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TOXIC HAZARDS RESEARCH UNIT ANNUAL TECHNICAL REPORT: 1966

J. D. MacEWEN
R. P. GECKLER

AEROJET-GENERAL CORPORATION

DECEMBER 1966

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The experiments reported herein were conducted according to the "Principles of Laboratory Animal Care" established by the National Society for Medical Research.

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DECEMBER 1966

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FOREWORD

This report was prepared by The Ohio State University Research Foundation under Contract No. AF 33(615)-2504. The contract was initiated under Project No. 1467, Task No. 146702. The work was administered under the direction of the Structures Division, Air Force Flight Dynamics Laboratory, Research and Technology Division, Mr. G. E. Maddux, Project Engineer.

The principal investigator and project supervisor was Dr. A. W. Leissa. Significant contributions were made by Dr. C. C. Lo, Dr. W. E. Clausen, and Mr. S. G. Sampath. Dr. Lo contributed heavily to the work described in Section II, Mr. Sampath to Section III, and Dr. Clausen to Section IV. Other graduate and undergraduate students of the Department of Engineering Mechanics of The Ohio State University also made contributions, particularly to the numerical solution of problems.

This report covers work from March, 1965 to July, 1966.

The manuscript released by the author, November 1966, for publication as an RTD Technical Report.

This technical report has been reviewed and is approved.

FRANCIS J. JANIK, JR.
Chief, Theoretical Mechanics Branch
Structures Division

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ABSTRACT

This report reviews the activities of the Toxic Hazards Research Unit (THRU) personnel over approximately a two-year period and is concerned primarily with the research accomplished. The research program has resulted in significant progress in areas of oxygen toxicity, toxicity screening of Apollo space cabin materials, fire extinguisher material evaluation, effects of reduced pressure and 100% oxygen on toxicity of materials in animals and effects of enriched oxygen-nitrogen mixtures at reduced pressure on toxicity of NO_2 and O_3. In operating the facilities during experimentation, various problems arose which required facility modification or additional equipment. Of special note were modifications and additions of fire protection equipment required as a result of a fire in one of the altitude chambers. An integrated alarm system was also designed and installed. Safety and operational procedures were reviewed and revised in accordance with the experience gained in the conduct of the research program of the THRU. A "Facility Operations and Maintenance Manual" reflecting that experience was prepared for the use of current and future operators of the Laboratory. Recommendations for modifying the facility in the future include additional fire protective devices within the Thomas Domes, improved automatic relative humidity control devices, additional altitude chamber isolation equipment, and special instrumentation for the weighing of laboratory animals under the experimental conditions of the domes.

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INTRODUCTION

The Toxic Hazards Research Unit (THRU), operated by Aerojet-General Corporation personnel, assists the Air Force in defining and solving toxicological problems arising from materials of either mundane or exotic use. Materials such as fire extinguishers, solvents and other substances for day-to-day use within the Air Force are investigated for their effects on animals at ambient pressure. Experiments in support of manned space flight programs are conducted under atmospheric conditions, simulating those found in space cabins to define a safe breathable atmosphere and to determine the effects of contaminants arising from materials of construction, equipment, and metabolic processes. These experiments are continuous exposures at reduced pressure in 100% oxygen and at varying pressures in mixed-gas environments.

The THRU facility includes preconditioning chambers, Rochester and Longley chambers for exposing animals to atmospheric contaminants at ambient pressure and air, and four altitude chambers (designated as Thomas Domes) for similarly exposing animals at pressures from ambient to as low as one-third atmosphere in either 100% oxygen or varying mixtures of oxygen and nitrogen. The animal exposure facility and related equipment are described in detail in AMRL-TR-65-125 (Entry 14 under Publications . . . page 27).

This second annual report presents primarily the research accomplishments during the first 23 months of operation of the facility. Facility modifications and special equipment required to meet changing experimental requirements are included. This report also describes various facility operational and experimental problems and their solutions, summaries of the annual toxicology conferences held, recommended future work, and the status of experiments in progress as of 1 August 1966.

SECTION II

FACILITIES

GENERAL

A set of 96 "as built" drawings of the facility has been prepared, and procedures for periodic up-dating of these drawings have been devised. A Facility Operations and Maintenance Manual has been written. These drawings, in conjunction with the manual, are used for training personnel in routine operation and maintenance tasks. This section presents the more important changes, additions to the equipment and some of the problems which have arisen since the preparation of AMRL-TR-65-125. Recommendations for future modifications are also made.

ALTITUDE LABORATORY

During the 23 months since the preparation of the first annual report, modifications to the altitude laboratory have developed as a result of the operating experience obtained by the THRU staff. Some modifications were incorporated as a result of mechanical accidents as well as a fire in one of the domes. The major items of modification and facility additions will be described hereunder:

Pass-Through Airlocks

A pass-through airlock was installed in each Thomas Dome.[1] These airlocks, constructed of aluminum plate 1/2 inch thick, were designed to occupy one window area in the top section of each dome; internally, the airlocks are 11-1/2 inches wide and 24 inches high. They are provided with doors, both inside and outside of the dome, that are gasketed and dogged at six locations and have valves for oxygen flushing, depressurization, and repressurization. A pressure gauge is mounted on each side of the dome wall for use in controlling the evacuation of the airlock. Depressurization can be effected by operating a laboratory vacuum pump when operating conditions are 100% oxygen at 5 psia or by opening the internal depressurization valve when operating conditions are a mixed gas atmosphere at 5 psia or at near-atmospheric pressure.

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[1] Designed by Aerojet-General Corporation; built by Wright-Patterson AFB Shop under the general supervision of MSgt. J. Naylor, Jr.

The airlock facilitates the passage of tools, animal food, animal cages, etc., into the controlled environment of the domes. The most significant advantage of the airlock, however, is that it facilitates the rapid removal of deceased animals for immediate necropsies.

Contaminant Venting System

A three-way solenoid valve was installed in the contaminant introduction system for each Thomas Dome. These valves were installed so that a power failure causing loss of air flow and vacuum pumping would not result in increased contaminant concentrations during periods of dome isolation. Such increases in contaminant concentration would seriously affect the outcome of an experiment and could also cause the experiment to be lost with subsequent loss of time and money. The contaminant vent solenoid allows the flow of contaminant into the chamber air supply system while chamber power is operative and vents to a safety exhaust line during periods of power failure or when manually switched over during other emergency periods.

Vacuum Exhaust System

A back check valve was incorporated in each dome exhaust line to prevent repressurization of the Thomas Domes in the event of power failure or vacuum pump failure. A manual shutoff valve was installed between the vacuum pump and the vacuum control valve to permit the isolation of individual domes for valve repairs. Rubber isolation spool pieces were installed before and after each vacuum pump to reduce vibration noise and to provide longer life for the pump.

Water Softener System

During the operation of the altitude facility, problems were encountered from the use of the hard water supply available at Wright-Patterson Air Force Base. Among the problems encountered was mechanical failure of each of the three large vacuum pumps controlling Thomas Dome pressures. The failure resulted from the accumulation of calcium and iron deposits within the pump housing which exceeded the fine tolerances of the pumps. To solve this problem, small water softeners were installed for those pieces of equipment requiring such protection. However, it became apparent that the majority of mechanically-operated equipment used in the THRU laboratory could fail from such accumulation of mineral deposits and, consequently, a water softening system capable of handling 20,000 gallons per day was installed in the primary water supply line to Building 79.

Liquid Oxygen Vaporizer System

As a result of several minor and one major mechanical failure in the critical temperature liquid oxygen vaporizer, a standby system of ambient temperature vaporizers was installed by the oxygen subcontractor, Air Products and Chemicals Corporation. To warn the laboratory shift operator of incipient or actual failure within the vaporizer system, a five-point alarm system was installed. This alarm system is diagnostic using lighted panels for each alarm point. These are identified as follows:

a. low heat exchange fluid temperature
b. circulating pump failure
c. high gas oxygen temperature
d. low gas oxygen temperature
e. low temperature gas flow shut off.

