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SPIRAL FISSION CHAMBERS

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ABSTRACT

Neutron detectors utilizing thin metal foils coated with fissionable material are described. Foils are wound into concentric spirals to eliminate supporting plates and bulky insulation. The chambers are characterized by large useful electrode areas in small volume and by very light construction. A method is described for coating large areas of aluminum or platinum foil with heavy deposits of U_3O_8.

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SPIRAL FISSION CHAMBERS

INTRODUCTION

O.R. Frisch conceived the idea that compact and sensitive neutron detectors employing fissionable substances could be constructed by winding two strips of coated foil into concentric spirals; he communicated this idea to group R-3. An urgent need for such detectors prompted the development of the spiral-type chamber.

The intense ionization produced by a fission fragment, especially at the beginning of its path, permits chamber construction employing closely spaced electrodes. Spiral construction of the chamber favors close spacing and is, mechanically, a very simple method of enclosing large electrode areas within a small volume. A further advantage of this construction is that the curvature of the electrode imparts good mechanical rigidity even to foils of 0.001" or 0.002" thickness. Thus microphonic disturbances are minimized although the mass and volume of a chamber of specified sensitivity are very materially reduced.

PREPARATION OF SPIRALS

Spirals have been wound by two methods. The first, illustrated in Figs. 1 and 2, makes use of a strip of material for spacing the foils as they are wound. Ordinary sewing thread of the desired diameter is wound on a straight, stiff metal bar somewhat longer than one of the foils. The turns are wound tightly together until the width of the winding is slightly less than the width of a foil. A dilute solution of Amphenol 912 Cement and thinner or benzene (about 1 to 5), or of rubber cement and benzene (1 to 10), is now painted on the threads. After drying, the threads are cut at one end of the bar and are removed from it as a strip twice the length of the bar. In either solution the concentration of cement should be as small as will produce a coherent strip.

The winding form in Fig. 1 is a piece of ¼" metal tubing with a narrow, smooth-edged longitudinal slot a little deeper than the width of a foil. A flat-faced cylinder 1" in diameter and drilled with a ½" hole is pushed into the tube to provide a guide surface to prevent the foils from wandering axially as they are wound. The foil ends, provided with wire leads soldered across the ends, are inserted into the slot and are bent over against the inside of the tube as shown in Fig. 2. The middle of the thread strip is inserted into the slot and the spiral is formed by winding, under tension, half a turn at a time, foil and thread alternately. The fingers are used to smooth the foil and thread to aid in producing a tight, evenly spaced spiral. When the winding is completed, narrow strips of an adhesive tape may be wound around the spiral to hold it together temporarily.

Final stages in producing a spiral consist of sealing the ends in supporting and insulating material and removing the threads. By means of a force exerted on the guide cylinder, the spiral is pushed partly off the mandrel and about a third of the threads are pulled, one at a time, from the end of the spiral. Wrinkled edges of the foils may be straightened with a scribe.

Sulphur or ordinary red sealing wax provides satisfactory support and insulation for the ends of the spiral. If sulphur is used the lead wires should be platinum or another metal which does not form a conducting sulphide. Otherwise flakes of sulphide may fall from the wires and short the foils. Ordinary flowers of sulphur does not seem to insulate the foils satisfactorily. Better insulating and mechanical properties are obtained by using a mixture of three parts by weight of sulphur flowers and one part of finely powdered aluminum oxide.

A small quantity of this mixture is melted to the viscous stage on a pyrex plate or in some shallow flat-bottomed vessel and is stirred to keep the

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aluminum oxide in suspension. The exposed end of the spiral, still on the mandrel, is carefully lowered into the molten mixture and gently rotated to aid in wetting the entire end of the spiral. Unless care is taken in adjusting the temperature, sulphur in its fluid phase will rise to a considerable height between the foils. Excess sulphur may be removed by judicious application to a heated glass surface. The central hole in the spiral must be reopened if sulphur has covered it. A heated wire may be used in removing sulphur.

Temporary support for the sealed end is provided by applying a narrow strip of adhesive tape around the spiral at this end. The tape previously applied is now gently removed and the remaining threads are pulled from the open end of the spiral as before. Tape should be reapplied to keep the outside ends of the foils in place. The wire leads are now bent back on themselves and are pulled through to the completed end of the spiral so that they will not interfere with the sealing of the remaining end.

If sealing wax is used for insulation care is necessary in sealing the second end of the spiral to avoid softening the wax at the other end.

A set of foils used in one of these spirals is shown in Fig. 6. One of the large spirals in Fig. 3 is ready for dipping while the other is completed and ready for installation in its chamber.

Should the spiral be damaged after completion, the foils may be easily salvaged. Sulphur-insulated spirals may be taken apart by pulling the two foil ends. Those employing sealing wax are placed in acetone or alcohol until the foils may be easily pulled apart. All remaining wax is then removed with clean solvent. After all visible traces of insulating material have been removed, the foils should be baked for a few minutes at about 500° C. They may then be smoothed

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and straightened by placing them between sheets of paper on a flat surface and drawing a smooth cylinder along the foils.

A second method of winding spirals uses only two or three threads in the winding process and these remain in the spiral, serving both to support and insulate the foils. This method is particularly adapted to the winding of very small spirals but may also be used in preparing the larger ones. It requires accuracy in thread spacing and foil alignment which cannot be maintained by hand. Hoogterp has devised a winding machine which is capable of the necessary precision. Fig. 4 shows the entire machine and Fig. 5 is a closeup of the actual winding mechanism in use.

