Title
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Two 1-π clinostats have been designed and recently built in our laboratory under a joint program of the NASA Bioscience Division (Purchase Order No. W-12, 792, Task 6 to the Atomic Energy Commission) and AEC. One of these units will be employed in a 1,000-curie nominal-strength cesium irradiator; the other will serve as a "control." The purpose of these instruments is to study radiation effects on small organisms while they exist under various degrees of gravity compensation. Such experiments can help interpret results of biological studies in space flight and serve as controls for future satellite experiments.

Clinostat Design

The clinostats (see Figs. 1 and 2) are identical, measuring 17 in. high, 17 in. broad, and 7 in. deep (excluding attached specimen holders), and weigh approximately 120 pounds each. They consist of eight parallel, horizontal, ventilated rotating shafts capable of operating at speeds of 1/2, 1, 2, 4, and 8 rpm. These shafts are evenly spaced on the circumference of a 9-in.-diameter circle. At the center is another similar horizontal shaft which will rotate at speeds of 2, 4, 8, 16, and 32 rpm.

In addition, there is a vertical shaft that will rotate at the same speed as the eight horizontal ones, thus providing for simultaneous control.

Each clinostat is run by two three-speed synchronous electric motors in water jackets. The motors are placed in parallel and situated on diagonally opposite sides of the clinostat to ensure proper balance. Motion is transmitted to the shafts from the motors via capstans engaging a flywheel, which then move endless Mylar belts snaking over the shaft pulleys. The stated shaft speeds can be reduced by replacing said motors with gear head motors. Conversely, the shaft speeds can be increased, perhaps by more than a factor of 4, by changing the relative diameters of the flywheel and capstans.

The ends of the horizontal shafts are accurately faced and threaded, 3/8-in. diam by 16 threads per in., the thread extending 3/8 in. from the end of the 3/4-in. shaft. Thus, any type of specimen holder adapted to fit onto this attachment can be employed. Because the clinostat must fit within the cesium irradiator, the length of the specimen holders must be less than 5 in. The vertical shaft consists of a polycarbonate tube (1.250 in. o.d. $\times$ 1.030 in. i.d.) with an operating length of approximately 9 in. Specimen holders have been made for use on the shafts interchangeably. One is shown in Fig. 3, along with the pertinent dimensions. Thus, if size permits, biological specimens can be constrained within pieces designed to fit in these holders.

Each clinostat is fitted with multiplane shock mounts to attenuate external vibrations. These mounts are effective down to 11 Hz, e.g., 80% isolation at 20 Hz.

Operating Characteristics

Reference to gravity is made by means of bubble levels. One level, along the axis of the horizontal shafts, is readable to 1 part in 10,000. A second horizontal level, at right angles to this one, is readable to 1 part in 2,000. Manual precision leveling screws will permit base adjustment. The shafts are parallel to one another within 1 part in 10,000, and the vertical shaft is perpendicular to the horizontal to 1 part in 1,000. The sag of a typical specimen holder on the shaft was found to be negligible.

Quartz-crystal oscillators (30, 60, and 120 Hz) are employed in the ac motor power supply. These, in conjunction with multiple-pole motor windings, provide a total of five speeds. Tests show that vibrations are lowest when only one drive motor is used for each clinostat. The quietest motor has therefore been selected, and for each speed the electrical LC circuit values are optimized to give the least vibration. The resulting induced vibrations seen at the shaft ends are as follows for both clinostats:

rpm	Fraction of 1G
1/2	0.004
1	0.002
2	0.002
4	0.003
8	0.005 to 0.010

The self-generated noise of the clinostats was measured with an H. H. Scott type 410C sound-level meter in combination with an H. H.

Scott type 420A sound analyzer. When the clinostats were housed within their respective environmental chambers (described below), the resulting noise levels were between 33 and 40 db (flat "C" weight), depending on the motor speed. The frequency range covered was 20 Hz to 20 kHz. The corresponding ambient noise level was 35 db. The zero-db reference level was 2×10^{-4} dynes/cm^2.

Any fraction of the gravitational vector can be applied by the proper inclination of the rotating shafts from the horizontal plane. The component of gravity is proportional to the sine of the angle of tilt. The leveling screw on the clinostat can be precisely adjusted up to 2 deg (0.035G). In addition, the cesium irradiator in which the clinostat is housed can be rotated (see next section), thus providing larger inclinations and consequently larger G forces.