With the installation of the ambient temperature liquid oxygen vaporizer, a new standard operating procedure was developed for shifting operation from one unit to another. This procedure requires the opening of one pair of manually-operated valves and the closing of a second pair. Valve operation, however, was hindered by the naturally occurring formation of ice around the valves. Consequently, a line from the building steam system was installed in the oxygen storage pad for periodic defrosting of the valve handles. Later, the standard valve stems were replaced with cryogenic-type valve stems which extend above the ice layer and thus insure more readily operable valves.

Main Alarm System

A master alarm system was installed to provide alert signals to indicate malfunction in any of the independent operating alarm systems. This main alarm system consists of five alarm-light panels, installed in strategic locations throughout Building 79, which immediately indicate the independent system causing the signal. The display lights on the panels show the alarm points listed in Table I. Also included in the master system is an alarm relay unit, a series of conveniently-placed connection boxes, and an emergency power supply system for use in periods of electrical failure.

The master alarm system is interconnected with each (see Figures 1 and 2) critical alarm subsystem in the THRU facility through a relay and an alarm light. An alarm silence button is installed at each subsystem to acknowledge the alarm condition.

TABLE I

MAIN ALARM SYSTEM DISPLAY LAMP PANEL

	Alarm Light Designation	Subsystem
1.	Contaminant Control	Ambient Contaminant Control Panel
2.	Ambient Control	Ambient Laboratory Master Control Panel CP-1
3.	Ambient Power	Ambient Laboratory Power
4.	Air Compressor	Instrument Air Compressor
5.	Altitude Control	Altitude Laboratory Master Control Panel CP-A1
6.	Altitude Power	Altitude Laboratory Power
7.	MSA	Apollo Exposure Chamber Environmental Monitoring and Alarm Console
8.	Apollo Control	Apollo Master Control Center
9.	Oxygen Control	Oxygen Control Console
10.	LOX Pad	Liquid Oxygen System
11.	Ambient Air	Thomas Dome Ambient Air-Supply System
12.	Vacuum Pump	Thomas Dome Vacuum Pump System
13.	Package Chiller	
14.	Spare	

