provided the signal is strong enough to be detected. Provision is made for tuning so that other transmitters on adjacent wave bands may be received successively. Visual and auditory monitoring are provided by an electric eye and a phone jack supplied by a special A.F. amplifier.

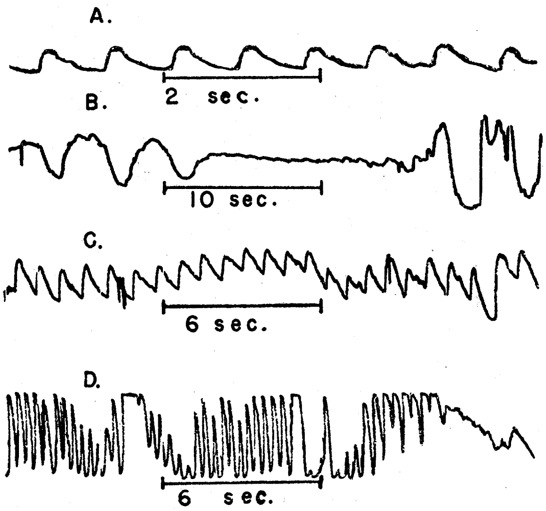

FIG. 2. Sample records made with Radio Inductograph: 1, human carotid pulse; 2, human pneumogram (note that heart rate can be read during period of apnea); 3, human finger pulse; 4, dog pneumogram.

(4) As a recorder we have used a Grass Model III electroencephalograph in which a special low-speed paper-moving mechanism has been installed. The output of the receiver is plugged into the input board of the electroencephalograph, taking care that a common ground connection is made. Because of the relatively high input voltage, the preamplifier of the electroencephalograph is not used, and the receiver output is applied directly to the power amplifier. Sample records made with this arrangement are reproduced in Fig. 2.

The performance of the Radio Inductograph has not been completely determined. Using an antenna zigzagged across an open field approximately 100′ × 25′, it has been possible to obtain satisfactory records of respiration over the entire area. Some difficulty has been experienced with interference from radio direction beacons operating in the same frequency range. A simple loop antenna hung from the wall will pick up satisfactorily from any part of an average-sized laboratory room. Care has been taken in designing the device to keep the power output within the limitations of the Federal Communications Commission's regulations.

Two types of artifacts may be troublesome. Microphonics may be produced by excessive jarring, but records can be satisfactorily made during moderate activity. Capacitance effects may change the frequency as the subject approaches a large object or turns so as to block the transmitter from the antenna. These difficulties will be corrected in later models.

When adapted to animal or human subjects, the device is inconspicuous and is not uncomfortable when worn for considerable periods of time. Thus, it may be used to indicate physiological changes with the subject practically unaware that his responses are being recorded. It can also be used in situations when the restraint of the subject would defeat the purpose of the experiment.

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Design of a Collapsible, Lightweight "Iron Lung" Respirator[1]

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When the muscles providing respiration are paralyzed, as in poliomyelitis or high section of the spinal cord, life can be sustained by subjecting the patient to rhythmic negative pressure over all the body excepting the head. The recumbent patient is placed in an iron cylinder (the "iron lung") with the head and neck protruding through an adjustable airtight seal, such as sponge rubber or a rubber iris diaphragm, so that suction in the cylinder can be produced without much leakage around the neck. The suction is commonly produced by a motor-driven bellows or diaphragm attached to the cylinder. Controls are provided so that positive pressure may be eliminated and the desired rate and depth of respiration are obtained. With a peak vacuum rarely higher than 20 cm of water, the chest is expanded, and inspiration occurs. The elasticity of the lungs and chest wall, aided by gravity, produces expiration when the suction is released in the remaining portion of the cycle of the bellows or diaphragm.

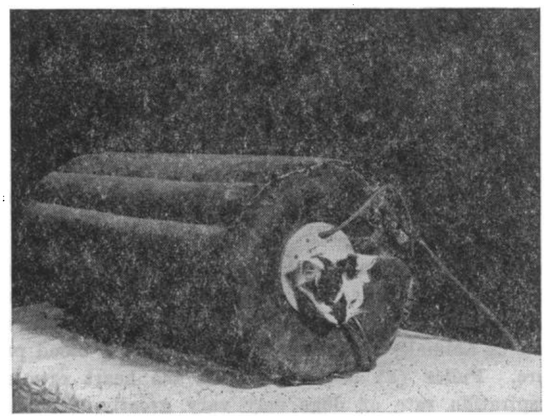

FIG. 1

The "iron lung" has disadvantages under particular circumstances. It is heavy and rigid so that it is difficult to transport, occupies considerable storage space, and is expensive. A rubber bellows modification of the "iron

[1] Aided by a grant from the Fluid Research Fund of the Yale University School of Medicine.

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lung'' (Iron Lung Company of America) offers improved portability, since it can be transported by ambulance, while the steel cylinder requires a truck.