<u>Cesium Irradiator</u>

The clinostat has been designed to allow admittance into a nominal-strength 1,000-curie cesium-137 irradiator (1042 Ci on 8/28/65), which weighs approximately 13,500 pounds (see Figs. 2 and 4). The clinostat is attached to a metal chassis which in turn is bolted onto the floor of the irradiator chamber. Heavy-duty chassis slides allow the clinostat to leave the irradiator for ease of access. In order to ensure that there has been no misalignment when closing the irradiator door, there has been provided a lead glass periscope to allow checking the bubble level on the clinostat. Leveling screws on the irradiator base allow for necessary corrections. In addition, the irradiator is on a gimbal mount so that it can be turned 90 deg. In this latter position, the original horizontal shafts can be aligned to the vertical to within 1 part per 1,000.

The cesium-137 source is located on the axis of the center horizontal shaft (the faster rotating one), when the clinostat is in place. Consequently, the eight test shafts will be the same distance from the source. Figure 5 gives isodose curves in the bare irradiator chamber. Available lead shielding can reduce these values by up to a factor of 100. Since the precise dosage seen by a biological specimen will be dependent on the particular experimental geometry, it is proposed to monitor all irradiation experiments with small LiF disks which can sandwich the specimens.

Test Controls

As noted above, there are provided two means of running vertical irradiation controls: The vertical shaft on the clinostat allows for simultaneously running test and control (although the control dosage will be slightly different due to the system configuration), and the rotation of the irradiator provides a means for a sequential control run. Of course, the second clinostat is available, too, for non-irradiated controls.

Environment

The cesium irradiator and a specially constructed "environmental control chamber" will house the clinostats. Both chambers have the same interior dimensions as well as similar lighting arrangements, air inlets, etc.

Conditioned air, supplied by an Aminco-Aire conditioner, will pass in parallel through both systems and then exhaust to the ambient. The amount of air flow to both chambers can be varied with a bypass-bleeder arrangement. Currently, a temperature range of 20–33°C is available (with a corresponding variation of 0.5°C between the two chambers), with a concurrent relative humidity range of 30–80%, depending on the temperature. The temperature is monitored by four thermocouples in each chamber; the output is automatically printed on a multichannel recorder. The relative humidity is similarly recorded by employing wet- and dry-bulb thermocouples in the air inlet to each chamber. Drier environments will be available in the future by placing a liquid nitrogen cold trap in the air-conditioning line, or by utilizing desiccators within the chambers.

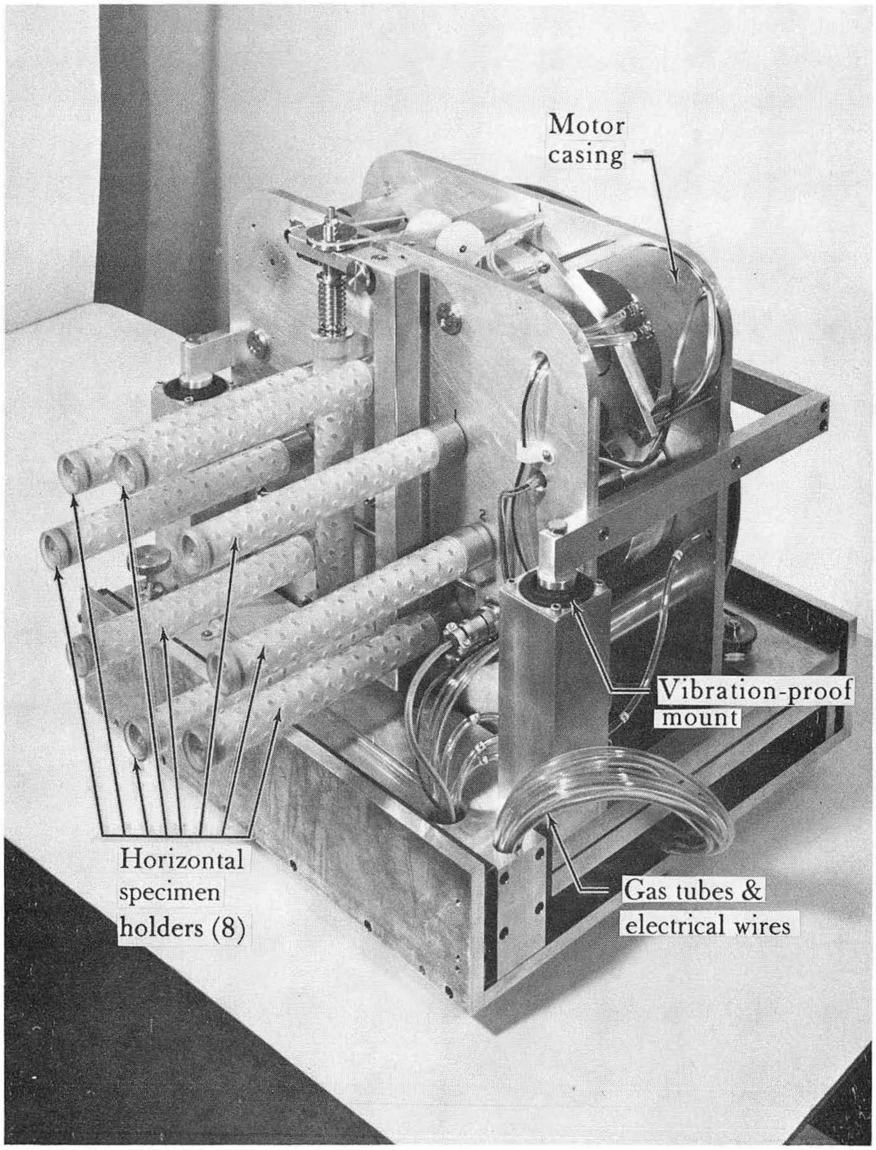
Ultraviolet and white light, and provision for another light, are currently available. As with the clinostat motors, the lights are water-cooled to preclude excessive heat generation and the consequent demand for increased cooling-air flow. Tests with a light meter, Photovolt 200 M, indicate that leakage of visible light into the darkened chambers is less than the meter's sensitivity; i.e., less than 0.05 foot candle.

