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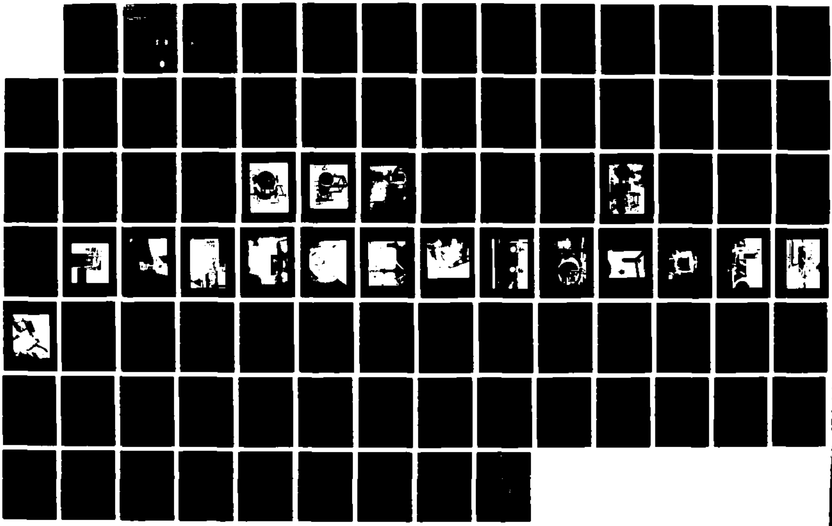

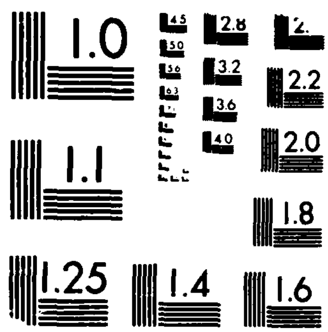

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USAF HYPERBARIC ANIMAL TRANSFER CHAMBER SYSTEM

Rocky D. Calcote, Major, USAF, BSC

January 1988

Final Report for Period August 1986 - February 1987

Approved for public release; distribution is unlimited.

USAF SCHOOL OF AEROSPACE MEDICINE
Human Systems Division (AFSC)
Brooks Air Force Base, TX 78235-5301

NOTICES

This final report was submitted by personnel of the Hyperbaric Medicine Division, USAF School of Aerospace Medicine, Human Systems Division, AFSC, Brooks Air Force Base, Texas, under job order HM888202.

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The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

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The Animal Transfer Chamber (ATC) is an especially designed and constructed test system for research use in the study and evaluation of the physiological effects of high barometric pressures on laboratory animals. The purpose of this technical report is to provide the user organization with guidance, procedures, and safety precautions related to the installation and operation of the USAF hyperbaric ATC system.

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USAF HYPERBARIC ANIMAL TRANSFER CHAMBER SYSTEM

INTRODUCTION

The Animal Transfer Chamber (ATC) is an especially designed and constructed test system for the study and evaluation of the physiological effects of high barometric pressures on laboratory animals.

The purpose of this technical report is to provide the user organization with guidance, procedures, and safety precautions related to the installation and operation of the USAF hyperbaric ATC system. The simple ATC engineering design incorporates high system reliability and maintainability with a minimal amount of building modification being required for overall installation.

This report contains a basic description of the equipment, its operational capabilities and limitations, operational procedures, and safety hazards. Installation facility requirements are discussed, with additional emphasis being placed on ancillary equipment to be provided by the user organization. Basic requirements for scheduled maintenance inspections are also provided; however, this report does not contain instructions for repair, adjustment, or other means of correcting defective conditions occurring within any part of the system. A suggested list of spare parts (Appendix A) is provided to the user, for information only. Citations of commercial organizations and trade names in this report do not constitute either an official Department of the Air Force endorsement or approval of the products or services provided by these organizations.

EQUIPMENT DESCRIPTION

System Certification

Although the ATC vessel is not a man-rated system, a system failure caused by any defects in the vessel, materials, or workmanship, could endanger the life of operating personnel. To help negate hazards to operating personnel, special performance requirements and standards must be met. The ATC vessel--workmanship, material, and fabrication--has been certified by the American Society of Mechanical Engineers (ASME), in full accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, including provisions for lethal and low temperature service, paragraphs AM 204 and AF 402, respectively (1). The ATC vessel is also designed for fatigue service, in accordance with the same vessel code, paragraph AD-160.

Chamber Types and Modifications

General Information

The ATC compression chamber was manufactured by the Tube Turn of Louisville, KY. The clamshell door closure was produced by the Dixie Manufacturing Co., Inc., of Baltimore, MD. Both types (II and III) of ATC compression vessels have the same operational system modifications. The ATC

Type II Vessel has an elliptical end with a bolted flange connection. A Pressurized Transfer Chamber (PTC) clamps to the stationary ATC to maintain a specific test environment (gas mixture, pressure, temperature, and humidity). Animals are transferred from the ATC to the PTC in the same test conditions. The ATC is depressurized, cleaned, restocked with food and water, and repressurized to the same environment. The animals are then returned to the ATC. Since the PTC has not been provided with the ATC Type II unit, the mating flange must be kept permanently sealed during compression dives. The ATC Type III Vessel differs from the Type II, in that the Type III has a dished (hemispherical) end, does not mate with the PTC system, and has an independent stand-alone chamber design capability.

Life Support System

Each chamber type has the same life support system modifications to monitor pressure, temperature, and gas mixtures. Relative humidity can be monitored from an external gas sample port. Specific monitoring equipment must be provided by the user organization. Each ATC vessel has the necessary pressure gauges and regulators, ball valves, piping, and fittings to transport compressed gases to and from the chamber. Five small penetrations in the compression chamber are for miscellaneous purposes: one drain, one gas supply, one gas outlet, one safety pressure check valve outlet, and one thermostat probe input. Two 4-in. heater strips are wrapped around the circumference of the vessel for internal chamber temperature regulation. Each strip is controlled by an externally mounted thermostat with a remote temperature control bulb mounted inside the chamber. Relative humidity is controlled 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.

Chamber Design

General Information

The ATC is a Class "C" chamber (no human occupancy), as classified (2) according to guidelines established by the National Fire Protection Association (NFPA). The ATC vessel is a free-standing, cylindrical, steel structure mounted horizontally on four saddle support legs (Fig. 1) *. The legs are bolted to a 1/2-in. thick, 4 X 4 ft^2 steel deck plate. The right rear leg is bolted 6 in. in from the corner of the plate to help counterbalance the weight of the chamber when the door is fully opened. The combined weight of the ATC and the floor plate is approximately 3500 lb. The internal volume of the chamber is approximately 25 ft^3. Chamber access is provided by a hinged door with a clamshell door closure. The door is opened and closed either by a handwheel (Fig. 2) or by a motorized device (Fig. 3). Due to the different methods of controlling the door closure, the overall dimensions of the ATC unit (Fig. 4) are changed slightly. The ATC contains two 2-1/2-in. diam. viewports, one on each side of the chamber. (The engineering design computations for the strength and functionality of the chamber vessel and viewports are in Appendix B.)

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*EDITOR'S NOTE: For the convenience of the reader, all figures pertaining to the main body of the report have been grouped at the close of the text, pp. 21 - 50. (Appendixes, and figures relevant to the material therein, are at the end of the report.)

ATC Controls and Indicators

ATC controls and indicators, with individual component identification and description, are shown in Figure 5. Figure 6 is an ATC plumbing schematic diagram with the corresponding parts list. In addition to the basic valves, depth gauge, thermostat, humidifier, and regulators, already in place, the chamber has two externally mounted electrical power boxes, with two receptacles each, to interface with additional accessory equipment. The box has a 10-ft, 115V/15A power cord (12/3 wire) with a 3-prong male plug.

Exhaust and Gas Ports

The chamber exhaust port and external gas port are routed through an angle iron plate at the base of the left rear support leg (Fig. 7). The chamber supply gas port interfaces with an ancillary breathing gas system provided by the user organization. The pressurization medium serves also as the breathing medium for the experimental animals inside the chamber.

Temperature Control System

Temperature regulation (40°F to 180°F) is effected by two 4-in. heater strips (Fig. 8) circumventing the chamber vessel. The strips are electrically controlled by an externally mounted thermostat (Fig. 9), with a magnetic ON/OFF switch (Fig. 10). An amber light on the control box signals when the thermostat is turned ON. The red light indicates when the heater strips are activated to heat the chamber vessel. A remote thermistor is mounted internally to the chamber (Fig. 11), through an external access port (Fig.12). Gas flow within the chamber is sensed by the temperature probe, which sends a signal to the thermostat to maintain a constant temperature environment. A 10-ft, 120V/30A, electrical power cord (10/3 wire), from the thermostat control box, runs down the left rear support leg, and is secured to the deck flooring (Fig.13). The electrical wire must be hard-wired to an external electrical source. Two external power boxes (four receptacles) are also attached to the inside surface of the left rear support leg as additional electrical connection ports for ancillary equipment (Fig. 14).

ATC Door

The chamber door is mounted on a dual acting hinge, allowing the door to swing open freely (Fig. 15). Two "T" clamps, on the front of the door, secure it to a clamshell closure device when the door is fully closed and the chamber is ready to be pressurized. Each "T" clamp is tightened into place with a threaded hex lug. Both lugs are evenly tightened with finger pressure only. Each lug has a pressure release port drilled partially through its center core. When the chamber is decompressed, the lugs must be loosened to permit the chamber interior to vent fully to the outside, thus allowing the door to be opened.

ATC Door Closure

The standard ATC clamshell closure for Types II and III is manually opened and closed with a mechanical handwheel having an extremely low gear ratio. The clamshell device can also be operated by a right-angle, 3/4-HP, electric gearmotor designed for a constant low-speed, high-torque drive application. The motor's output shaft has a special coupler connection which mates with the clamshell gear mechanism. A reversible drum switch controls the operation of the gearmotor. The lever for the drum switch must be manually held in the "ON" position. When the lever is released, it is spring-loaded to the "OFF" position. The motor has a 17.6:1 gear ratio. The motor's 115V/15A power cord (12/3 wire) runs down the right front support leg, and is routed to one of the 2-way electrical boxes mounted on the left rear leg. The user organization will have the option to purchase the gearmotor as an accessory equipment item for either chamber.

External Drain Port

An external drain port is located beneath the chamber vessel (Figs. 16 and 17). An internal petcock valve is used to control the amount of standing water inside the pipe while the chamber is pressurized to 10 psig. The compressed atmosphere aids the expulsion of moisture from the chamber interior, thus minimizing rust damage to the vessel walls.

Pressure Relief Valve

A Kunkle pressure relief (or "pop-off") valve is installed on the upper surface of the compression chamber, and is calibrated to relieve pressure at 90 psig (Fig. 12). The valve diaphragm begins to open at 82 psig, and completely vents to the atmosphere at 90 psig. The chamber pressure will bleed down to about 45-50 psig, and shut off. The pressure relief valve prevents chamber overpressurization in case of supply system malfunction or operator error.

Pressure Supply System

The ATC pressure and exhaust systems are operated through a series of compressed gas controls mounted on the left side of the chamber vessel (Fig. 18). The gaseous medium is supplied from standard high pressure cylinders (2000 psi) attached to a separate breathing gas manifold. The breathing-medium and pressure-regulating manifold must be provided by the user organization. (The procedural and operational checklist for this gaseous system is described in Appendix C.) The pressure manifold reduces the high pressure gas supply to an operational level (400 psig), and directs this gas through a common supply line to the chamber. The supply enters a 2-way Whitey ball valve with "ON/OFF" control. When the supply line is open, gas flows to a Norgren Veriflow Pressure Reduction Regulator, which reduces the supply pressure (400 psig) to a maximum 100-psig pressure at 150°F. A Norgren variable pressure control knob is used to regulate the system pressure to the desired compressed chamber depth. The pressure is monitored on a low pressure (range 0-160 psig) gauge. An integral locking collar on the control knob prevents accidental pressure excursions by locking the input pressure to a predetermined setting (Fig. 19). Two supply lines branch off from the Norgren regulator and merge eventually into a 3-way Whitey ball valve control mechanism (Fig. 18). The ball valve has three settings: "OFF"; "O_2" (main gas supply); and "O_2 + H_2O" (humidified gas supply). When the control knob is in the "O_2" setting, the gas supply leaves the Norgren regulator, travels through the ball valve and enters the chamber compartment through an external access port (Figs. 12 and 18). When the control knob is in the "O_2 + H_2O" setting, compressed gas leaves the regulator and enters a heavy-duty gas-line filter (max. 150 psig at 125°F) encased in a polycarbonate bowl. The bowl is filled with water, and compressed gas is passed through the filter unit, thus saturating the gas supply with water vapor (humidified) before the gas supply enters the chamber compartment. The filter unit is further protected by a removable metal screen cage. At the base of the filter unit is a safety pressure relief valve (set at 120 psig) to prevent overpressurization of the polycarbonate bowl. The desired level of humidification can be attained by modulating gas flow through the "O_2" and "O_2 + H_2O" settings until the prescribed set point is reached. The user organization must provide the optional accessory equipment to monitor relative humidity levels within the chamber vessel.

Helicoid Depth Gauge

When the desired pressure is adjusted on the Norgren regulator and the gas supply enters the chamber vessel, the ATC becomes pressurized. A supply line from an external exhaust port, at the base of the pop-off valve, is connected directly to a Helicoid Depth Gauge (Fig. 12). Compressed gas travels through the line to the gauge, and the chamber depth is measured in feet of sea water (range 0-300 fsw).

Exhaust System

The ATC vessel is depressurized through an external line (Fig. 10) connected to a 3-way Whitey ball valve (Fig. 18). The ball valve has three settings: "OFF"; "DRAIN" (chamber exhaust); and "SAMPLE" (gas sample collection). When the control knob is in the "DRAIN" setting, the chamber interior is vented to the ambient environment through the exhaust opening at the base of the left support leg. The exhaust opening must be connected to an exhaust vent line routed to the building exterior. This connection is especially critical if the pressurization and/or breathing medium is oxygen. When in the "SAMPLE" setting, the operator will be able to collect gas samples, from the chamber interior, through a special sample port (Fig. 20) behind the control panel. Optional gas and humidity analyzers can be connected directly to the sample port to record gas concentrations and relative humidity levels inside the chamber. The different analyzers must be provided by the user organization as optional accessory equipment.

ATC Animal Cage System

During compression operations, test animals must be caged (3). The ATC cage system (not provided with Types II and III free-standing chambers), designed to accommodate small research animals (Table 1), uses three different cage sizes. Each cage has a spring-operated door to prevent the escape of the test animals. For the small and medium cages, the food and water dispensers are located in the center of the ATC, at the top of the chamber, between the rows of cages. These dispensers are attached to a common support shelf, shared by the waste trays. The food dispensers are mounted on a carrier actuator that operates against the ATC door when it is closed. As the door swings shut, the rod actuator is pushed inside the chamber, causing each dispenser to pivot downward into a cage, thus forcing the spring-loaded door open. When the ATC door is opened, the dispensers are retracted upward out of the cages by several extension springs attached to the actuator rod. As the dispenser swings out of position, the spring-loaded door closes in each cage.

Each dispenser is made up of a food basket with a solid stainless steel bottom and back, and a solid spring-loaded access cover. The water system is a gravity feed system which consists of a water storage bottle, at the top of the ATC, coupled to a central waterline with flexible vinyl hoses branching off to supply each water dispenser attached to a food basket. One food-and-water dispenser is provided for each of the small cages, and two are provided for each of the medium cages (Table 2). The dispenser assembly for the small cages can be used for four medium cages by removing the two center food-and-water dispensers. This dispenser system may be used with any combination of small or medium cages in the same ATC, if desired, by removing or replacing the appropriate food-and-water dispensers. The entire dispenser-activator assembly is easily removed from the chamber by giving a 1/4 turn to the retaining latches and disconnecting the waterline.

The food-and-water dispenser for the large cage is at the end of the ATC, and remains stationary as the large cage is placed inside the chamber. The spring-loaded door on the cage allows the entrance of the food tray and water device.

The cages are constructed of 300 series, 24-gauge sheet stainless steel and 16-gauge stainless-steel woven wire cloth. Cage floors are 1/2-in. mesh, 12-gauge, polished stainless-steel woven cloth. All edges and corners are smoothed and welded to ensure all surface areas are readily cleanable, and to minimize injury to animals and cage-handling personnel. Each cage configuration permits the gravity removal of animal waste products from the cage into a waste tray at the bottom of the ATC.

TABLE 1. DIMENSIONS OF ATC ANIMAL CAGES

Cage Size	Floor Area of Cage (in.^{2})	Dimensions (in.) Height	Width	Length	Total No. of Cages in ATC
Small	28	7	5	5 1/2	10
Medium	144	7	8	18	4
Large	756	16	18	42	1

TABLE 2. FOOD AND WATER DISPENSER CAPACITIES

Cage Size	Water Reservoir Capacity [a] (qts)	Dry Food Capacity of Tray (in.^{3})
Small	3	15
Medium	3	15
Large	2	22

[a] Shared by 10 small cages, 4 medium cages, and 1 large cage, respectively.

OPERATIONAL CAPABILITIES AND LIMITATIONS

Operational capabilities of the Animal Transfer Chamber are listed in Table 3 to familiarize the operators with the various subsystem capabilities and limitations. Great importance is attached to fully understanding these operational ranges before operation and before beginning any new hyperbaric experiments utilizing the ATC.

ANCILLARY EQUIPMENT REQUIREMENTS

Breathing Gas Systems

General Information

A breathing gas and/or gas pressurization system, which will interface with the ATC gas inlet line and pressure regulator, must be provided by the user organization. The gaseous system will provide a dual function: pressurize the ATC vessel, and supply a regulated breathing gas mixture to the animal occupants during the compressed chamber operations. The current chamber configuration does not allow delivery of a dual gas system through separate inlet ports.

TABLE 3. ATC OPERATIONAL CAPABILITIES AND LIMITATIONS

CHAMBER MANUFACTURER	Tube Turn Louisville, KY
CHAMBER PRESSURE	
Maximum	1850 psi @ 100^{o}F
Minimum	14.7 psi
Maximum Test Pressure	134 psi
Operational Pressure	75 psi
POP-OFF VALVE	
Make	Watts No. 174A
Model	M^3
Size	3/4 in.
Maximum Pressure	90 psi
Minimum Pressure	82 psi
Capacity	90 ft^3/min (CFM)
PRESSURE REDUCTION REGULATOR	
Make	Norgren Veriflow
Part Number	P/N R07-100-RGKA
Maximum Pressure Inlet	400 psig @ 150^{o}F maximum
Maximum Pressure Outlet	100 psig @ 150^{o}F maximum
LOW PRESSURE GAUGE	
Make	Norgren
Part Number	P/N 18-013-252
Size	1-5/8 in. diameter
Pressure Range	0-160 psig
HUMIDIFIER AIR LINE FILTER	
Make	Grainger
Part Number	P/N 2Z764
Maximum Pressure	150 psig @ 125^{o}F maximum
Safety Relief Pressure	120 psig @ 125^{o}F maximum
DEPTH GAUGE	
Make	Nautilus
Model	Helicoid
Part Number	P/N G4E300010037BAF
Size	6 in. dial
Depth Range	0-300 feet sea water (fsw)
Accuracy	1/4 of 1% accuracy

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TABLE 3. ATC OPERATIONAL CAPABILITIES AND LIMITATIONS (Cont'd.)

