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## A Body Plethysmograph for the Study of Respiratory Movements in Human Beings.

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The difficulty of obtaining satisfactory records of the depth and rate of respiration in untrained human subjects is known to all who have attempted to make these measurements. Even training, though it results in regular, quiet breathing, undoubtedly alters the normal, unrecorded respiratory movements. These difficulties are much magnified when dealing with patients who are suffering from embarrassed breathing, such as occurs in pneumonia. The presence of a mask or mouthpiece may alter the depth and rate of breathing profoundly. More important may be the changes brought on by the subject's consciousness of the fact that his respirations are being studied.

To circumvent these sources of error we have constructed a body plethysmograph, by means of which it is possible to record the respiratory movements of a patient sick with pneumonia without further embarrassment to his breathing, and, indeed, without his knowledge that his respirations are being observed. The apparatus consists of an air-tight box in which the subject's body is enclosed, his head projecting out of it through a rubber dam, which makes a tight seal about the neck.

The plethysmograph is not in principle different from ones used in animal experimentation. Since the adaptation of such an apparatus to the human subject required certain changes to meet the needs of comfort and convenience, particularly of temperature regulation, we have thought it worth while to publish a more or less detailed description of it.

The subject is transferred from his bed on to a hair mattress 152 cm. long by 79 cm. wide and 8 cm. thick. This mattress is countersunk into a solid platform which forms the base of the plethysmograph. A pillow is placed under the subject's knees. His neck lies in a semicircular yoke, and his head on an adjustable head rest. A rubber dam having at its center a circular hole approximately 6 cm. in diameter is pulled over the patient's head in such a manner that the edges of the hole fit snugly to the skin of the neck. The rubber dam is fortified about its periphery by a frame of heavy rubber sheathing 28 cm. square to which is has previously been cemented.

When the patient is accustomed to his new position and is quite comfortable, the cover of the plethysmograph is put into place. This consists of a tunnel-shaped aluminum structure supported and made rigid by iron arches and flanged by an iron frame 158 cm. by 87 cm. in dimensions. The radius of the arc of the tunnel is 47 cm. To fasten the aluminum tunnel securely to the oak platform, the flat surface of the iron frame is clamped by a series of eccentric clamps on to a gasket of thick walled pressure tubing which is countersunk into the oak platform. A semicircular opening at the head end of the tunnel coincides with the previously mentioned semicircular yoke to make a circular orifice through which the patient's neck projects. The diameter of the orifice is 17 cm. This is closed by the rubber dam, held in place by a hinged metal hoop which presses the rubber

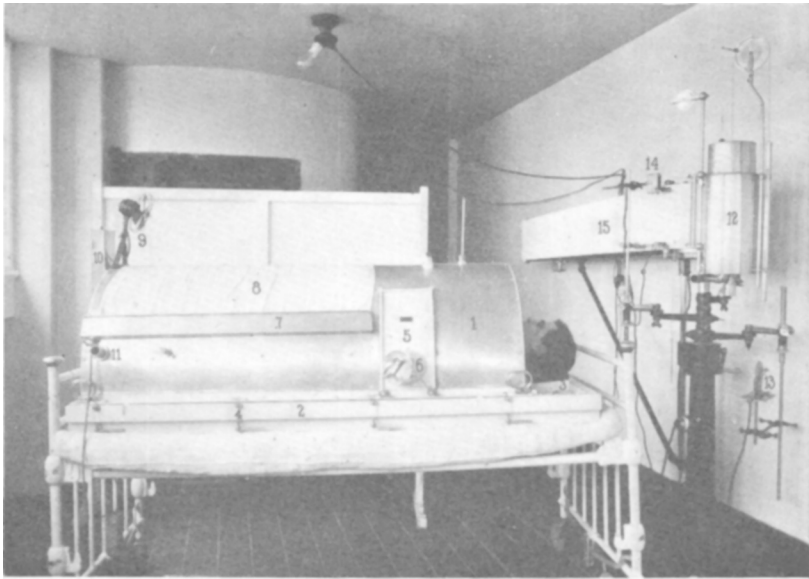


FIG. 1.

