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2,889,464

SHIELDING MANIPULATOR FOR RADIO-ACTIVE MATERIAL

Filed Aug. 23, 1954

4 Sheets-Sheet 1

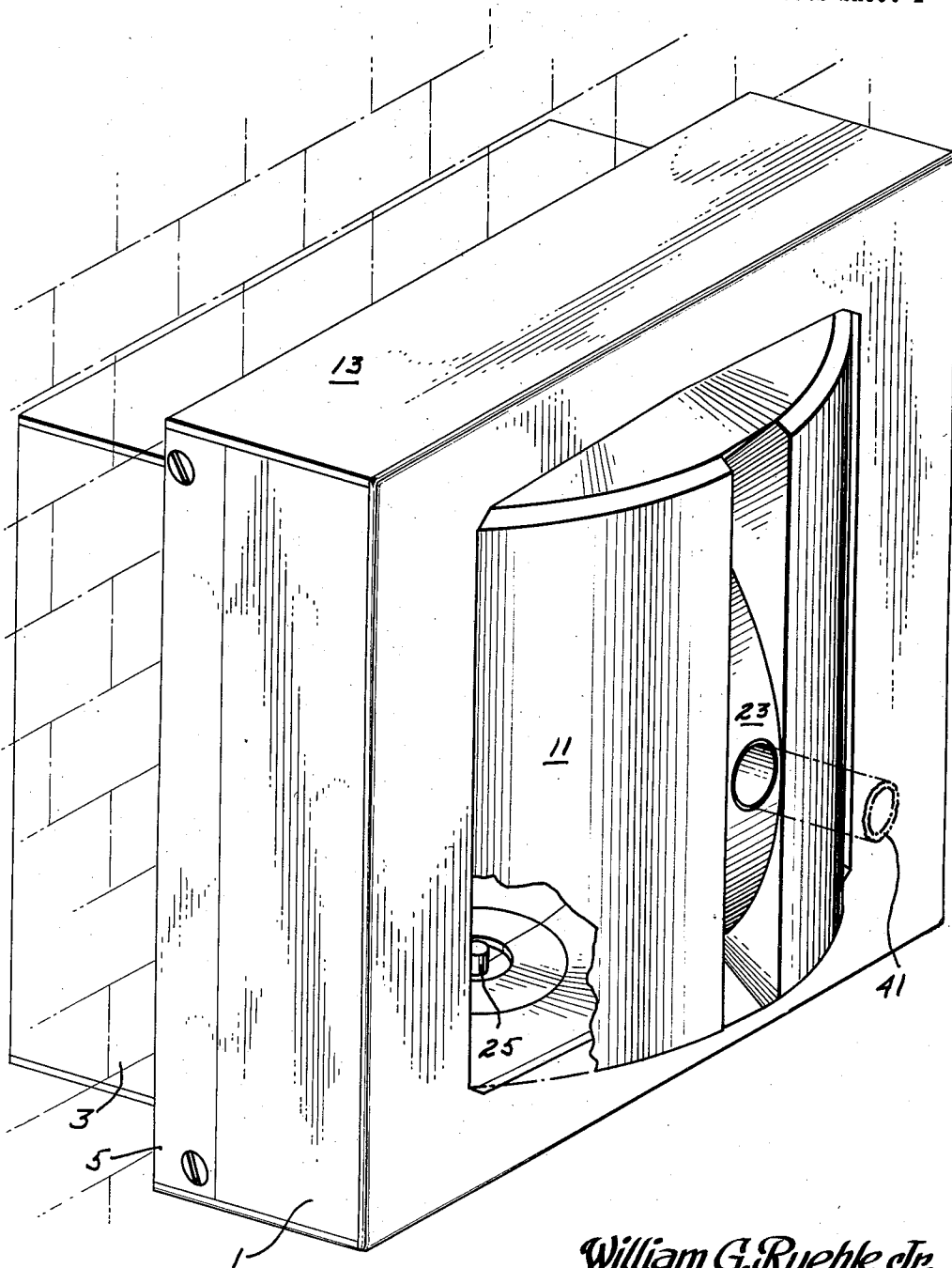


FIG. 1

