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| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
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| 1. REPORT NUMBER M22/85 | 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE (and Subtitle) An Environmentally-Controlled Extended-Use Small Animal Hypobaric Chamber | | 5. TYPE OF REPORT & PERIOD COVERED |
| | | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s) James A. Devine | | 8. CONTRACT OR GRANT NUMBER(s) |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Rsch Institute of Environmental Medicine Natick, MA 01760-5007 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 3M161102BS10 54682101002 |
| 11. CONTROLLING OFFICE NAME AND ADDRESS US Army Research & Development Command Fort Detrick Frederick, MD 21701-5012 | | 12. REPORT DATE 21 Mar 85 |
| | | 13. NUMBER OF PAGES 16 |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Same as above | | 15. SECURITY CLASS. (of this report) unclassified |
| | | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |
| 16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution is unlimited. | | |
| 17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) | | |
| 18. SUPPLEMENTARY NOTES | | |
| 19. KEY WORDS (Continue on reverse side if necessary and identify by block number) rodents; atmospheric pressure simulation; altitude; temperature; relative humidity | | |
| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number) An environmentally-controlled extended-use small animal hypobaric chamber has been designed to study small laboratory animals at low barometric pressures for long periods of exposure. The rectangular chamber (91.4 X 71.1x 50.8 cm) is constructed of aluminum plate and acrylic resin, with a volume of 32.3 cm ³ . A computer/data acquisition control unit provides for controlling and collecting data on pressure, temperature and relative humidity (RH) for an indefinite period of time. Altitude simulation is achieved using a two-stage, air-cooled vacuum pump with a displacement of 30 cm ³ /min. The pressure within | | |

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the chamber is controlled by an incremental throttling valve in the vacuum line. Temperature (0-100°C) is measured with a platinum thermometer and is accomplished by using a remote-controlled constant temperature circulating bath. RH (20-80%) is measured with a sulfonated polystyrene resistance grid with pre-conditioned air being supplied to the chamber using the purge air ventilation system. Saturation is controlled by modulating air through a moisture condensing tube or a water-jacketed aerator. Drinking water and electrical feed-throughs are passed into the chamber using airtight bulkhead adapters. Combined long-term environmental simulations were conducted at 380 and 522 ± Torr, temperature at 21 ± 2°C and RH 50 ± 5% for 3 weeks.

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AN ENVIRONMENTALLY-CONTROLLED EXTENDED-USE
SMALL ANIMAL HYPOBARIC CHAMBER

James A. Devine and Allen Cymerman

US Army Research Institute of Environmental Medicine
Natick, MA 01760-5007

Abbreviated Title: Small Animal Hypobaric Chamber

Mailing Address:
Mr. James A. Devine
Altitude Research Division
US Army Research Institute of Environmental Medicine
Kansas Street
Natick, MA 01760-5007



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ABSTRACT

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An environmentally-controlled extended-use small animal hypobaric chamber has been designed to study small laboratory animals at low barometric pressures for long periods of exposure. The rectangular chamber (91.4 x 71.1 x 50.8 cm) is constructed of aluminum plate and acrylic resin, with a volume of 32.3 cm³. A computer/data acquisition control unit provides for controlling and collecting data on pressure, temperature and relative humidity (RH) for an indefinite period of time. Altitude simulation is achieved using a two-stage, air-cooled vacuum pump with a displacement of 30 cm³/min. The pressure within the chamber is controlled by an incremental throttling valve in the vacuum line. Temperature (0-100⁰C) is measured with a platinum thermometer and is accomplished by using a remote-controlled constant temperature circulating bath. RH (20-80%) is measured with a sulfonated polystyrene resistance grid with pre-conditioned air being supplied to the chamber using the purge air ventilation system. Saturation is controlled by modulating air through a moisture condensing tube or a water-jacketed aerator. Drinking water and electrical feed-throughs are passed into the chamber using airtight bulkhead adapters. Combined long-term environmental simulations were conducted at 380 and 522 ± 2 Torr, temperature at 21 ± 2⁰C and RH 50 ± 5% for 3 weeks.

