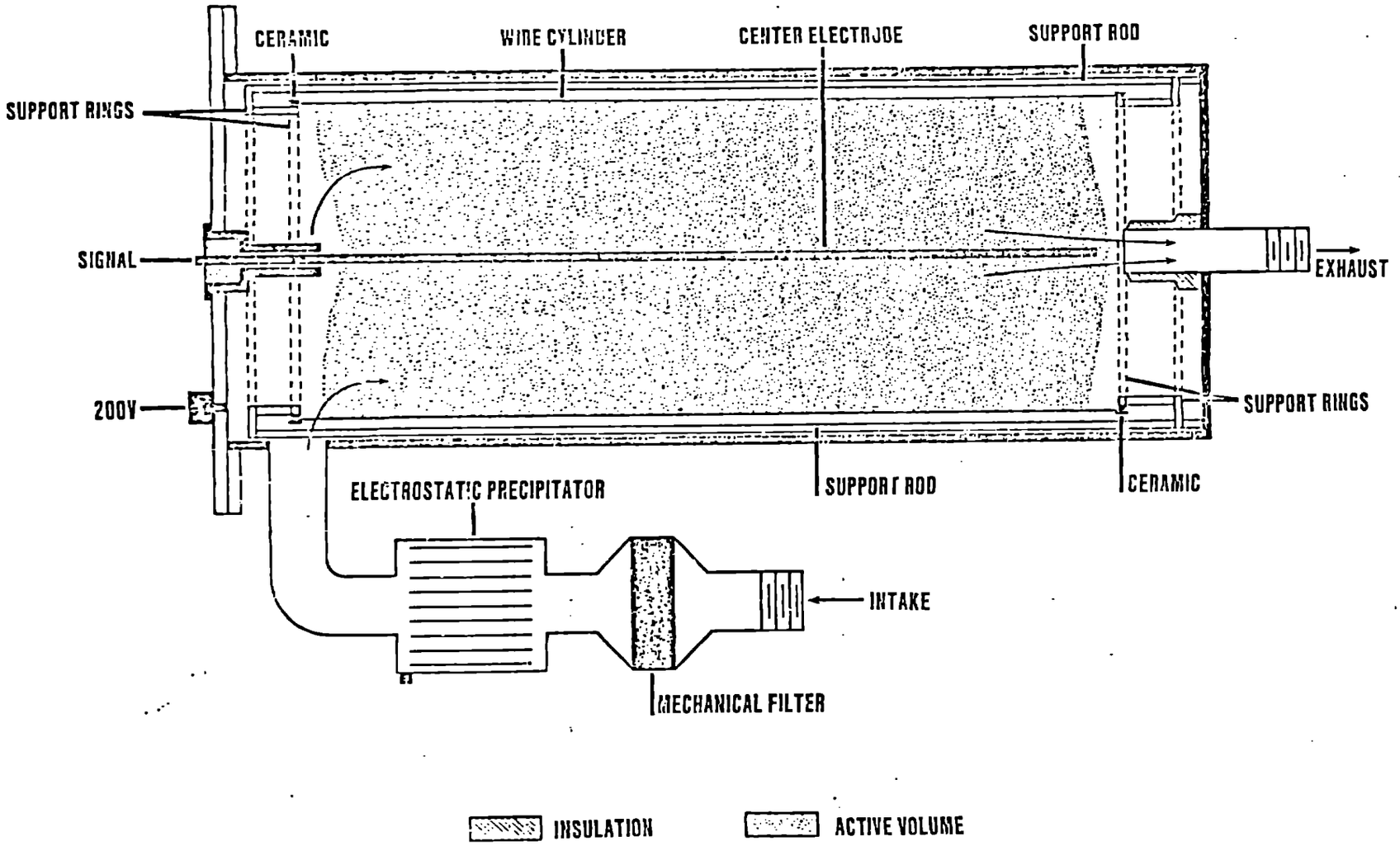

FIGURE 2

DETAIL OF