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4 Sheets-Sheet 2

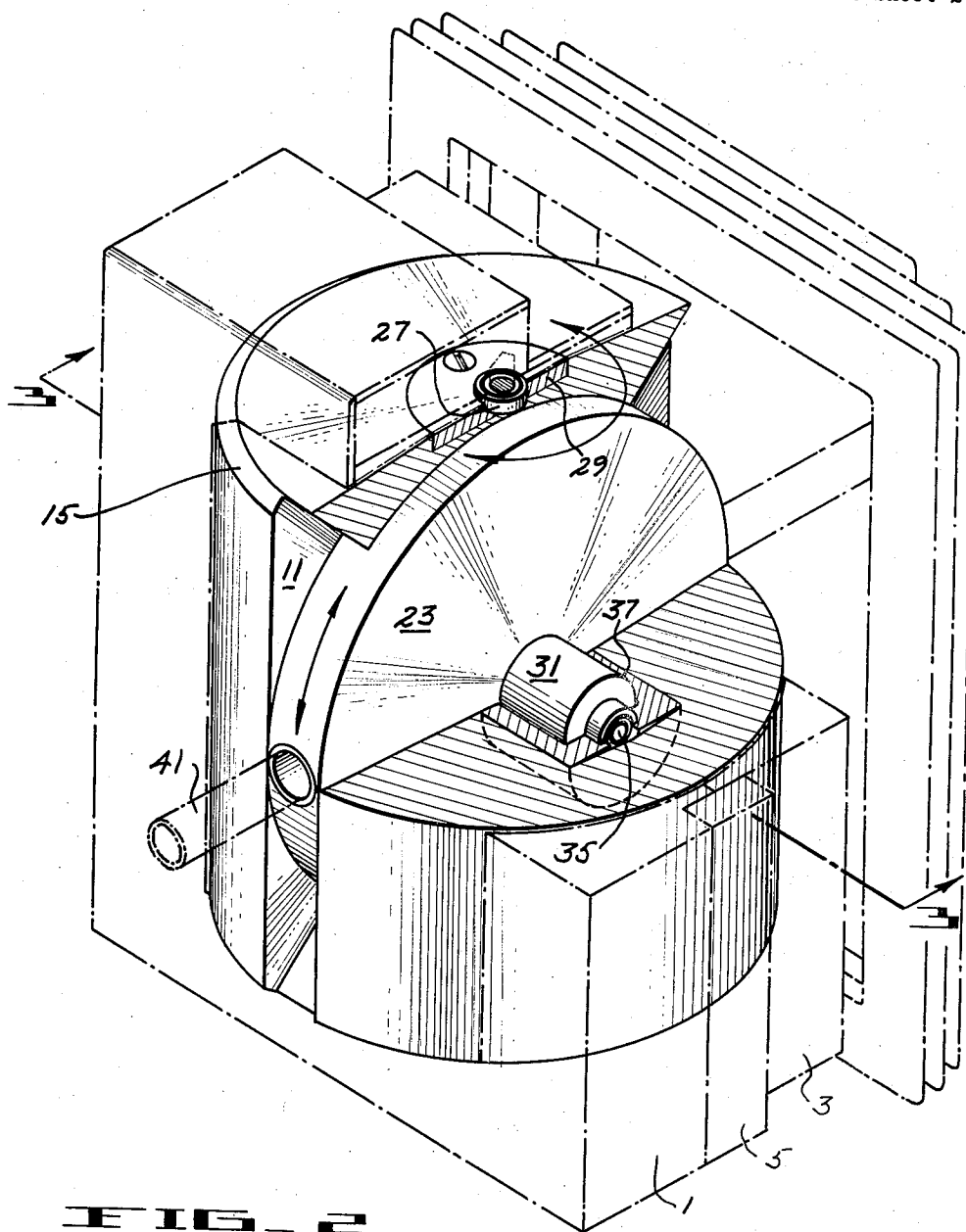


FIG. 2

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4 Sheets-Sheet 3

FIG. 3

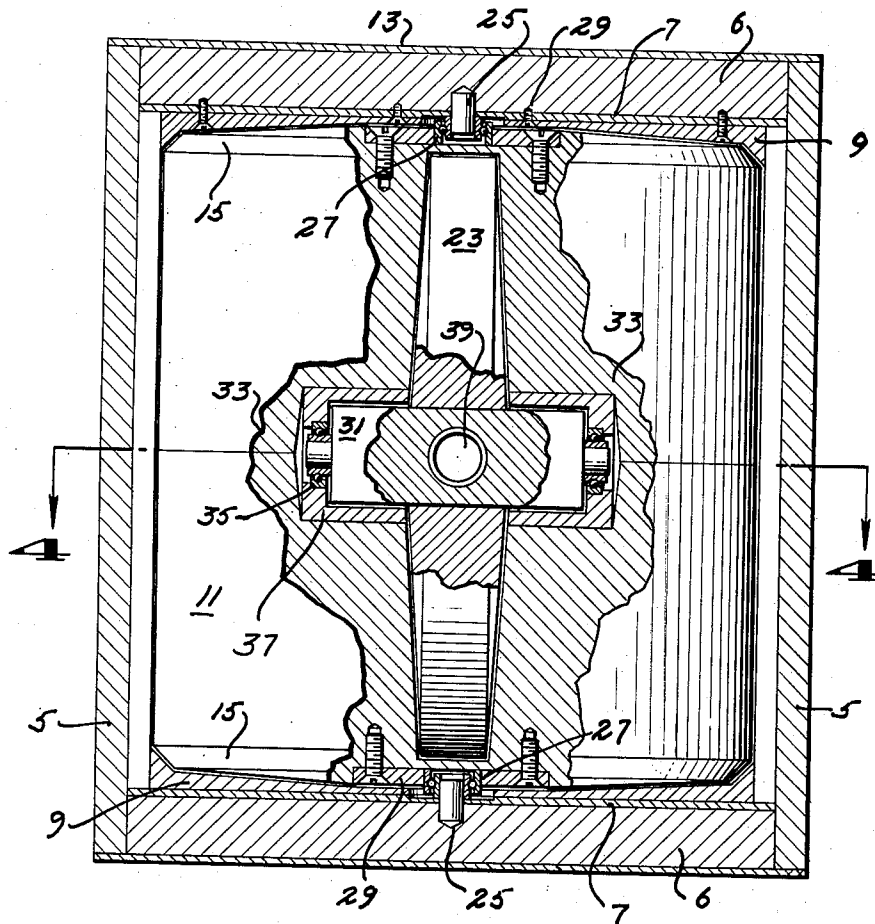