The winding mandrel consists of two lengths of 1/16" steel rods each milled to a semi-circular cross section for about an inch of its length. These are inserted into the bearings of the apparatus so that the milled sections overlap. Threads which have been previously soaked in dilute Amphenol cement and dried are inserted between these sections. Their spacing is determined by the grooved rods in the foreground and background of Fig. 5. The ends of the foils are inserted between and on opposite sides of the threads for a little less than 1/16" of their length. They are carefully aligned and the small cylinders are pushed onto the split section to serve as clamps and as guides for the foils. The free ends of the foils are then placed in the clamps shown at the top and bottom of Fig. 5.

Tension of the foils and threads is provided by weights and must be adjusted to the foil and thread which are used. Too much tension causes the foils to be creased and the threads to wander. Too little tension produces a loose spiral which will come apart when it is removed from the machine.

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In the case illustrated one lead is soldered to the inside end of one foil and one to the outside end of the other.

After the alignment has been completed, the spiral is wound by turning one of the knurled knobs shown in Fig. 4. When about 1" of foil remains unwound, the top clamp is loosened and a strip of .001" Amphenol polystyrene tape slightly wider than the foils and about 3" long is cemented to the last $\frac{1}{4}$" of this foil. Tension on the foil is maintained manually and winding is continued until the bottom clamp must be disconnected. The threads will guide the bottom foil for the last half turn or so. When the end of the top foil has reached the spiral, a sharp razor blade is used to cut the top threads just beyond the end of the top foil. After a further half turn the other threads are similarly cut. With the guide cylinders pushed back, several layers of the Amphenol tape are applied and the end is fastened down with a small drop of Amphenol cement.

The spiral is now completed and is removed from the machine by loosening the set screws which hold the split rods in their bearings and pulling the rods from the spiral. If the spiral is shorted, the trouble will generally be found in the center of the winding. Careful probing in the 1/16" central hole will usually remove the distortion which shorts the foils.

Small spirals produced by this technique are shown in Figs. 3 and 7.

CHAMBER ASSEMBLY

Because of the small foil spacing, the spirals must be placed in an atmosphere of gas under high pressure so that the range of the fission fragments is comparable to the spacing.

Three types of chamber assemblies are illustrated in Fig. 6. The assembly of one of the larger chambers is shown at the top of the picture. Insulation

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for the side of the spiral is provided by wrapping several turns of 0.001" Amphenol tape around it before assembly. The leads are soldered to longer wires which run through glass tubes to the upper end of the chamber where they are brought out through commercial Kovar to glass seals. The long leads are shielded from one another by wrapping the glass tubes in thin metal foil which makes contact to the long connecting tube. The spiral is insulated at top and bottom by mica discs and is wedged into the steel cup with thin mica shims. A butt-soldered fuse-wire gasket is pressed onto the shoulder in the steel cup which is then pushed over the steel disc on the end of the long tube. The threaded washer is screwed into the cup and eight set screws in this washer are turned against the disc, squeezing it against the gasket. A very reliable seal is made.

The next two chambers illustrate the installation of a much smaller spiral. Two such spirals are pictured in Fig. 3. Mechanical assembly is the same as that of the larger chamber. In this assembly, only one of the spiral leads is brought out of the chamber. The other lead makes contact with the steel cup. The long tube is 1/16" Monel tubing. A glass capillary inside of this tube insulates the wire which connects to the spiral. A Kovar-to-glass seal is used for the lead-through and an Amphenol male connector is screwed onto the brass end for a cable connection.

Neutron distribution measurements undertaken by Group R-3 required even more sensitive and compact chambers than those already described. The lower chambers in Fig. 6 illustrate a simple method of chamber construction aimed at increasing the useful volume in a chamber of a given size. The end of the chamber is a flanged disc which is soldered into the thin-walled spiral container. A more practical scheme is demonstrated by the two chambers in Fig. 7. The container is a

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thin-walled brass cup with a close-fitting cap. The parts which overlap are thoroughly tinned with a low-melting-point solder (40 Bi, 40 Sn, 20 Pb; M.P. 111° C. The spiral is installed in the cup with its ends protected by mica discs and the cap is placed over it. As rapidly as possible, a fairly cool soldering iron is applied to the tinned top of the cap, the cap pressed down, and the whole chamber cooled by a rag saturated with water or alcohol.

FILLING

A completed chamber is connected to the filling system at the valve which is provided and is evacuated. The entire chamber is baked until evolution of vapors is negligible. The temperature of the spiral end of the chamber will be limited, of course, by the melting or softening temperatures of the insulating material of the spiral or by the solder used in sealing the chamber. Argon of commercial purity is admitted to the chamber through a cold trap of dry ice and acetone. The larger chambers are filled to gauge pressures of 80 to 150 lbs/in^2 while the smaller ones, employing closer foil spacing, are filled to 150 to 300 lbs/in^2.

The chambers are capable of rapid counting without special precautions regarding out-gassing and filling. Tests indicate that the time of rise of a pulse is less than 0.2 microsecond.

OPERATION

Spiral chambers must be operated with lower electrode potentials than are usual for most ionization chambers. A spiral will usually become noisy because of erratic leakage currents through or across the insulating material before the potential reaches a value which may permanently damage the thin layer of insulation between the foils. A collecting potential of 135 volts has proved satisfactory for all spirals tested regardless of foil spacing.