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Index Terms: rodents; atmospheric pressure simulation; altitude; temperature; relative humidity

In recent years there has been a growing number of scientists interested in the adaptive mechanisms of experimental animals to conditions of environmental stress, particularly temperature and altitude. Despite considerable attention, research has been limited due to restricted access of facilities that simulate altitude. Many investigators have fabricated hypobaric chambers from existing laboratory hardware, e.g., Baumel et al. (1) used a series of plastic desiccators, Blatteis et al. (2) describes a salvaged pressure-dressing sterilizer, and Malette et al. (4) utilized a rapid decompression chamber of their own design. Various other hypobaric chambers have been designed in-house using unique control instrumentation. Valdivia et al. (5) performed a continuous exposure study on guinea pigs at low barometric pressure in a large steel tank with view ports. Calcium chloride driers collected moisture and pressure was measured with a mercury manometer. Brubach et al. (3) described a sophisticated dual pressure chamber with automatic safety devices. Temperature was regulated using a condenser unit with refrigeration coils wrapped around the center of the chamber for cooling. The inside was equipped with an electric lamp to raise the temperature. Although the creativity in design and construction of these apparatuses are remarkable, there is a need to standardize a system that will make hypobaric research possible at all institutions.

Man-rated and equipment hypobaric chambers in which animal research could be performed are not readily available to the scientific community. Most are expensive to operate and lack the sophistication in control systems for long-term confinement studies. The small animal hypobaric chamber was designed for

construction in the laboratory or department machine shop. The control system can be assembled with off-the-shelf instrumentation and other equipment usually available in a research laboratory.

SPECIFICATIONS

The chamber is a rectangular shaped vessel, primarily constructed of aluminum plate and cast acrylic resin (fig. 1) measuring 91.4 x 71.1 x 50.8 cm with an internal volume of 32.3 cm³. The skeletal structure is a framework of aluminum angle 0.6 x 5 x 5 cm that is designed to support loads imposed by the differential pressure. The end caps and base are cut from 0.6 cm aluminum plate and reinforced with transversed structures (stiffeners) that divide the unsupported areas into smaller configurations for maintaining the metal integrity when under large differential pressure stresses. Electrical penetrations utilize air-tight fittings and are fed through the aluminum end caps. The sides and top are 2.5 cm acrylic resin providing maximal visual surveillance of inside activities without compromising basic requirements of selecting material with high strength to weight ratio. Thermoplastic acrylic resin is tailor-made for this type of vacuum vessel because of its outstanding memory and flexure characteristics. Each side is bolted to the frame through a 0.3 x 5 cm rubber gasket using 52 stainless steel nuts and bolts. They are designed for easy removal in the event maintenance or repairs become necessary. The gasket material is 40 durometer hardness, silicone-impregnated rubber and is cut from sheeting as one piece (seamless). Access to the chamber interior for experimental set-up and cleaning is provided by a removable top. Quick release cam-lock type clamps are used for securing the

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Figure 1
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top to the chamber. Clamps are strategically placed to apply an even distribution of compression on the rubber gasket to facilitate the initial vacuum application. The plenum housing which contains a heat exchange coil is located externally to the aluminum end cap of the chamber. Also located within the plenum is a miniature air circulating fan and an air channeling baffle plate for smoothing and concentrating air flow through the coil.

CONTROL SYSTEMS

Altitude Simulation: Chamber pressure is automatically controlled using a computer (Hewlett Packard 200S-16) and a data acquisition/control unit (DACU, Hewlett Packard 3497A). The DACU digitizes an analog voltage derived from a digital pressure gauge (Mensor 8240). The computer then uses the digitized signal in a feedback loop software program to control an incremental Solenoid valve on a thermal mass flowmeter (Porter F-2-2MFC). A vacuum pump (Gast 1022) is used to reduce pressure in the chamber compartment.

Ventilation air: Acceptable levels of oxygen and carbon dioxide gases are maintained by purging the chamber with sufficient volumes of fresh air. Incorporated in the software program are additional feedback signals in which chamber oxygen and carbon dioxide concentrations are compared to reference values and appropriate adjustments made by a second mass flow controller to the purge ventilation line. Medical gas analyzers (Beckman OM-14, oxygen; LB-2, carbon dioxide) are used to measure gas concentrations.