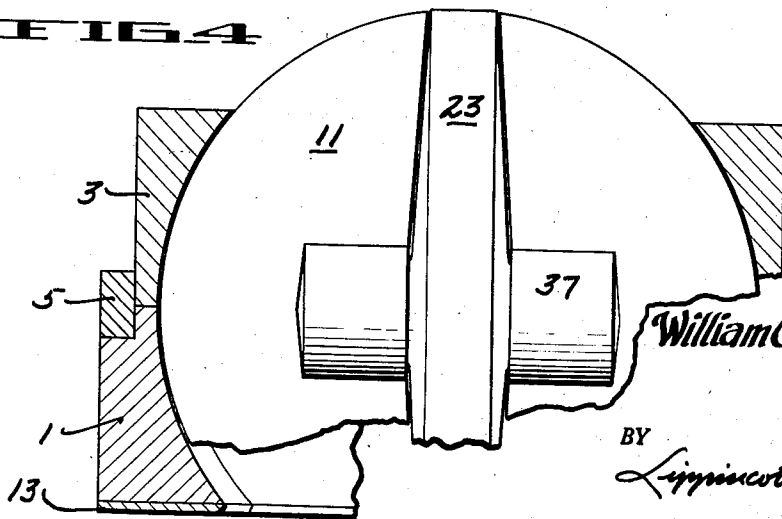


FIG. 4



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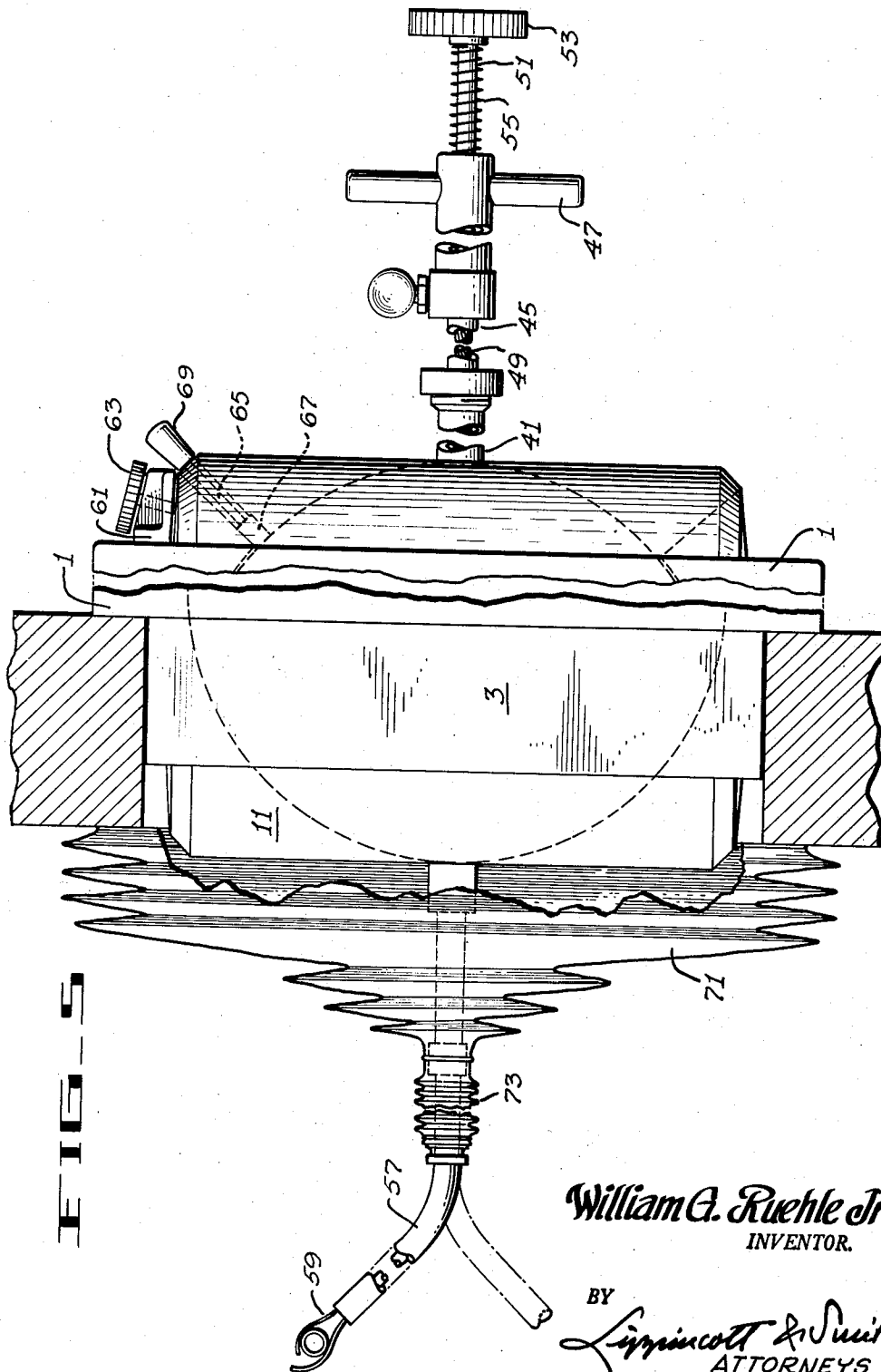
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4 Sheets-Sheet 4