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Chambers with both foil leads insulated from the case are connected directly to the amplifier. The grid of the first stage is grounded through a resistance of about 0.1 megohm. The chamber case and one side of the chamber battery are grounded directly. Foil leads are connected to the high side of the battery and to the grid.

If one foil of the spiral is grounded inside of the chamber, condenser coupling to the amplifier is employed. The insulated spiral lead is connected through a resistor to the battery and also, through a condenser, to the first stage grid. Both grid leak and chamber resistor may be 0.25 megohm and the coupling capacity may be from 100 to 500 mmf.

It is important that the battery and battery cable, as well as the chamber connections, be well shielded and that grounding of all shielding be done at one point.

CHARACTERISTICS

Most of the spiral chambers which have been used do not permit recording of all fissions which occur. It is evident that fission fragments originating deep in a thick oxide layer may not emerge from the layer at all or may not produce as much ionization in the gas as an alpha particle which gives its full energy to the gas. Thus, bias on the recording circuit must be high enough to prevent appreciable background due to alpha particles and the counting efficiency depends partially on the background which may be tolerated.

The relatively large capacitances of spiral chambers also tend to limit counting efficiency. With chamber capacitance as large as 500 mmf, the voltage pulse produced by a fission fragment may no longer be considered large as compared to inherent amplifier noise and the effective ratio between fission and alpha pulse sizes is further reduced.

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All chambers which have been used show counting efficiencies of at least 80 to 90% with biases which permit not more than one or two background counts per minute. Two chambers, with foils coated to 0.25 mg of U_3O_8 per square centimeter and with the entire coated area usefully exposed, have shown narrow "plateaus", indicating nearly 100% efficiency.

SENSITIVITY

The gasket-sealing chambers contain, within a cylinder one inch in diameter and one inch long, usefully exposed foil areas of over 200 cm^2 and up to 240 mg of useful uranium. Solder-sealed chambers of similar size contain useful areas up to 360 cm^2 and as much as 550 mg of useful active material. Foil spacing in these chambers is about 0.020" provided by strips of number 10 sewing thread. The small solder-sealing chambers (Fig. 7) are 0.375 inches in diameter and 0.300 inches long. Useful area in the spiral is about 22 cm^2 and up to 35 mg of uranium are counted.

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APPENDIX

PREPARATION OF COATED FOILS

When development of spiral chambers was begun, foils coated with fissionable materials were prepared, in this laboratory, chiefly by an electroplating process which was used only for limited foil areas and relatively thin (0.2 to 0.4 mg/cm^2) deposits. T. Jorgensen had previously produced thin, uniform coats of uranium oxide by another process (LA-56). Further development of the process described in this report has made it possible to produce dense layers of U_3O_8 of almost any desired thickness on thin foils of platinum or aluminum. One foil of 0.002" aluminum, 50 cm x 10 cm, was coated with 2.8 mg/cm^2 of uranium oxide on each side by this method.

Uranyl nitrate is dissolved in the minimum quantity of alcohol necessary for its solution. A solution of 1 or 2% of Zapon lacquer in Zapon thinner is prepared and added to the first solution until the concentration of uranyl nitrate is about 50 mg/cc. The nitrate concentration may be much lower, but the value mentioned should not be greatly exceeded.

This solution is applied to the foil, in a thin layer, by means of a soft brush. The brush should not again touch any portion of the foil from which the solvent has evaporated. The foil is then baked for three or four minutes at about 550° C to burn off the Zapon lacquer and to convert the uranyl nitrate to U_3O_8. If platinum foil is used the baking temperature may be 800 or 900° C. The higher temperature will result in more nearly complete elimination of Zapon and quantitative conversion of uranyl nitrate to U_3O_8.

When the foil has cooled, it is rolled flat between sheets of paper and the coated side is rubbed smooth with a soft tissue. Initially, the coated sur-