VIEWPORTS	
Viewing Diameter	2-1/2 in.
Thickness	2-1/4 in.
Cone Angle	60° angle
Maximum Operating Pressure	1,500 psi
Maximum Implosion Pressure	24,000 psi
DRUM HEATER STRIP	
Make	Watlow
Part Number	P/N 04067700A
Size	4 in. wide (55 gal), 22-1/2 in. NDM
Electrical	120 volt, 1,500 watt
AC MAGNETIC CONTRACTOR	
Make	NEMA Size 1
Model	2 pole single phase
Type	SGG-1
TEMPERATURE CONTROLLER	
Model	Remote bulb, general purpose
Part Number	P/N TY031E
Temperature Range	40°F-180°F
Maximum Inhabited Temperature	110°F
Minimum Inhabited Temperature	60°F
Accuracy	±.5°F
REVERSING DRUM SWITCH (OPTIONAL)	
Make	Square-D
Model	Class 2601
Type	AG2
Horsepower Rating	1-1/2 HP
Electrical	115-Volt, AC Single Phase
DOOR AC GEARMOTOR (OPTIONAL)	
Make	Dayton
Model	No. 5K546B
Type	Right-angle, single reduction
Electrical	115/230 volts, 60 Hz, Single Phase
Full Load Output RPM	100 RPM
Input Motor Horsepower	3/4 HP
Gear Ratio (In:Out)	17.6:1

Air Manifold and Gas Cylinders

The breathing gas system will provide either mixed gases, 100% oxygen or compressed air. Commercial breathing gases are supplied in 244 ft^3 (6.9 m^3) high pressure cylinders filled to 1,800 - 2,000 psi. Most operational and/or research facilities utilize a series of three to six high pressure gas cylinders connected by a common manifold header (4). Gas, which flows through the header under cylinder pressure to the breathing gas manifold regulator, is reduced to the desired working pressure (200-400 psi). Airflow from the manifold to the chamber is further reduced, through an ATC pressure reduction regulator, to a maximum operational line pressure of 100 psi. The breathing gas manifold (Fig. 21) contains: six flexible hoses; two common headers; four shutoff valves; one crossover valve; one bleed-off valve; two C-1 regulator assemblies; tubing; and fittings for connecting the manifold to the chamber's gas inlet line (5). The manifold is divided into two sections to accommodate banks of three cylinders each. (Operation of the breathing gas manifold is described in Appendix C. Hazards and safety precautions in handling compressed breathing gas (6) are discussed in Appendix D.)

Exterior Chamber Lighting

The ATC chamber interior can be illuminated by two free-standing, external, incandescent floor lights, as provided by the user organization. Each light source should be equipped with a reflector device to direct the light through the two separate viewports on top of the chamber vessel. To avoid overheating the window glass, the lights must be positioned about 6 in. from the viewports. When these become quite warm to the touch, the light source must be turned off to allow the glass to cool. Each light source can be connected to the electrical power box on the left support leg of the rear chamber.

Fire Extinguishers

During chamber compression operation, a pressurized, water-filled fire extinguisher (Type A) should be kept immediately available outside the ATC vessel. The extinguisher must be capable of being pressurized to 150 psig to provide adequate working pressure. The extinguisher should be secured in a free-standing rack device (Fig. 22) which should prevent accidental damage, yet provide ready access during emergency needs. Under no circumstances should carbon dioxide, dry chemical, or any other type of extinguisher be used in hyperbaric chambers. To combat fires external to the chamber, however, a Halon 1211 (Type B, C) fire extinguisher should be provided within the facility working area.

Clocks and Stopwatches

A clock is required outside the chamber in order to indicate real time during chamber operations. This clock must be placed where it can be easily seen by all operations personnel, and should be checked for accuracy every 60 days.

If desired by the user organization, a minimum of four stopwatches (not a single standard clock), with sweep-second hands, are required for hyperbaric chamber operations. In Table 4, examples are given of the use of the stopwatches for decompression and no-decompression dive profiles (7). One stopwatch can be used to record the total time of the dive (TTD); i.e., all the time from leaving the surface until regaining the surface. A second stopwatch can either record the total bottom time (TBT)--i.e., the time from leaving the surface until leaving maximum depth--or record the time at different decompression stops. A third stopwatch can be used to record the total decompression time (TDT); i.e., all the time spent in ascending from maximum depth to the surface, including time spent at decompression stops. The fourth stopwatch can record the ascent time (AT) in between decompression stops. The most critical times affecting the safety of the animals inside the chamber vessel are the total bottom time (TBT), the time of ascent to the first stop, and the time at stops. Usually, no more than three watches are in use at the same time, thus leaving at least one stopwatch available for unexpected requirements. The stopwatches should be checked for accuracy every 60 days. Compare all stopwatches with the real-time clock for a 30-min interval. Replace any stopwatch that gains or loses more than 1 sec in 30 min.

INSTALLATION FACILITY REQUIREMENTS

General Information

The ATC hyperbaric system will arrive with the necessary life support subsystem connections in place (as already described in the section on "Equipment Description"). The dimensions of each major component of the ATC system are included in Figure 4. (Special requirements for ancillary equipment have already been described in the section on "Ancillary Equipment Requirements".) In the unpacking of components for ATC installation, particular care should be used to ensure that the special packing material is salvaged and retained for future reshipment of the ATC system.

The purpose of this section is to offer some guidance to the user organization installing the ATC system, and to help minimize potential hazards inherent in hyperbaric operations (7). The chief administrator of the user organization which will possess the ATC systems is responsible for adopting and enforcing appropriate regulations for hyperbaric operations and associated facilities. Full use should be made of technical personnel highly qualified in hyperbaric chamber operations and safety.

TABLE 4. EXAMPLES OF THE USE OF STOPWATCHES FOR VARIOUS DIVE PROFILES (7)

TIMEKEEPER'S OPERATION OF STOPWATCHES					Real-time Clock
EVENT	TTD[a]	TBT[b] Time at Stops	DT[c] TDT[d]	AT[e]	
1. Decompression Dive - 1 Delay on Descent, 2 Decompression Stops					
Start Dive	Start	Start	Start	None	Read and Record
Stop Delay	Running	Running	Read but keep running	Start	
Resume Dive	Running	Running	Running	Stop, Record, and Reset	
Reach Bottom	Running	Running	Stop and Reset	None	
Leave Bottom	Running	Stop, Record and Reset	Start	Start	
Reach Stop 1	Running	Start	Running	Stop, Record, and Reset	
Leave Stop 1	Running	Stop, Record, and Reset	Running	Start	
Reach Stop 2	Running	Start	Running	Stop, Record, and Reset	
Leave Stop 2	Running	Stop, Record, and Reset	Running	Start	
Reach Surface	Stop and Check	None	Stop, Record, and Check	Stop and Check	Read and Check
2. No Decompression Dive - No Delays					
Start Dive	Start	Start	Start	None	Read and Record
Reach Bottom	Running	Running	Stop and Reset	None	
Leave Bottom	Running	Stop, Record and Reset	Start	Start	
Reach Surface	Stop and Check	None	Stop, Record, and Check	Stop and Check	Read and Check

[a] TTD = total time of dive
[b] TBT = total bottom time
[c] DT = decompression time
[d] TDT = total decompression time
[e] AT = ascent time.

Facility Housing

Specific space requirements for ATC installation are based primarily on providing the minimum safeguards for operating personnel (7) and the human engineering design criteria for equipment and facilities (8).

The ATC vessel is a Class "C" (animal, no human occupancy) chamber designed for animal experimentation, and is classified in accordance with NFPA guidelines (2). The ATC system should be housed in a sprinkler-protected, fire-resistant construction, isolated from other buildings or separated from a continuous construction by a 2-hr noncombustible wall construction (2). Sprinkler protection is not required if the effluent gas from the chamber is vented to the exterior of the building. If connecting doors are in such common walls of contiguity, these doors must be at least "B" level; i.e., 1-1/2-hr fire-protection doors. All construction and finish materials must be noncombustible under standard atmospheric conditions. Operations personnel must ensure that the chamber working area is free of extraneous equipment, combustible materials, and volatile substances. Since the compressed air supply system will (in all probability) be within the same building, this system must also be protected against fire hazards. Warning signs must be posted to warn against open flames within 50 ft of the compressed gas cylinders while they are in operation. The floor foundation must be structurally capable of supporting the ATC system (3,500 lb) and any additional ancillary equipment provided by the user organization.

The minimum work area required to install the ATC vessel is 124 in. by 146 in. This requirement is based on the ATC door position when fully opened (Fig. 23), and design requirements as stated in MIL-STD 1472C(8). Sufficient work space must be provided to permit cleaning, ready inspection, and any maintenance actions for the ATC which may be necessary. Whenever feasible, free floor space of at least 4 ft should be provided in front of the chamber control gauges and indicators on the left side of the ATC vessel. Clearance in front of the chamber, from the front edge of the ATC door (fully opened in line with the ATC vessel) to the nearest facing surface or obstacle, should be 42 in. or more. Lateral chamber clearance should be 18 in. for each side, respectively, from its greatest protuberance; i.e., from the manual handwheel on the right side of the chamber, and from the front edge of the ATC door when fully opened to the left side of the chamber entrance. Access behind the chamber should be at least 8 in. The chamber room must have an access entrance 70 in. wide and 8 ft high, to permit movement of the ATC vessel in or out of the room. Storage space must be provided to house the breathing gas cylinders and air manifold, as provided by the user organization.

Within a permanent or semi-permanent facility, provisions must be made for adequate ventilation, as well as for heat to maintain an effective temperature of not less than 18°C (65°F). Effective temperature control within the work area, over extended periods of time, must be maintained at or below 29.5°C (85°F) through an adequate airconditioning system. Relative humidity should be 45% at 21°C (80°F). A minimum of 15% relative humidity is required to prevent irritation and drying of body tissues (i.e., eyes, skin, and respiratory tract).

Power Supply

The building must have a standard 110-115V/15A, single-phase, 60-Hz alternating current supply for the two electrical power boxes attached to the chamber. The power boxes supply electrical power through four internal receptacles. An electric gearmotor, if installed by the user organization for the ATC door closure, can be hardwired to one of the power boxes. The power boxes can be used for external chamber lighting and ancillary monitoring equipment supplied by the user organization. In addition, a 120V/30A (10/3 wire) power supply must be furnished for the ATC Thermostat Control System. The user organization may elect to hardwire the system to the alternating power source, or to use a specialized coupling device. All switches, connectors, terminals, and function boxes must be completely waterproof. All electrical components of the chamber and ancillary equipment should be protected by resetting, self-tripping circuit breakers of adequate amperage. All electrical fixtures used inside the chamber must be capable of withstanding the pressures and pressure changes required by the chamber. All electrical wiring contained within the chamber must comply with the requirements of NFPA 70: National Electrical Code, Article 500, Class I, Division I (9). No electrical equipment--with the exception of intrinsically safe equipment (9) and equipment listed for use in 100% oxygen at 3 ATA pressure--shall be used in the ATC chamber in which the percent by volume of oxygen exceeds 23.5%. Equipment which is used in the chamber with a 23.5% by volume or less atmosphere, must be purged continuously with nitrogen or must be intrinsically safe for that atmosphere (9).

Plumbing Facilities (Water and Gas)

Standard water service with a 1-1/4-to 1-1/2-in. line is required to support cleaning of the chamber interior and small animal cages. A standard connection for a common garden hose should be available for ease in chamber cleanup. A large floor drain with a trap should be provided for disposal of waste water and animal excrement. A large sink with a drainboard or rack assembly should be provided to clean the animal cages and the water and food dispensers.

After ATC installation, all unions, joints, valves, and connectors must be inspected for security before preoperational testing. Both breathing gas and pressurized air lines should be as short as practicable to preclude pressure loss and the increased possibility of leaks due to an excessive number of unions and joints. If an air line must be run on the floor, it is mandatory that the line run through a floor trench with a suitable covering (10). A performance test must be made after ATC installation and inspection to ensure that the chamber is properly installed, calibrated, adjusted, and in proper configuration. A chamber leak test must be conducted using the following test procedures (a-f):

a. Dive the chamber to 165 fsw.

b. Vent the chamber until the temperature stabilizes (approx. 2 min).

c. Turn off the compressed air supply.

d. Assure that all chamber valves are closed.

e. Assure that the pressure does not fall more than 1 psig per 10-min interval.
Test all joints for leakage (soapy water or standard leak test fluid).

f. Take the chamber to depth and ensure that the pop-off valve is functioning properly. The valve diaphragm will become activated at approximately 82 psi and fully vent at 90 psi.

Illumination

Permanent lighting fixtures within the chamber facility must be adequate for conducting maintenance tasks and chamber operations (8). Specific illumination requirements range from a minimum of 325 lux (30 fc) to a recommended level of 540 lux (50 fc) to 775 lux (70 fc). Additional sources of illumination can be mounted outside the pressure chamber and arranged to shine through the chamber viewports. Incandescent floor lights may be employed for illumination, provided that they have reflectors and are positioned at least 6 in. or more from the windows to avoid overheating the window glass. All lighting fixtures used inside the chamber (fluorescent or portable surgical spot lamps) must be individually pressure tested to withstand the maximum proposed pressure and oxygen concentration of the chamber (9).

Ventilation Facilities

Adequate ventilation of the chamber room should be supplied at a minimum rate of 30 ft^3/min/person (8). Approximately two-thirds of the ventilation should be outside fresh air. Air-flow rates for hot climate operation [temperatures above 32°C (90°F)] should be maintained between 150 and 200 ft^3/min/person. Intakes for the ventilation system should be so installed as to minimize the introduction of contaminated air from external sources, such as exhaust pipes, etc.

Fire Protection

A sprinkler system must be installed in the chamber room housing the ATC system, ancillary equipment, and compressed breathing gas cylinders. An exception to this standard occurs when the effluent gas from the chamber is vented to the <u>exterior</u> of the building. Installation of a fire alarm protection system, and all sprinkler system components, must be in accordance with "NFPA 13: Standard For The Installation of Sprinkler Systems" (11). The chamber must be equipped with an external, hand-held water fire extinguisher (Type A), capable of being pressurized to 150 psig. Under <u>no</u> circumstances should carbon dioxide, dry chemical, or any other type of extinguisher be used in hyperbaric chambers. For additional safety precautions, a Halon 1211 fire extinguisher should be provided in the chamber room to combat types B and C fires (wood, paper, liquids, grease, and electrical equipment). Smoking, open flames, hot objects, and ultraviolet sources which could cause premature operation of the flame detectors should be prohibited from the hyperbaric facility.

Storage of Nonflammable Gases

When the ATC system will be routinely and frequently operated with nonflammable gases supplied through a manifold compressed system, the manifold should consist of not more than six cylinders secured in position. A pressure-reducing valve must be connected to each gas cylinder and adjusted to a setting to limit pressure in the piping system at the minimum required gas pressure. If more than six cylinders of gas are required, they must be stored in a separate room having a fire-resistance classification of at least 1 hr (12), and must be ventilated in accordance with "Chapter 3, Use of Inhalation Anesthetics" (2). Another alternative would be to store the cylinders outside the building and to connect them to the ATC system by a permanently installed piping system (12). Operational and procedural checklists for the handling, storing, and transferring of compressed gas cylinders are in Appendix C.

Other Equipment

The exhaust from the ATC vessel must be piped outside the building, the point of exit being clear of all neighboring hazards and clear of possible re-entry of exhaust gases into the building through the ventilation system.

Sensors should be installed within the chamber vessel, if possible, to detect levels of carbon dioxide (above 0.2%), carbon monoxide (above 15 ppm), and volatilized hydrocarbons (above 500 ppm). As an alternative, periodic sampling of chamber air can be achieved by utilizing the gas-sample port on the left side of the chamber. Monitoring equipment, located on the outside of the chamber, can be used to record the appropriate readings.

Oxygen containers, valves, fittings, and interconnecting equipment, must be all nonsparking metal when possible. Valve seats, gaskets, hoses, and lubricants must be selected for oxygen compatibility under high barometric pressures.

All storage areas for animal cages, feed, maintenance equipment, compressed air cylinders, etc., must be remote from the hyperbaric chamber environment.

Staffing

Due to its simple design, one technician or professional staff member will be necessary to operate the ATC system. The user organization should establish adequate rules and regulations with respect to the use of the hyperbaric facilities. Upon adoption, these rules and regulations should be prominently posted in and around the hyperbaric chamber. Clearly defined supervision is imperative to safe chamber operation. A safety director should be in charge of all hyperbaric facilities, equipment, operations, and maintenance practices. All operational personnel should have thorough knowledge and understanding of hyperbaric operations and safety precautions. All personnel must be familiar with NFPA fire/safety codes, and all existing emergency procedures for chamber operation and any emergency equipment, as related to its purposes, applications, operation, and limitations.

CHAMBER OPERATION

Pre-Dive Procedures

The chamber operator must perform certain pre-dive inspections before the chamber can be safely pressurized. All controls and indicators for the chamber subsystems, ancillary equipment, and the gas manifold should be in the "OFF" position. This position will insure that, during the normal operation phase, specific controls, regulators, etc., will not be overlooked before diving the chamber. (Such oversights could result in operational delays or aborted dives.) The pre-dive inspection should flow in a well organized, uniform manner, beginning at the gas manifold control panel (Appendix C), and working systematically through all equipment subsystems to the ATC vessel. The chamber operator should be familiar with all hazards and safety precautions, as related to the ATC system operation (Appendix D). Operational checklists for the ATC system are in Appendix E.

The following is a suggested step-by-step procedure for a pre-dive inspection of the ATC system:

a. Close all valves on the high pressure gas cylinders.

b. Open the vent valve on the breathing gas manifold to bleed-off any residual pressure in the lines and then close the valve.

c. Close all high and low pressure valves and the crossover valve.

d. Be sure the C-1 regulators are backed-off in a counterclockwise direction.

e. Make sure the inlet supply line is connected to the pressurization gas system.

f. All supply and exhaust valves on the chamber should be closed.

g. The main power switch to the thermostat control box should be in the "OFF" position.

h. The petcock valve for the chamber external drain port must be closed.

i. Be sure the Type A water fire extinguisher is near the chamber door.

j. Inspect the chamber viewports for scratches, cracks, or any suspected damage.

k. Prepare the inside of the chamber vessel to receive the animal cages. Place a flat tray of water in the chamber bottom to help control the humidity inside the vessel during compressed operations. It is desirable to have the water absorbed in a diaper, paper, or sponge. The additional humidity in the chamber environment will help eliminate the problem of static discharge from the animal's dry fur. If the walls of the chamber sweat, or if the window ports tend to fog while in use, the water tray is not needed.