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SHIELDING MANIPULATOR FOR RADIO-ACTIVE MATERIAL

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8 Claims. (Cl. 250-106)

This invention relates to manipulators for radio-active materials, that is, mechanisms whereby such materials may be subjected to various chemical and physical treatments without subjecting the operator to dangerous radiation.

Developments in the atomic energy field have resulted in products of constantly increasing intensity of radiation. In order to subject such materials to the treatment which they require it is accepted practice to operate upon them in shielded boxes or "caves," usually of lead or other heavy metal, but sometimes of concrete. The actual manipulation is accomplished by tongs so constructed that they can reach most portions of the cave, being provided with a cylindrical barrel which will slide in and out, grip an article within the cave and maintain or change its orientation as may be desired. This requires that the tongs penetrate the walls of the cave through some mechanism that permits freedom of motion, vertically and horizontally in any plane, but which has all the parts so shielded and protected that there is no straight line passage for radiation between the inside and outside of the cave.

In the past the shielded manipulators through which the tongs project have been very simply constructed in the form of a ball-and-socket joint, mounted in a panel in the wall of the cave, the ball being pierced by a bearing through which the tong barrel may slide.

When the activity of the materials which had to be handled was such that only one or two inches of lead shielding was required to attenuate the radiation to safe values, the type of manipulator just described was adequate. The opacity of shielding materials varies almost directly as their density. Since lead is the heaviest of the materials of reasonably low cost it is the material of choice for shielding. Even when hardened by the addition of a few percent of antimony, lead-to-lead surfaces are not satisfactory when used for bearings, particularly under any material load. When the shielding requirements rose, say, from two inches of lead to six inches of lead, the mass of the ball used for the ball-and-socket joint of the manipulator increased, not three-fold, but twenty-seven fold, for a manipulator giving the same freedom of motion. To give such freedom for an equivalent of shielding of six inches required a ball of eight-and-one-half inches in diameter, weighing some 130 pounds, and it was found that even hard, antimonial lead of such weight was subject to cold flow, which distorted the ball, caused the bearing to seize, and became utterly impractical for actual use. The problem has become so serious that ball and socket type manipulators have been constructed using balls of uranium, costing many thousands of dollars for the ball alone, uranium being one of the few materials which could be worked mechanically to a sufficient degree of precision which also had a high enough density to give the necessary shielding.

The over-all purpose of this invention is to provide a type of manipulator which is not subject to limitations of the type mentioned. Among the specific objects of

2

the invention are to provide a manipulator which may be constructed in any size, to operate in a wall of any thickness; to provide a manipulator in which the bearing surfaces are small and bearings of the antifriction type may be used; to provide a manipulator which has a larger field wherein manipulation can be accomplished than the conventional type; and, above all, to provide a manipulator which will give, in all positions and under all circumstances, as complete shielding as the wall of the cave in which it is installed.