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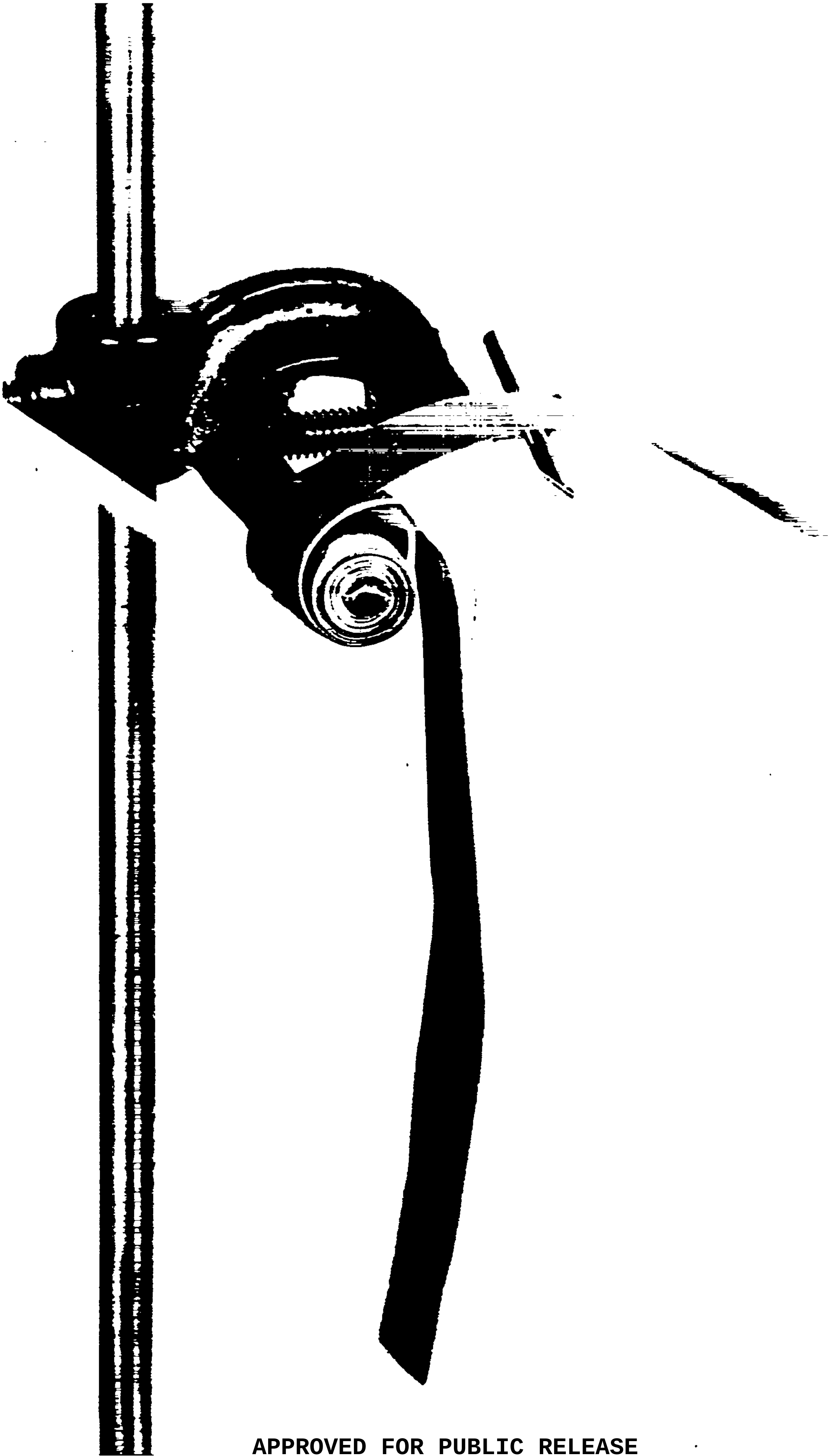
face will exert considerable frictional drag on the tissue but this rapidly diminishes, without apparent removal of oxide, and a smooth, lustrous surface is produced.

A single layer of U_3O_8 applied by this method is, and apparently must be, quite thin. However, the procedure may be repeated until the desired surface density is reached. The coating is very tenacious and will withstand sharp bending of the foil.

If the foil is to be coated on both sides, as for spirals, it is wise to paint alternately on the two sides rather than to complete the coating of one side before beginning the other.

Small areas of foil are conveniently painted, on a flat surface, by hand. Larger areas are more easily handled if the foil is wrapped around an aluminum drum which is rotated against the brush.

Aluminum foil, which has been used in most of the spirals, is prepared for coating by lightly etching the surfaces in a dilute sodium hydroxide solution. It is carefully cleaned with water and alcohol and thoroughly dried before painting is begun.