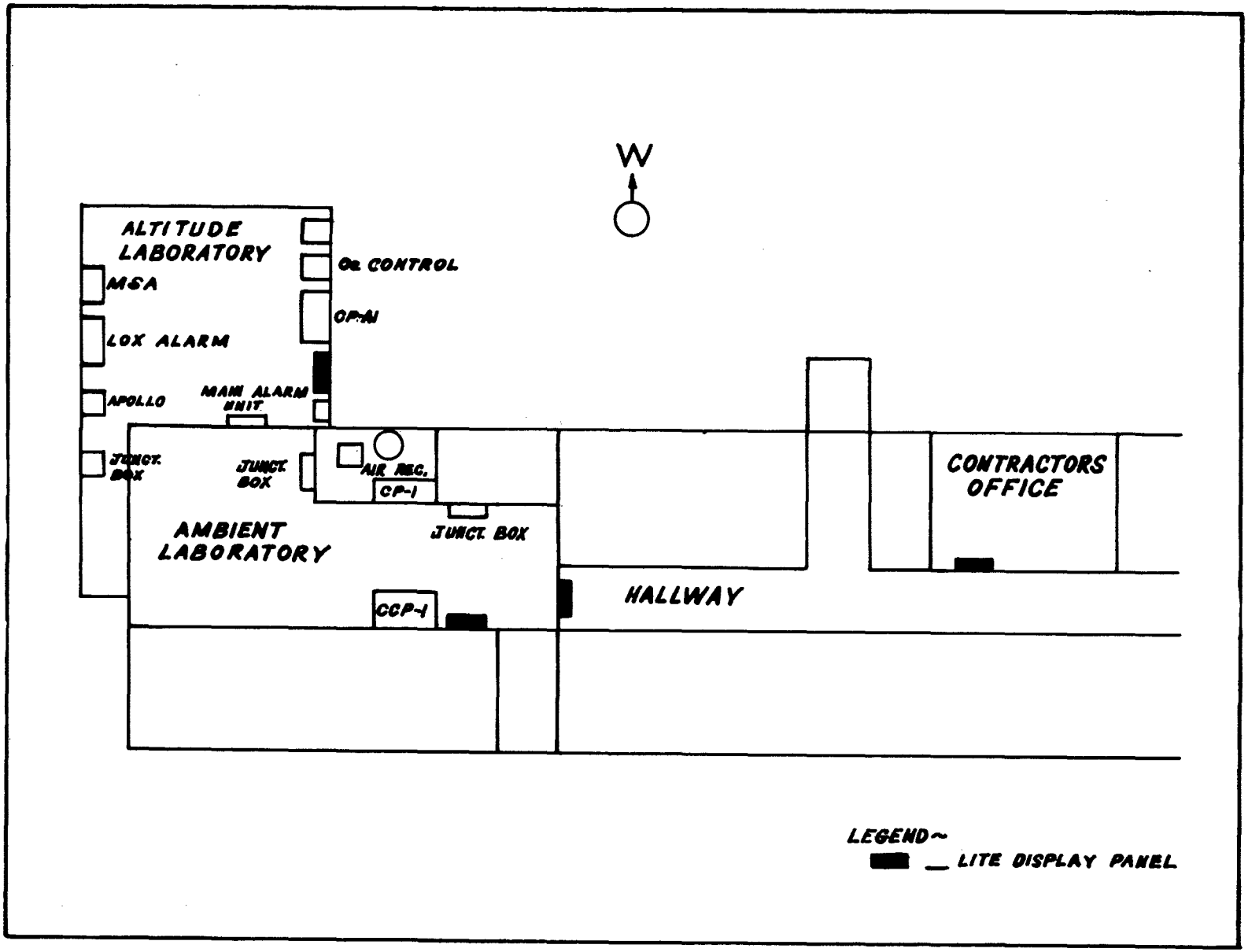

FIGURE 1
MAIN ALARM SYSTEM -- FIRST FLOOR

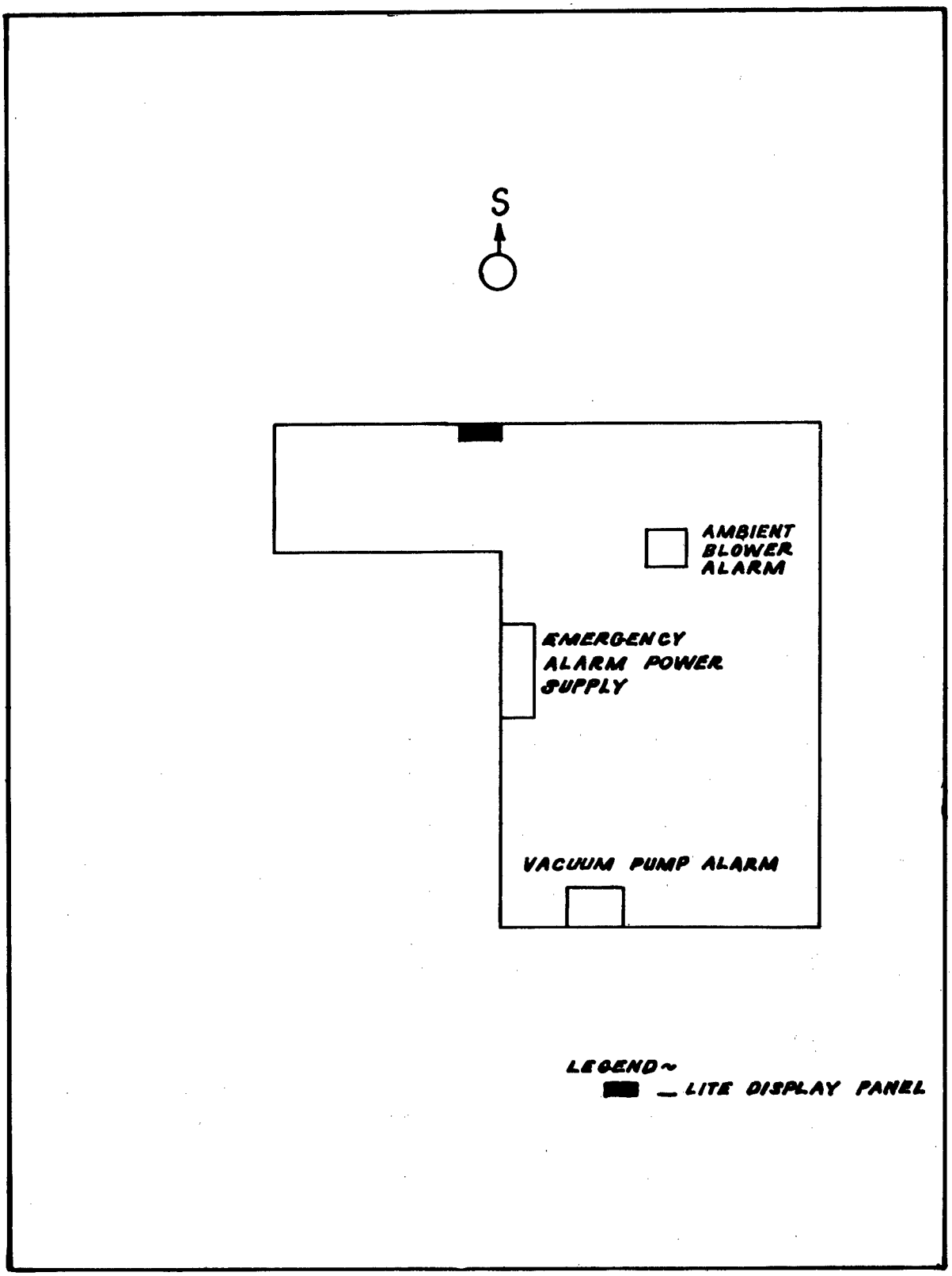

FIGURE 2
MAIN ALARM SYSTEM -- BASEMENT

Fire Prevention Equipment

As the result of a fire which occurred in Thomas Dome No. 2, an additional water sprinkler system was installed within the dome. This water deluge system is equipped with a manually-operated, externally-mounted valve permitting the shift operator to quench a fire. An additional fire-quenching system was installed in the dome vacuum exhaust line. After the dome has been isolated, this latter system provides for the flow of carbon dioxide into the dome through the annular exhaust ring located around the bottom wall. The carbon dioxide quench system is also operated through an external manual valve located at the periphery of the dome and will completely repressurize the chamber within 90 seconds after activation. An oxygen regulator has been installed to which each dome entrant is instructed to connect his breathing mask should carbon dioxide repressurization become necessary. [1]

Apollo Toxicity Screening Equipment

Equipment has been designed and constructed for toxicity screening of the gas-off products emanating from space cabin construction materials (Figure 3). This equipment has been incorporated into Thomas Dome No. 2. The design simulates as closely as possible actual space cabin environmental conditions. Specifically, the systems are operated at 5 psia pressure with a 100% oxygen-gas supply utilizing a life-support loop comprised of a water vapor and carbon dioxide removal system. Space cabin construction materials placed in an oven within the closed loop are heated to 155°F and the gas-off products produced under these environmental conditions are presented to experimental animals for prolonged periods of continuous exposure. The environmental parameters described above can be modified to meet the requirements of programs which may utilize other environmental conditions of varying pressures and gas mixtures.

Life-Support Console

The life-support console for the Apollo toxicity screening program consists of a cabinet containing three separate life-support units, each connected to a separate small animal chamber by means of a closed-loop system. Each unit of the console is comprised of a vacuum oven, water condensation chiller, a lithium hydroxide filter bed, a vacuum pump, and appropriate flowmeters.

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[1] Regulators acquired and installed by MSgt. J. Naylor, Jr.

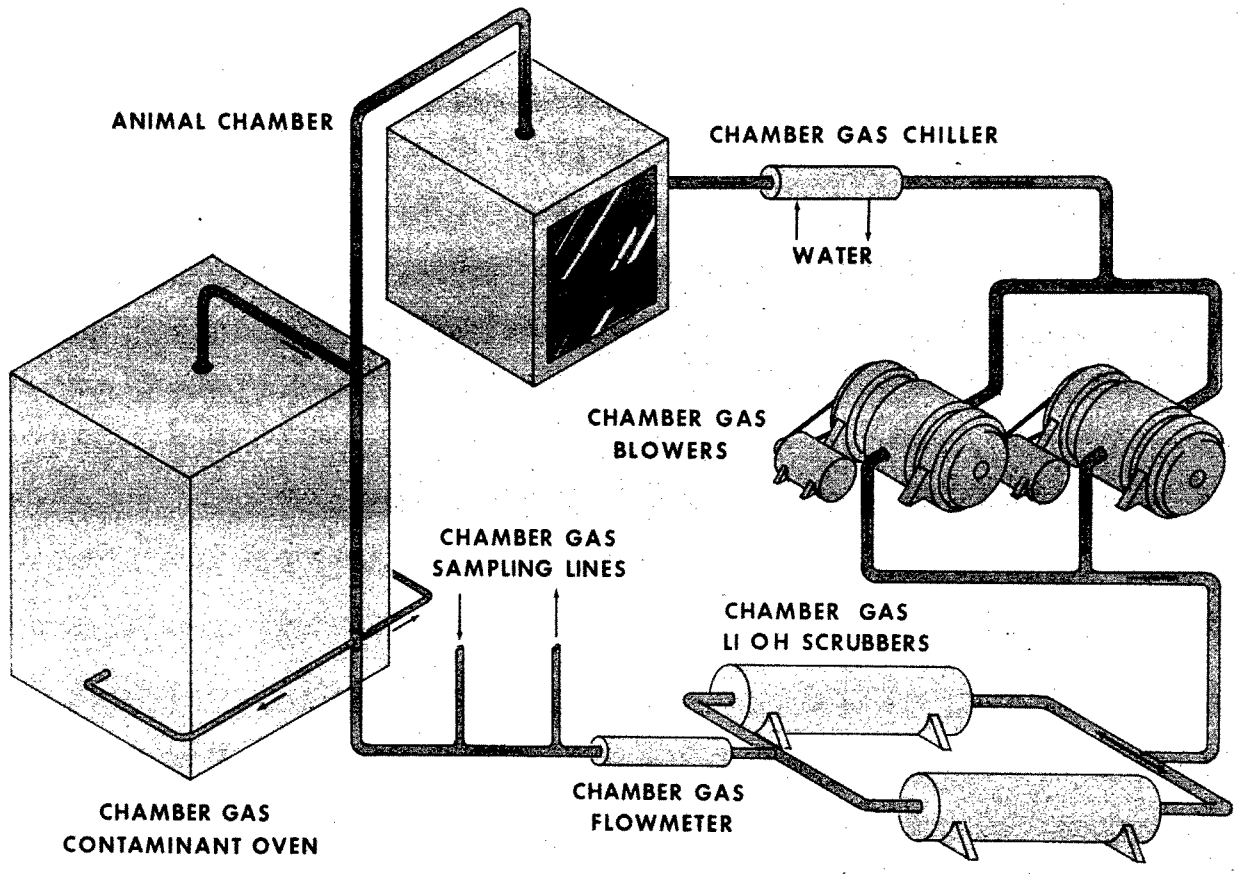

FIGURE 3

APOLLO MATERIALS CONTAMINANT TOXICITY TEST FLOW SCHEMATIC

Return oxygen flow from the animal exposure chamber enters the console through a chiller unit which is operated at $40^{o}F$. This unit removes water vapor generated by the metabolism of experimental animals. At the end of the chiller, a tap permits the drainage of liquid water through a sight gauge and into an anti-siphon drip leg.

The effluent dry oxygen leaving the chiller next passes through the vacuum pump. This pump, a carbon-vane type using sealed bearings, has proved to be oxygen compatible. Two pumps are installed in each line and are automatically switched at 30-minute intervals by a timing mechanism to prevent overheating. Each pump is equipped with a check valve to permit recycling. The valving in the pumps is installed in a manner to permit a portion of the oxygen to be recycled through the operating pump if it is necessary to operate at reduced flow levels. The recycling will minimize the possibility of overheating in the pumps due to gas flow starvation.