1. Check the "O"-ring door seal, making sure the surface is free from dirt, grease, etc. The "O"-ring may be lightly lubricated with silicone grease (only the oxygen-compatible type). Use only enough to feel the presence of the grease on the ring. Do not use any other type of lubricant on any surface or valve.

The ATC system is now in a fully "OFF" or shut-down condition, and is ready to be brought on-line for compression operations. Using guidelines established by the user organization, calibrate all ancillary monitoring equipment. Turn on the breathing gas manifold using the procedures listed in Appendix C. Perform the "Pre-Dive Checklist" (Appendix E) to prepare the ATC system for pressurization. Place the animals in the chamber. Make sure metal cages are used to prevent any buildup of static electricity. Close the door carefully, and secure it with the clamshell device by using either the manual handwheel or the electric gearmotor (as provided by the user). Secure the "T" clamps on the door, and evenly tighten the door hex lugs. The chamber is now ready to pressurize.

Pressurizing the Chamber

The chamber operator must maintain accurate dive records for each compression operation (Appendix F). To pressurize the chamber, follow the operational checklist in Appendix E. A descent rate of 60 ft/min is an appropriate compression rate. While the animals can stand a more rapid rate of compression, the noise in the chamber may become severe and even painful to them. Experimental data could thus be unfavorably biased, due to undesirable physiological reactions produced in the animals.

Ventilation of the Chamber

If the treatment and/or experimental dive profile calls for a 100% oxygen environment, for more than 1-2 hr at 60 fsw, the chamber operator must be very attentive to oxygen toxicity convulsions in the animal occupants. If such convulsions tend to occur, they may be avoided by reducing the treatment depth, shortening the treatment time, or by flushing the chamber with air for a 5-min period each 30 min. The chamber must be flushed again with oxygen at the end of this air-breathing period. Close all supply and exhaust valves on the chamber. Switch over to the oxygen cylinders by using the crossover control valve on the breathing gas manifold. Slowly open the supply inlet line to establish an oxygen flow into the chamber, thus flushing the chamber with pure oxygen. Slowly open the one-way chamber exhaust valve to a predetermined setting, while maintaining a constant depth with the one-way supply valve. Allow the chamber to flush for 5-10 min at a flow rate of about 4 liters/min. An oxygen analyzer can be connected to the air-sample port to monitor the oxygen concentration during the flushing process. When the percent oxygen level is reached, close all supply and exhaust valves. This procedure is costly in terms of oxygen utilization. During normal operations, the chamber should be ventilated as soon as possible after reaching maximum depth in order to cool the chamber and improve comfort inside. If carbon dioxide readings rise above 0.2%, the chamber interior should be flushed with fresh air or oxygen, as required by the dive profile.

Depressurizing the chamber

Upon completion of the treatment-experimental dive, the chamber is decompressed to the surface. Follow the operational checklist described in Appendix E. If pure oxygen is used in the treatment, pausing during decompression is not necessary, since no danger of decompression sickness exists. For rats and mice which have been exposed to pure oxygen, the ascent rate may be 60 ft/min. If the chamber was operated with compressed air or other inert gas mixtures, staged decompression must be employed since the animals will contain dissolved inert gas.

Post-Dive Procedures

After decompression to the surface, the chamber door is opened and the animals are removed. Follow the "Post-Dive Checklist" described in Appendix E. The chamber interior must be thoroughly cleaned with a mild liquid detergent in warm water. The chamber has been painted with an epoxy paint, and therefore is reasonably resistant to corrosion. As a safeguard, however, the following procedure is recommended to remove all standing water and residual moisture from the chamber interior:

a. Pressurize the chamber to approximately 10-15 fsw.

b. Open the petcock valve inside the external chamber exhaust drain port. This action will allow pressurized air inside the chamber to vent most of the interior moisture to the atmosphere.

c. Decompress the chamber to surface.

d. Towel-dry any residual moisture remaining in the chamber interior.

e. The chamber door should be lightly closed after the chamber is thoroughly dry.

When the chamber is not in use, the pressure should be relieved in the regulator and in all lines. If the decompression procedure is followed (as described in Appendix E), the lines will automatically be relieved.

After cleaning the chamber interior, clean the ATC animal cages (Appendix E), and restock them with food and water if they are to be used again for a subsequent dive.

Perform any required minor maintenance authorized locally for the ATC system. Emergency requests for assistance in repair requirements that have caused, or will cause the ATC chamber system to become inoperative or unsafe, can be made by telephoning the:

USAF School of Aerospace Medicine
Hyperbaric Medicine Division
Brooks Air Force Base, TX 78235-5301
PHONE: 512-536-3281 (OR--Autovon: 240-3281)

Telephone calls for assistance must be confirmed by written communication. All requests for chamber modifications must be in writing, and must be submitted for U.S. Air Force approval.

CONCLUSIONS

The hyperbaric ATC system has been especially designed for research application, to study and evaluate the physiological responses of laboratory animals to high barometric pressures. As shared interests in hyperbaric research continue to advance in civilian and military communities, it is hoped that newer applications of hyperbaric therapy will be discovered, with possible application to military and aviation medicine.

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10. T.O.43D8-3-4-61, Technical Manual, Operation and Maintenance Instructions Hyperbaric Compression Chamber Type A/F99S-3, Secretary of the Air Force, Washington, D.C., 21 Sep 1978.

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12. NFPA 26F: Standard For Nonflammable Medical Gas Systems, National Fire Protection Association, Quincy, Mass., 1983.

FIGURES 1-23

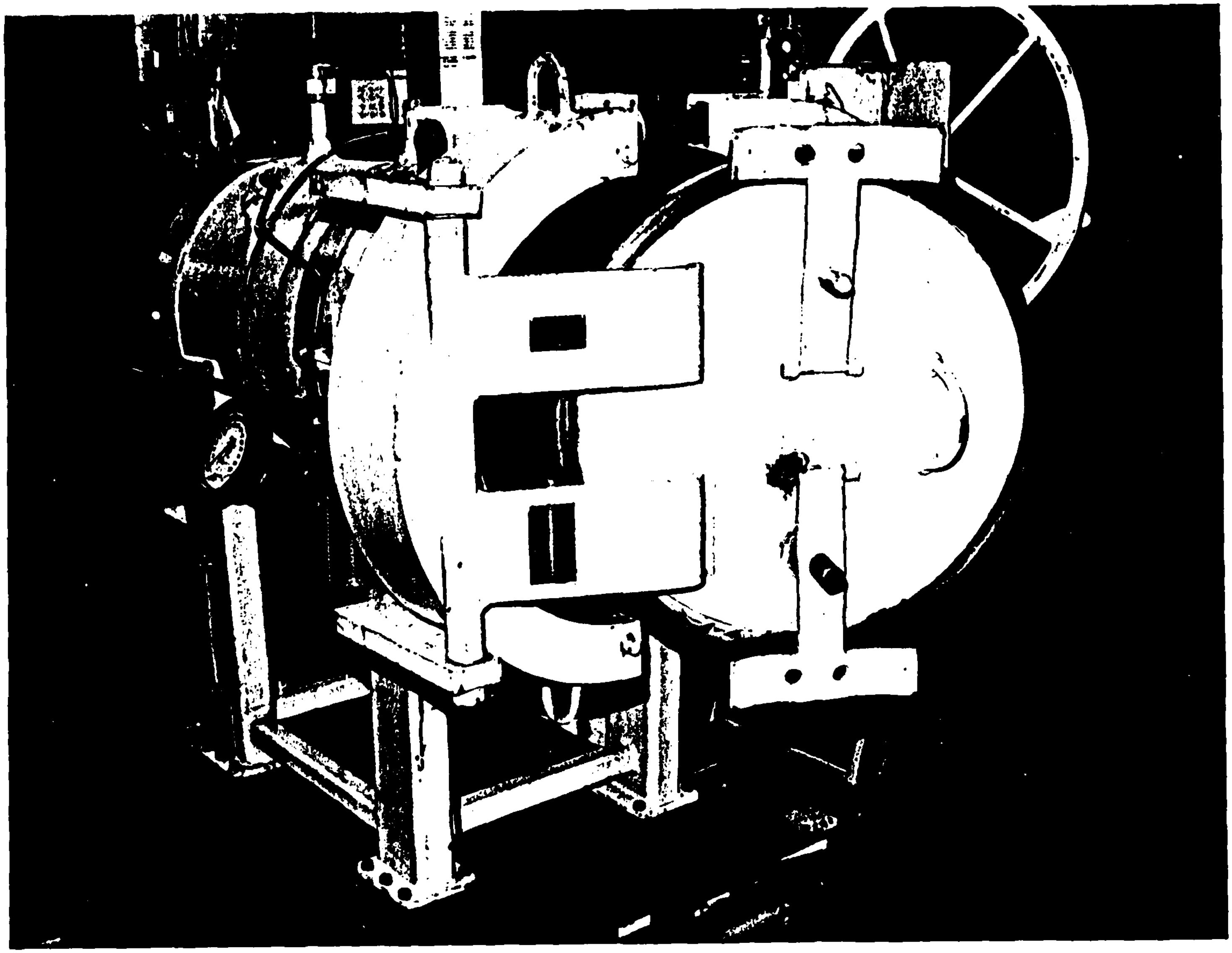

Figure 1. Animal Transfer Chamber (ATC)--frontal view.

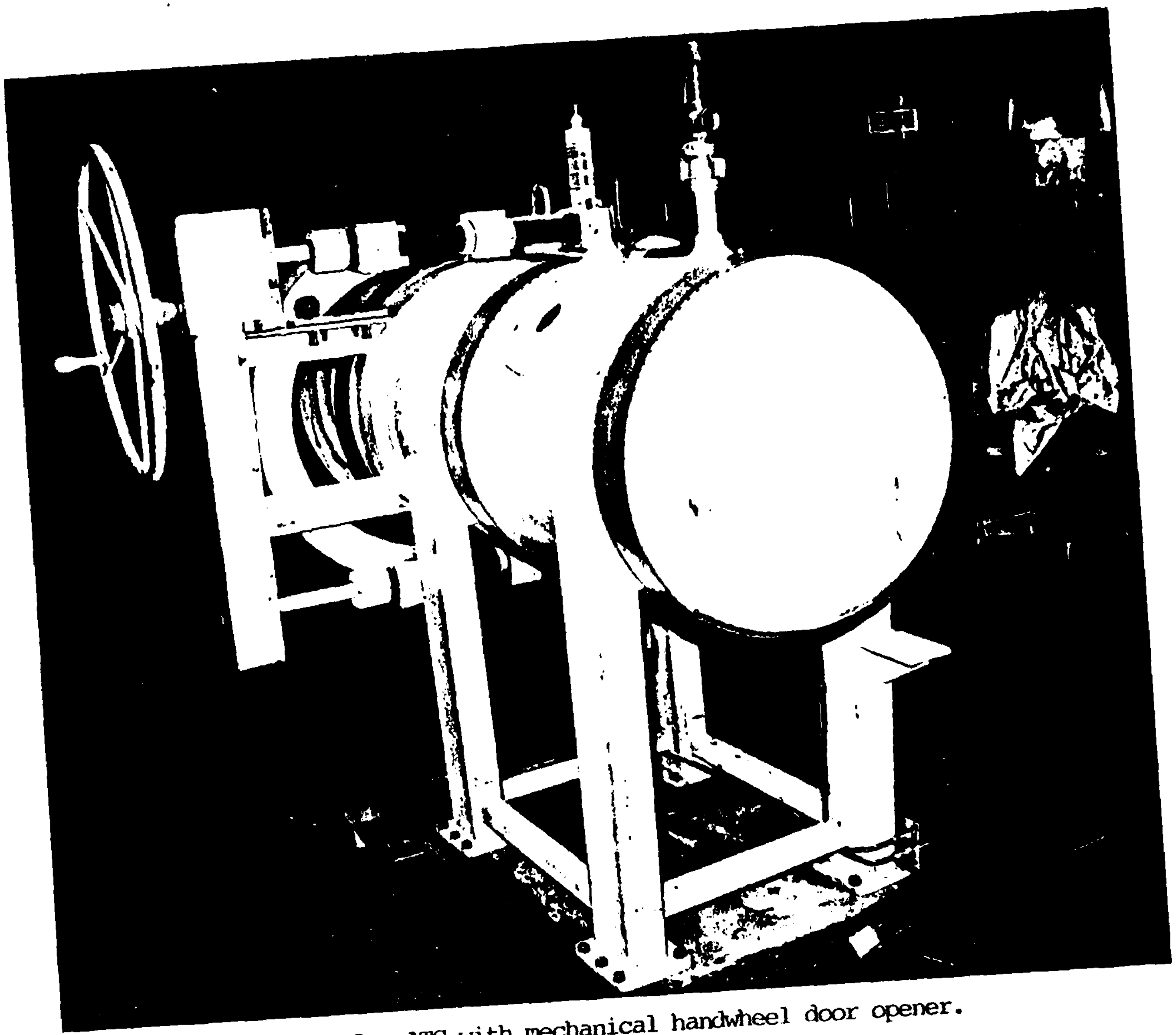

Figure 2. ATC with mechanical handwheel door opener.

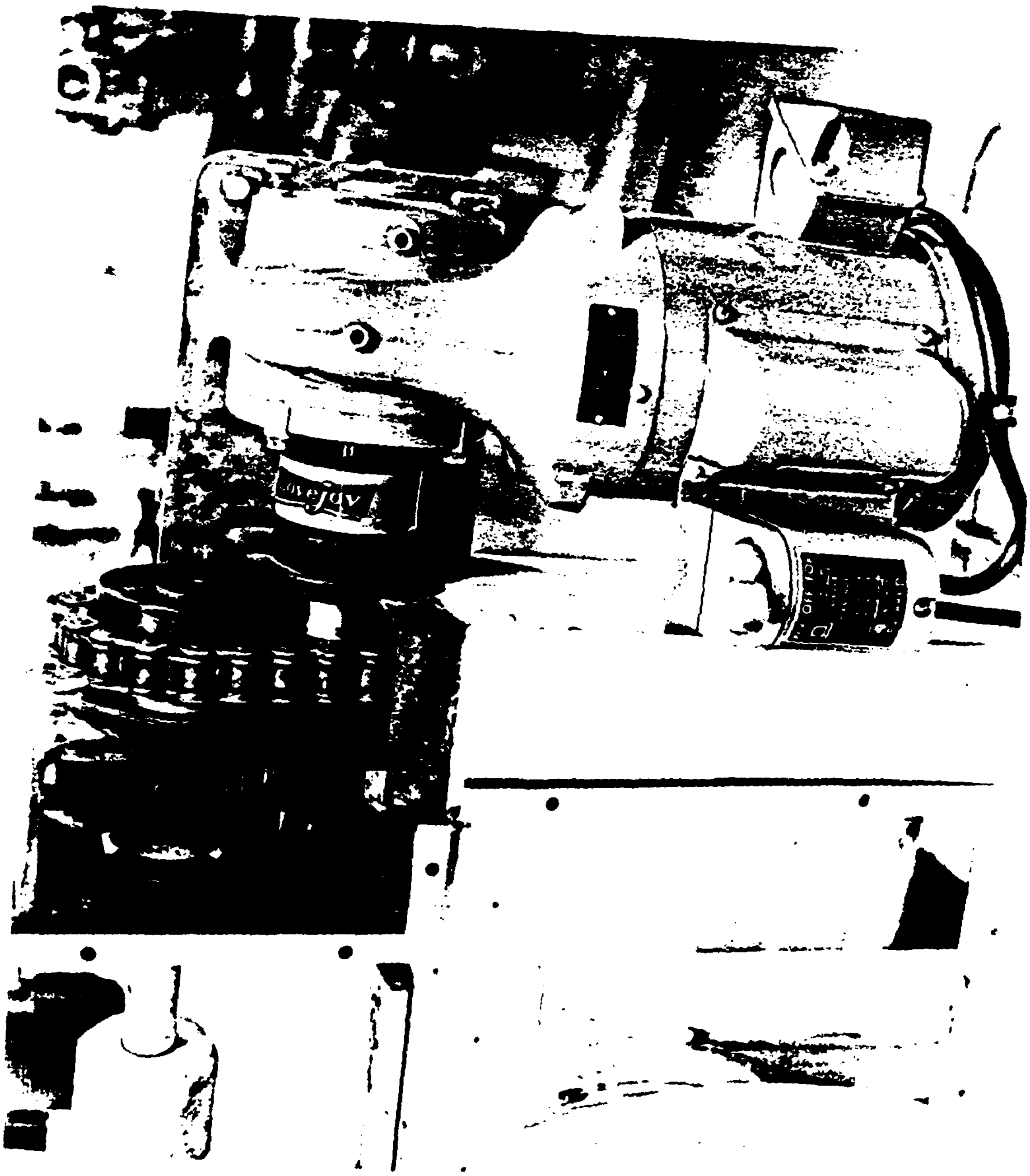

Figure 3. ATC with motorized door opener.