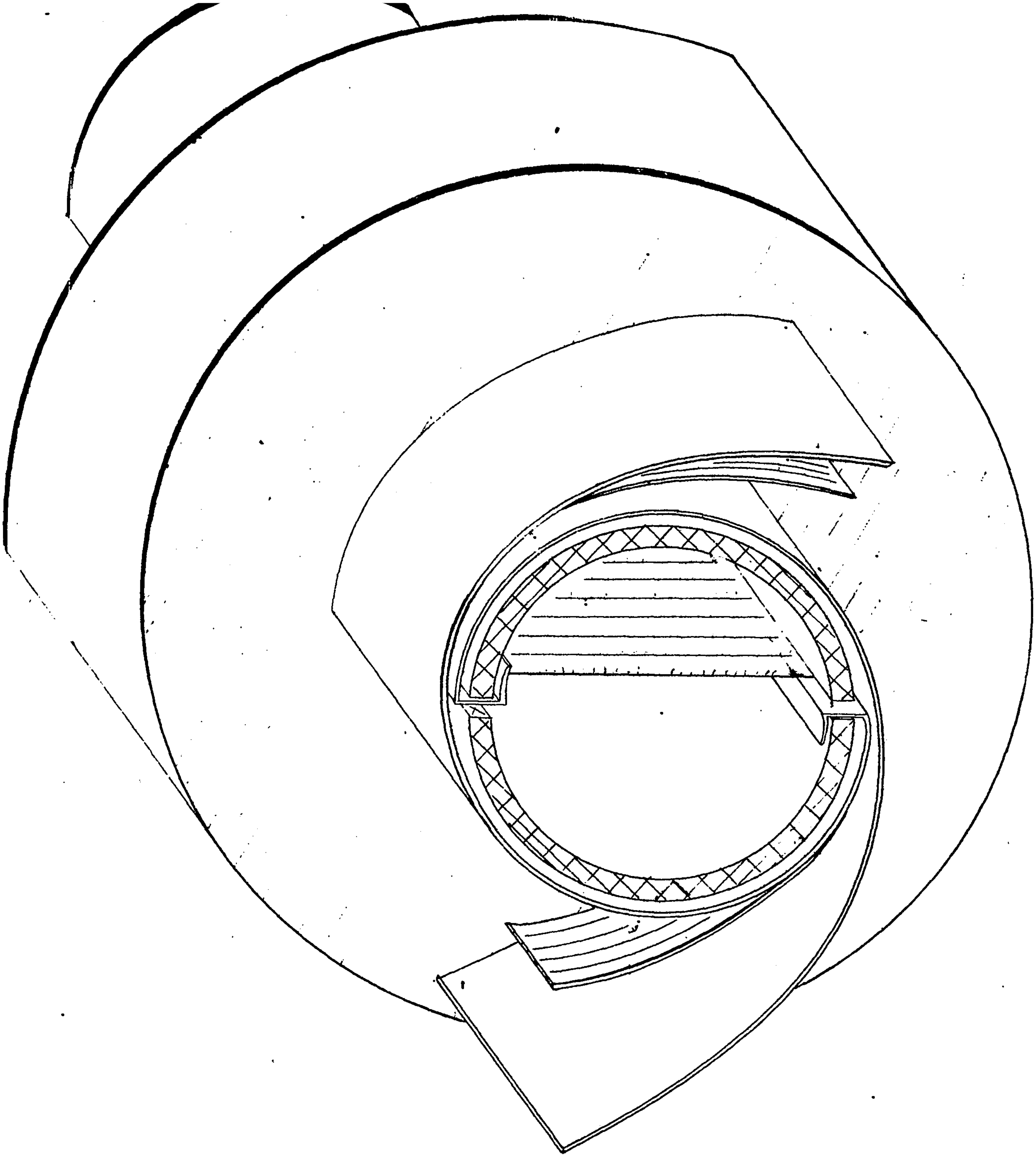
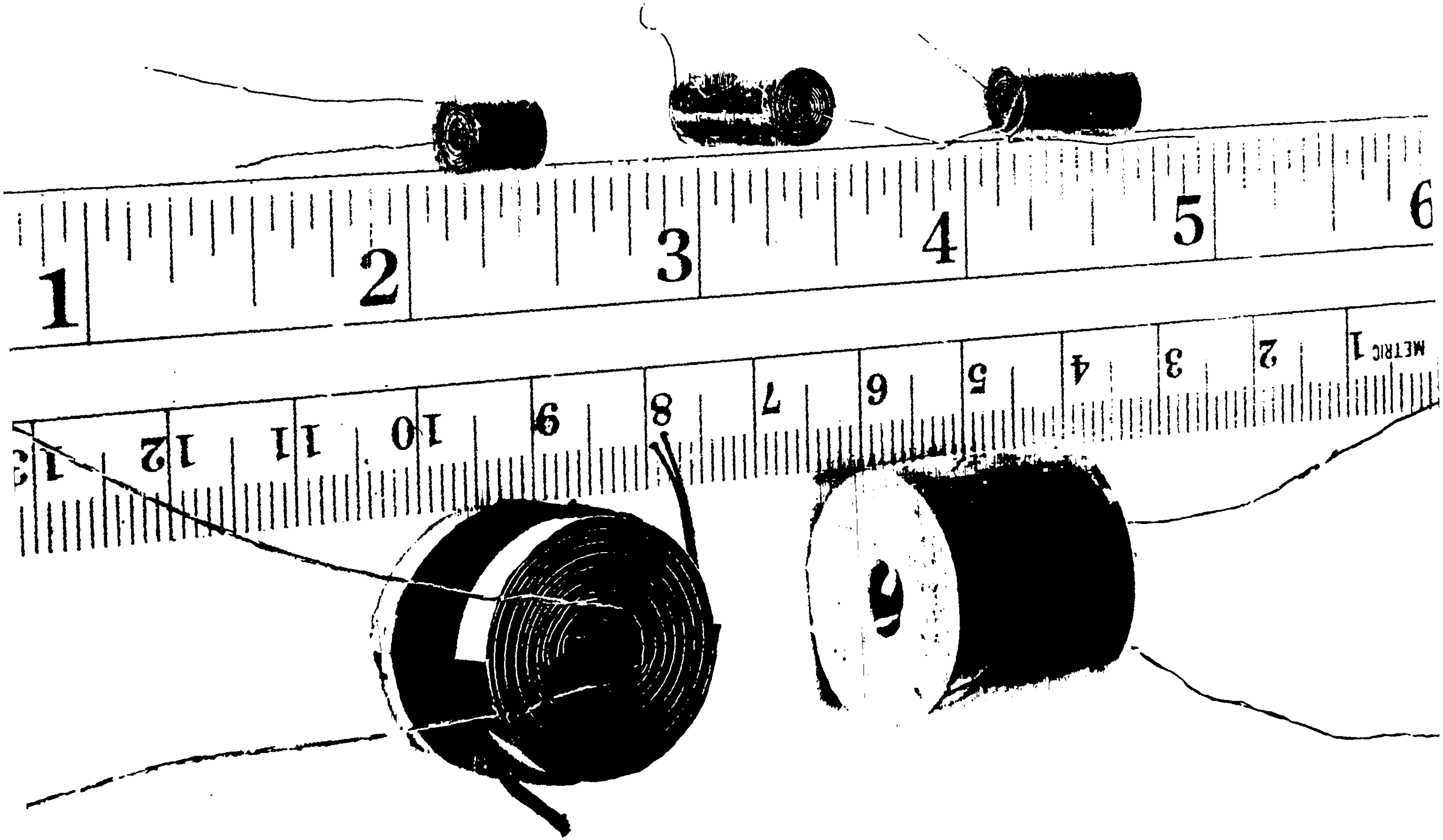