We have found that it is possible to design a cylinder which will be sufficiently rigid to serve as a respirator, and yet which will be composed of lightweight rubberized cloth or pliable plastic sheeting so that it can easily be folded compactly into a suitcase for storage or transportation. A model of Neoprene-impregnated Nylon, which has been tested satisfactorily on an anesthetized cat curarized to arrest respiration, is illustrated in Fig. 1.[3]

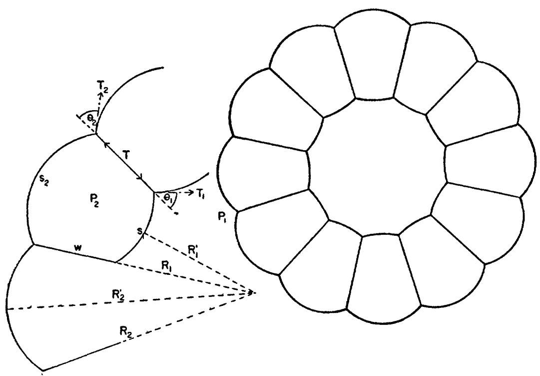

FIG. 2

A spirometer indicated that any desired degree of ventilation can be attained, up to levels several times that obtaining in the control period with voluntary respiration. In fact, the 32″-long cylinder, which weighed less than 2 lbs, was easily able to withstand a vacuum of 55 cm of water.

Fig. 2 shows cross sections of a respirator cylinder. It consists of two impervious walls, like a thermos flask, but differing in that they are interconnected by radial partitions which extend the length of the cylinder. These partitions are not attached to the airtight material at the ends of the cylinder so that air flows freely throughout the double-walled annular enclosure from a single inlet. In the model seen in Fig. 1, a plywood disc carrying a sponge-rubber neckpiece sealed one end of the inner cylinder and also included tubes to permit evacuating the chamber and to measure pressure. The design dimensions and other characteristics of the model constructed are shown in Table 1, the symbols corresponding to those in Fig. 2. An analysis of the forces involved permits one to choose workable dimensions, since not all choices will support an inner evacuated cylinder. In order to equalize the tensions in the outer and inner cylinder sheaths when they are maximal, the angles formed with the line of the partition by the inner and outer sheaths were chosen equal at zero inner cylinder pressure for the projected design of the human respirator, as outlined in Table 1. The tensile strength of the coated fabric used in the model is given as 150 lbs/in in either direction, so that the peak stress of 23 lbs/in to be reached in the partitions in the larger design is not excessive. The mathematical analysis has not allowed for the deformation of the pneumatic cylinder by the weight of the mattress and patient. However, the air pressure of 6 lbs/in² is quite able to sustain such a load with little deformation; actually, the resulting change in shape would probably reduce the over-all bulk.

The mode of evacuating the air-supported chamber to induce rhythmic respiration need not be different from the methods now in use: bellows; diaphragm; vacuum pump and flexible hose. If desired, a diaphragm can be driven by air pressure alone; in fact, the diaphragm can be two-walled impervious cloth rendered rigid by the same pneumatic principles utilized to support the evacuated chamber. However, since the hollow pressurized wall can be made quite gastight, no constant source of air pressure is required. A tire pump or a cylinder of compressed gas are adequate, inexpensive, freely available, and interchangeable.

TABLE 1

DIMENSIONS AND CHARACTERISTICS OF COLLAPSIBLE RESPIRATOR

Type	Pressure inside		No. of partitions (n)	Width of partition in inches (w)	Arc length in inches		Radius of inner cylinder in inches		Radius of outer cylinder in inches		Angle in degrees between radius and arcs		Tension in cloth in lbs/in		
	respirator in cm of H_2O (P_1)	wall in lbs/in² (P_2)			inner (S_1)	outer (S_2)	minimum (R'_1)	maximum (R_1)	minimum (R_2)	maximum (R'_2)	inner cylinder (θ_1)	outer cylinder (θ_2)	inner cylinder (T_1)	outer cylinder (T_2)	partition T
Model for cat	0	2.0	12	3.0	1.5	4.0	2.6	2.8	5.8	6.8	57.9	33.0	5.0	3.2	5.3
Design for	0	6.0	24	3.0	3.7	5.0	12.2	13.0	16.0	17.1	38.2	38.2	14.6	14.6	23.0
human	−20	6.0	24	3.0	3.7	5.0	11.6	12.5	15.5	16.6	31.7	34.5	13.3	13.7	22.6

[3] We are indebted to David Clark & Company for the Neoprene-coated cloth, to Seamless Rubber Company for dipping it in latex, and to Helen Lebensky for sewing the model. A model of vinyl plastic sheeting, made on the electronic sewing machine, was not technically satisfactory but has considerable promise because of the possibility of obtaining a transparent respirator.