The oxygen leaving the pumps is then passed through one of a pair of lithium-hydroxide canisters installed in parallel with manual valving. The lithium-hydroxide canisters remove carbon dioxide produced by animal metabolism or by gas-off of the test materials. The canisters are replaced as needed in the inoperative portion of the loop. The carbon dioxide concentration is monitored continuously. The procedure for the monitoring is described below:

The discharge air from the lithium-hydroxide bed passes through a laminar flow element which measures the differential pressure drop through the unit. This differential pressure drop is visually measured with a water monometer. After establishing the desired air flow, a bypass valve is opened and the flow element is removed from the circuit to prevent its clogging by condensed contaminant materials.

The oxygen stream subsequently passes through a series of valves by which it is split so that 10% of it passes through the vacuum oven. After passing through the oven, the oxygen again rejoins the main stream to effect recooling.

The vacuum oven is constructed with a stainless steel liner and aluminum shelving. In this oven are placed representative samples of space cabin construction materials for toxicity screening study. The materials are heated to $155^{o} \pm 2^{o}F$; this temperature is maintained by a thermostat control system. In the presence of the 100% oxygen stream flowing through the oven at 5 psia pressure and at this elevated temperature, the test materials are expected to produce gas-off products which are then transported to the animal exposure chambers.

The oxygen stream is next fed into the top of an animal exposure chamber designed to house 20 rats and 25 mice. The contaminant-laden oxygen is introduced through a plenum system to insure a uniform distribution of contaminant concentration throughout the animal exposure chamber. The oxygen is exhausted from the exposure chamber through a five-point manifold system located below the animal cage level and returned with its load of animal metabolic waste products (carbon dioxide and water) to the console chiller completing the closed-loop.

The master control center for the Apollo toxicity screening program is a monitoring and alarm system for such environmental conditions as temperature, pressure, gas flow, and pump power. Further, it provides for automatic or manual switching of the vacuum pumps at 30-minute intervals.

Wet bulb and dry bulb temperatures are sensed by thermocouple probes inserted into the animal chambers. The temperature signal is transmitted from the exposure chamber to a multi-point recorder located in the console where a continuous record of experimental conditions is displayed. The temperature of the vacuum oven is also monitored by means of a thermocouple probe and it, too, is recorded. No alarm has been provided since the oven is thermostatically controlled, and a technician manually records readings at 1/2-hour intervals.

A differential pressure sensor was installed in each animal chamber to measure a reduction in pressure due to removal of carbon dioxide in the lithium-hydroxide bed. A bleed valve normally provides maintenance of the desired pressure level by addition of oxygen to the chamber to replace the absorbed carbon dioxide. If the bleed valve fails to work, a reduced chamber pressure results which activates a visual and audio alarm on the console.

A differential pressure switch is installed at the output end of each chiller unit. The switch senses negative static pressure due to a pressure drop across the chiller. Loss of flow results in a pressure drop which activates the switch of the low-flow alarm.

The pump power alarm monitors 110 VAC power to the pumps. If this power is lost or fails due to an overload on the pump motor or other malfunction, a circuit will trip, thereby activating the alarm. Located on the panel of this master control center is a 1-inch diameter, red overload indicator and fuse. This indicator activates simultaneously with the pump power alarm.

Exposure Chamber Environmental Monitoring and Alarm Console

The chamber environmental monitoring and alarm console consists of three series of oxygen and carbon dioxide monitors. Each series of monitoring devices measures the concentration of these gases in individual animal exposure chambers. This system utilizes the closed-loop technique by drawing gas samples from the life-support console immediately after the lithium-hydroxide bed and returning them further downstream. A diaphragm pump and series of pressure regulators are used to bring the sample gas stream to ambient pressure (14.7 psia) which is the maximum sensitivity point of the monitoring instruments. The gas sample is first passed through a silica-gel moisture trap to remove condensed water resulting from the increased pressure.

The gas stream is then passed through a non-dispersive infrared analyzer. The animal exposure chamber is maintained at a carbon dioxide concentration of less than 0.5 per cent. If the concentration of carbon dioxide exceeds this level, the console alarm horn is activated and a red light flashes. The chamber technician must then change lithium-hydroxide canisters in the life-support console.

The gas sample finally passes into a paramagnetic oxygen sensor to evaluate the oxygen concentration within the animal exposure chamber and to detect minimal nitrogen leakage. When operating at 100% conditions, the alarm is set for 98%. A drop in oxygen concentration below this level activates the alarm horn and turns on a red light. Remedial action must then be taken.

AMBIENT LABORATORY

Relatively few modifications were required in the ambient chambers since the equipment designed or obtained was based on standard operating principles. These modifications, which will be described individually, were made to improve operational safety of the laboratory and to provide more uniform contaminant concentrations within the exposure chambers.

Emergency Ventilation and Warning Light Systems

Emergency ventilation and warning light systems were installed in the ambient laboratory. These systems are to be used in conjunction with hazardous experiments to be conducted in the chambers. Signs are posted at each control location describing switch locations and their functions. Signs are also posted at each warning light location describing the three light signals.

Warning Light System Signals and Associated Procedures

1. Lights Off: No experiments of a hazardous nature are being conducted. Normal duties and traffic is permitted.

2. Continuous Red Light: Hazardous experiment is being conducted. Normal duties in ambient laboratory are permitted. Traffic in and out of the laboratory is to be kept to an absolute minimum.

3. Flashing Red Light: Emergency conditions. Absolutely no entrance to the ambient laboratory is permitted. Personnel in the ambient laboratory are to leave by the nearest exit as quickly as possible.

Occupancy of the laboratory is not to be resumed until authorization is given by a responsible member of the decontamination team.

Location of Warning Light Signals

The warning lights are installed over each door at the following entrances to the ambient laboratory:

1. Center hallway
2. Cage washing room
3. Animal room
4. Outside stairwell
5. Air compressor room - room 3A
6. Dome room of altitude facility
7. Laboratory ceiling of ambient chamber area.

Controls for the Warning Light System and Their Locations

1. Flashing Red Light: This system can be turned ON or OFF by a switch at either the door to the animal room or in the center hallway.

2. Continuous Red Light: This switch, located at the entrance to the animal room only, is used for routine hazardous experiments in the laboratory.

3. Emergency Exhaust Fan: This fan can be turned ON or OFF by a switch located at either the door to the animal room or in the center hallway. This will exhaust the ambient laboratory of any contaminants in the air.

Contaminant Introduction Systems

A Venturi section was incorporated into the air supply duct of each Rochester and Longley chamber. Contaminant introduction at the throat of the Venturi insures more rapid and complete mixing of the contaminant with the air supply stream. Within the Longley chambers, a stainless steel honeycomb baffle and perforated metal plate were installed in each subsection to further enhance contaminant mixing and produce a uniform flow down the chamber. This baffle system enables the contaminant to be introduced in a visible wavefront when smoke-like or colored gaseous materials are used.

At the time of the above installation, the original air flow control valves and dampers were replaced by multistaged butterfly valves which more effectively controlled air flow.

PROBLEMS ENCOUNTERED

The unique nature of the altitude facility led to a number of operating difficulties which were generally associated with the learning processes of operation and maintenance of the equipment. The experience acquired by the THRU staff during the past two years in the operation of this facility has shown the need for a strong preventive maintenance program. A maintenance program has been established and a facility engineering staff comprised of two senior engineers and five technicians has been developed to provide continuous preventive maintenance and to handle mechanical failures as they occur. In addition to the inhouse capability of the THRU staff in the area of facility engineering, a subcontract was let to a local general contractor providing for emergency service in the fields of refrigeration, electrical, and mechanical equipment maintenance and repair.