Provision has been made to allow any desired "atmosphere" to pass over the test specimens. The shafts on the clinostat are hollow. Tubes are attached to them through the clinostat face plate (see Fig. 1) and then passed out of the respective chambers to any desired gas supply. In fact, one tube services two horizontal shafts, so that four separate atmospheres can be employed simultaneously.

An air silencer is placed in series with the air conditioner to reduce the noise level caused by the conditioner, within both environmental chambers. If it is deemed necessary, the inner walls of the chambers will be covered with sound-damping material. With the air conditioner and the clinostats running, the noise level within the chambers was found to be 46-48 db, compared with the ambient value of 60 db (the measuring instrument and reference level were described above.

Local external "spiked" vibrations are found to be in the magnitude of 10^{-3} G for frequencies down to 2 Hz, and less than 10^{-4} G between 0.5 and 1.5 Hz. In a new structure, to be completed about June 1970, and designed to house these and any future clinostats, vibration isolation pads will be provided to reduce all external stimuli by an approximate order of magnitude.

Special acknowledgement is made to Dr. Solon A. Gordon of the Division of Biological and Medical Research, Argonne National Laboratory, Argonne, Illinois, who has served as a consultant on this clinostat development. The clinostats built in Argonne under Dr. Gordon's auspices served as models for the design of these present clinostats.



