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BRIEF COMMUNICATIONS

Closed-system habitat for high pressure exposures of animal colonies

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Morin, R. A., and B. S. Laraway. 1976. Closed-system habitat for high pressure exposures of animal colonies. Undersea Biomed. Res. 3(1): 57-62.—A deep-diving system has been designed for use with colonies of small rodents at pressures up to 170 ATA. The system consists of a triple-envelope arrangement in which a modular habitat serves as the animal living quarters. The habitat contains provisions for temperature control, gas analysis, and measurement of physical performance and social interaction; it also contains food and water supplies. The surrounding envelope (an acrylic box) is used to control the composition of the gaseous environment presented to the animal colonies. The outermost envelope (a high pressure chamber) maintains the desired pressure conditions. Colonies of five deer mice have been successfully studied at pressures up to 100 ATA. Their performance has been evaluated during 1- to 4-day exposures to various gaseous environments.

hyperbaric environment — saturation diving
closed environment — bioengineering
atmosphere control — performance
life support equipment — group behavior

Small mammals are classically used as models in studies whose results are ultimately applied to man. The choice of colonies of deer mice to evaluate the effects of prolonged exposure to high pressures inspired the design of a system that met biosupport requirements and provided for the monitoring of wheel-running activity during controlled photoperiods. The system that was developed, its operation, and its uses are described.

SYSTEM DESCRIPTION AND OPERATION

The system consists of a three-in-one package: a modular mouse habitat is enclosed in an acrylic box that permits control of the immediate mouse environment; the box, in turn, is enclosed in a high pressure chamber.

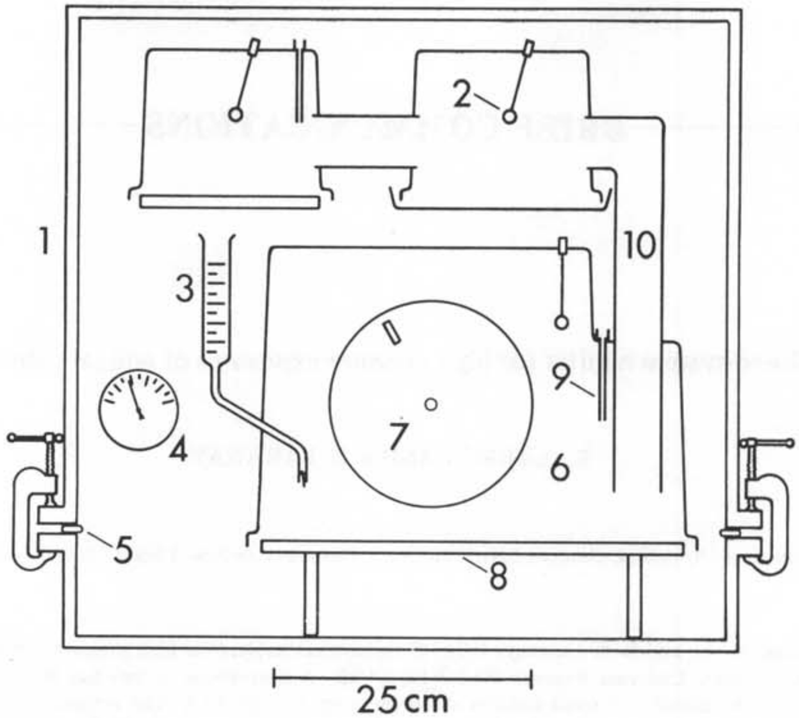

Fig. 1. Features of the habitat and controlled environment box. (1) Controlled environment box, (2) thermistor probe, (3) water reservoir, (4) hygrometer, (5) flat gasket, (6) habitat, (7) activity wheel, (8) heat plate, (9) gas-sample site, (10) climbing tower.

Habitat

The animal quarters were constructed using selected components of a commercially available housing unit known as Habitrail.[1] When arranged as shown in Fig. 1, the modular habitat provides a large lower compartment with an activity wheel, a vertical climbing tower, and a water reservoir fitted with a tilt-action valve.[2] The two upper compartments are interconnected and contain the food supply. Gas-sample lines and thermistor probes were positioned throughout the habitat (as indicated in the figure).

Controlled-environment box

A 100-liter, clear acrylic, two-part box was designed to contain the habitat described. As shown in Fig. 2, the lower section of the box provided penetrations for electrical wiring[3] and gas supply and sampling lines. A flat gasket-clamp arrangement provided a gas-tight seal when the upper portion of the box was in place (see Fig. 1).

High pressure chamber

The 5000-liter spherical compartment of the 170-ATA pressure chamber (Lanphier, Morin, Canty, and Miller 1971) was used for all exposures to high pressure. Its relationship

[1] Metaframe Corporation, East Paterson, NJ.

[2] Lifeguard Watering Systems, Napa, CA.

[3] Ductorseal Feedthrus, Douglas Engineering Co., Rockaway, NJ.