Temperature Control System: Temperature control (0-100 °C) is effected by using a remote-controlled circulating bath (Lauda KTC-4). Constant temperature control capabilities are provided by built-in mechanical

refrigeration and heating units. A remote thermistor is mounted inside the chamber allowing the interior to be the control point. Fluid (glycol/water) is circulated through the chamber's heat exchange coil (Eastern Industries E/HT 200) and returned to the circulating bath. Concurrently, air is circulated around the fins of the coil transferring fluid temperature into the chamber interior. A ceramic enclosed platinum resistance sensor element is used to measure the temperature. The sensor is housed in an environmentally-rated anodized aluminum collar (pressure boss) designed for pressure/vacuum applications. The pressure boss enables the sensor to be installed in the vacuum pump exhaust line, where air being drawn from the chamber circulates around the sensor providing the measurement. Temperature and relative humidity data are displayed on a digital readout instrument (General Eastern 400E) with analog output for recording.

Relative Humidity Control System: Relative humidity (RH) is controlled by employing the chambers ventilation air system (0-20 liters per minute, L/min) as a means for injecting pre-conditioned air. Humidification is accomplished by passing ventilation air through a water jacketed-aerator. The amount of saturation is controlled by modulating an ambient air bypass line to mix with the humidified line until desired set-points are reached. Dehumidification is accomplished by passing ventilation air through a condenser (Allihn C7930) where moisture collects on the inner surface of the cooled tube with water droplets collecting in a condensate container below. The condenser is cooled using an instrument (Vortex 104) that converts ordinary compressed air (1137 kg/cm) into a cold stream of air (-40°C).

sulfonated polystyrene resistance (AC) grid housed in the pressure boss. Both humidification and dehumidification are balanced with an ambient air by-pass to achieve desired RH within the chamber.

DISCUSSION

Chamber Design: The hypobaric chamber combines a computer with a data acquisition control unit for monitoring, controlling and collecting data with a design goal for simulating conditions found at high terrestrial elevations. The chamber's pressure, temperature, and relative humidity are automatically controlled and monitored. Ventilation air purges animal metabolic gases to maintain normal partial pressures of oxygen and carbon dioxide. Concurrently, air is circulated by a variable speed boxer fan through the heat exchanger and returns to the chamber proper creating a thoroughly mixed homogeneous environment. Portability was considered in the structural design. Materials (acrylic resin and aluminum) were chosen on the basis of high strength to weight ratios. Additionally, acrylic resin permits maximal surveillance of inside activities and a natural insulation for cold environment simulations. The chamber's rectangular shape allows for housing a number of animals or cages simultaneously.

OPERATING CHARACTERISTICS

After assembly, the operating characteristics were evaluated to verify the adequacy of the design and construction, and to determine the sensitivity and precision of the pressure, temperature, and relative humidity controllers. Test results can be seen in Figs. 2,3,4.

Altitude Test: The chamber was evacuated from 760 to 380 Torr in less

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than 14 minutes, with the final pressure maintained within ± 2 Torr. An additional test was conducted at high altitude (140 Torr) to observe for structural deformation and excessive leakage.

Temperature Test: Low (10°C) and high (50°C) temperature operations were conducted to ensure that the system will respond to large changes as well as maintain the required accuracy of $\pm 2^{\circ}\text{C}$ at 21°C during low (522 Torr) and high (380 Torr) terrestrial elevation simulations.

Relative Humidity Test: Small RH changes between 35-55% were quickly achieved, and control was effected within the required range of $\pm 5\%$ at 50%. Since ventilation air (0-20 L/min) is the means of removing metabolic products, it was expected that large changes in RH would be reflected in comparatively longer periods of time before equilibration.

Complete System Operation: After testing each of the separate environmental components, a combined test was performed at 2 different pressures. Using an initial controlled ascent rate of 450 m/min, pressures of 380 and 522 ± 2 Torr were maintained for 3 weeks at a temperature of $21 \pm 2^{\circ}\text{C}$, a relative humidity of $50 \pm 5\%$ and a ventilation flow rate of 10 L/min.