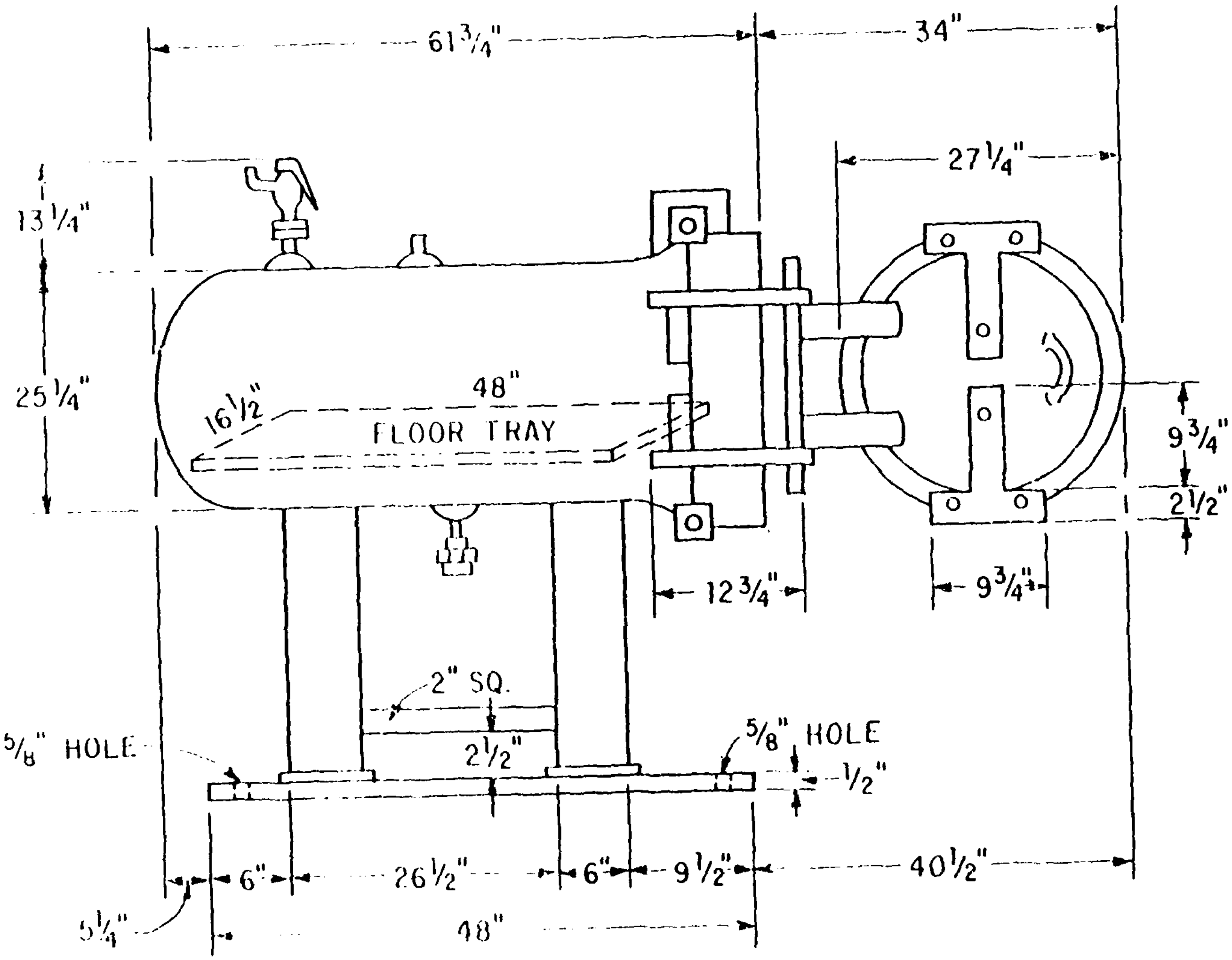

Figure 4-a. ATC dimensions: side view.

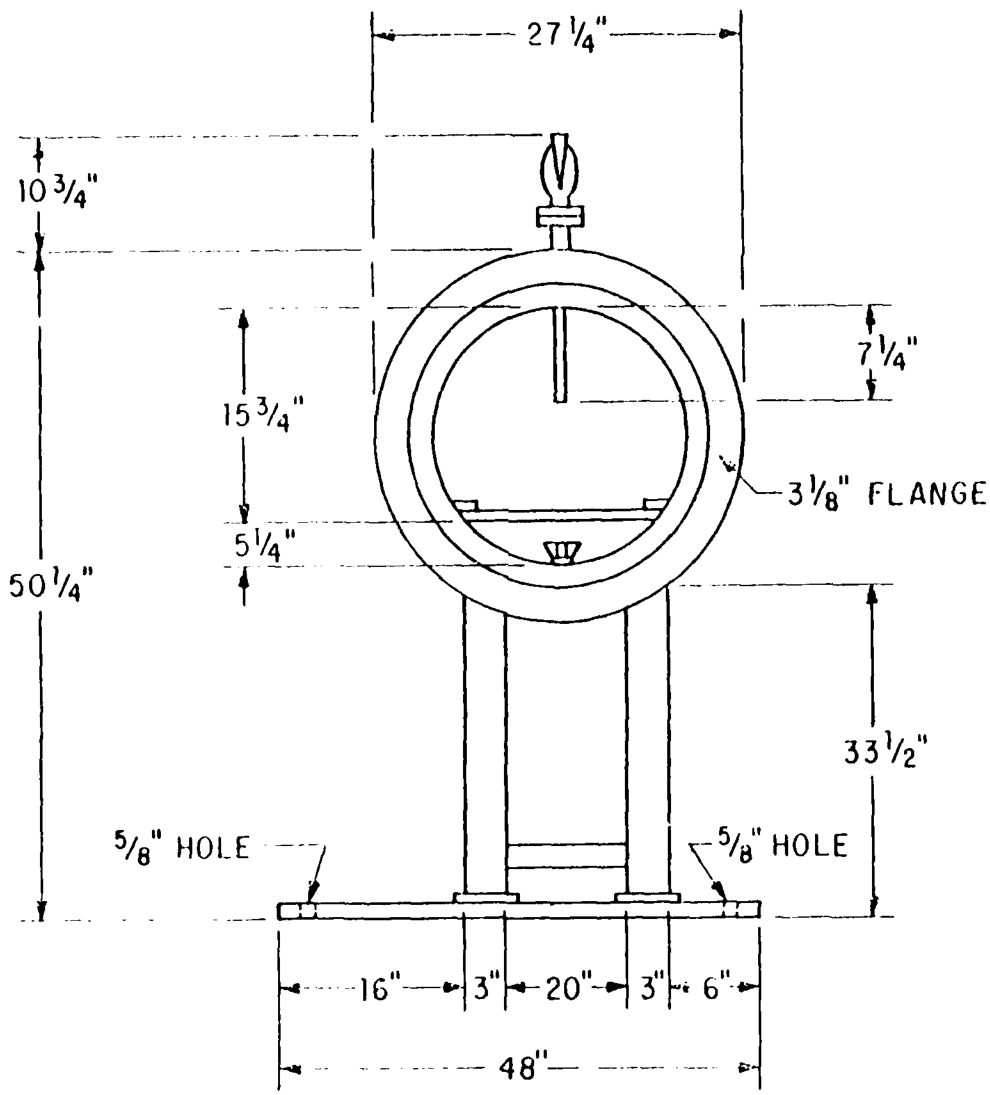

Figure 4-b. ATC dimensions: front view.

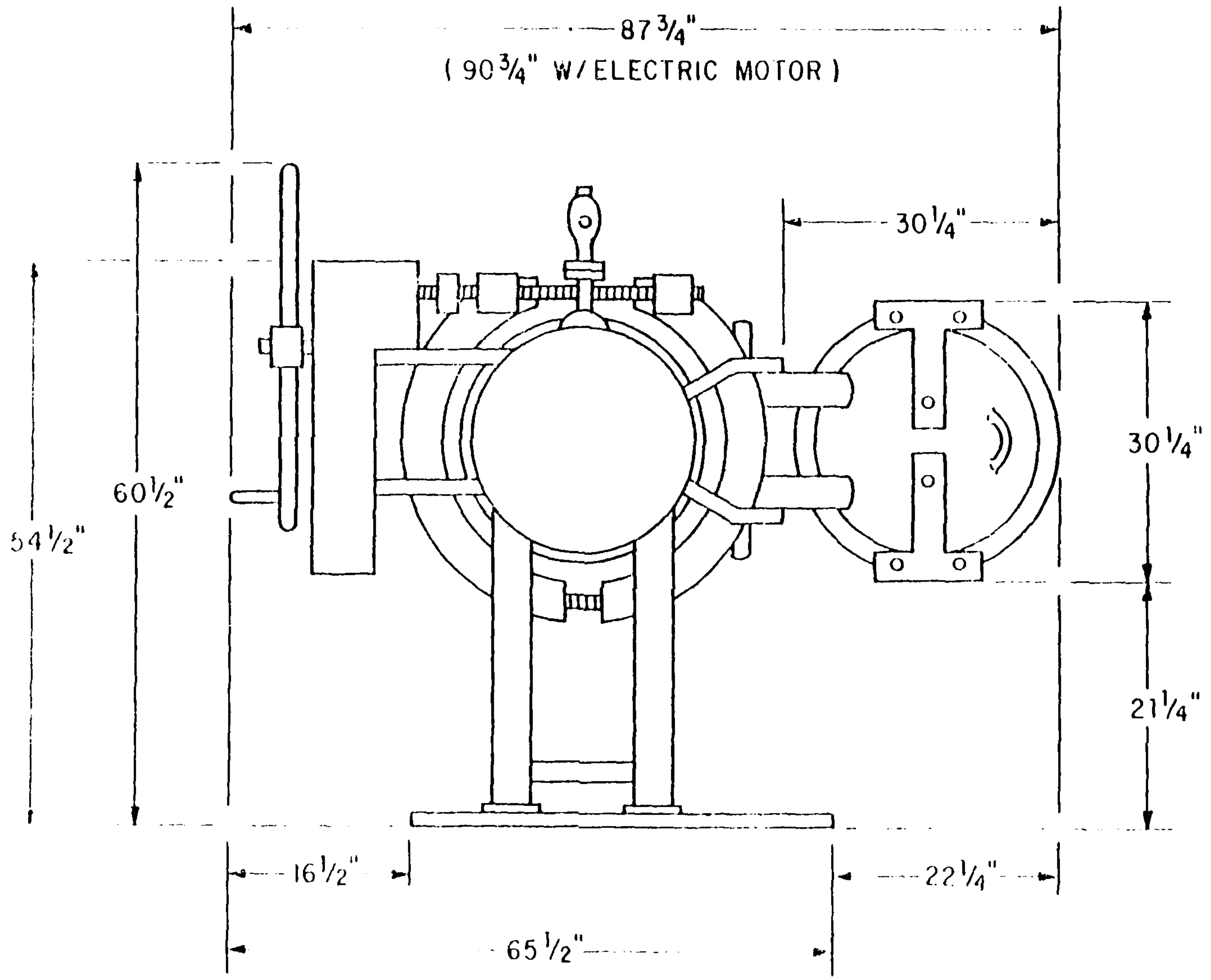

Figure 4-c. ATC dimensions: rear view.

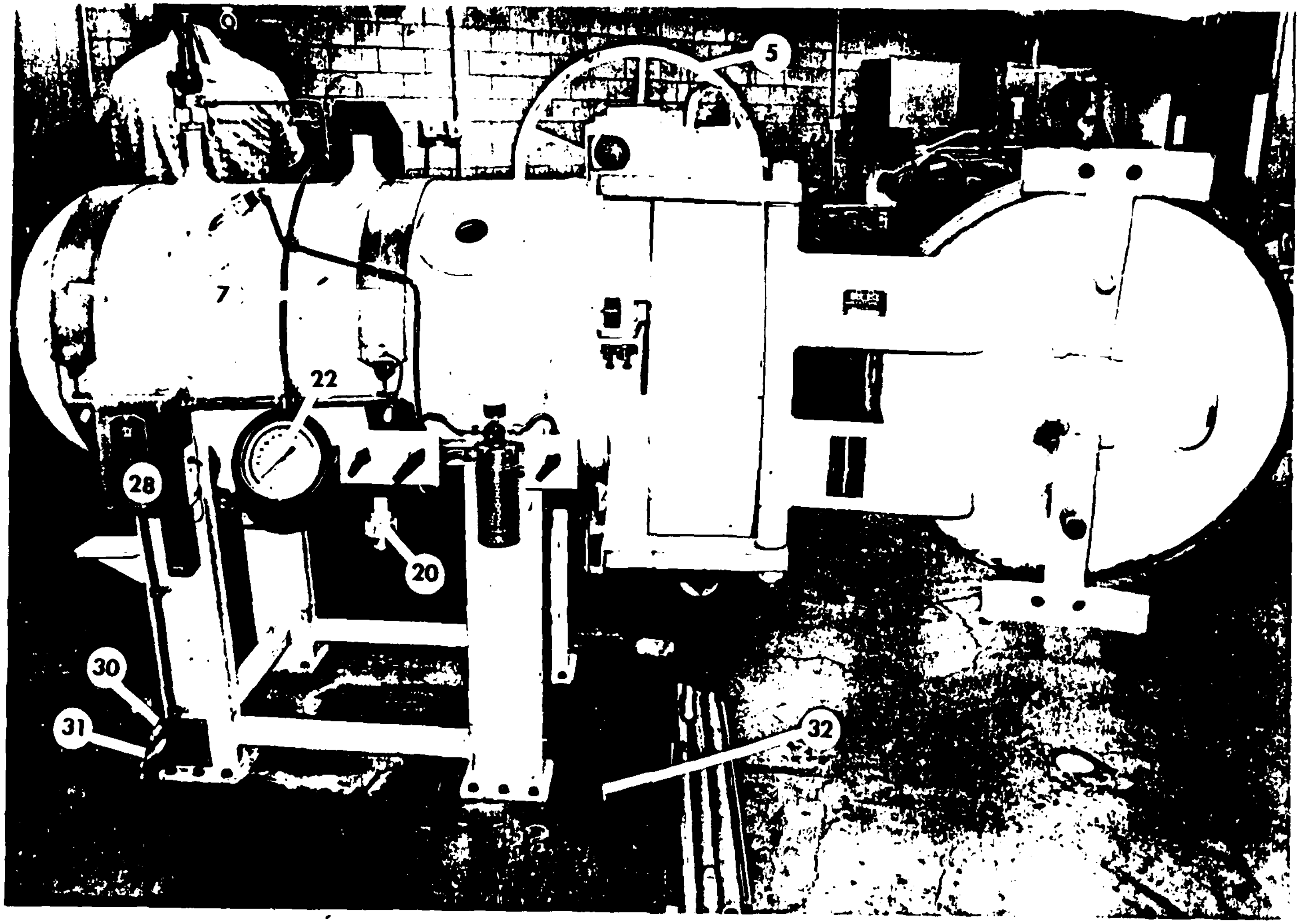

Figure 5. ATC system controls and indicators. (See Key on following pages.)

KEY TO FIGURE 5: ATC System Controls and Indicators. (Eight items are numbered within Fig. 5; and the additional numbers serve as keys for Figs. 7, 11, 12, 15, 18, 19, and 20.)

NO.	IDENTIFICATION	FUNCTION
1	Watts Pop-off Valve	Safety pressure relief set at 90 psi
2	Pressure Gauge Supply Outlet	To chamber pressure indicator; 0-300 fsw
3	Temperature Thermistor	Chamber temperature sensor; $40^{o}F-180^{o}F$
4	Viewport	Visual access to chamber interior
5	Mechanical Handwheel	Controls clamshell door closure
6	External Supply Port	Compressed gas supply inlet to chamber
7	Drum Heater Strip	Heats chamber interior
8	Door Clamshell Closure	Secures chamber door for compression
9	Chamber Door	Seals Chamber Vessel
10	Door "T" Lock	Secures door to clamshell closure
11	Stud Alignment Holes	Aligns "T" lock to clamshell closure
12	Hex Head Pressure Cap	Relieves residual pressure in the chamber so the door can be opened
13	Supply Inlet Control Valve	ON/OFF control of gas supply inlet
14	Low Pressure Gauge	Pressure indicator for supply inlet
15	Pressure Reduction Regulator	Reduces inlet pressure of 400 psi to an outlet pressure of 100 psi maximum @ $150^{o}F$ maximum
16	Humidifier Gas Line Filter	Humidifies gas supply
17	Pressure Relief Port	Safety pressure relief set @ 120 psi @ $125^{o}F$ maximum

(Cont'd. on next page)

KEY TO FIGURE 5: ATC System Controls and Indicators (concluded)

NO.	IDENTIFICATION	FUNCTION
18	O_2/O_2+H_2O Supply Control Valve	Controls humidified/non-humidified gas to the chamber
19	Gas Sample Port	Collect gas samples from the chamber interior
20	Chamber Drain Port	Petcock valve used to drain moisture from the chamber
21	Chamber Exhaust Control Valve	Controls chamber exhaust to the environment or through the gas sample port
22	Helicoid Depth Gauge	Chamber pressure indicator; 0-300 fsw
23	External Exhaust Port	Outlet line for chamber exhaust
24	AC Magnetic Contactor	Activates heater strips
25	ON/OFF Toggle Switch	ON/OFF control of the AC Magnetic Contactor and thermostat regulator
26	Amber Control Light	"ON" indicator for AC Magnetic Contactor
27	Red Control Light	"ON" indicator for heater strip activation
28	Thermostat	Controls temperature of chamber interior ($40^{o}F-180^{o}F$)
29	Thermostat Power Cord	120 V/30A electrical cord (10/3 wire) to supply power to the thermostat and heater strips
30	External Exhaust Drain	Exhaust drain port to vent the chamber interior
31	Compressed Gas Supply Inlet	Gas supply inlet from an external compressed gas supply system
32	Deck Flooring Plate	Flooring support for the chamber (4 ft sq)

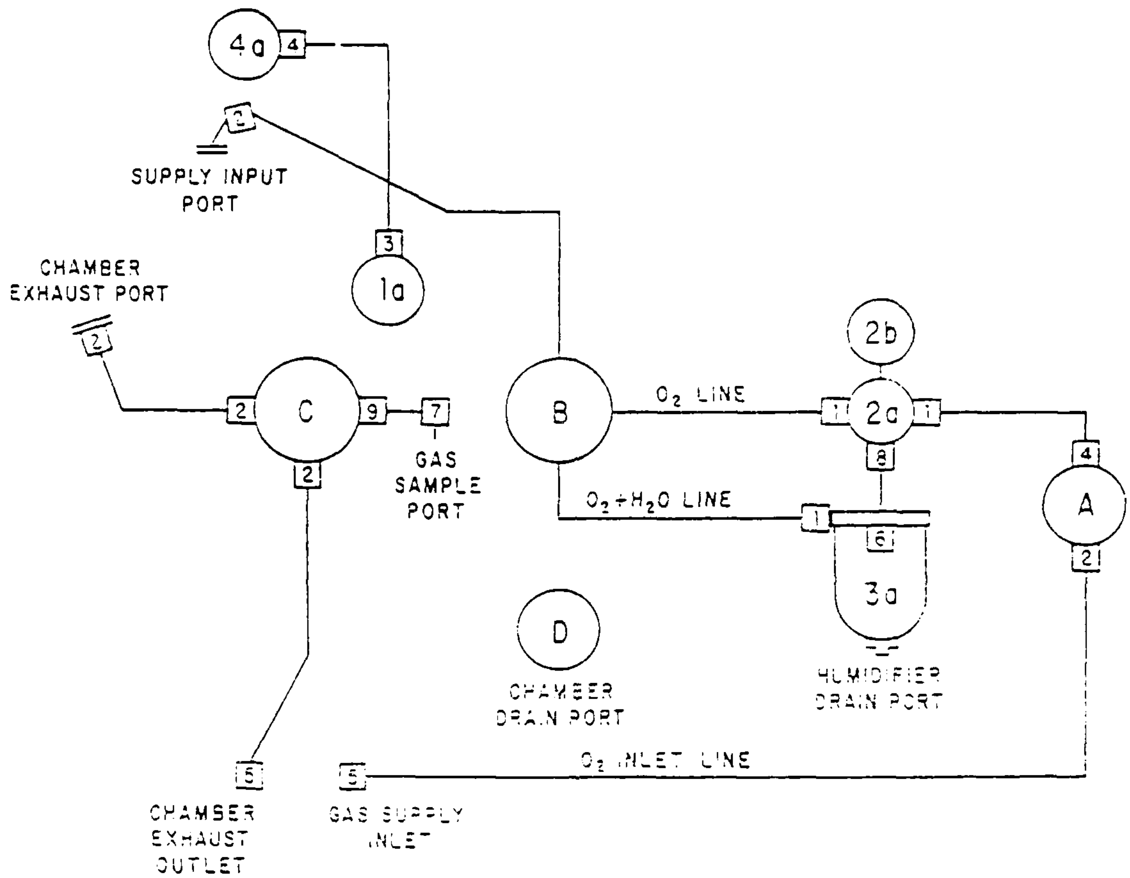

Figure 6. ATC plumbing and list of parts. (Key on facing page)

KEY TO FIGURE 6: List of ATC plumbing parts.