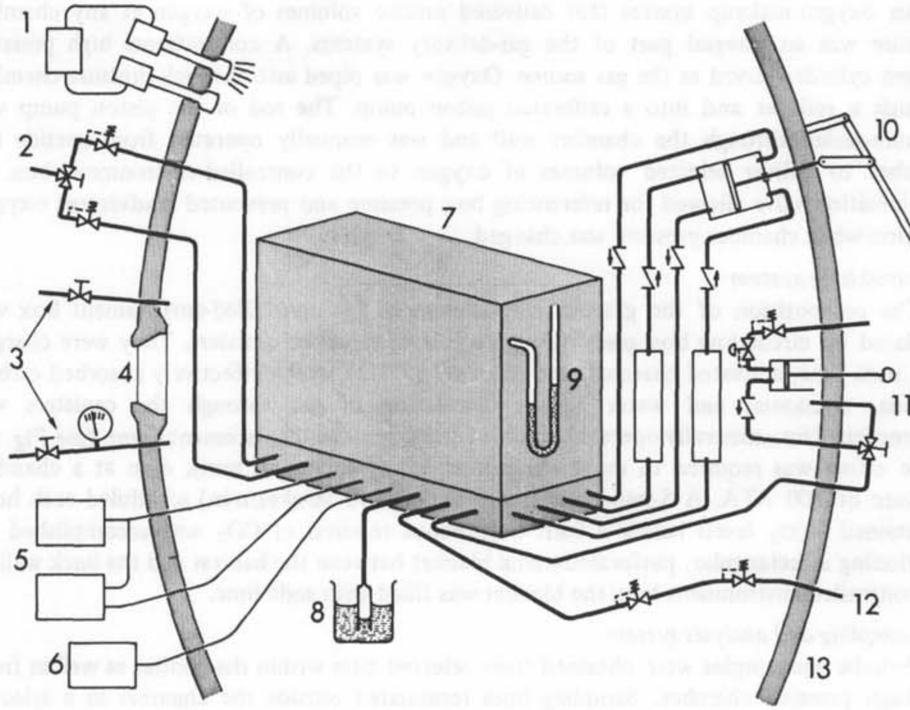

Fig. 2. High pressure chamber/habitat system. (1) Canty lights and timing system, (2) gas sampling system, (3) air pressure controls, (4) chamber window, (5) heating system, (6) activity counter, (7) controlled-environment box, (8) water-seal reservoir, (9) water manometer, (10) gas-scrubbing system, (11) oxygen-makeup system, (12) mixed-gas supply, (13) 170-ATA chamber wall.

to the controlled environment box is represented in Fig. 2, which is a schematic view of the various systems that are linked to the habitat via the chamber.

Gas delivery systems

Depth simulation was achieved by delivering compressed air to the high pressure chamber while simultaneously delivering a selected gas mixture to the controlled-environment box. The latter mixture was supplied to the box by way of a single-hose, scuba-type regulator. A 5-cm pressure head was produced in the box by channeling the exhaust through a large-bore tube (2 cm) into a water reservoir. This box pressure head (as indicated by a water manometer[4]) provided for leak testing at the surface and prevented inboard leaks to the box while at pressure. The large-bore tube served as an exhaust from the box during ascent of the chamber.

An additional feature of the gas-delivery system provided for the changing of gas mixtures in the box at depth. By placing a different gas mixture on the supply manifold and opening an exhaust valve on the outside of the chamber, exhaust gases were directed to a 100-liter spirometer that provided a measure of gas exchange. Thus, an investigator could alter the composition of the mouse environments without changing ambient pressure.

[4] An apparent increase of the pressure differential across the water manometer occured as chamber pressure increased. This was due to the overpressure regulator being located below the level of the manometer. The specific gravity difference between air and $He\text{-}O_2$ is magnified at high pressure and a vertical pressure gradient becomes more pronounced.

An oxygen-makeup system that delivered precise volumes of oxygen at any chamber pressure was an integral part of the gas-delivery systems. A conventional high pressure oxygen cylinder served as the gas source. Oxygen was piped into the high pressure chamber through a reducer and into a calibrated piston pump. The rod of the piston pump was pressure-sealed through the chamber wall and was manually operated from outside the chamber to deliver selected volumes of oxygen to the controlled-environment box. A multiposition valve allowed for referencing box pressure and prevented inadvertent oxygen addition when chamber pressure was changed.

Gas-scrubbing system

The composition of the gaseous environment in the controlled-environment box was regulated by circulating box gases through a pair of scrubber canisters. They were charged with soda lime, activated charcoal, and silica gel (5:3:2), which effectively absorbed carbon dioxide, ammonia, and water vapor. Circulation of gas through the canisters was accomplished by a manually operated, double-acting, positive-displacement pump (see Fig. 2.) Little effort was required to move the piston rod (diameter–6 mm), even at a chamber pressure of 100 ATA. A 5-min period of pumping (40 strokes/min) scheduled each hour maintained P_{CO_2} levels below 3 torr. Continuous removal of CO_2 was accomplished by positioning a rectangular, perforated-metal blanket between the habitat and the back wall of the controlled-environment box; the blanket was filled with soda lime.