A number of mechanical problems encountered during the operation of the facility led to the foregoing modifications. One additional major problem which occurred in the operation of the facility was the outbreak of a fire in Thomas Dome No. 2., which occurred at approximately 0817 on 24 February 1966. An experiment had been initiated in this dome at 1430 the preceding day, 23 February 1966. That experiment consisted of the exposure of rats and mice to the gas-off products of Apollo space cabin construction materials subjected to 155°F temperature in the presence of 100% oxygen at 5 psia pressure. Three groups of experimental rats and mice were housed in closed life support systems within the dome and each group was exposed to a separate mixture of Apollo construction materials. A control

group of rats and mice located on the periphery of the dome was subjected to essentially the same environmental parameters of oxygen pressure and temperature. Shortly before the fire, it was noted that some of the rats in chamber No. 3 were wet with a solution which was causing severe skin burns and eye irritation. The cause of this problem was being investigated when the fire started.

The immediate cause of the fire was overheating of a rubber belt drive connecting a motor and an atmospheric circulation pump of one life support system. The pump had stalled due to internal mechanical failure resulting from accumulation of fluid within the pump chamber. The motor continued to run with the drive pulley slipping on the belt. When the belt temperature reached its ignition point in the presence of pure oxygen, the belt began to burn. The force of the rotating pulley threw flaming pieces of laminated rubber and fiber into other portions of the Apollo console. These flaming pieces of drive belt ignited the two adjacent pump drive belts and the immediately adjacent electrical cable insulated by fireproof thermoplastic. The fire progressed at a slow rate from this point upward in the No. 3 module of the Apollo control console and, ultimately, laterally across the top portion of the console. The fire was extinguished approximately 20 minutes after ignition. The damage sustained during the 23-minute period of the fire was primarily the progressive combustion of 71 feet of the thermoplastic insulation of the electrical cables.

Immediately upon ignition of the fire, all dome oxygen supply and vacuum control valves were isolated at the master control panel. Within 30 seconds after the domes were isolated, the main circuit breaker in the electrical supply to the altitude facility was opened to prevent facility power failure due to short circuiting of the burning cables. At 0840, the other three Thomas Domes were back in normal operation without change in pressure or oxygen concentration.

RECOMMENDED FACILITY MODIFICATIONS

The operational experience acquired during the past two years in conducting toxicity experiments in the Toxic Hazards Research Unit has revealed the need for a number of equipment modifications, in addition to those previously described, which would add to the safe and efficient operation of the exposure chambers. The fire protection equipment added to Thomas Dome No. 2 should also be installed in the other three domes. These items specifically are the manually-operated externally-mounted water and carbon dioxide fire quenching systems.

The installation of a manual shutoff valve in the vacuum exhaust line of each dome permits repair or replacement of the vacuum control valve. These shutoff valves have proved very useful during the past year since their installation. In a parallel manner, a manual shutoff valve installed in the air supply line between the dome and the flow control valve would permit emergency replacement or repair of the flow control valve without loss of the experiment being conducted within the chamber.

Noise levels were greatly increased when experiments were conducted at reduced pressure levels in the Thomas Domes. This increase in noise was initially attributed to sonic flow. However, experiments have shown that the excessive noise is produced by high velocity airflow when the flow control valve throttles down to maintain a standard flow at reduced pressures. This problem should be investigated further so that the noise level can be controlled. Noise suppressing devices, such as mufflers, which will satisfactorily reduce the noise to an acceptable level without affecting contaminant concentration, may be commercially available.

The relative humidity control system originally installed in each Thomas Dome has proved unsatisfactory for use at reduced pressure. Recommendation has been made for the incorporation of a new relative humidity control system, operating from within the dome, which is insensitive to the range of pressures used in the experimental program.

The weighing of experimental animals within the Thomas Domes has created problems during the two years. Animal balances of sufficient accuracy to provide good statistical data are too large to be transported in and out of the Thomas Domes through the airlock. The weighing of rodents does not prove too difficult since a smaller balance can be taken into the dome via the pass-through airlock. These balances, however, can not be left within a dome, because they are not adequately protected from the corrosive environment to which animals are exposed. An animal weighing system utilizing noncorrosive stainless-steel components should be installed in each dome. The system would be operated on the strain gauge principle with the signal being transmitted outside the dome into a digital voltmeter and printed out on a standard printer.

SECTION III

RESEARCH PROGRAM

GENERAL

First attention of the research activities was directed to the problem of oxygen toxicity and the effects of reduced pressure on toxicity of selected model compounds with continuous exposure for periods varying up to 235 days. The model compounds were chosen because of the extensive data already available for ambient pressure experiments. Some of these experiments are still in progress. A study of fire extinguisher materials and their pyrolysis products has been completed. Currently underway is a series of experiments testing the toxicity of gas-off products of materials used in construction of the Apollo spacecraft cabin. Table II is a list of all experiments, along with their pertinent conditions, completed or in progress with one exception; i. e. , a series of experiments concerned with monochloromethane and monochlorotrifluoromethane and their pyrolysis products. These were conducted prior to the experiment numbering system currently used.

OXYGEN TOXICITY EXPERIMENTS

Twenty of the individual experiments listed in Table II dealt with various aspects of oxygen toxicity at pressures varying from 260 to 760 mm Hg oxygen for periods ranging from 4 to 235 days. Results of these studies are reported in the proceedings of the first and second Annual Conference on Atmospheric Contamination in Confined Spaces (Entries 1 and 2 under Publications . . . page 26).

Briefly, the experiments cited above demonstrated that oxygen was not as toxic under some conditions as other workers had reported; differences in THRU results may be ascribed to the conditions of exposure. The THRU facility does not attempt to purify and recycle respiratory gases; whereas, in most experimental systems reported in the literature, carbon dioxide and other contaminants are presumably removed and the gases recycled. However, unknown materials might accumulate in the atmosphere and their effects be interpreted as those of oxygen.

Three general conclusions have been drawn from these twenty experiments. Although 100% oxygen was shown to be quite toxic at ambient or near ambient conditions, at reduced pressure (5 psia, 260 mm Hg) no

TABLE II

SUMMARY OF EXPERIMENTS

Expt. No.	Exposure Dates	Facility	Exposure (Days)	Contaminant	Concentration (mg/M^3)	Environment mm Hg Gas
	(1964)					
100	23 Sept. - 7 Oct.	D3*	14	CCl_4	80	260 O_2
101	24 Sept. - 8 Oct.	D2	14	CCl_4	32	260 O_2
102	25 Sept. - 9 Oct.	D1	14	CCl_4	13	260 O_2
103	28 Sept. -12 Oct.	D4	14	O_2	C (100-102)	260 O_2
104	28 Sept. -30 Dec.	D4	91	O_2	100%	260 O_2
105	19 Oct. - 2 Nov.	D3	14	NO_2	17	260 O_2
106	20 Oct. - 3 Nov.	D2	14	NO_2	10	260 O_2
107	21 Oct. - 4 Nov.	D1	14	NO_2	38	260 O_2
108	22 Oct. - 5 Nov.	D4	14	O_2	C (105-107)	260 O_2
109	23 Nov. - 7 Dec.	D3	14	O_3	8.0	260 O_2
110	24 Nov. - 8 Dec.	D2	14	O_3	4.2	260 O_2
111	25 Nov. - 9 Dec.	D1	14	O_3	1.9	260 O_2
112	26 Nov. -10 Dec.	D4	14	O_2	C (109-111)	260 O_2
113	14 Dec. -28 Dec.	D1	14	O_3	15.4	260 O_2
114	14 Dec. -28 Dec.	D2	14	NO_2	81.0	260 O_2
115	15 Dec. -29 Dec.	D3	14	CCl_4	594	260 O_2
116	16 Dec. -30 Dec.	D4	14	O_2	C (113-115)	260 O_2
	(1965)					
117	15 Feb. - 1 Mar.	D1	14	O_3	14.9	700 Air
118	16 Feb. - 2 Mar.	D2	14	NO_2	89	700 Air
119	17 Feb. - 3 Mar.	D3	14	CCl_4	576	700 Air