NO.	PART IDENTIFICATION	PART NUMBER
A	WHITEY 2-WAY BALL VALVE	B-44F4
B	WHITEY 3-WAY BALL VALVE	B-44XS6
C	WHITEY 3-WAY BALL VALVE	B-44XF4
D	DRAIN COCK	FSN 4820008491220
1a	HELICOID DEPTH GAUGE	G4E300010037BAF
2a	VERIFLOW PRESSURE REGULATOR	R07-100-RGKA
2b	LOW PRESSURE GAUGE	18-013-252
3a	HUMIDIFIER GAS LINE FILTER	2Z764
4a	WATTS POP-OFF VALVE	174A
1	3/8 SWAGELOK TO 1/8 NPT MALE 90°	B-600-2-2
2	3/8 SWAGELOK TO 1/4 NPT MALE 90°	B-600-2-4
3	3/8 SWAGELOK TO 1/4 NPT FEMALE 90°	B-600-8-4
4	3/8 SWAGELOK TO 1/4 NPT MALE	B-600-1-4
5	3/8 SWAGELOK TO 1/4 NPT FEMALE	B-600-71-4
6	1/8 NPT MALE TO 1/8 TUBE CAJON	B-2-TA-1-2
7	1/4 NPT MALE TO 1/8 TUBE CAJON	B-2-TA-1-4
8	1/8 NPT MALE TO 1/8 NPT MALE CAJON	B-2-HN
9	1/4 NPT MALE TO 1/4 NPT FEMALE CAJON 90°	B-4-SE

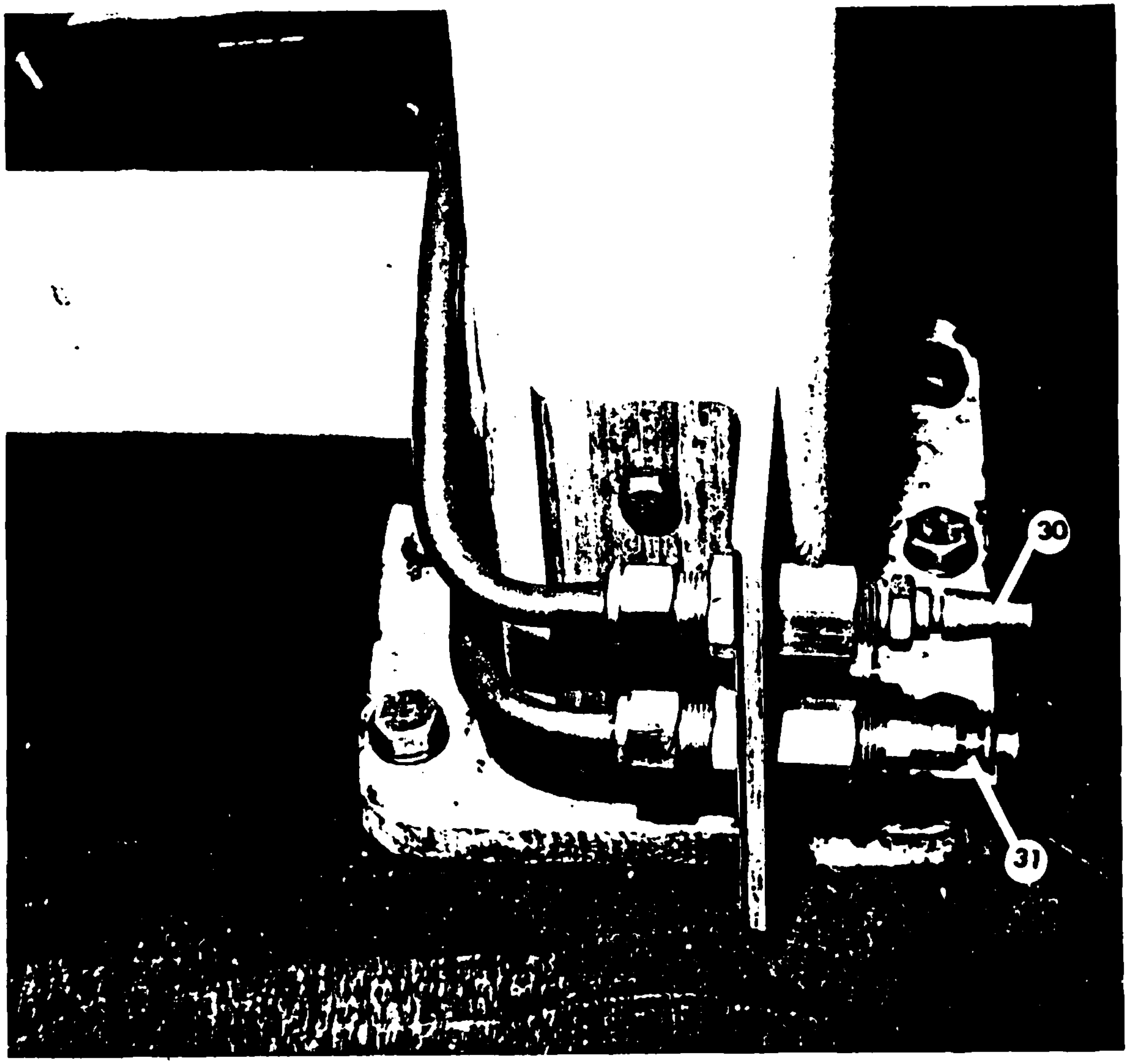

Figure 7. Exhaust and external gas ports. (For numbered items, refer to Key to Fig. 5.)

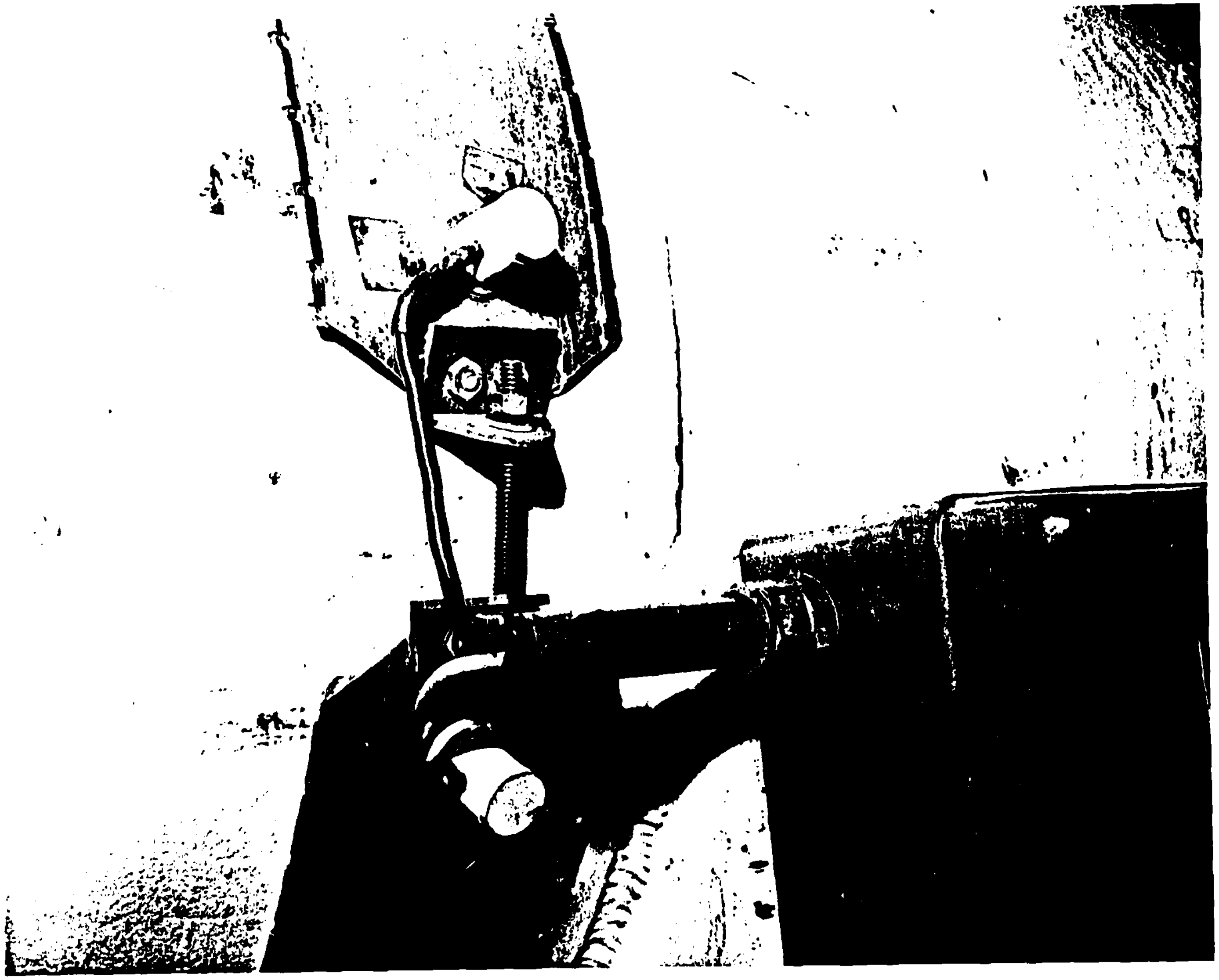

Figure 8. ATC heater strip.

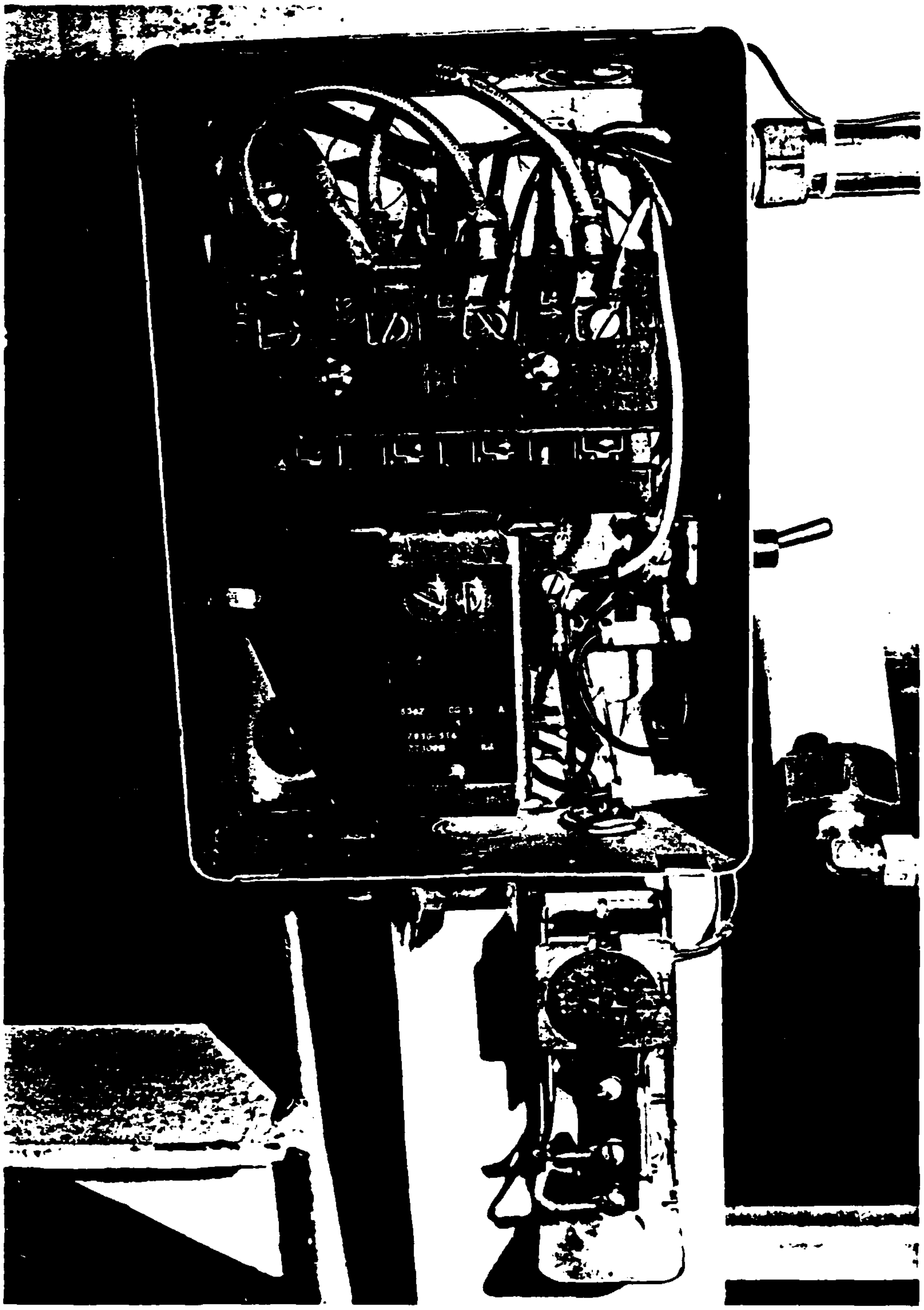

Figure 9. ATC thermostat.

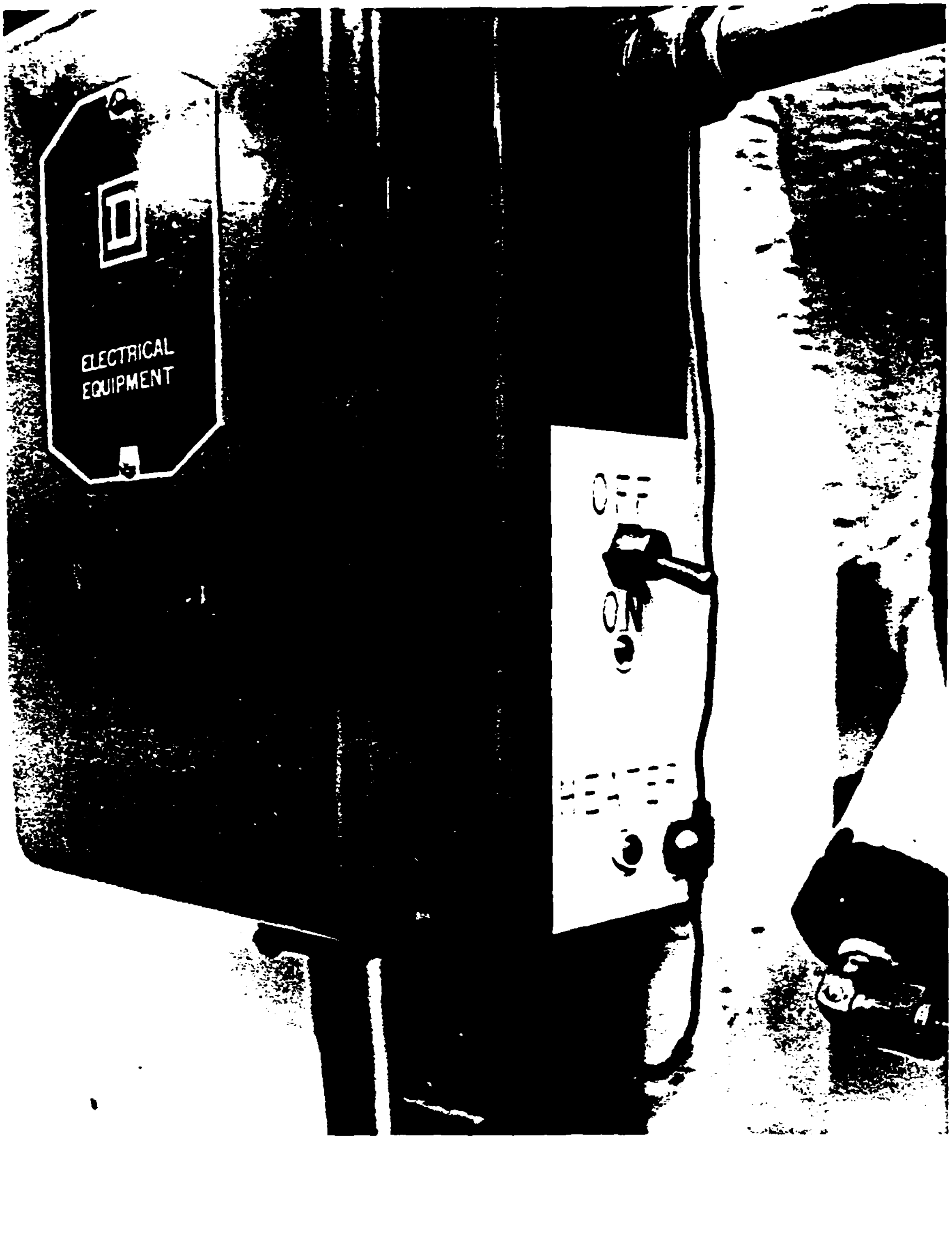

Figure 10. ATC thermostat magnetic ON/OFF switch.