Gas-sampling and analysis system

Periodic gas samples were obtained from selected sites within the habitat as well as from the high pressure chamber. Sampling lines terminated outside the chamber in a selector valve. Following pressure reduction to 4 psi, the gas samples were directed to a gas-analyzer, plug-in manifold. Gas analyzers found compatible with our needs were an F3 Beckman oxygen analyzer, a 315B Beckman carbon dioxide analyzer, an MGA 1100 Perkin-Elmer mass spectrometer, a Thermox I oxygen analyzer, and Dräger gas detector tubes.

Temperature regulation

Habitat gas temperatures were controlled by two aluminum heat plates, situated beneath the wire-mesh floors of the lower compartment and one of the two upper compartments (Fig. 1). Several thermistors (banjo probes YSI type 408) were secured into machined slots on the upper surface of the plates and heating elements were attached onto the undersides. By wiring one probe to a proportional temperature controller (YSI Model 72) and several others to a scanning telethermometer (YSI Model 47), plate and gas temperatures were obtained. Although the heating elements were 220 VAC, wiring them through a voltage regulator at 80 VAC and incorporating a ground fault circuit interruptor removed the threat of electrical mishap.

Lighting Control

Translumination of the habitat and high pressure chamber was carried out by using two Canty lights (Canty 1973). One of the lights was modified to produce red light, thus simulating the nocturnal phase of a light cycle while providing for visual observation of animals in the habitat. Alternate 12-hour periods of red and white light were maintained by automatic timing devices (Fig. 2).

Activity counter

A magnet attached to the activity wheel (shown in Fig. 1) and a glass-encapsulated reed switch secured to the outer wall of the habitat completed an electrical circuit that was closed and reopened by each revolution of the wheel. These closings and openings were automatically recorded over 1-hour periods by an electronic activity counter.

THE INTEGRATED SYSTEM IN USE

The exposure of colonies of five deer mice to pressures up to 100 ATA has been accomplished using the system described. A companion paper, published in this issue of *UBR* (Rahn and Rokitka 1976), documents a series of saturation dives wherein the effects of several inert gas mixtures were studied. The flexibility of the system described in the present paper is reported in another publication (Rokitka and Rahn in press), which describes the use of oxygen make-up and inert gas delivery systems to vary gas tensions while at maximum pressure. Exposures to 100 ATA are also reported in the same reference.

Although the habitat and environmental-control systems were specifically developed to accommodate colonies of deer mice at pressures up to 170 ATA, their successful use has suggested other applications. The systems could be adapted for use at 1 ATA for the purpose of evaluating the effects of environmental variables on a closed social system. With minor structural modifications, larger animals could be studied. By changing the geometry of habitat components (living compartments, climbing tower, and connecting tunnel), different kinds of activity could be observed and quantified. In addition, the positive-displacement piston pump has proven to be an effective tool for moving known volumes of gas quietly through a scrubber system at high pressure. The principle on which it operates has dictated the design of a prototype pump for manned chamber operations. A modified version of this pump has been built and is currently being tested.

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Morin, R. A., and B. S. Laraway. 1976. Loge en système fermé pour l'exposition de groupes d'animaux à des hautes pressions. Undersea Biomed. Res. 3(1): 57-62. Un appareil de plongée profonde pour des pressions jusqu'à 170 ATA a été créé pour l'étude de petits rongeurs. Le système est arrangé en "enveloppe triple," dont l'élément intérieur sert de loge aux animaux; il est appareillé pour l'analyse des gaz, le contrôle de la temperature, des mesures de performance physique, et l'observation des comportements sociaux, et pour l'approvisionnement des animaux. Le deuxième "enveloppe" (une boite en acrylique) sert à controler la composition de l'atmosphère gazeux présenté aux animaux. L'enveloppe extérieur, une chambre hyperbare, maintient la pression désirée. On a reussi à étudier des groupes de *Peromyscus* (Rongeurs) à des pressions jusqu'à 100 ATA. Leur comportement a été évalué au cours de periodes d'exposition de 1-4 jours en milieux gazeux divers.

milieu hyperbare
milieu fermé
contrôle de l'atmosphère
comportement social
plongée à saturation
biotechnique
performance
Peromyscus

REFERENCES

Canty, J. M. 1973. Hyperbaric chamber lighting. Am. Soc. Mech. Eng. [N.Y.C.] Publ. 73-PET-9. [Presented at Petroleum Mechanical Engineering Conference, Los Angeles, Calif., Sept. 6-20, 1973.]

Lanphier, E. H., R. A. Morin, J. M. Canty, and J. N. Miller. 1971. Pressure capability of 170 atm for physiological research at Buffalo. Med. Dello Sport 24: 238-240.

Rahn, H., and M. A. Rokitka. 1976. Narcotic potency of N_2, A, and N_2O evaluated by the physical performance of mouse colonies at simulated depths. Undersea Biomed. Res. 3(1): 25-34.

Rokitka, M. A., and H. Rahn. (in press) Physical performance of mouse colonies as a measure of inert gas narcosis, oxygen toxicity, and the Chouteau effect. Proceedings of the Sixth Symposium on Underwater Physiology, San Diego, Calif.