* Dome Number
** Animal Room
*** Rochester, Longley Ambient Exposure Chambers

TABLE II, Continued

Expt. No.	Exposure Dates	Facility	Exposure (Days)	Contaminant	Concentration (mg/M^3)	Environment mm Hg Gas
120	18 Feb. - 4 Mar.	A. R.**	16	None	C (117-119)	Amb. Air
121	19 Feb. -25 Feb.	D4	7	O_2	100%	760 O_2
122	16 Mar. -30 Mar.	D1	14	O_3	7.9	700 Air
123	17 Mar. -31 Mar.	D2	14	NO_2	35.6	700 Air
124	19 Mar. - 2 Apr.	D3	14	CCl_4	34.9	700 Air
125	15 Mar. -29 Mar.	D4	14	None	C (122-124)	700 Air
126	13 Apr. -27 Apr.	D1	14	O_2	100%	700 O_2
127	13 Apr. -27 Apr.	D3	14	O_2	33%	700 O_2
128	13 Apr. - 4 Dec. (11-14 Jan.)	D4	235	O_2	100%	260 O_2
129	13 Apr. - 4 Dec. (11-14 Jan.)	A. R.	235	None	C (128)	Amb. Air
130	22 Apr. -20 July	D2	90	NO_2	9.3	260 O_2
131	22 Apr. -20 July	A. R.	90	None	C (130-133)	Amb. Air
132	4 May -27 May	D3	23	O_2	100%	700 O_2
133	6 May - 3 Aug.	D1	90	O_3	0.19	260 O_2
134	8 June -11 June	D3	4	O_2	100%	750 O_2
135	12 June -15 June	D3	4	O_2	100%	725 O_2
136	23 June - 8 July	D3	16	O_2	100%	760 O_2
138	10 July -25 July	D3	16	O_2	100%	725 O_2
139	31 July -16 Aug.	D3	16	O_2	100%	650 O_2
140	9 Aug. - 8 Nov.	D1	90	O_3	0.19	700 Air
141	9 Aug. - 8 Nov.	A. R.	90	None	C (140)	Amb. Air
142	23 Aug. - 9 Sept.	D3	17	O_2	100%	600 O_2
143		Amb. Fc.	--	$CBrF_3$	LC_{50}, etc.	Amb. Air
144	15 Nov. -29 Nov.	D1	14	O_2	100%	760 O_2

TABLE II, Continued

Expt. No.	Exposure Dates	Facility	Exposure (Days)	Contaminant	Concentration (mg/M^3)	Environment mm Hg Gas
145	16 Nov. -23 Nov.	D2	7	Apollo	---	260 O_2
146		Amb. Fc.	--	MMH	LC_{50} etc.	Amb. Air
147	6 Dec. -20 Dec	D1	14	O_3	8.3	260:70% O_2/30% N_2
148	7 Dec. -21 Dec.	D4	14	O_2/N_2	70%/30%	260:70% O_2/30% N_2
149	8 Dec. -15 Dec.	D2	7	Apollo	---	260 O_2
150	6 Dec. -20 Dec. (1966)	A. R.	14	None	C (147-148)	Amb. Air
151	18 Jan. -18 Apr.	D4	90	CCl_4	63	260 O_2
152	18 Jan. -15 Apr.	A. R.	90	None	C (151)	Amb. Air
153	18 Jan. - 1 Feb.	D1	14	NO_2	36.4	260:70% O_2/30% N_2
154	18 Jan. - 1 Feb.	A. R.	14	None	C (153)	Amb. Air
155	8 Feb. -12 May	Roch. ***	90	NO_2	9.3	Amb. Air
156	10 Feb. -11 May	Long.	90	CCl_4	63	Amb. Air
157	8 Feb. -10 May	A. R.	90	None	C (155-156)	Amb. Air
158(1)	7 Feb. -25 Feb.	D1	19 (30)	O_2	100%	260 O_2
159(1)	23 Feb. -24 Feb.	D2	2 (7)	Apollo	---	260 O_2
160	6 Mar. - 9 Mar.	D1	4	O_2	100%	760 O_2
161	24 Mar. - 6 Apr.	D1	14	O_3	8.0	260 pO_2: TP720
162	24 Mar. - 6 Apr.	A. R.	14	None	C (161)	Amb. Air
163	14 Apr. -27 Apr.	D1	14	NO_2	38	260 pO_2: TP720
164	14 Apr. -27 Apr.	A. R.	14	None	C (163)	Amb. Air
165	21 Apr. -26 Apr.	D4	6 (14)	NO_2	85	260 pO_2: TP720
166	21 Apr. -26 Apr.	A. R.	6 (14)	None	C (165)	Amb. Air

(1) Experiments not completed due to accidents of fire and oxygen failure.

TABLE II, Continued

Expt. No.	Exposure Dates	Facility	Exposure (Days)	Contaminant	Concentration (mg/M^3)	Environment mm Hg Gas
167	2 May -	D1	180	None	---	260:70% O_2/30% N_2
168	2 May -	A. R.	180	None	C (167)	Amb. Air
169	1 June -14 June	D1	14	O_3	8.0	260 pO_2: TP700
170	1 June -14 June	A. R.	14	None	C (169)	Amb. Air
171	17 June -23 June	D2	7	Apollo	---	260 O_2
172	22 June - 6 July	D1	14	None	---	260 pO_2: TP700
173	22 June - 6 July	A. R.	14	None	C (172)	Amb. Air
174	28 June - 5 July	D2	7	Apollo	---	260 O_2
175	11 July -13 July	D1	3	O_3	4	Amb. Air
	28 July -10 Aug.	Roch.	14	NO_2	38.8	Amb. Air
176	12 July - 9 Sept.	D2	60	Apollo	---	260 O_2
177	18 July - 1 Aug.	D1	14	NO_2	50	260:70% O_2/30% N_2
178	18 July - 1 Aug.	A. R.	14	None	C (177)	Amb. Air
179	4 Aug. -10 Aug.	D2	7	Apollo	---	260 O_2
180	5 Aug. -19 Aug.	D1	14	NO_2	60	260:70% O_2/30% N_2
181	5 Aug. -19 Aug.	A. R.	14	None	C (180)	Amb. Air

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significant changes occurred in experimental animals for periods as long as 235 days. Sensitivity of a Wistar-derived strain of rats to pressure changes was discovered. Under conditions in which Sprague-Dawley-derived rats showed no mortality, some 16% to 20% of the Wistar-derived rats died. A significant discovery was that animals exposed to pulmonary irritants in an atmosphere containing increased pO_2 are protected against the immediate effects of the irritant. A report of these results is in preparation (Entry 13 under Publications . . . page 27).

FIRE EXTINGUISHER MATERIAL

Experiment 143 was concerned with the toxicity of monobromomonochloromethane (CB), monobromotrifluoromethane ($CBrF_3$) and their pyrolysis products. As part of the overall experiment, a six-month chronic intermittent exposure using CB was performed (Entry 9 under Publications . . . page 27). LC_{50} determinations for rats were made for the pyrolysis products for both materials pyrolyzed at 800°C. Pyrolyzed $CBrF_3$ was considerably less toxic than pyrolyzed CB, and the effects were attributed primarily to HF in the pyrolysis products. The LC_{50} for 15-minute exposures to CB pyrolysis products was 465 ppm (424 to 511 at 95% confidence limits) while that for $CBrF_3$ pyrolysis products was 2300 ppm (1890 to 2799 at 95% confidence limits).

APOLLO MATERIALS TOXICITY SCREENING

Beginning in 1965, a series of animal experiments was begun, on behalf of the National Aeronautics and Space Administration, in which materials used in the construction of Apollo space cabins are studied to determine whether or not they release toxic gaseous products into the atmosphere. Rats and mice are exposed to an atmosphere of 100% oxygen at 260 mm Hg pressure in which samples of the materials are heated to 155°F to accelerate the gas-off process. The toxicity screening equipment for this program has been discussed in Section II.

Mixtures of up to 18 construction materials are placed in a single oven for initial screening; the samples of the materials are about 10 grams each. As of 1 August 1966, approximately 125 materials had undergone 7-day tests. Following exposure, animal weights are determined weekly and representative groups sacrificed for gross and histopathological purposes. During the period of testing, two suspicious mixtures had been found, as demonstrated by animal weight loss following exposure. Upon retesting, one of the mixtures (Group A) was found to be inocuous. The other (Group F) is currently undergoing further testing.