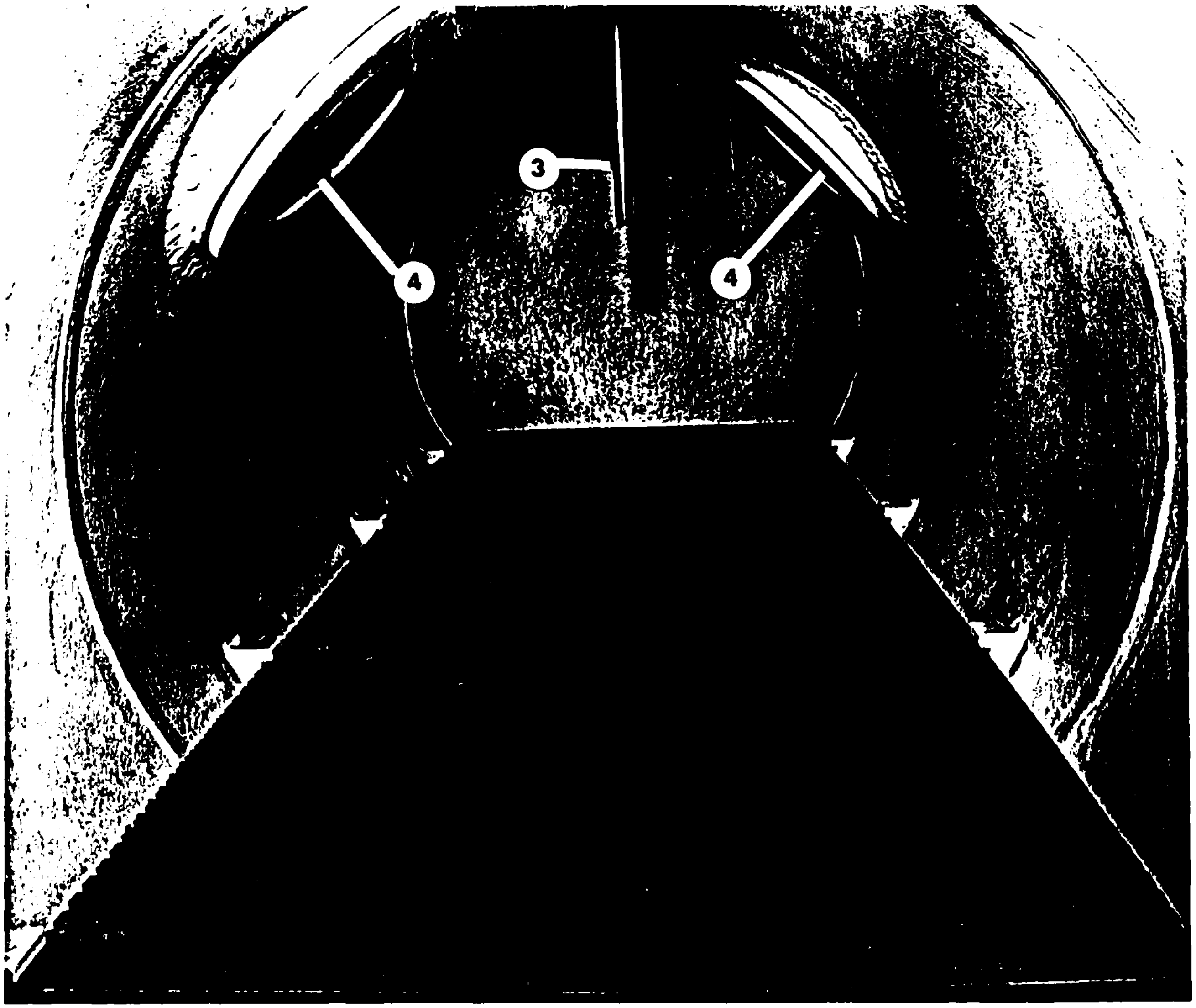

Figure 11. Internal chamber thermistor. (For numbered items, refer to Key to Fig. 5.)

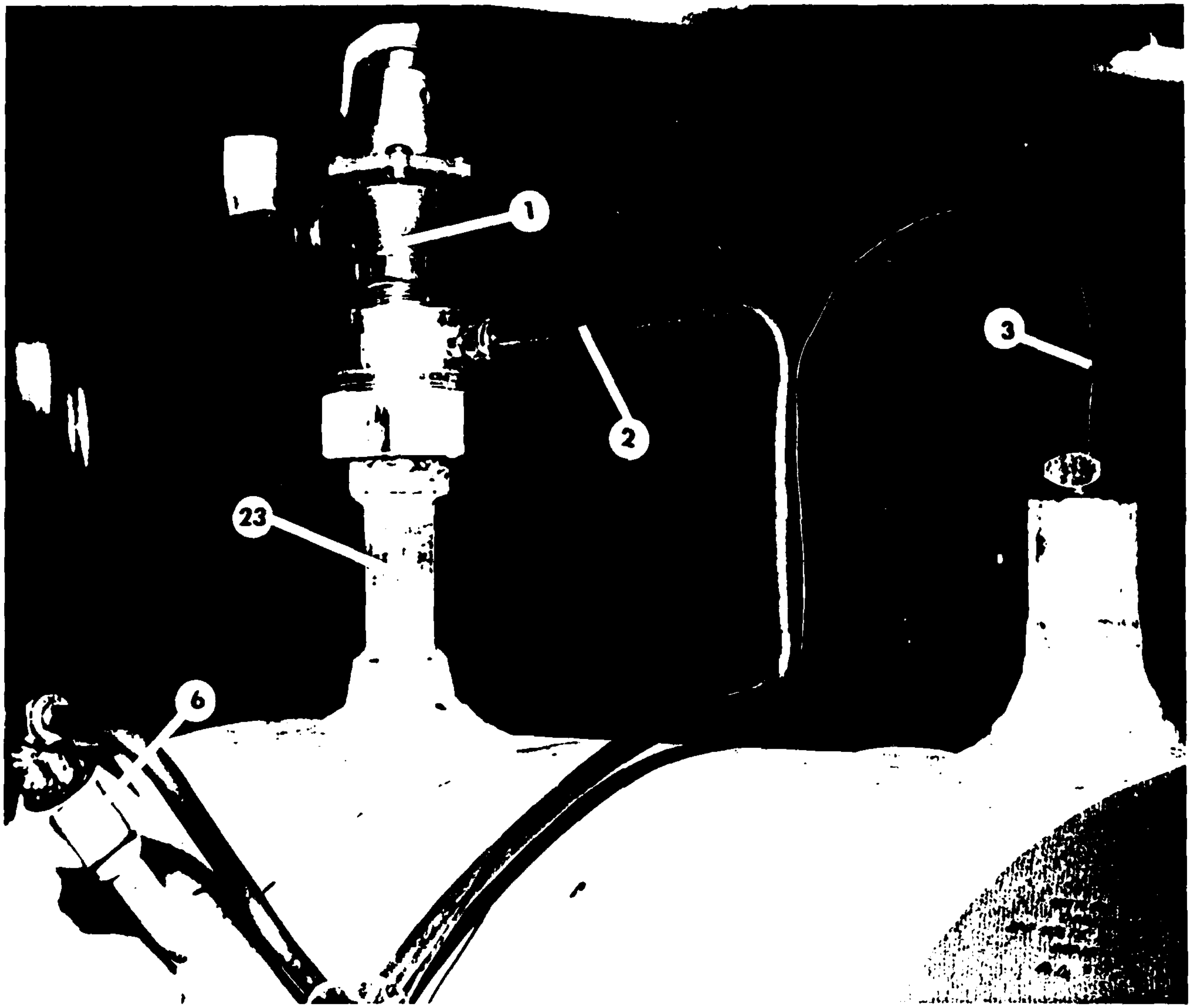

Figure 12. Pop-off valve and temperature probe and supply inlet access ports. (For numbered items, refer to Key to Fig. 5.)

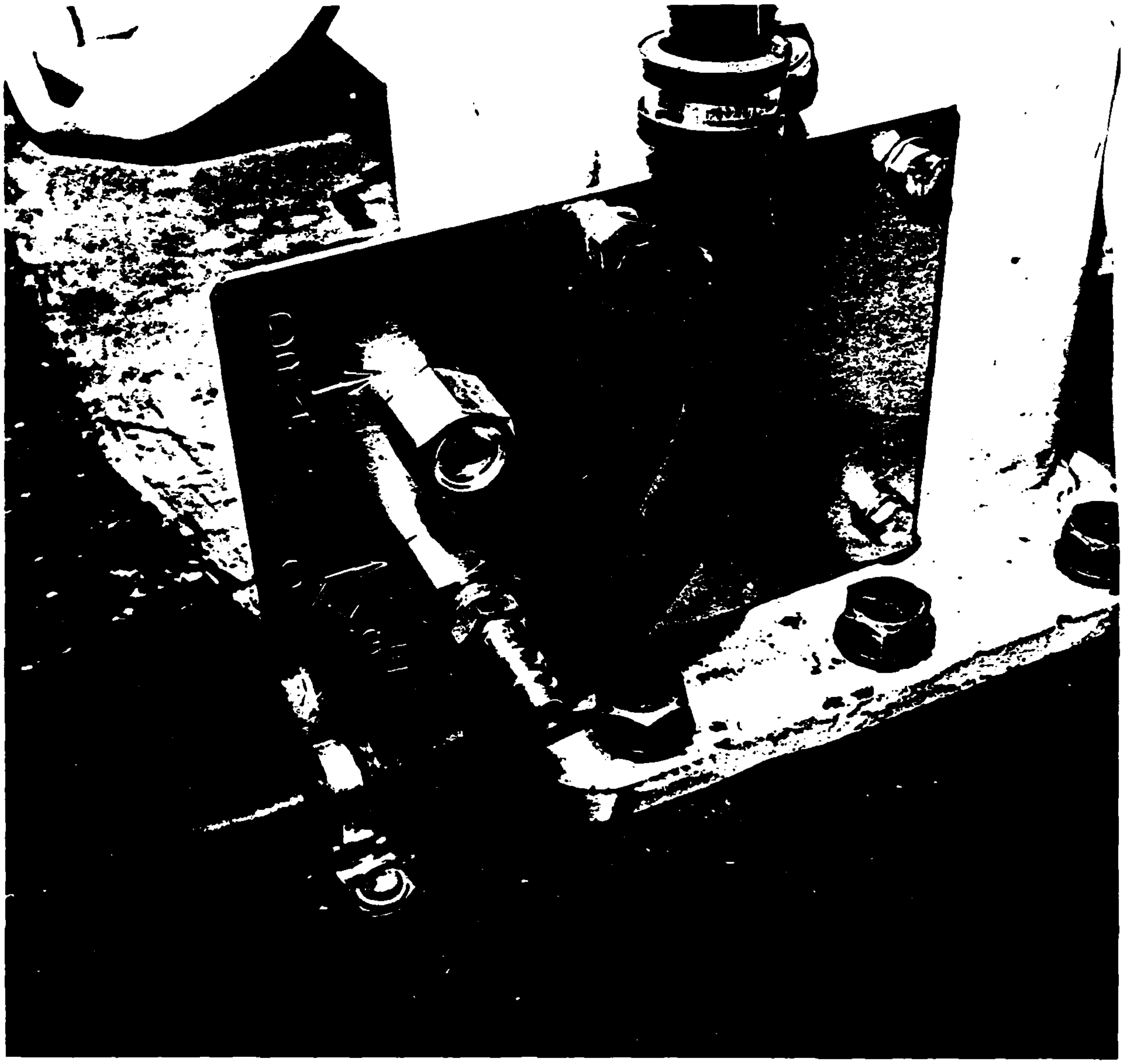

Figure 13. Routing of thermostat power cord.

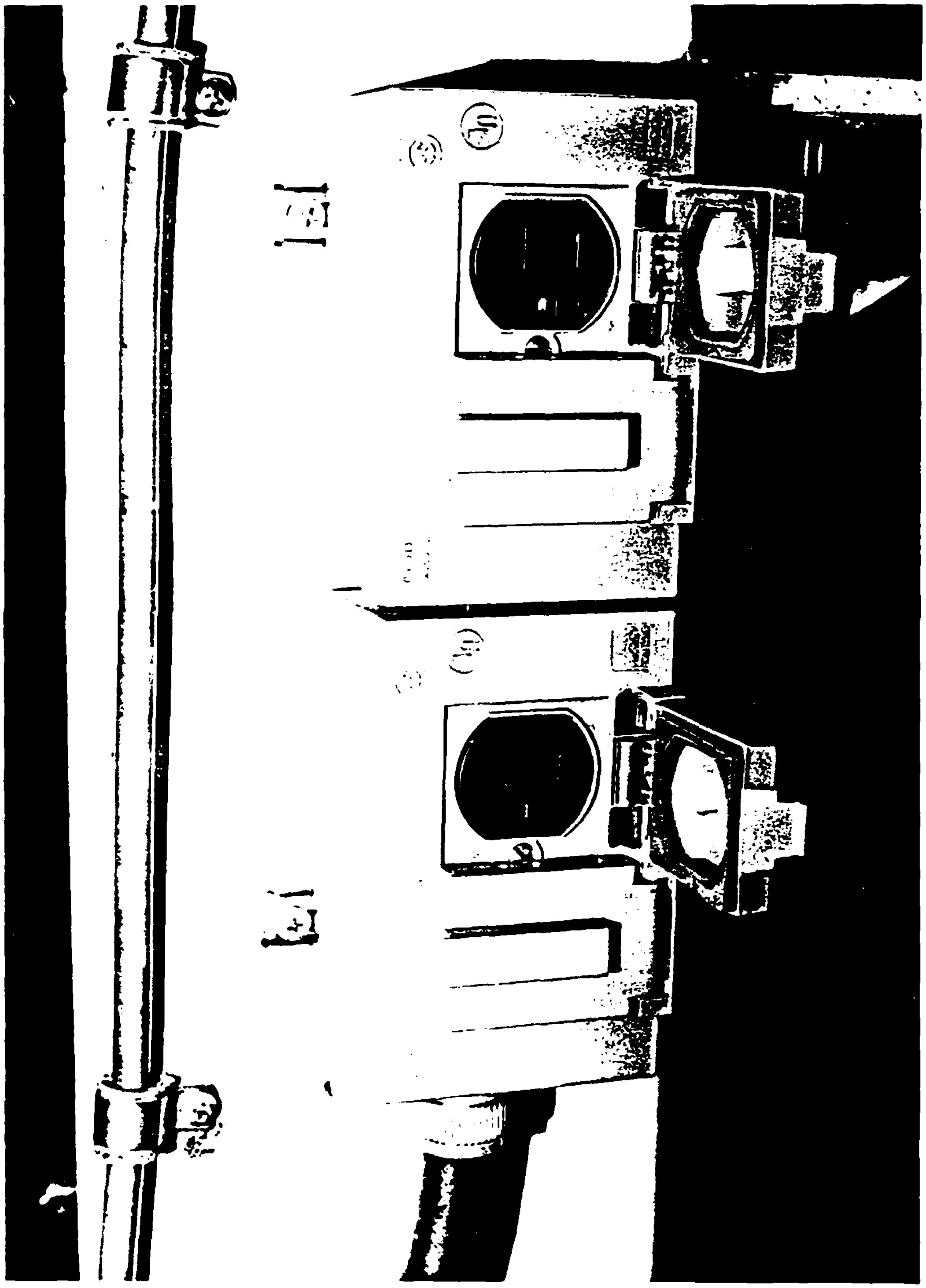

Figure 14. External power receptacle boxes on left rear support leg.

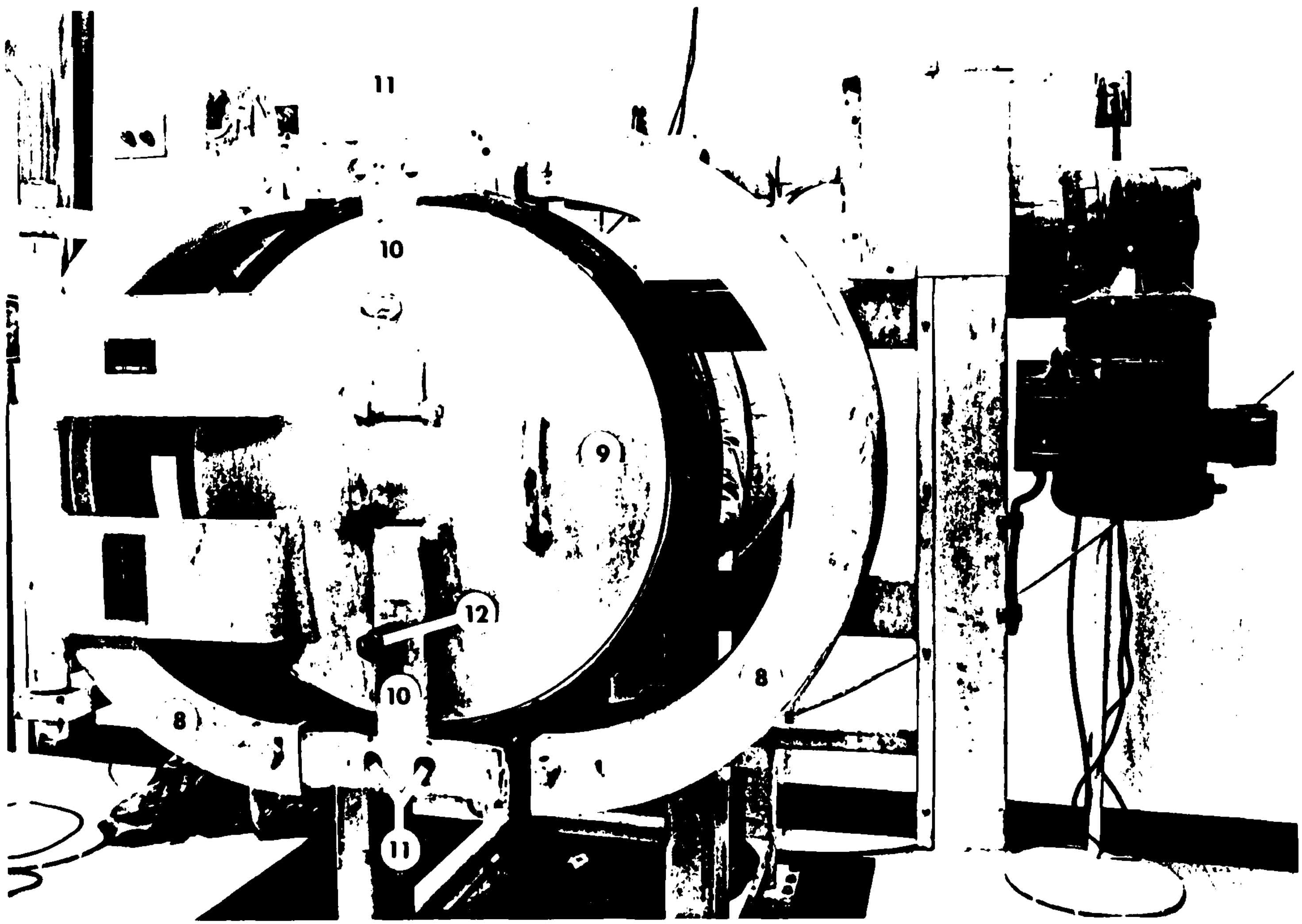

Figure 15. Chamber door with clamshell closure. (For numbered items, refer to Key to Fig. 5.)