CBB 696-3937-A

Fig. 1

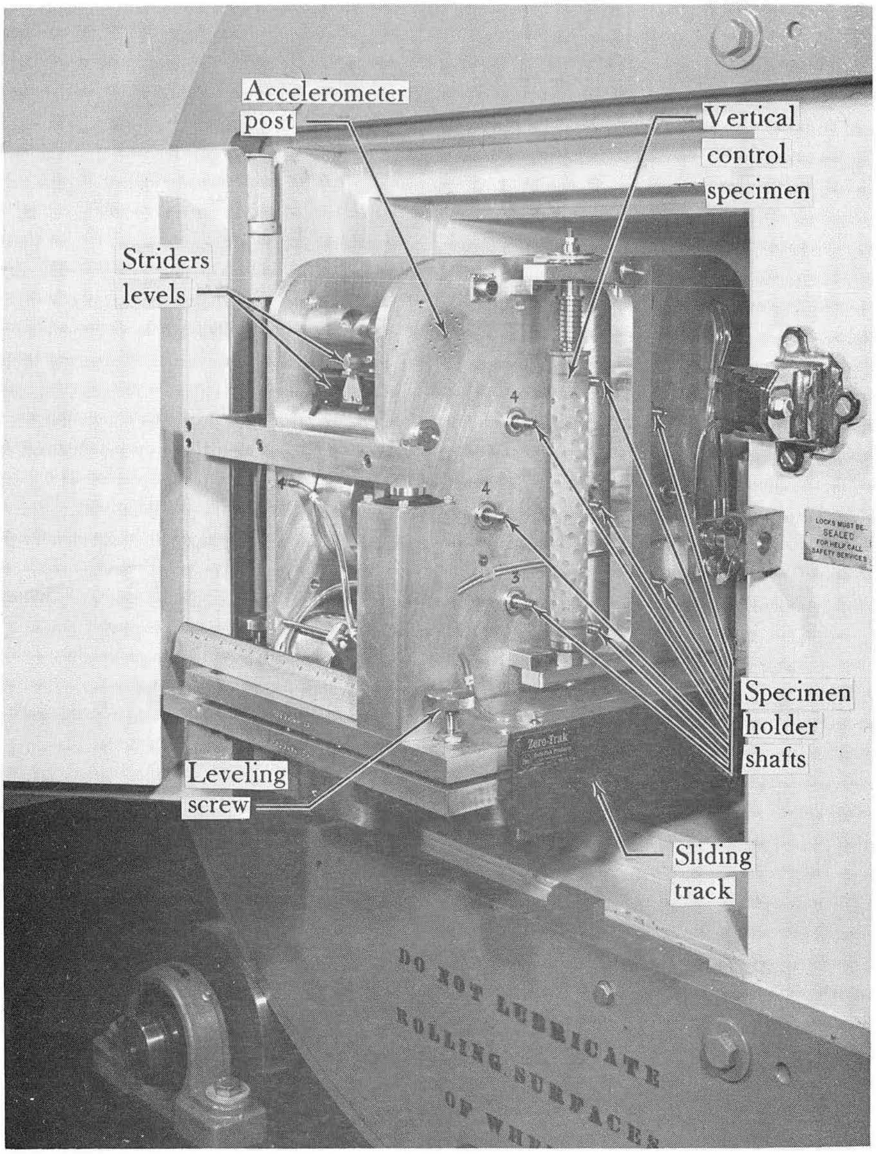


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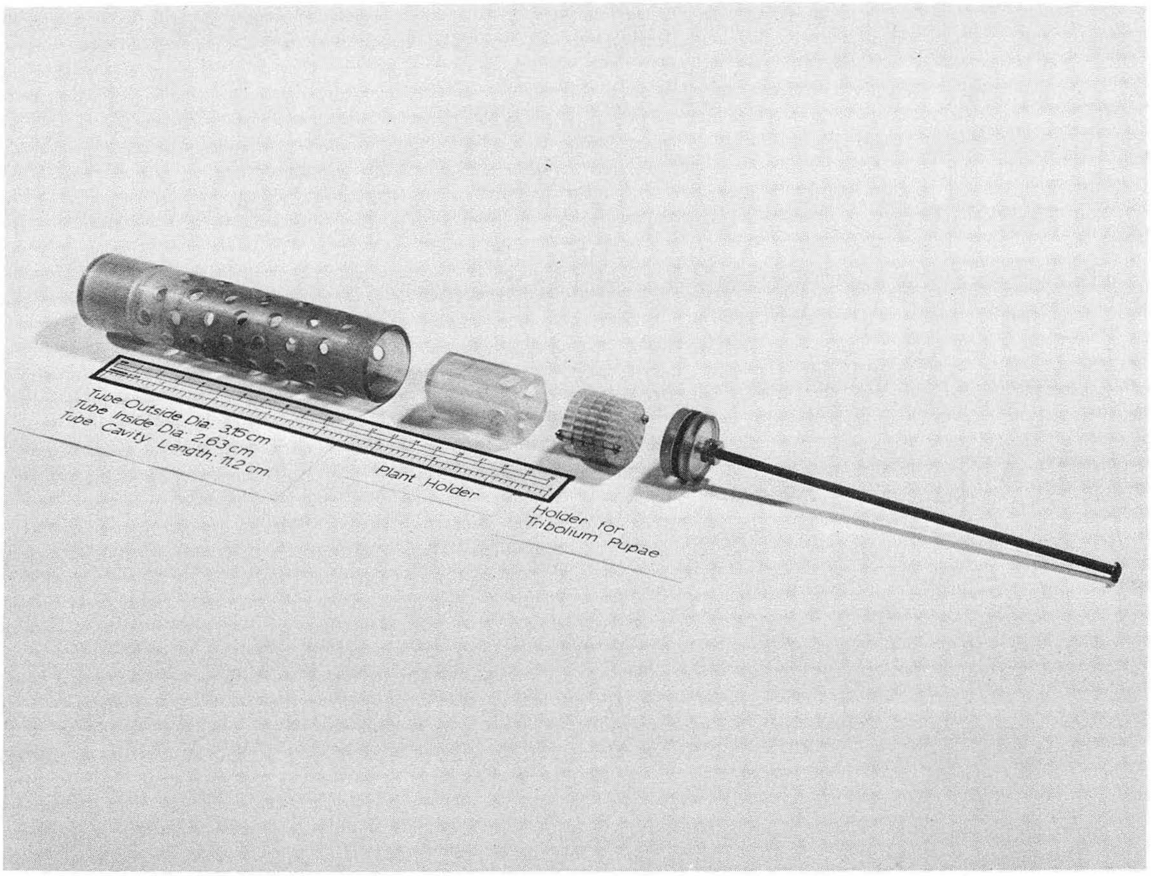
Fig. 2