FIG. 2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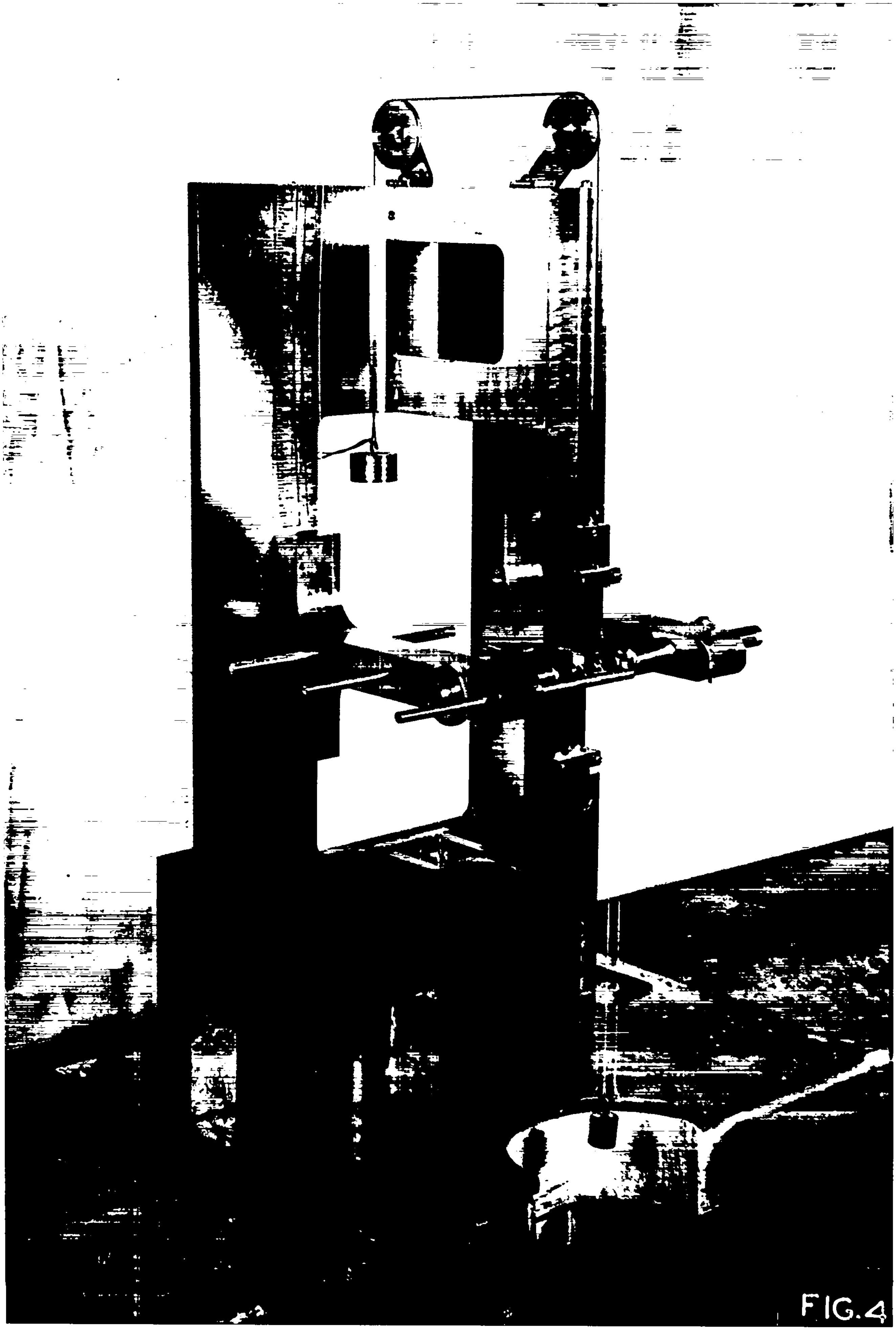