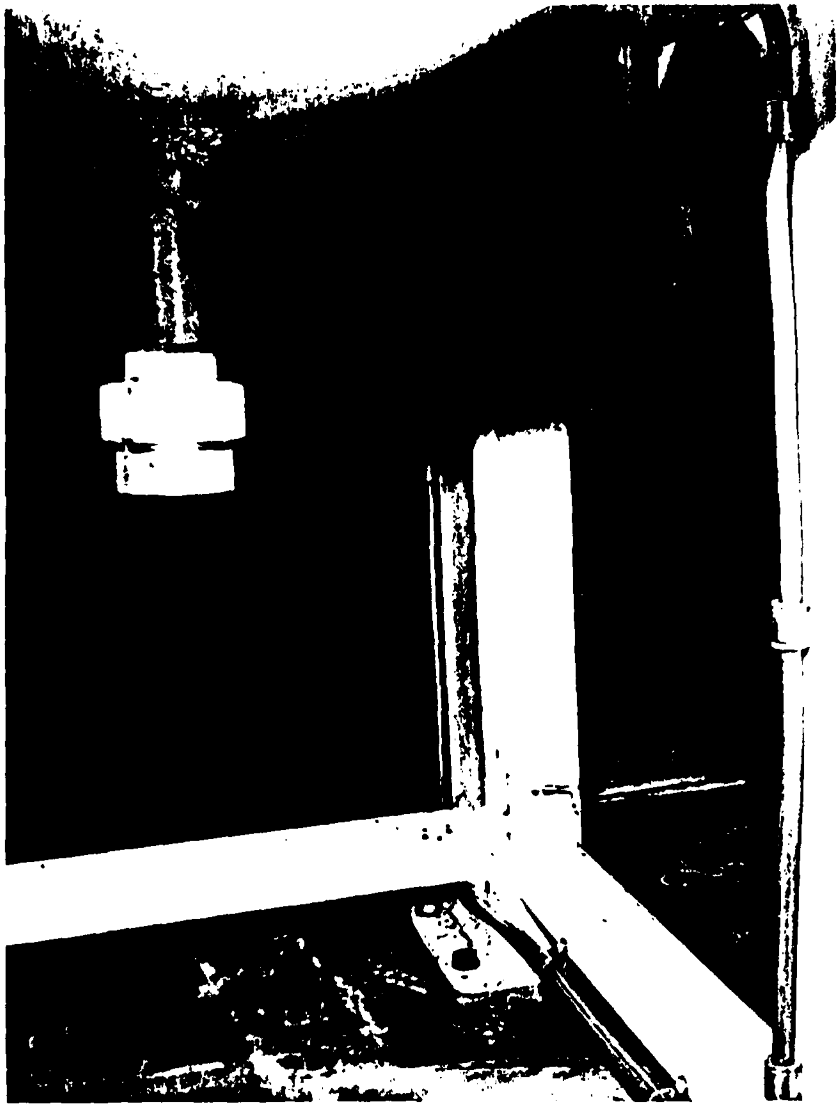

Figure 16. External drain valve port.

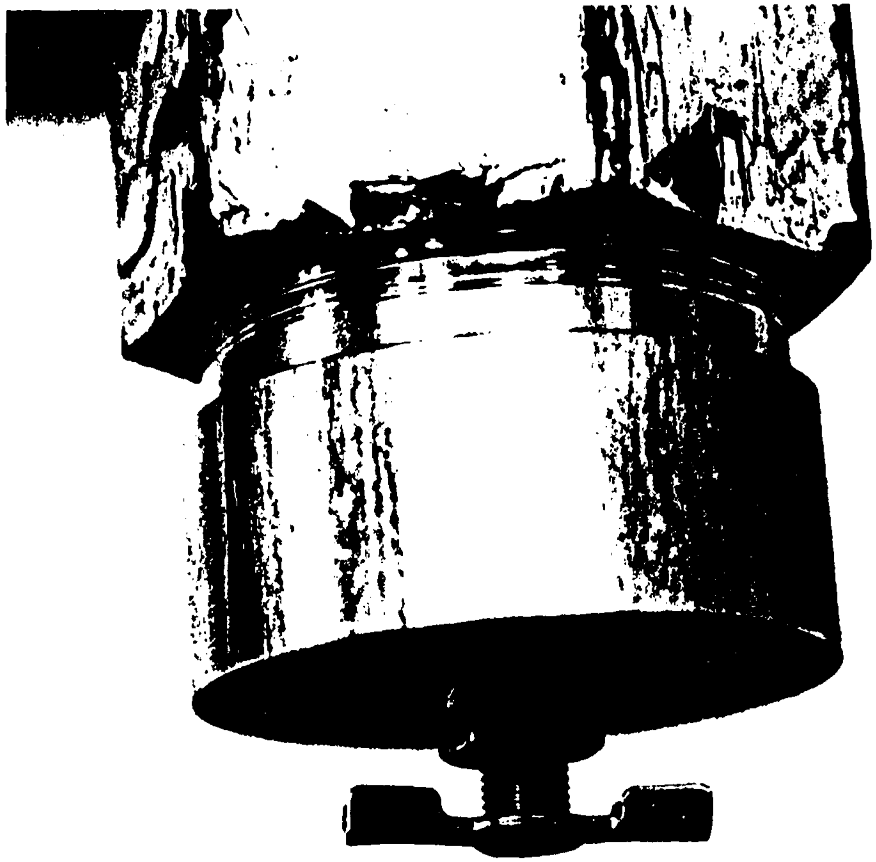

Figure 17. External drain valve port with petcock.

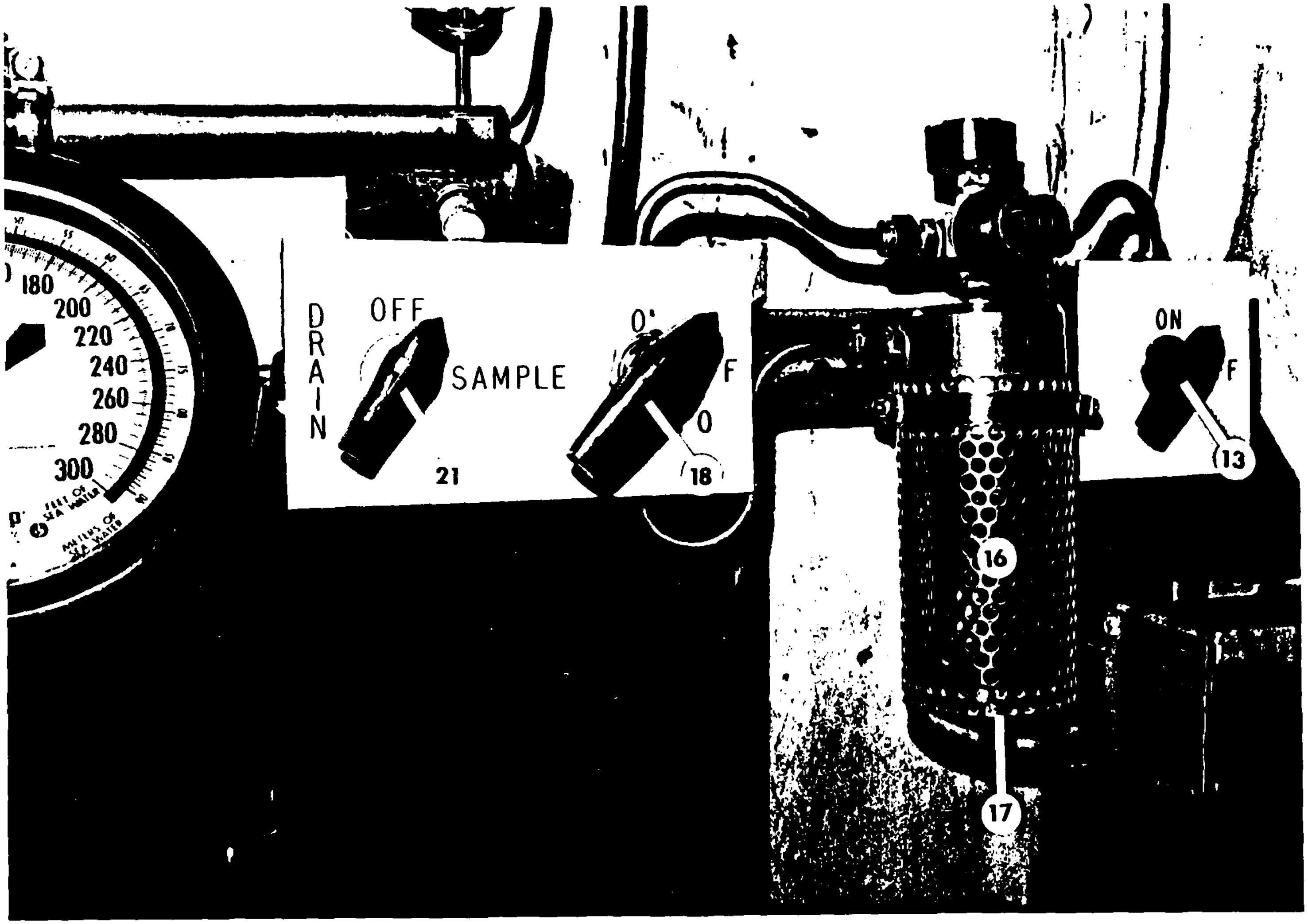

Figure 18. ATC system controls and indicators. (For numbered items, refer to Key to Fig. 5.)

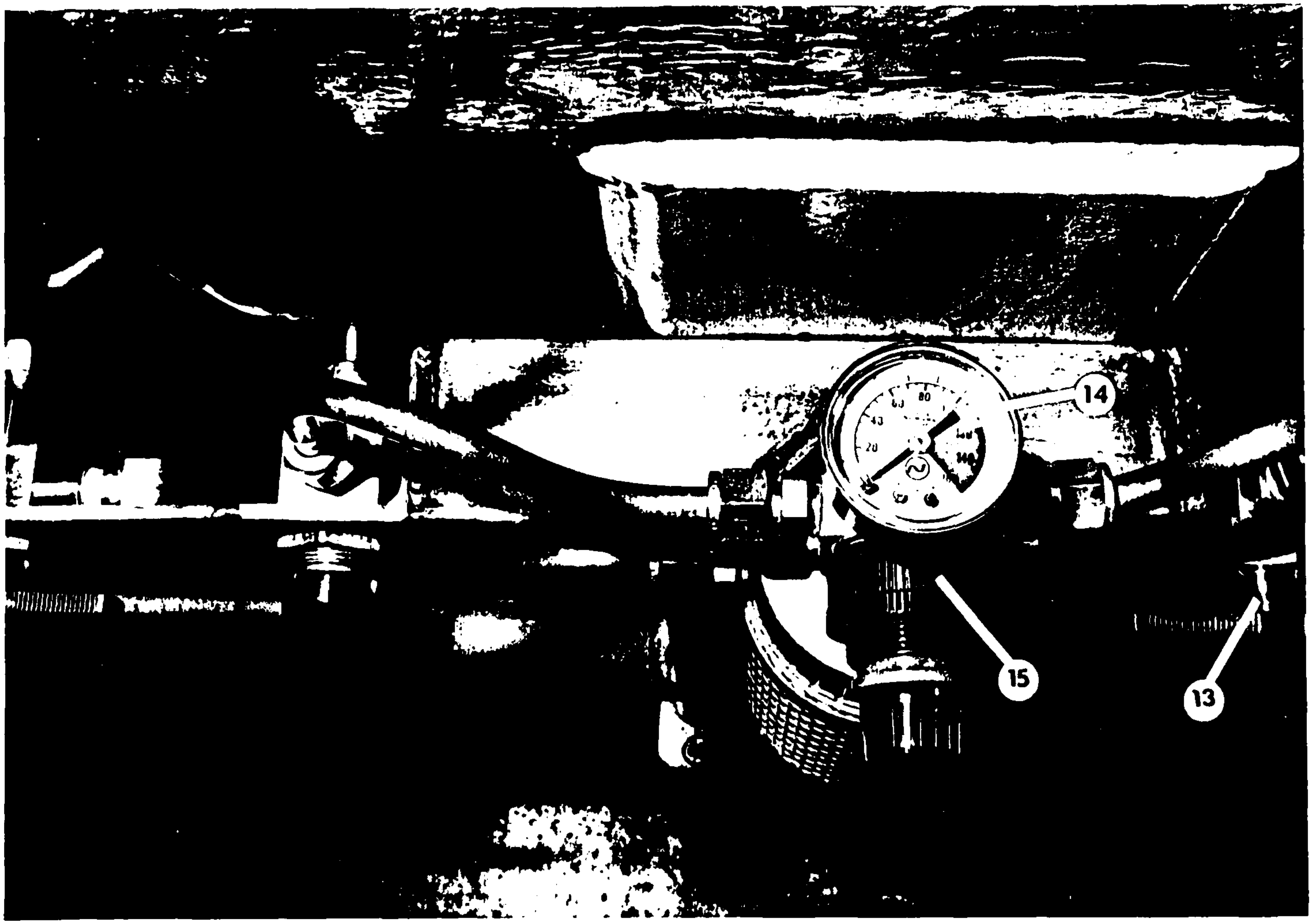

Figure 19. System reduction regulator and pressure gauge control. (For numbered items, refer to Key to Fig. 5.)

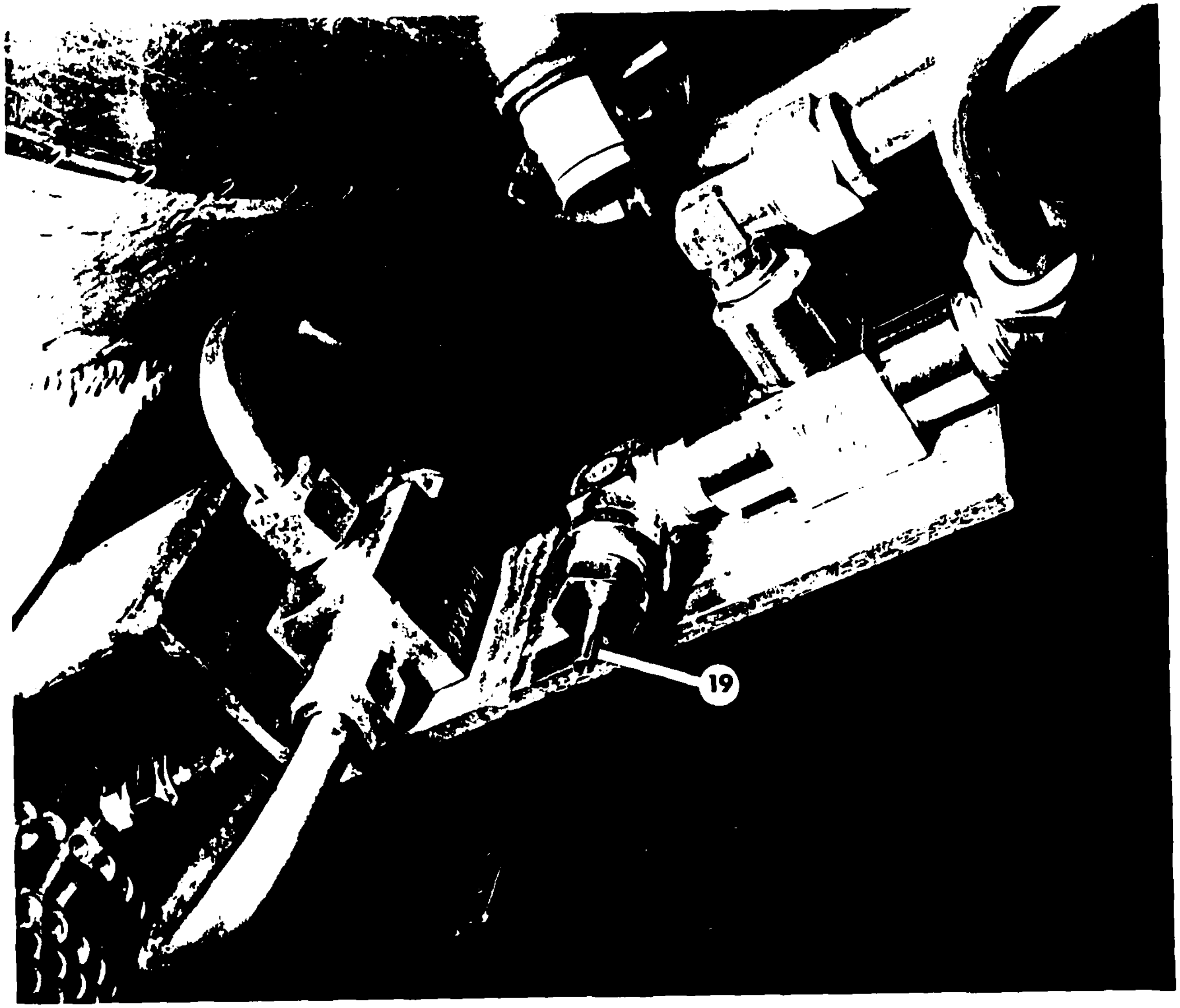

Figure 20. External gas sample port. (For numbered items, refer to Key to Fig. 5.)

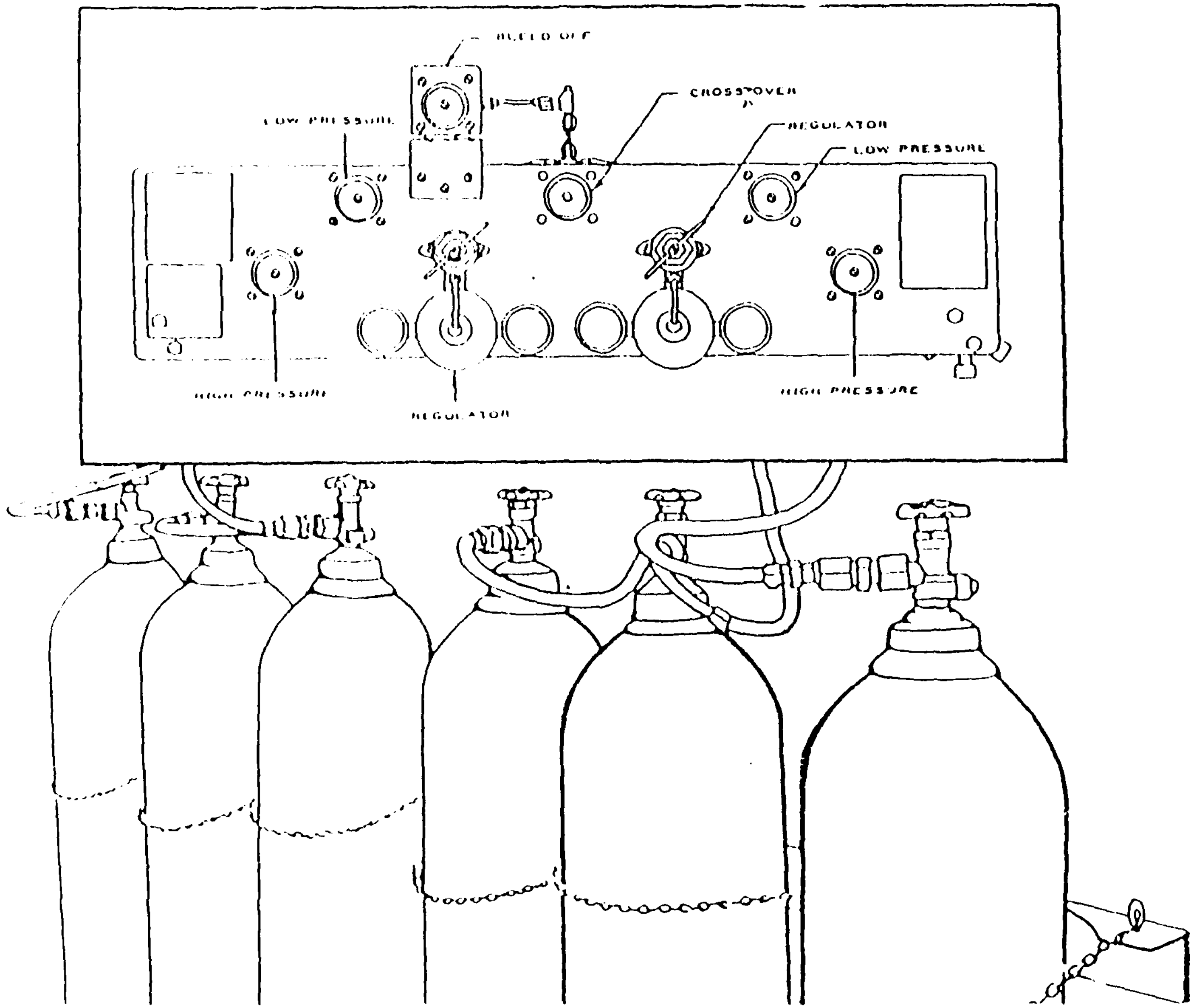

Figure 21. Breathing gas manifold, oxygen.