CONTINUOUS EXPOSURES TO MODEL COMPOUNDS AT REDUCED PRESSURE

A series of experiments was undertaken to investigate the effects of reduced pressure, 100% oxygen, and continuous exposure on the inhalation toxicity of three compounds, the toxicity of which was well understood at ambient pressure. CCl_4, NO_2, and O_3 were selected for study. Part of the experiments were 14-day exposures, the results of which are reported in the annual conference proceedings as well as entry 24 under Publications . . . page 28. Other experiments were concerned with continuous exposures for 90-day periods to the threshold limit values (TLV) of the contaminants, both at ambient and reduced pressure. An Aerospace Medical Research Laboratories Technical Report describing these experiments is in preparation (Entry 19 under Publications . . . page 28). Few significant changes due to reduced pressure and 100% oxygen were noted in the 90-day experiments. Ozone was the only contaminant producing significant mortality; only in mice was a statistically significant difference noted for the animals exposed to O_3 at ambient pressure as compared to reduced pressure. Minor transitory differences in serum glutamic oxalacetic transaminase (SGOT) and serum glutamic pyruvic transaminase (SGPT) and in certain other parameters were also noted.

SPECIAL STUDIES AND CONFERENCES

Occasional requirements arise for special investigations, usually in identifying the primary constituents of special materials used by the Air Force and evaluating their potential toxic hazard. These do not generally require extensive experimentation or analysis. Typical special determinations have included identification of fire retardant in blanket material and analysis of breathing oxygen for toxic contaminants.

An annual conference on toxicology is organized and held in cooperation with the Toxic Hazards Division of the Aerospace Medical Research Laboratories. The first conference was held 30 March to 1 April 1965. Among the 20 presentations relating to the problem of continuous exposure were 6 specifically dealing with the THRU program. One hundred and sixty-nine civilian and military scientists and engineers attended by invitation. The proceedings of the conference have been published (Entry 1 under Publications . . . page 26).

The second annual conference took place 4 and 5 May 1966 with 169 invited attendees. In contrast to the 6 presentations of the first conference, 16 of 21 technical presentations of the second conference were concerned

specifically with experiments conducted in the THRU facilities. These conferences have proved beneficial in the dissemination and exchange of technical toxicological information on the problems of prolonged space flight and specific research programs aimed at their solution.

EXPERIMENTS IN PROGRESS

Eight experiments were in progress as of 6 August 1966 (see Table II). Clinical chemistry data and organ and body weight data, along with their ratios, have been analyzed for all completed experiments. These data have been summarized, some of them actually presented, and discussed in the various technical reports Pathology data will, in most cases, also be made available through various publications (see Publications . . . page 26).

Three of the eight experiments in progress are concerned with Apollo materials. One is a continuous exposure of 60 days duration using 100 materials taken from those previously tested for 7 days. The second Apollo experiment in progress is a retest of Group F Apollo materials. In a previous experiment, following a 7-day exposure to this mixture, a group of rats showed a decline in body weight. The complete Group F materials and 50% of Group F materials are being tested in separate ovens. Results of experiment 179 will determine the necessity of testing the remaining 50% of the materials of that group, and of any further breakdown to identify the materials responsible.

Experiment 177, its control 178, 180 and its control 181, are a part of the series of tests being conducted to analyze protective effects of increased pO_2 on the toxicity of pulmonary irritants (in this case NO_2) previously described (See Section III, Oxygen Toxicity Experiments).

Experiment 175 involves short-term exposures of monkeys to O_3 and NO_2 with two weeks intervening between exposures. It is part of an investigation concerned with development of cross tolerances, wherein an animal exposed to one irritant may develop the ability to withstand what would have been a lethal exposure to another.

Finally, in progress are experiments 167 and 168, originally planned for 90 days but extended to 6 months, in which the long term effects of a 70% O_2-30% N_2 mixture at 260 mm Hg total pressure are being investigated. These experiments were begun in May 1966 and will terminate in November 1966. No adverse effects have been observed to date.

MONKEY PERFORMANCE STUDY

Thomas Dome No. 3 has been utilized since 25 September 1965 to investigate possible changes in the learned task performance of trained Macaca mulatta and Macaca iris monkeys under three sets of environmental conditions for 90-day continuous exposures: first at 5 psia 100% O_2, then in a 5 psia, mixed-gas environment, and currently the TLV for O_3 was added to the 5 psia gas mixture.

These experiments are not included in the Table II summary. This is a part of continuing investigations being conducted by personnel of Holloman Air Force Base, New Mexico, cooperatively with personnel of the Toxic Hazards Division of the Aerospace Medical Research Laboratories.

PLANNED FUTURE WORK

Current planned experiments will require the remainder of the calendar year for completion. The trained monkeys presently under exposure in Thomas Dome No. 3 will be replaced with a new group of monkeys from Holloman AFB and additional experiments on performance will be carried out. The present 60-day Apollo materials study will be completed and followed by other 60-day and other 7-day exposures as materials become available. The other two altitude chambers will be utilized for additional experiments investigating the effects of mixed gases at 5 psia pressure and a series of 2-week NO_2 exposures at concentrations higher than previously used. In addition, a special 6-week study will be carried out by the Air Force during September and October involving effects of 100% oxygen on kidney and liver function under ambient conditions using monkeys and rats.

Range-finding experiments are planned to determine appropriate dosages for use in an investigation of the inhalation toxicity of decomposition products of trichloroethylene, a compound used routinely as a cleaning agent and identified as the primary contributing toxic agent in a manned space cabin simulator experiment.

The experiments concerned with development of cross-tolerances will be continued and expanded if warranted by experimental results. Additional determinations are planned also for the ETL (emergency tolerance limits) of monomethylhydrazine covering exposures of 10-, 30-, and 60-minute duration.

PUBLICATIONS RELATED TO THE THRU RESEARCH PROGRAM

The first publication arising from the activities of the Toxic Hazards Research Unit was AMRL-TR-65-125, September, 1965, in which was described the experimental inhalation toxicology research laboratories. Another description appeared in the AMA Archives of Environmental Health (1965). The "Proceedings" of the first conference as well as several other Aerospace Medical Research Laboratories Technical Reports were also published in 1965. Two scientific journal articles dealing with experimental results appeared during late 1965 and early 1966.

During 1966, the number of reports dealing with experiments performed in the Air Force facility increased; other groups also began to report on special studies conducted in the altitude facilities or on special aspects of certain experiments. Thus, a significant number of reports dealing with experiments performed in the altitude facility is attributable to Air Force personnel and contractor personnel other than those of Aerojet-General Corporation. The list of publications given below includes all reports which relate to THRU experiments:

1. Proceedings of the Conference on Atmospheric Contamination in Confined Spaces, 30 March - 1 April 1965, AMRL-TR-65-230, Wright-Patterson Air Force Base, Ohio.

2. Proceedings of the Second Annual Conference on Atmospheric Contamination in Confined Spaces, 4-5 May 1966, AMRL-TR-66-120, Wright-Patterson Air Force Base, Ohio.

3. Back, K. C., Toxicity Studies on Animals Exposed Continuously for Periods Up To 235 Days to a 5 psia-100% Oxygen Atmosphere, AMRL-TR-66-120, Wright-Patterson Air Force Base, Ohio.

4. Culver, B. C., Toxicological Screening of Space Cabin Materials, AMRL-TR-66-120, Wright-Patterson Air Force Base, Ohio.

5. Hagebusch, O. E., Pathology of Animals Exposed for 235 Days to a 5 psia 100% Oxygen Atmosphere, AMRL-TR-66-120, Wright-Patterson Air Force Base, Ohio.

6. Harper, D. T. and F. R. Robinson, Pathology of Animals Exposed to a Pure Oxygen Atmosphere at Reduced Pressure for Prolonged Periods, AMRL-TR-66-120, Wright-Patterson Air Force Base, Ohio.