IMPROVED KANNE CHAMBER

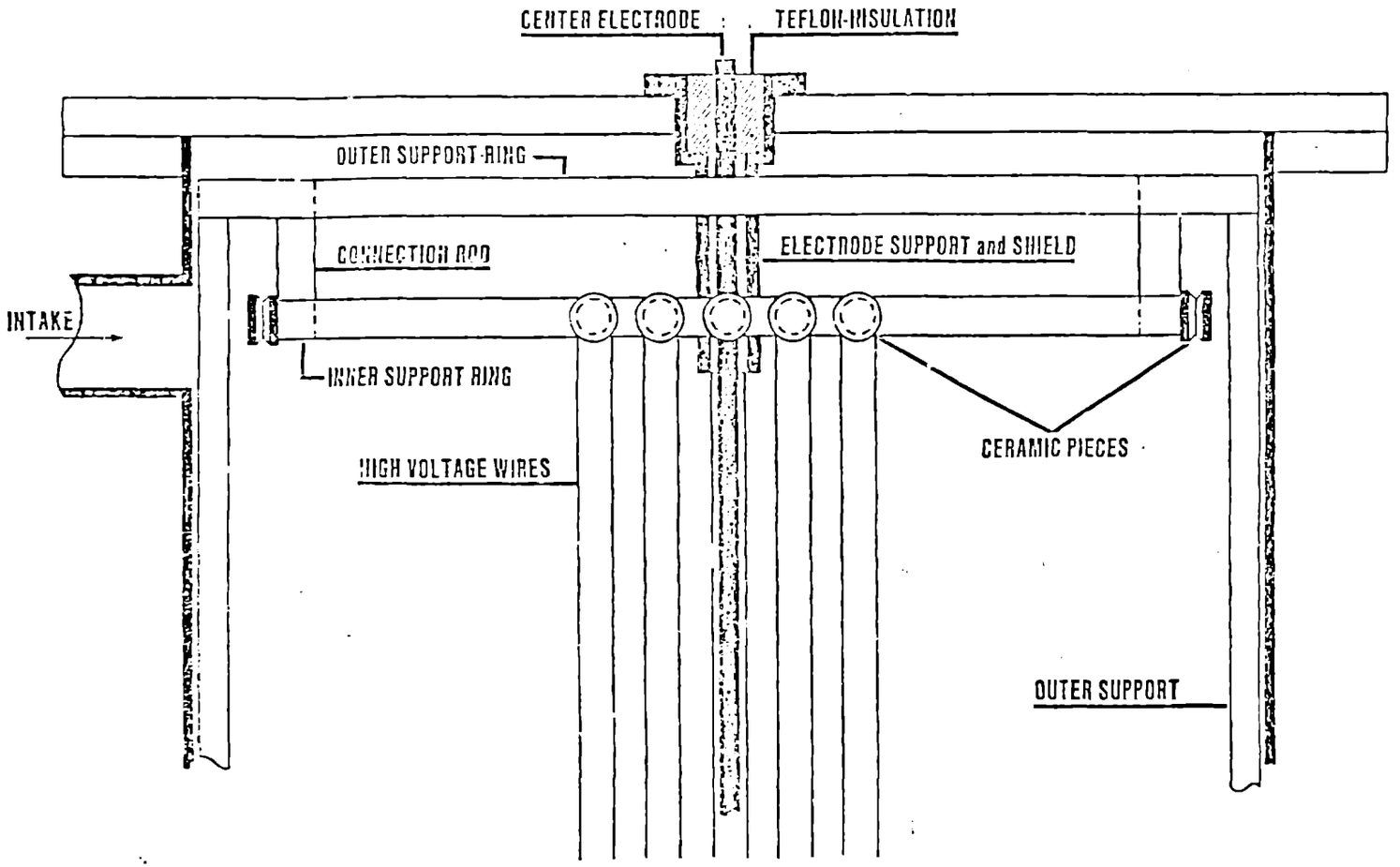