Considered broadly, a device of this invention comprises a heavy-metal frame, preferably of antimonial lead, having a thickness at least equal to that of the wall necessary for protection against the radioactivity of the materials to be handled. The frame surrounds a central, substantially rectangular opening, the walls of which conform with only a slight running clearance, to the surface of a cylindrical turret which is pivotally mounted for rotation about an axis which is centered in the thickness of the frame wall. Like the frame the turret is of heavy metal, and for maximum economy of design the turret has a diameter slightly over 40% greater than the wall thickness, so that the quadrants of its periphery alternately project through and are covered by the wall of the frame. The ends of the cylindrical turret are formed as non-planar surfaces of revolution. Preferably these surfaces are convex, approximating frusto conical or spherical surfaces. The turret in turn, has an opening extending diametrically therethrough, wherein there is pivoted, on an axis normal to that of the turret itself, a heavy-metal disc which is preferably of the same diameter as the turret. The faces of the disc are also non-planar surfaces of revolution, preferably convex. The walls of the turret opening conform, laterally, to the disc surfaces, again with a slight running clearance; peripherally of the disc the walls of the turret opening conform to its surface for substantially alternate quadrants, centered on the axis of the turret, flaring out on each side substantially parallel to the disc radii to the surface of the turret cylinder. The disc is pierced axially by a cylindrical bore for receiving, with a close, sliding fit, the barrel of a suitable manipulating tong, so that the latter may be rotated or slid longitudinally within the diametral bore through the disc. Preferably means are also provided for braking or locking both turret, disc and the tongs against movement.

Externally, the frame is preferably (although not necessarily) of stepped construction, so that one-half, preferably that mounted interiorly of the box or cave, is enclosed by the aperture in the wall of the cave wherein the manipulator is mounted, while the other half projects outwardly from the wall for about half of the thickness of the frame. It will be seen that with this construction and mounting there is no gap between any of the parts which offers a direct path through which radiation could leak out into the operating area. Both the turret and the disc can be mounted in conventional ball bearings of small diameter, so that a minimum frictional moment is offered against rotation of either. This renders manipulation much more delicate and certain than where the bearing area has a radius equal to the diameter of the rotating shielding element, as is in the case of the ball-and-socket type of device. Further it offers a rectangular field of operation 90° wide in both the vertical and horizontal dimension and nearly 110° wide on the diagonal.

This is in contrast to the conical field, having a maximum angle of 90°, of the conventional ball and socket manipulator. When used in combination with a manipulating tong of the type which will be described herein, but which is not a part of the present invention, the effective field of operation may be extended even to the

area immediately adjacent to the wall and directly under the point at which the manipulator is mounted.

The preferred form of the invention is shown in the accompanying drawings and will be referred to in a detailed description which follows. In the drawings:

Fig. 1 is an isometric view of a manipulator in accordance with the present invention as it is mounted in the wall of a cave, the wall being shown in phantom and a portion of the turret being cut away to illustrate the position of its bearing with relation to the wall;

Fig. 2 is an isometric view of the turret and disc, one quadrant of the turret being cut away to show vertical and horizontal sections thereof with the disc in place, and the frame being illustrated in dotted lines to show its relation to the turret, particularly with respect to the bearing structure;

Fig. 3 is a view, partly in elevation and fragmentarily in section, showing portions of the frame, the turret, and the disc, together with the bearing arrangements for the parts, the plane of section of the frame being indicated by the lines 3—3 of Fig. 2;

Fig. 4 is a horizontal sectional view through the turret and frame, the plane of section being that indicated by the lines 4—4 of Fig. 3; and

Fig. 5 is a sectional view through the walls of a shielded box or cave wherein the manipulator is mounted, showing in elevation a complete assembly of manipulator, tongs, and ancillary structure. Portions of this structure, otherwise illustrated, are cut away to make possible the condensation of the figure within the limits of a single sheet of drawing.

In the embodiment of the invention illustrated in all of the drawings, the rectangular frame in which the other elements of the device are mounted comprises two rectangular blocks 1 and 3, which are preferably die-cast of antimonial lead, having a combined thickness equivalent to that of the walls of the cave, although they may be otherwise fabricated of other heavy metal. Exteriously the block 1 is preferably of larger dimension than the block 3, except for a rabbet or step-back on its rearward edges where it comes in contact with the smaller block. A supporting girdle or frame, having side-members 5 and top and bottom members 6, preferably of steel, surrounds the junction between the two blocks to bind the assembly together. Lead bars, not shown in detail, build up the thickness of the forward portion of the frame to equal the dimension of the block 1.

Within the opening of the frame, under both the members 6 and the lead bars, are steel plates 7, extending the full width of both blocks, to which there are secured relatively thin lead members 9 of equal width, which define the shape of the ends of the cavity within the frame. The opening surrounded by the frame is substantially rectangular as viewed in elevation. The walls of the opening surround and conform closely to the surface of a cylindrical turret 11, pivotally mounted on an axis midway through the thickness of the frame, with just sufficient clearance between the frame and the turret to insure free rotation. The diameter of the turret is preferably greater than the thickness of the frame by a factor of a little over $\sqrt{2}$, so that the arcs of its surface encompassed by the walls of the frame are a little less than a quadrant. The axial length of the turret and hence of the opening which surrounds it, is a little greater than the diameter.