FIG. 4

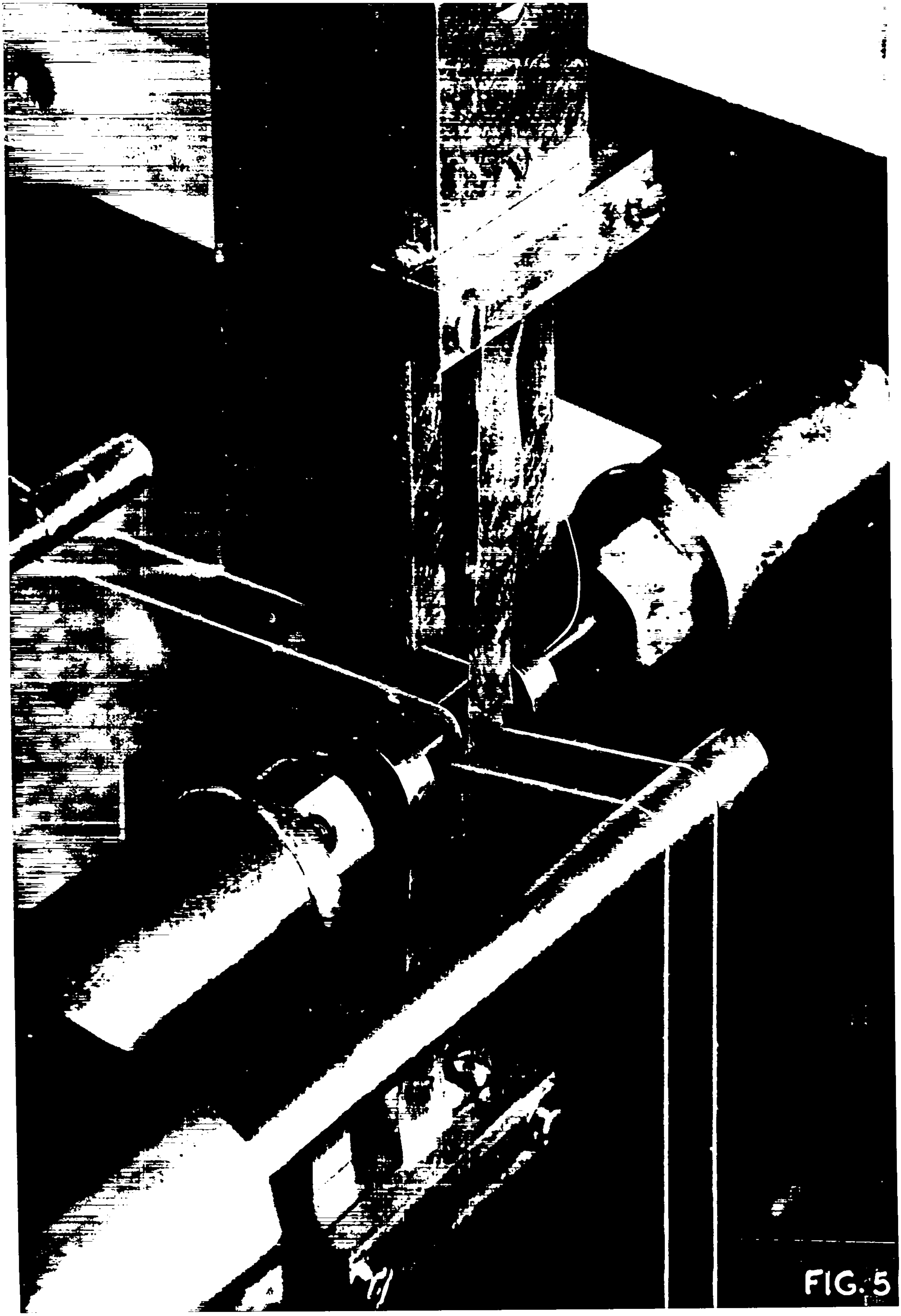


FIG. 5

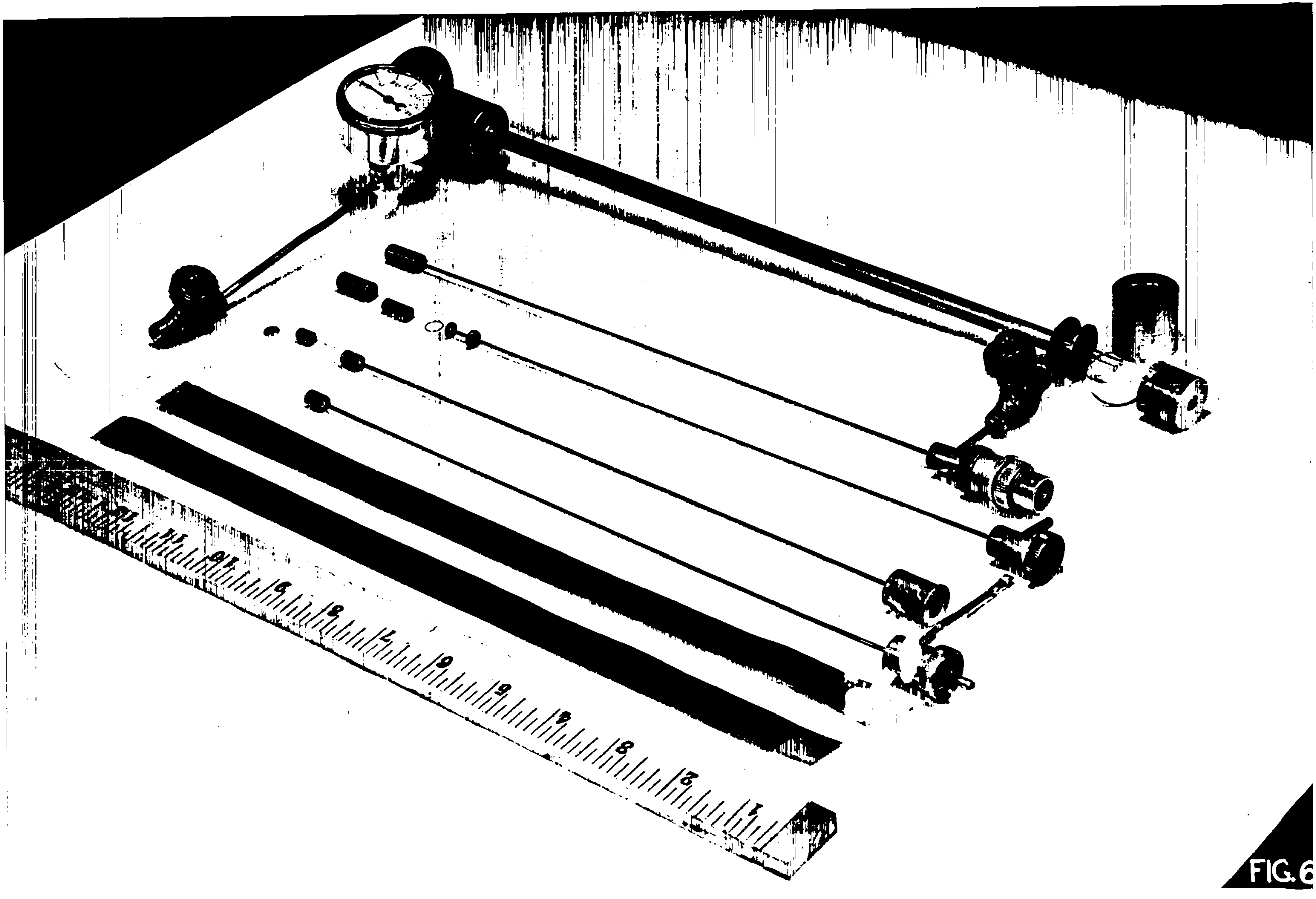