XBB 699-6005

Fig. 3

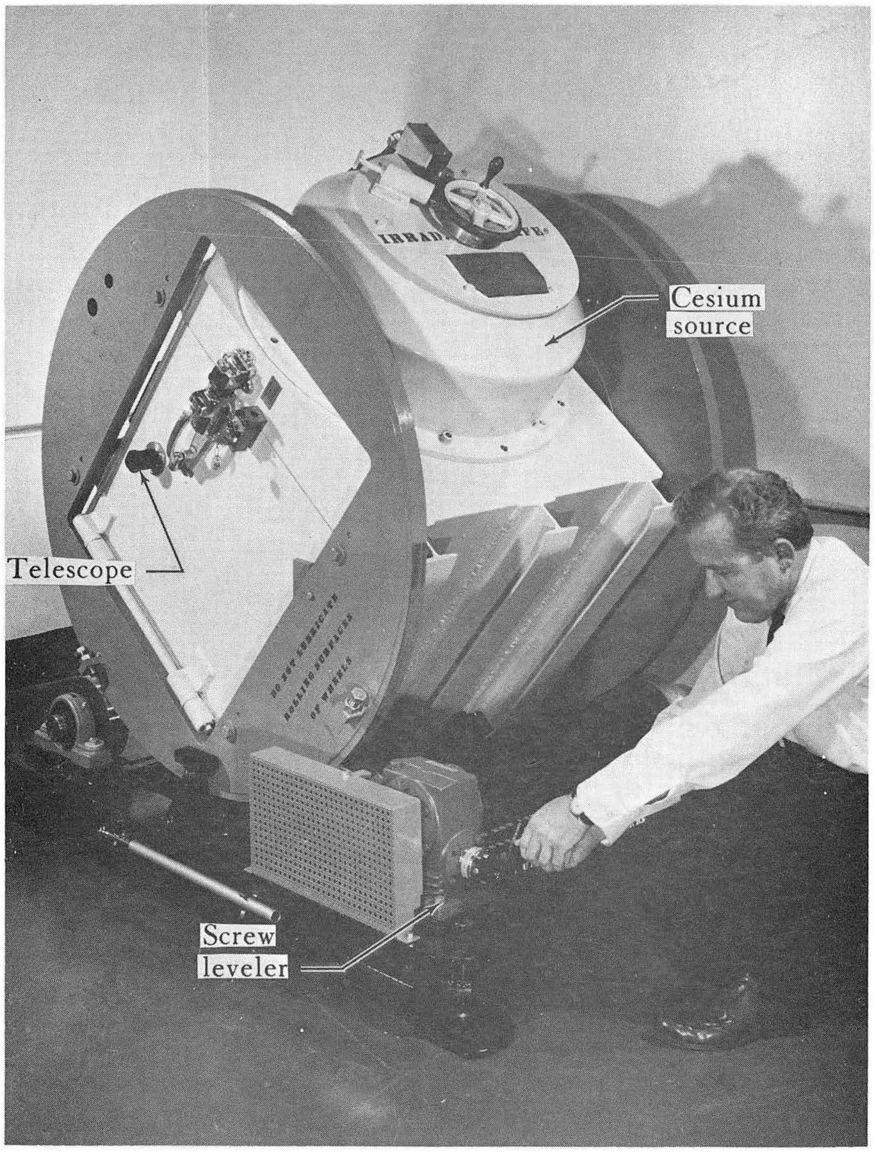


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Fig. 4

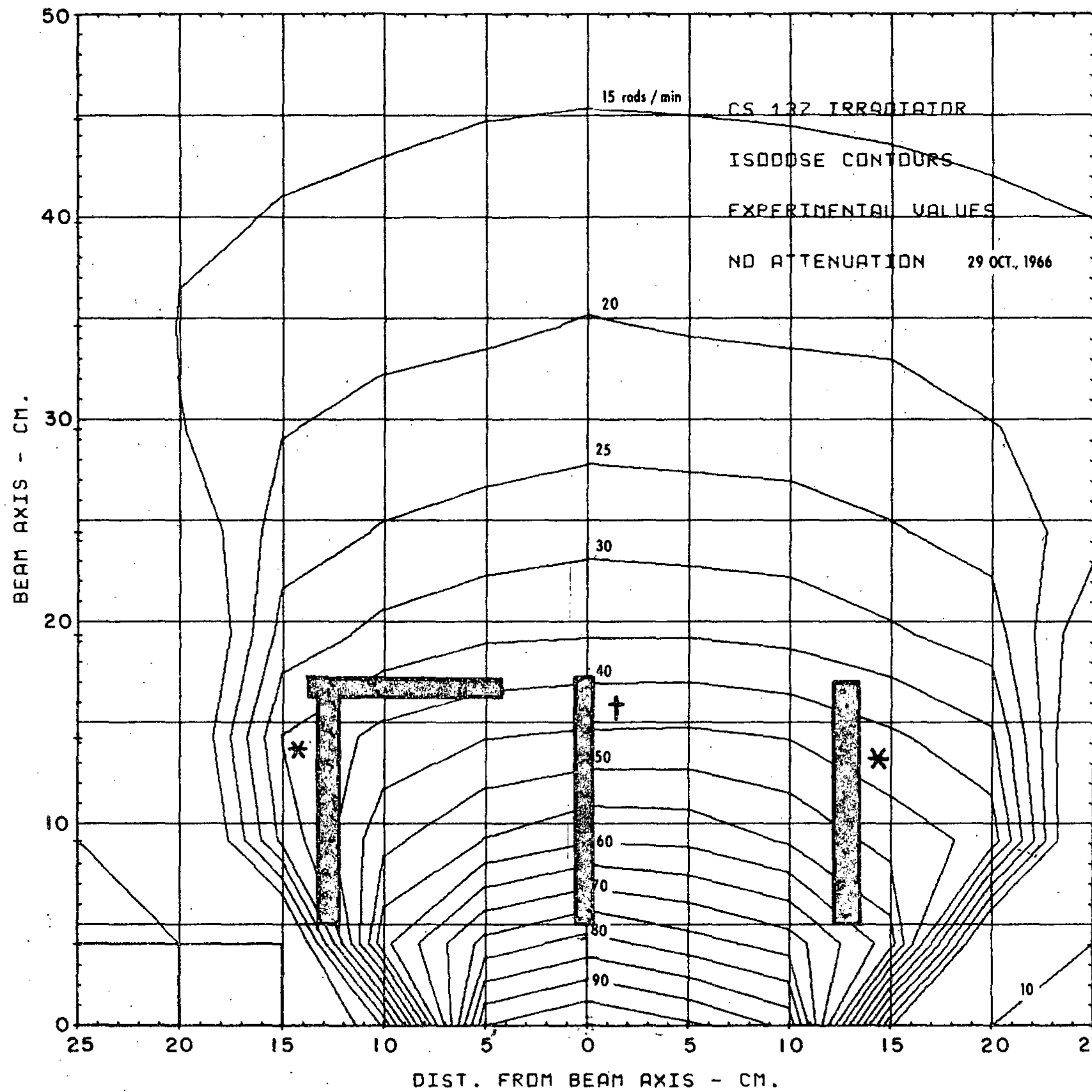

Fig. 5. Isodose curves within the empty irradiator chamber. No source attenuation. Data taken 10/66; strength reduced by 6.7% as per 10/69.

Possible locations of specimens on the horizontal shafts of the clinostat. * rpm = 1/2 to 8; † rpm = 2 to 32.

Possible locations of specimens on the vertical shafts of the clinostat.

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