For protection and finish the outer surface of the frame 1 may be covered with a jacket 13 of harder metal or plastic. The turret is also preferably of antimonial lead, die-cast in two identical halves. The line of division may be either axial, or, preferably, perpendicular to the axis, as shown. In either case the two halves may be held together by bolts, not shown in the drawings. The ends of the turret are non-planar surfaces of revolution, preferably convex, although they may be concave. The preferred shape is that illustrated, the cylindrical

body of the turret being chamfered where it joins the ends, as illustrated at 15, and then rising in a slightly domed or relatively flat, frusto-conical form to a level area surrounding the axis.

The turret has a diametral opening therethrough, shaped to conform to a heavy metal disc 23, preferably of a diameter substantially equal to that of the turret, with a running clearance similar to that described for the turret itself in the frame opening. The lateral surfaces of the disc, and hence of the opening which conforms to it, are non-planar surfaces of revolution, in this case frusto-conical. The walls of the opening in the turret which conform to the periphery of the disc preferably subtend an angle of a little less than a quadrant, the walls of the opening flaring outwardly at angles substantially 45 degrees to merge with the periphery of the cylindrical turret at the ends of the cylinder.

In the particular device here shown the turret is pivotally mounted on stub shafts 25, set into the upper and lower cross members 6 of the frame. Ball bearings 27, set into mounting discs 29 set into the ends of the turret cylinder, hold the outer race of the ball bearings.

The manipulator will give the same freedom of movement whether the turret is mounted horizontally or vertically. Mechanically, however, it is much better that the axis of the turret be vertical, as shown, and therefore the ball bearings 25 are made of the combined radial-thrust type. For a manipulator designed for a six-inch wall, the weight of the cylinder is in the neighborhood of 280 pounds, and a much better mechanical structure is obtained and the wear on the bearings is greatly decreased if this load is taken in thrust rather than radially.

The transverse bearing which carries the disc obviously carries a much lighter load. The disc is provided with a transverse shaft 31, preferably of steel, of much larger diameter than is required to carry the load imposed upon it. It has smaller diameter extensions 33 at its ends to carry the inner races of ball bearings 35. The outer races of these bearings are fitted into the ends of cylindrical cups 37, which fit snugly into cavities in the turret halves, prepared for the purpose.

The disc and shaft 31 are pierced diametrically by a cylindrical hole which is preferably provided by previously inserting a brass liner 39 through the shaft before the disc is cast. After the casting and assembly, a bearing-sleeve 41 is inserted and fixed in position, as by soft-soldering to the tube 39. The outer end of the bearing-sleeve is preferably threaded and split to form a collet, which can be tightened by a nut 43 around the barrel of the manipulating tongs to prevent either sliding or rotational movement of the latter.

One form of tong which may be used in connection with the present invention is illustrated in Fig. 5, which shows the manipulator, mounted in the wall of a cave. In this figure sections are broken out of the structure at intervals so that arrangements can be shown within the confines of a single sheet of drawing on a large enough scale to illustrate the arrangement of the parts. The structure, as used in a "6-inch manipulator" (a manipulator for use in a 6-inch wall) will be several feet in length. Within the bearing-sleeve 41 there is mounted a rotatable tubular barrel 45, materially longer than the sleeve 41 and slidable within the latter but which may be locked against both rotation and sliding motion by the nut 53. When the nut is released the position of the shaft 43 within the sleeve may be adjusted, both as to sliding and rotation, by a handle 47. Within the tubular barrel 45 is a flexible cable 49, terminating in a plunger 51 attached to a handle 53. A spring 55 interposed between the handles 47 and 53 tends to retract the latter and the cable to which it is attached.

An angular extension 57 of the barrel 53 is fastened to the inner end of the latter, the cable, or an extension thereof, passing through the extension and fastening to spring tong jaws 59. The angle of the extension 57 is

preferably substantially 45°. The jaws 59 tend to spring apart when unstressed, but when retracted within the tubular extension 57 they are brought together so as to grasp whatever article is to be manipulated. For various purposes other types of jaws, may, of course, be used.

The cable 49 is sufficiently rigid in torsion so that the barrel 45 may be rotated without rotating the jaws. Therefore, by holding the handle 53 against rotation and turning the handle 47 whatever it may be that is held by the tongs (as, for example, a test tube) may be swept in a circle without tilting it from its original orientation. On the other hand, by rotating the handle 53 but holding the handle 47 in a fixed position, the article held may be tipped without changing its position relative to the cave in which it is being operated.