7. Harper, D. T. and F. R. Robinson, Pathology of Animals Exposed for Prolonged Periods to a Pure Oxygen Atmosphere at Reduced Pressures. Submitted to Aerospace Medicine for publication.

8. Harper, D. T., Comparative Pathology of Animals Exposed to Carbon Tetrachloride at Ambient Air vs. 5 psia-100% Oxygen Atmosphere, AMRL-TR-66-120, Wright-Patterson Air Force Base, Ohio.

9. Haun, C. C., E. H. Vernot, J. D. MacEwen, D. L. Geiger, J. M. McNerney, and R. P. Geckler, The Acute Inhalation Toxicology of Pyrolysis Products of Monobromomonochloromethane (CB) and Monobromotrifluoromethane ($CBrF_3$). (AMRL-TR in preparation)

10. Haun, C. C., The Inhalation Toxicity of Monomethylhydrazine, (Presented at 1966 Propellant Toxicology Seminar, Wright-Patterson Air Force Base, Ohio).

11. Kaplan, H. P., Hematological Effects of Increased Oxygen Tensions, AMRL-TR-66-120, Wright-Patterson Air Force Base, Ohio.

12. Kistler, G., Electron Microscopic Investigations of Oxygen Effects on Tissue, AMRL-TR-66-120, Wright-Patterson Air Force Base, Ohio.

13. MacEwen, J. D. and C. C. Haun, Oxygen Toxicity at Near-Ambient Pressures, AMRL-TR-66-120, Wright-Patterson Air Force Base, Ohio.

14. MacEwen, J. D., Toxic Hazards Research Unit Design and Construction Phase, AMRL-TR-65-125, September, 1965, Wright-Patterson Air Force Base, Ohio.

15. MacEwen, J. D., Contaminant Generation Methods and Techniques, AMRL-TR-65-230, Wright-Patterson Air Force Base, Ohio.

16. MacEwen, J. D. and J. M. McNerney, Effect of a Mixed Gas Atmosphere at 5-psia on the Toxicity of NO_2 and O_3 in Animals, AMRL-TR-66-120, Wright-Patterson Air Force Base, Ohio.

17. MacEwen, J. D. and A. A. Thomas, Observations on the Occurrence of a Fire in 100% Oxygen at 5-psia. (AMRL-TR in preparation)

18. MacEwen, J. D., K. C. Back, and J. M. McNerney, Responses of Animals in Oxygen at Reduced Pressure. (AMRL-TR in preparation)

19. MacEwen, J. D., and R. P. Geckler, Comparative Toxicity Studies at Reduced and Ambient Pressures: II. Chronic Exposures to Model Compounds O_3, NO_2, and CCl_4. (AMRL-TR in preparation)

20. MacEwen, J. D., and R. P. Geckler, Comparative Toxicity Studies on Animals Exposed Continuously for Periods up to 90 Days to NO_2, O_3, and CCl_4 in Ambient Air vs. 5-psia 100% Oxygen Atmosphere, AMRL-TR-66-120, Wright-Patterson Air Force Base, Ohio.

21. MacEwen, J. D., J. M. McNerney, C. C. Haun and R. P. Geckler, The Effect of a Mixed Gas Atmosphere at 5 psia on the Inhalation Toxicity of NO_2 and O_3. (AMRL-TR in preparation)

22. MacEwen, J. D., J. M. McNerney, E. H. Vernot, and D. T. Harper, Chronic Inhalation Toxicity of Chlorobromomethane, AMRL-TR-65-90, Wright-Patterson Air Force Base, Ohio.

23. McNerney, J. M., Preliminary Results of Toxicity Studies in 5 psia-100% Oxygen Environment, AMRL-TR-65-120, Wright-Patterson Air Force Base, Ohio.

24. McNerney, J. M., and J. D. MacEwen, Comparative Toxicity Studies at Reduced and Ambient Pressures: I. Acute Response, AMRL-TR-65-210, Wright-Patterson Air Force Base, Ohio. Also in Am. Ind. Hyg. Assoc. J. 26, 568-573 (1965).

25. Mautner, W., Electron Microscopic Investigations of Oxygen Effects on Kidney Tissue, AMRL-TR-66-120, Wright-Patterson Air Force Base, Ohio.

26. Patrick, R. L., Pathological Effects of Exposure to Pulmonary Irritants at Ambient Air vs. 5 psia-100% Oxygen Atmosphere for Periods Up to 90 Days, AMRL-TR-66-120, Wright-Patterson Air Force Base, Ohio.

27. Pinkerton, M. K., Clinical Laboratory Methods, AMRL-TR-65-230, Wright-Patterson Air Force Base, Ohio.

28. Riesen, W. H., Cellular Biochemistry of Oxygen Toxicity, AMRL-TR-66-120, Wright-Patterson Air Force Base, Ohio.

29. Robinson, F. R. Pathological Evaluation of Oxygen Toxicity at Near-Ambient Pressures, AMRL-TR-66-120, Wright-Patterson Air Force Base, Ohio.

30. Robinson, F. R., D. T. Harper, and H. P. Kaplan, Comparison of Strains of Rats Exposed to Oxygen at Various Pressures. Submitted for publication in the Laboratory Animal Care Journal. Presented at the 16th Annual Meeting of the Animal Care Panel, Philadelphia, Pennsylvania, 18 November 1965, (AMRL-TR-66-62)

31. Robinson, F. R., D. T. Harper, A. A. Thomas, and H. P. Kaplan, Proliferative Pulmonary Lesions in Monkeys Exposed to High Concentrations of Oxygen. Submitted to Aerospace Medicine for publication. Presented at the 37th Annual Meeting of the Aerospace Medical Association, Las Vegas, Nevada, 20 April 1966. (AMRL-TR-66-36)

32. Schaffner, F., Electron Microscopic Investigations of Oxygen Effects on Liver Tissue, AMRL-TR-66-120, Wright-Patterson Air Force Base, Ohio.

33. Thomas, A. A., Chamber Equipment Design Considerations for Altitude Exposures, AMRL-TR-65-230, Wright-Patterson Air Force Base, Ohio.

34. Thomas, A. A., Low Ambient Pressure Environments and Toxicity. AMA Arch. Environ. Health 11, 316 (1965).

35. Vernot, E. H., Analytical Control of Contaminant Concentration in Exposure Chambers, AMRL-TR-65-230, Wright-Patterson Air Force Base, Ohio.

36. Vernot, E. H. J. D. MacEwen, D. L. Geiger, and C. C. Haun, The Air Oxidation of Monomethylhydrazine, AMRL-TR-66-105, Wright-Patterson Air Force Base, Ohio.

37. Wolfle, T. L., Psychopharmacological Evaluation of Primates Exposed to 5 psia-100% Oxygen Atmosphere, AMRL-TR-66-120, Wright-Patterson Air Force Base, Ohio.

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13. ABSTRACT This report reviews the activities of the Toxic Hazards Research Unit (THRU) personnel over approximately a two-year period and is concerned primarily with the research accomplished. The research program has resulted in significant progress in areas of oxygen toxicity, toxicity screening of Apollo space cabin materials, fire extinguisher material evaluation, effects of reduced pressure and 100% oxygen on toxicity of materials in animals and effects of enriched oxygen-nitrogen mixtures at reduced pressure on toxicity of NO_2 and O_3. In operating the facilities during experimentation, various problems arose which required facility modification or additional equipment. Of special note were modifications and additions of fire protection equipment required as a result of a fire in one of the altitude chambers. An integrated alarm system was also designed and installed. Safety and operational procedures were reviewed and revised in accordance with the experience gained in the conduct of the research program of the THRU. A "Facility Operations and Maintenance Manual" reflecting that experience was prepared for the use of current and future operators of the Laboratory. Recommendations for modifying the facility in the future include additional fire protective devices within the Thomas Domes, improved automatic relative humidity control devices, additional altitude chamber isolation equipment, and special instrumentation for the weighing of laboratory animals under the experimental conditions of the domes.

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