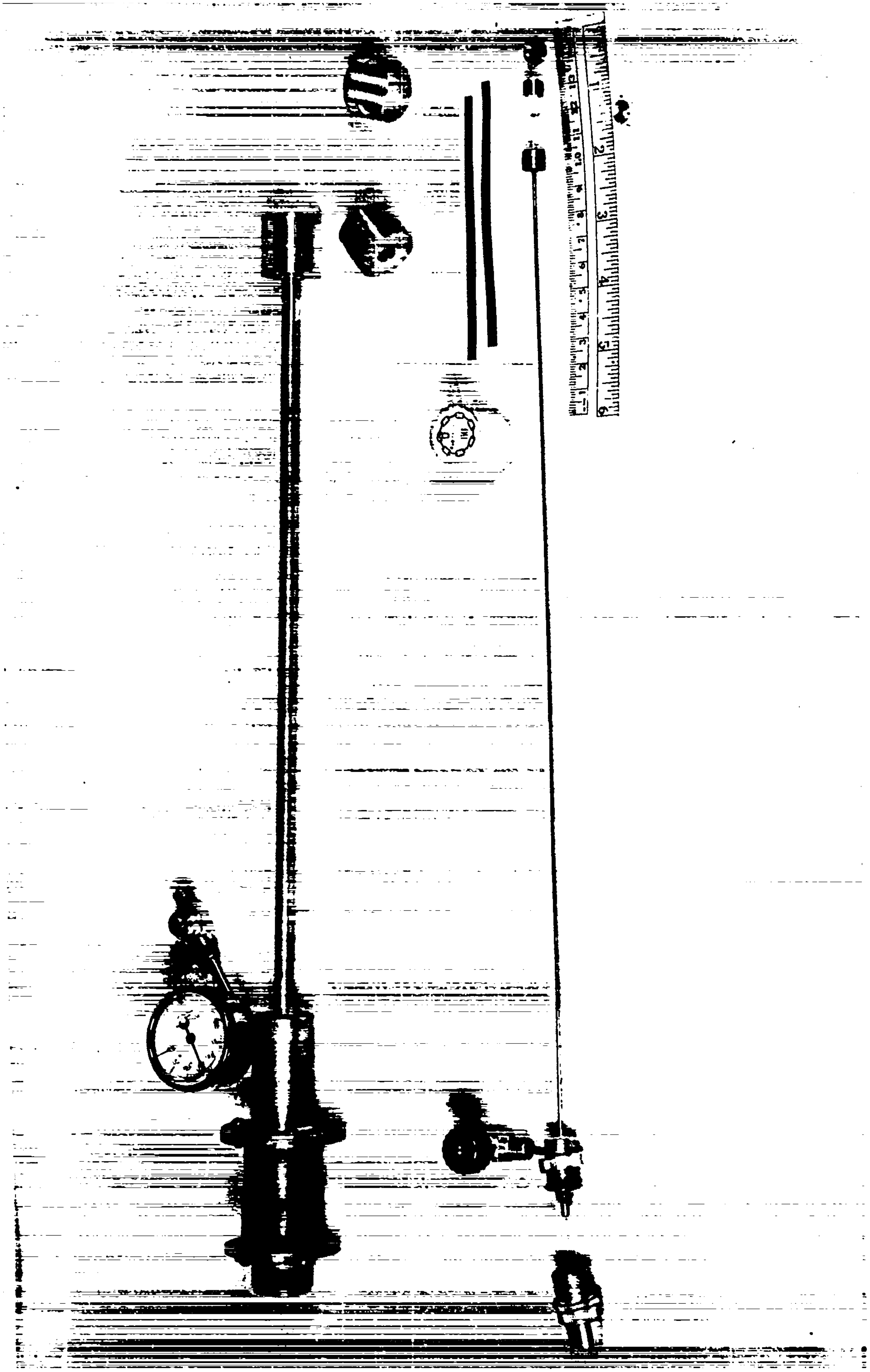


FIG. 6



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