This freedom of motion of the tongs is in addition to that afforded by the manipulator itself. The latter can be rotated through substantially 90 degrees about either the vertical or horizontal axis. Rotation about one axis does not limit possible rotation about the other, as in the case of a ball and socket manipulator, which has, for example, no freedom of lateral motion when it is fully depressed. With the 45 degree bend in the tongs, plus maximum motion around either manipulator axis, the field of operation is extended to within a very short distance from the wall in which the apparatus is mounted.

It is frequently desirable to lock the manipulator against rotation about either axis. A lock may easily be added to the device as thus far described, one form of the mechanism for this purpose being shown in Fig. 5. A bracket 61 is secured to the front face of the block 1, and a pressure screw 63 is threaded into this bracket into such manner that it can press against the upper surface of the turret. Preferably such a screw is tipped with a soft friction material (not shown) such as leather, rubber, or plastic, to prevent the end of the screw marring the surface of the drum and possibly interfering with its free rotation. The brake on the disc is also of the friction type, comprising a screw 65 having a plastic friction tip 67 which bears against the periphery of the disc when operated by knob 69. The screw is threaded into the turret in line with the disc and the tongs projecting through it. For a given size turret and disc this limits the motion around the horizontal axis slightly in comparison with the latitude of movement available when the lock is omitted. Other, more complicated, forms of lock can be employed which do not have this limitation, but in practice it has been found that the very slight limitation in motion is preferable to the use of more complicated locks. The lock can, of course, be mounted below instead of above the turret, giving full movement in the lower range of the tong end and limiting only the upper motion. Actually this is only a question of which orientation is chosen in mounting the device.

Fig. 5 also shows the preferred mounting arrangement. The front section of the frame is here mounted wholly in front of the shielding wall of the cave, so that the drum, as it projects beyond the frame, is substantially in line with the inner wall. The overlap between the frame portion 1 and the wall insures that there is a full thickness of protective shielding at all portions of the manipulator.

Since it is always possible that there may be occasion to handle materials giving off radio-active vapors or gases it is desirable that the manipulator be sealed gas-tight (although not necessarily pressure tight) to prevent the escape of radio-active gases. For this purpose there is provided a bellows (or "sock") 71 of flexible plastic, such as, for example, one of the vinyl plastics, which surrounds the opening in the wall of the box or cave wherein the manipulator is mounted and which tapers down to the tong barrel, where it is tightly secured. Also secured at this point is a "tong barrel sock" or bellows 73, which extends to the end of the barrel and is there sealed, gas-tight. Provisions are made so that the bent end of the tongs can be detached from the barrel and the tongs

changed without opening the cave, but these are not a portion of the present invention and need not be described here.

The motion of the turret and disc has been described as being 90 degrees, and the arc of the turret subtended by the frame and of the disc subtended by the turret have been referred to as substantially quadrants. As constructed these arcs are little less than a quadrant since the diameter of the tong barrel and its bearing would prevent a full 90 degree motion if full quadrants were used. It is in order to permit the 90 degree motion the diameters of both drum and disc are made slightly larger than $\sqrt{2}$ times the thickness of the wall so that the blocking of movement by the edges of the openings does not occur until the full 90 degree motion has been obtained.

The device can, of course, be constructed with turrets and discs bearing other relationships to the wall thickness. If, however, the turret and disc are of smaller diameter than that specified there will be further limitation to their angular movement and the field of operation of the device will be similarly limited. If the target and disc are larger in relative diameter it will result in no material increase in the field of operation over that of the preferred structure when used with a tong having a 45 degree bend therein as shown, but the mass and cost of the device will be materially increased without any corresponding gain. A 90 degree freedom of movement, about both vertical and horizontal axes, with the motion around one axis unrestricted by movement about the other, therefore offers a definite optimum.

The manipulator may, of course, be made of material other than lead. From a practical point of view, however, the antimonial lead here specified also offers a definite optimum. It is sufficiently hard so that as here used it is not subject to cold flow, and will maintain the necessary clearances, even in large sizes, which pure lead would not. It is the densest of the relatively inexpensive metals. To provide an equal amount of shielding the diameter of a turret of some other metal would be inversely as its density. Thus a steel turret would have to be about 43% bigger in diameter than a lead turret in order to give the same shielding, but its weight would be over twice as great as that of a lead turret. On the other hand, a gold or tungsten turret would only need to have about 59% of the diameter of a lead turret to give the same shielding effect and would weigh only about 35% as much, but the difference in cost per pound is so great that the lead shield is obviously the one to be preferred from a commercial point of view. Therefore, while any heavy-metal may be used in the construction of the manipulator, in order to meet special conditions, lead will almost always be used in practice.