FIGURE 3

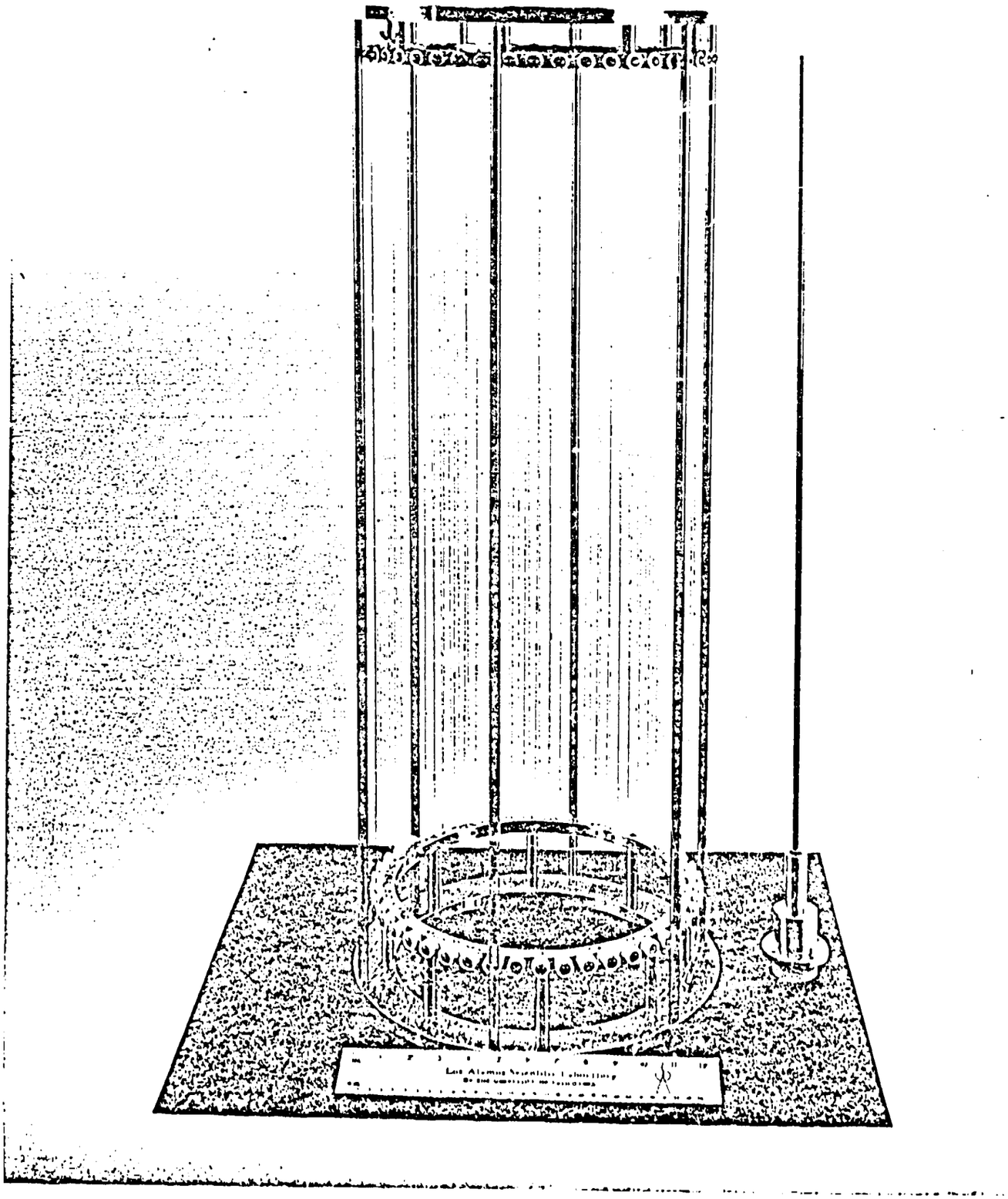

FIGURE 4