ACKNOWLEDGMENTS

The authors would like to thank Mr. Jose Milette for technical assistance on the instrumentation interface, SP5 William Sawyer for the mechanical drawing, and Mrs. Ruth Saleson for preparing the document.

Additional dimensional data available upon request.

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Legends

Fig. 1. Isometric view of the chamber showing the basic design structure: aluminum plate base and end caps, aluminum angle skeletal frame, cast acrylic resin top and sides, and the plenum chamber on the right end cap containing the heat exchange coil.

Fig. 2. Typical evacuation rate from 760 to 380 Torr at maximum pump capacity with no ventilation.

Fig. 3. Temperature change from 50 to 10⁰C at a constant barometric pressure of 380 Torr.

Fig. 4. Relative humidity change from 80 to 40% at a constant temperature of 30⁰C and a barometric pressure of 380 Torr.

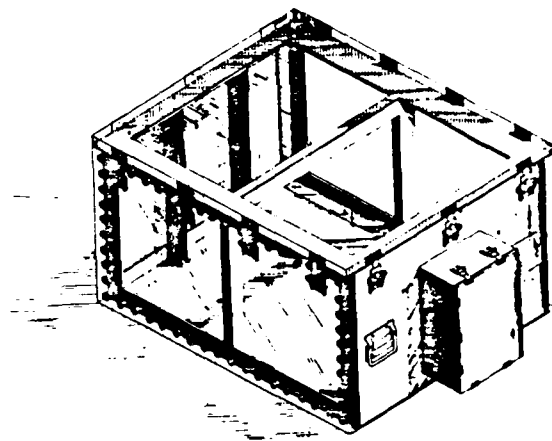


Figure 1

MAXIMUM EVACUATION RATE
NO VENTILATION (TEMP. $30 \pm 2^\circ\text{C}$)

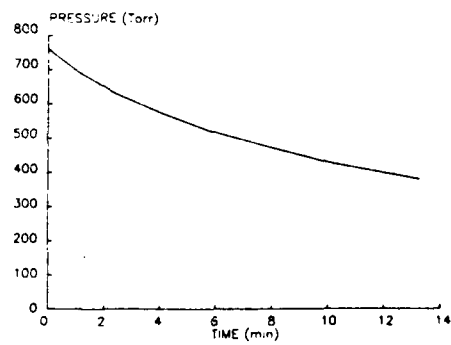


Figure 2

TEMPERATURE CHANGE
AT A CONSTANT PRESSURE (380 TORR)

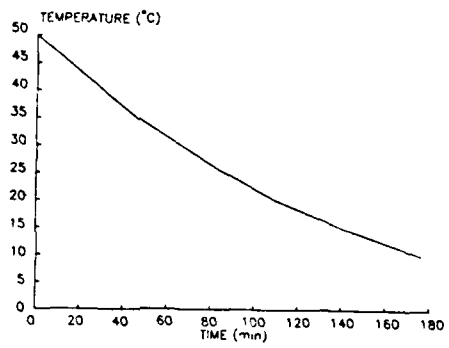


Figure 3

DEHUMIDIFICATION CAPACITY AT
CONSTANT TEMP. (30°C) AND PRESSURE (380 TORR)

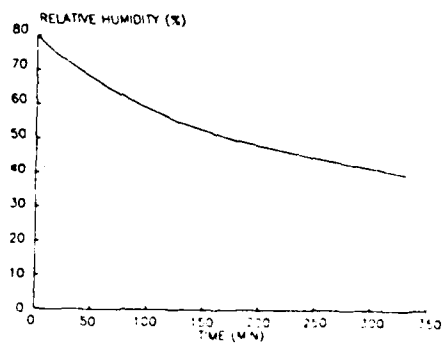


Figure 4

In conducting the research described in this report, the investigators adhered to the 'Guide for the Care and Use of Laboratory Animals' as prepared by the Committee on Care and Use of Laboratory Animals of the Institute of Laboratory Animal Resources, National Research Council.

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