Although the mechanical details of construction shown and described are those which thus far have proved to be most advantageous, satisfactory manipulators have been built and used differing materially in such features from that here described. The detailed description here given is therefore not to be considered as limiting the scope of the invention, all intended limitations being specifically expressed in the following claims.

What is claimed is as follows:

1. A manipulator for radio-active materials comprising a heavy-metal frame having a substantially rectangular opening therein the side walls whereof are concavely curved to conform substantially to arcs of a circular cylinder and the end walls whereof comprise non-planar surfaces of revolution coaxial with said arcs, a heavy-metal cylindrical turret pivotally mounted within said opening and generally conforming to the walls thereof with sufficient clearance to permit free rotation and too small to afford any straight-line path through said opening, said cylinder also having an opening therethrough, a heavy-metal disc having non-planar surfaces pivotally mounted within said turret-opening on an axis substantially normal to said turret axis, the walls of said turret-

opening conforming laterally of said disc to the walls of said disc with clearance substantially like that of said turret and frame, said disc having a tubular aperture therethrough substantially normal to said disc axis to permit sliding and rotary motion of a manipulating-tong barrel therethrough.

2. A manipulator as defined in claim 1 wherein each of the arcs in the opening in said frame subtends substantially a quadrant.

3. A manipulator as defined in claim 1 wherein the surfaces defining said turret and said disc are all convex.

4. A manipulator as defined in claim 1 wherein said turret and said disc are of substantially equal diameter.

5. A manipulator for radio-active materials comprising a heavy-metal frame having a substantially rectangular opening therein the side walls whereof are concavely curved to conform substantially to arcs of a circular cylinder and the end walls whereof comprise non-planar surfaces of revolution coaxial with said arcs, a heavy-metal cylindrical turret pivotally mounted within said opening and generally conforming to the walls thereof with sufficient clearance to permit free rotation and too small to afford any straight-line path through said opening, said cylinder also having an opening therethrough, a heavy-metal disc having non-planar surfaces pivotally mounted within said turret-opening on an axis substantially normal to said turret axis, the walls of said turret-opening conforming laterally of said disc to the walls of said disc with clearance substantially like that of said turret and frame, and conforming peripherally to said disc for substantially the quadrants thereof centered on said turret-axis and flaring outwardly therefrom parallel to the radii of the remaining quadrants, the clearance between said disc and said turret-opening being substantially like that between said turret and said frame opening, said disc having a cylindrical aperture therethrough intersecting the axes of both said turret and said disc to permit sliding and rotary motion of a tong barrel therethrough.

6. A manipulator for radio-active materials comprising a heavy-metal frame having a substantially rectangular opening therein the side walls whereof are concavely curved to conform substantially to arcs of a circular cylinder and the end walls whereof comprise non-planar surfaces of revolution coaxial with said arcs, a heavy-metal cylindrical turret pivotally mounted within said opening and generally conforming to the walls thereof with sufficient clearance to permit free rotation and too small to afford any straight-line path through said opening, said cylinder also having an opening therethrough, a heavy-metal disc having non-planar surfaces pivotally

mounted within said turret-opening on an axis substantially normal to said turret axis, the walls of said turret-opening conforming laterally of said disc to the walls of said disc with clearance substantially like that of said turret and frame, and conforming peripherally to said disc for substantially the quadrants thereof centered on said turret-axis and flaring outwardly therefrom parallel to the radii of the remaining quadrants, the clearance between said disc and said turret-opening being substantially like that between said turret and said frame opening, said disc having a cylindrical aperture therethrough intersecting the axes of both said turret and said disc to permit sliding and rotary motion of a tong barrel therethrough, and means for locking both said turret and said disc against rotation about their respective axes.

7. A manipulator for radio-active materials comprising a heavy-metal parallel walled frame having a substantially rectangular opening therein, said opening being defined by the intersection with the walls of said frame with a cylindrical bore of greater diameter than the thickness of said frame, axially centered with respect to said bore, the ends of said bore being non-planar surfaces of revolution coaxial with said bore, a heavy-metal turret pivotally mounted, coaxially within said bore and substantially filling the same with sufficient clearance to avoid frictional engagement therewith, a heavy-metal disc the opposite faces whereof are non-planar surfaces of revolution pivotally mounted within said turret on an axis substantially normal to the axis of said turret and a bearing sleeve for receiving the barrel of manipulating tongs mounted diametrically through said disc and projecting beyond the periphery thereof, said disc being mounted in an opening through said turret the walls whereof conform closely to the faces of said disc and to sectors of the periphery of said disc centered substantially on the axis of said turret, flaring outwardly from said sectors to the ends of said turret, the chords of said sectors being substantially equal to the thickness of said frame.

8. A manipulator as defined in claim 7 including means mounted on said bearing sleeve for locking a tong-barrel projecting through said bearing sleeve.

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