- |   |   |
|---|---|
| 1. Plethysmograph.  |   |
| 2. Oak base.  |   |
| 3. Adjustable head rest.  |   |
| 4. Eccentric clamp.   |   |
| 5. Door for access to patient.                                    |   |
| 6. Arm hole.  |   |
| 7. Trough containing water.                                       |   |
| 8. Moistened cloth.   |   |
| 9. Fan.   |   |
| 10. Housing containing relay and thermostat contacts. (The toluol |   |
|   | tube projects into the plethysmograph for a distance of 35 cm.)             |
|   | 11. Hose connection to communicate with volume recorder.                    |
|   | 12. Volume recorder.  |
|   | 13. Work adder.   |
|   | 14. Signal lever activated by each complete revolution of work adder wheel. |
|   | 15. Kymograph.  |

NOTE: The apparatus shown in the figure was made by Mr. Joseph Becker, 437 West 59th Street, New York City. The authors wish to thank him for his skill and helpful ingenuity.

against the rim of the opening. The general plan of the plethysmograph is shown in Figure 1.

*Temperature Control.* Without some provision for temperature control the air surrounding the subject will be gradually warmed by the heat given off from his body. This may cause a rise of temperature within the plethysmograph of 2° C. in 1 hr. (Table I), or more in the case of a febrile patient. A simple method of cooling was devised by playing a current of air from an electric fan on to the surface of the plethysmograph previously covered by a moistened cloth. The fan is automatically operated by a relay which in turn is activated by a toluol-mercury thermostat, the bulb of which lies within the plethysmograph. To keep the cloth moist, its longitudinal edges are allowed to dip into 2 water-containing troughs fixed to either side of the aluminum tunnel. With this arrangement the temperature within the plethysmograph can be kept fairly constant, the fluctuations usually not exceeding 0.5° C.

TABLE I.

*Showing increase of temperature inside Plethysmograph when no cooling device is used.*

Time	Room Temperature	Plethysmograph temperature
11:20	23.0	24.1
11:30	Subject introduced into plethysmograph	
11:35	22.7	27.0
11:40	22.6	27.5
11:50	22.6	28.0
12:03	22.5	28.1
12:12	22.6	28.6
12:23	22.5	28.9
12:33	22.7	29.0

TABLE II.

*Showing relative constant temperature inside Plethysmograph when thermostatically controlled fan is used.*

Time	Room Temperature	Plethysmograph temperature
11:10	21.2	25.0
11:18	21.3	25.2
11:30	21.1	25.2
11:45	21.2	25.1
11:55	20.8	25.2
12:05	20.7	25.0

*Recording Device.* For purposes of registering graphically the respiratory movements, the plethysmograph is made to communicate by means of a wide bore rubber tubing with a sensitive, well counterpoised spirometer. The movements of the spirometer bell are recorded in the usual manner on a kymograph. To obviate the

necessity of separate measurements of each line in the tracing the spirometer bell is connected with a work adder which integrates the excursions of the volume recorder. Each complete revolution of the work adder wheel is graphically recorded by a signal lever electrically through a relay. One revolution is equivalent to an air flow of 12.34 liters.

To make sure that the apparatus is leak-tight it is necessary only to place a 10 gm. weight on the top of the spirometer bell. If the level of the bell does not progressively fall there is no leak.

*Use of Apparatus.* The apparatus here described is at present being used for the quantitative study of the respiratory movements in patients suffering from pneumonia. An attempt is being made to correlate the condition of oxygen want, as measured by the percentage saturation of the arterial blood, with the rate and depth of the respiratory movements. The effect of morphine and oxygen on the state of anoxemia and on the character of the breathing is being studied.

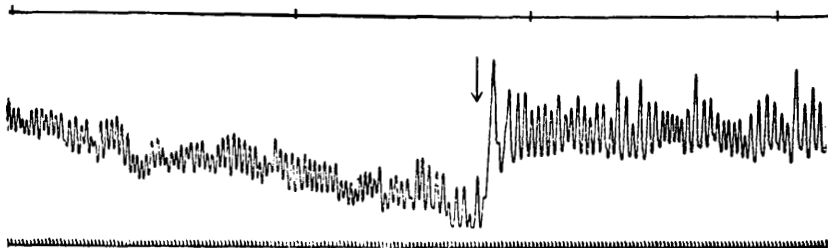


FIG. 2.

Graphic tracing showing the effect of applying a respiratory mask lightly to the face. The arrow indicates the point at which the mask was put into position. Upper line traced by work adder signal lever. The distance between marks records an air flow of 12.34 liters.

Lower line records time in 2 second intervals.

To show the artificial conditions imposed by the use of a mask, a graphic record is reproduced in Fig. 2. The first part of the record shows rate and depth of breathing when the patient in the plethysmograph was breathing naturally. In the second part of the record a light metal face mask with pneumatic rubber gasket was fitted over the patient's nose and mouth. There resulted an immediate change in the character of the breathing.