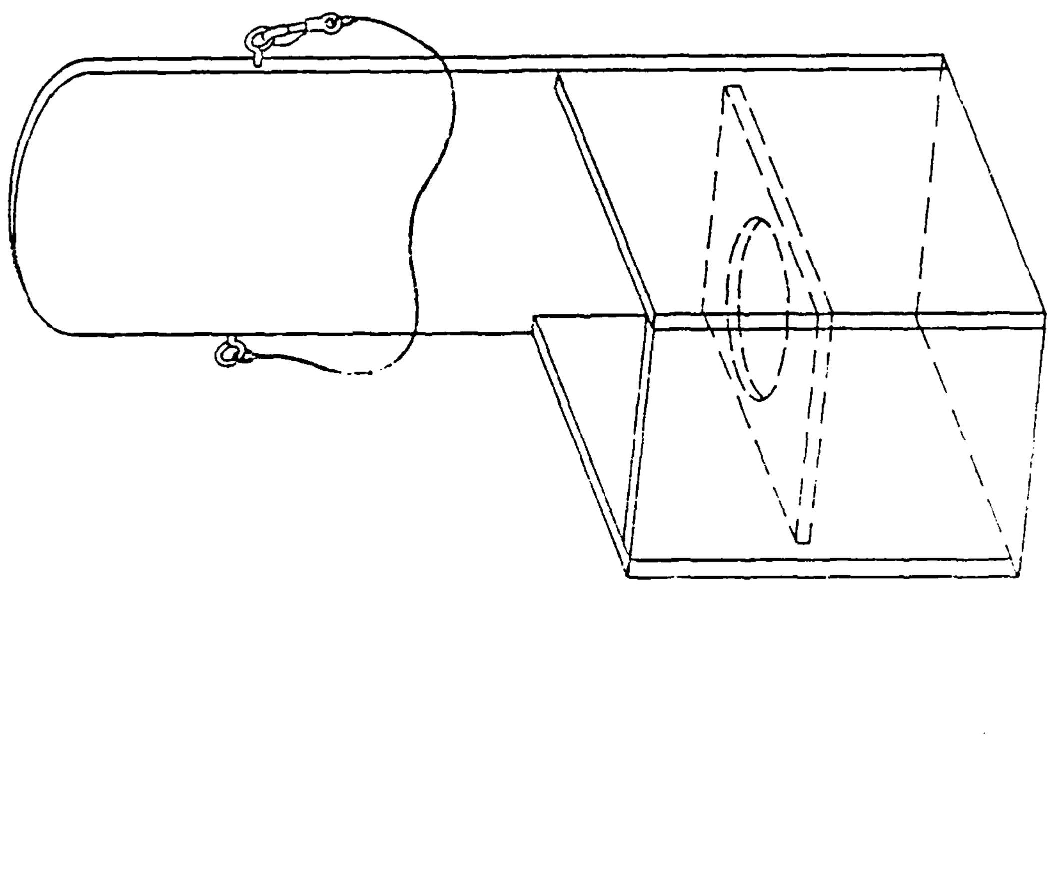

Figure 22. Fire extinguisher support rack.

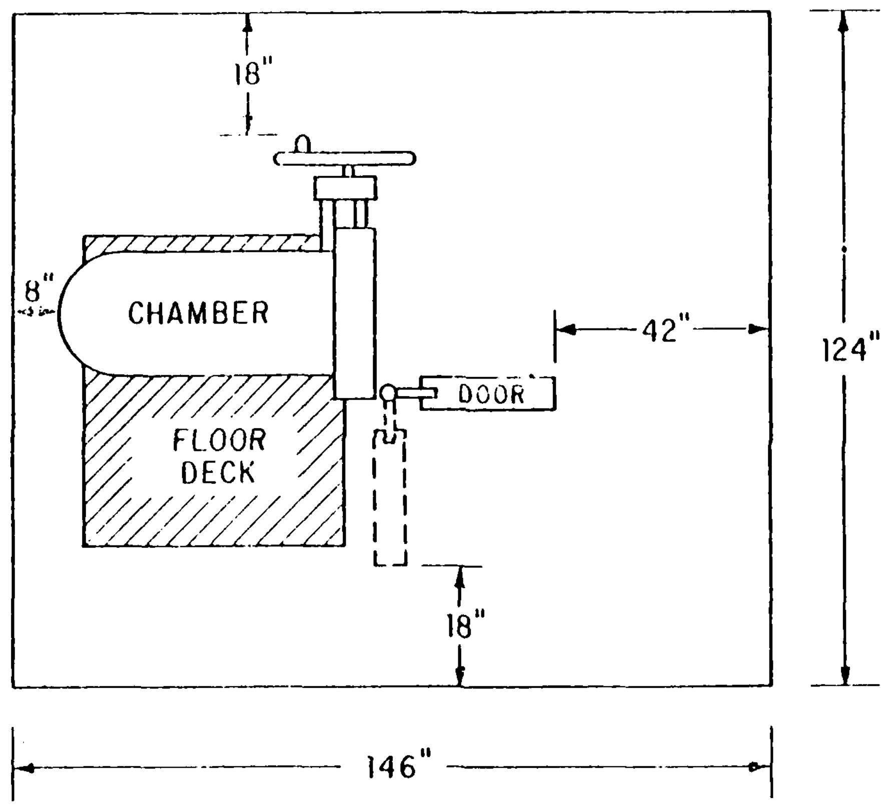

Figure 23. ATC work space requirements.

APPENDIX A:

SPARE PARTS LISTS AND COMMERCIAL SUPPLIERS

The following list of ATC spare parts is provided to the user organization for information only. Citations of product trade names and commercial suppliers constitute neither an official Department of the Air Force endorsement nor approval of the products or services provided by these organizations.

TABLE A-1. SPARE PARTS LIST AND COMMERCIAL SUPPLIERS

PART IDENTIFICATION	PART NUMBER	SUPPLIER	PRICE
WHITEY 2-WAY BALL VALVE	B-44F4	ARTHUR VALVE & FITTING CO.	\$35.70 ea
WHITEY 3-WAY BALL VALVE	B-44X56	5449 GRISSON RD.	\$46.50 ea
WHITEY 3-WAY BALL VALVE	B-44XF4	SAN ANTONIO TX 78238	\$42.00 ea
3/8 SWAGELOK TO 1/8 NPT MALE 90°	B-600-2-2	(512) 681-7043	\$ 1.90 ea
3/8 SWAGELOK TO 1/4 NPT MALE 90°	B-600-2-4		\$ 2.00 ea
3/8 SWAGELOK TO 1/4 NPT FEMALE 90°	B-600-8-4		\$ 4.95 ea
3/8 SWAGELOK TO 1/4 NPT MALE	B-600-1-4		\$ 1.90 ea
3/8 SWAGELOK TO 1/4 NPT FEMALE	B-600-71-4		\$ 4.85 ea
1/8 NPT MALE TO 1/8 TUBE CAJON	B-2-TA-1-2		\$ 2.00 ea
1/4 NPT MALE TO 1/8 TUBE CAJON	B-2-TA-1-4		\$ 2.20 ea
1/8 NPT MALE TO 1/8 NPT MALE CAJON	B-2-HN		\$ 1.20 ea
1/4 NPT MALE TO 1/4 NPT FEMALE CAJON 90°	B-4-SE		\$ 6.30 ea
YELLOW INDICATOR LIGHT	P/N 2120A3	FSN 6210-00-927-1366	\$ 1.49 ea
RED INDICATOR LIGHT	P/N 2110A1	FSN 6210-00-111-3187	\$ 1.07 ea
TOGGLE SWITCH	P/N 8801K22	FSN 5930-00-655-1514	\$ 2.83 ea
CLAMP, LOOP	-	5340-00-985-6633	\$ 0.02 ea
COPPER TUBING, 3/8 O.D., CL 50 Ft	-	FSN 4710-00-203-3172	\$ 7.70 ea
COCK DRAIN, 1/4" OPENING	-	FSN 4820-00-849-1220	\$ .25 ea
PRESSURE SAFETY RELIEF VALVE (MODEL M^3)	WATTS NO. 174A	WATTS REGULATOR FRANKLIN N. H.	\$27.50 ea

(Cont'd. on facing page)

TABLE A-1. SPARE PARTS LIST AND COMMERCIAL SUPPLIERS (Cont'd.)

PART IDENTIFICATION	PART NUMBER	SUPPLIER	PRICE
150 psi HEAVY DUTY AIR LINE FILTER	P/N 22764	W.W. GRAINGER, INC. 5011 RITTIMAN RD SAN ANTONIO TX 78218 (512) 654-4020	$23.10 ea
DEPTH GAUGE, HELICOID, 0-300 fsw	P/N G4E 300010037BAF	NAUTILUS ENVIRONMENTALS, INC. 5400 MITCHELLDALE, SUITE B-4 HOUSTON TX 77092 (713) 89-0909	$253.20 ea
AC MAGNETIC CONTRACTOR, NEMA SIZE 1	SCG-1	SUMMERS ELECTRIC SUPPLY, INC. 318 W. JOSEPHINE SAN ANTONIO TX 78212 (512) 222-2666	$110.00 ea
DRUM HEATER STRIP, 55 GAL, WATLOW	P/N 04067700A	THE KEN DAWSON CO. 11105 SHADY TRAIL, SUITE 102 DALLAS TX 75229 (214) 241-3843	$72.00 ea
PRESSURE REDUCTION REGULATOR, NORGREN VERIFLOW LOW PRESSURE GAUGE, NORGREN	P/N R07-100-RGKA P/N 18-013-252	C.A. NORGREN CO. 5400 S. DELAWARE ST. LITTLETON CA 80120 (303) 794-2611	$15.80 ea
REMOTE BULB TEMPERATURE CONTROL ($40^{0}F-180^{0}F$)	P/N T4031E	BLACKBURN DRIVES & CONTROLS, INC. 422 E. RAMSEY SAN ANTONIO TX 78216 (512) 349-2621	$27.19 ea

(Concluded on next page)

TABLE A-1. SPARE PARTS LIST AND COMMERCIAL SUPPLIERS (Concluded)

PART IDENTIFICATION	PART NUMBER	SUPPLIER	PRICE
HEAVY-DUTY WIRE, 600 V/30 AMP, 250 FT (ROLL) MADE BY CARROLL (COLUMBIA)	STOCK #02728-85	SHERMAN ELECTRONICS, INC. 702 SAN PEDRO AVE SAN ANTONIO TX 78212 (512) 224-1004	$161.39 RL
ELECTRIC MOTOR, DAYTON, 3/4 HP, RIGHT ANGLE (OPTIONAL EQUIPMENT)	STOCK #5K546B	W. W. GRAINGER, INC. 5011 RITTIMAN RD. SAN ANTONIO TX 78218 (512) 654-4020	$333.61
REVERSING DRUM SWITCH, 1-1/2 HP, RIGHT ANGLE	STOCK # AG2	SUMMERS ELECTRIC SUPPLY, INC. 2400 BROCKTON SAN ANTONIO TX (512) 824-1451	$43.00
LOVEJOY COUPLINGS (2), 1" BORE STYLE L110, RATED TORQUE 693 LBS	STOCK # 3X709	W.W. GRAINGER, INC. 5011 RITTIMAN RD. SAN ANTONIO TX 78218 (512) 654-4020	$13.16 EA
RUBBER SPIDER	STOCK # 3X715	W. W. GRAINGER, INC 5011 RITTIMAN RD. SAN ANTONIO TX 78218 (512) 654-4020	$6.02 EA
		REMODIFICATION COST GRAND TOTAL (MATERIALS ONLY)	$1,266.87
		REMODIFICATION COST WITHOUT ELECTRIC MOTOR, COUPLINGS AND DRUM SWITCH	$889.26

APPENDIX B:

DESIGN ENGINEERING COMPUTATIONS

Sanders and Thomas, Inc., Pottstown, PA, prepared the following design engineering computations for strength and functionality of the ATC vessel and viewports.

SANDERS & THOMAS
INCORPORATED

NATIONAL NAVAL MEDICAL CENTER
ENVIRONMENTAL HEALTH EFFECTS LABORATORY
CHESAPEAKE DIV., NAVAL FACILITIES ENGR. COMMAND
CONTRACT NO. N62477-73-0293 (A&E)
SANDERS & THOMAS PROJECT NO. 3422
TITLE: MILESTONE III

ENGINEERING DESIGN

FILE KEY
SECT. 33d
PAGE
DATE 11-16-75
BY McNABB
REV. 10-28-77
REV.
REV.

REF ASME BOILER & PRESSURE VESSEL CODE SECTION VIII DIV. 1

MIN ALLOWABLE THICKNESS $= \dfrac{PR}{SE - .6P}$

MATERIAL SA-106 GRADE B SEAMLESS PIPE

ASME-G8 TABLE UCS-23 (PG 110)

S = 15000 PSI USE SCHED. 100 → 20.938" I.D.

R = INSIDE R

$$R = \frac{20.938''}{2} = 10.469''$$

E = 1 P = 1500 PSI

$$t = \frac{1500\ (10.469)}{15000(1) - .6(1500)} = 1.113$$

SCH 100 = 1.531" WALL OK

TRY SCHED 80 @ NOM. THK OF 1.218

ACCTG. MFG TOL. → MIN. THK = 1.218(.875) = 1.066

R = INSIDE R

$$\text{WITH 24'' MAX OD, MAX } R = \frac{24'' - 2(1.066)}{2} = 10.934''$$

$$t = \frac{1500\ (10.934)}{14100} = 1.160\ ,\ \text{UNSATISFACTORY}$$

SANDERS & THOMAS
INCORPORATED

NATIONAL NAVAL MEDICAL CENTER
ENVIRONMENTAL HEALTH EFFECTS LABORATORY
CHESAPEAKE DIV., NAVAL FACILITIES ENGR. COMMAND
CONTRACT NO. N62477-73-0293 (A&E)
SANDERS & THOMAS PROJECT NO. 3422
TITLE: CALCULATIONS ATU-PCAS

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CALCULATE DISHED HEAD THICKNESS
REF. ASME BOILER & PRESSURE VESSEL CODE
SECTION VIII DIV. 1

MATERIAL SA 516 GR70
$S = 17,500$ PSI (TABLE UCS-23 P. 110)

$t = \dfrac{PLM}{2SE - 0.2P}$ (UA-4 P. 204 TORISPHERICAL HEADS)

$D = 24''$ O.D.
$P = 1500$ PSI $L = 24''$ $E = 1$ $r = 5.25''$

$M = \frac{1}{4}\left(3 + \sqrt{\frac{L}{r}}\right)$ $M = \frac{1}{4}\left(3 + \sqrt{\frac{24}{5.25}}\right)$
$M = 1.28$

$t = \dfrac{1500 \times 24 \times 1.28}{2 \times 17,500 \times 1 - 0.2 \times 1500}$

$t = 1.33''$ MIN. THICKNESS REQ'D

SANDERS & THOMAS
INCORPORATED

NATIONAL NAVAL MEDICAL CENTER
ENVIRONMENTAL HEALTH EFFECTS LABORATORY
CHESAPEAKE DIV., NAVAL FACILITIES ENGR. COMMAND
CONTRACT NO. N62477-73-0293 (A&E)
SANDERS & THOMAS PROJECT NO. 3422
TITLE: ATU PCAS

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ATU VIEW REINFORCEMENT (REF ASME SECT VIII DIV 2)

MIN ALLOWABLE WALL THICKNESS

$t_{min} = \frac{PR}{S - .05P}$ FOR SA-106 PIPE GR B OR SA-516 GR 60 } S = 20,000

$t_{min} = \frac{1500 \times 12}{20000 - 750} = .935''$

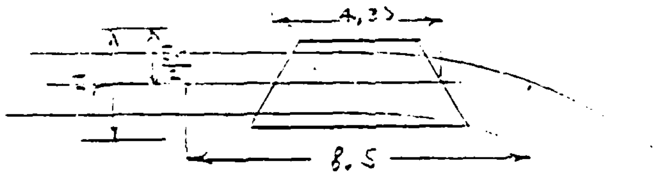
ASSUME MIN PIPE WALL 24" SCH 100 = .875 X 1.531 = 1.340

EXCESS WALL THICKNESS AVAILABLE FOR REINFORCEMENT

$W_x = 1.340 - .935 = .405''$

MEAN DIA OF OPENING = 3 + 2.25 TAN 30° = 4.30"

REQ'D REINF AREA = 4.30 X .935 = 4.021 IN²



DIAMETRAL LIMIT = 4.30 (AD 540.1)
LIMIT NORMAL TO SHELL (AD 540.2 c) = [illegible] OR T_e [illegible]

$\text{MIN REQ'D } t_e = \frac{(8.5 - 4.3).935 + 4.021}{8.5 - 4.3} = [illegible]887''$

SINCE THICKNESS OF LENS [illegible] GREATER THAN THE
ANY REINFORCEMENT CONSISTING OF [illegible]
[illegible] BAR WILL BE ADEQUATE

SANDERS & THOMAS
INCORPORATED

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NATIONAL NAVAL MEDICAL CENTER
ENVIRONMENTAL HEALTH EFFECTS LABORATORY
CHESAPEAKE DIV., NAVAL FACILITIES ENGR. COMMAND
CONTRACT NO. N62477-73-0293 (A&E)
SANDERS & THOMAS PROJECT NO. 3422
TITLE: ATV - PCAS

VIEW PORT DESIGN (REF J.D. STACHIW & K.O. GRAY - "PROCUREMENT OF SAFE VIEWPORTS FOR HYPERBARIC CHAMBERS" ASME PAPER NO 71-PVP-1)

CHOOSE A 60° CONE ANGLE AND A CONVERSION FACTOR OF C=16
MAX OPERATING PRESSURE = 1500 PSI

SHORT TERM IMPLOSION PRESSURE = C×P = 16×1500 = 24000 PSI

ENTERING FIG 1 (REPRODUCED AT THE RIGHT FROM THE REFERENCE PAPER) AT 24000 PSI, READ THE REQ'D t/D_i FROM THE 60° CURVE (EXTRAPOLATED) AS .69

∴ FOR A $D_i = 3''$

$t = 3 \times .69 = 2.07$ USE $2\frac{1}{4}''$ THICK WINDOW.

THEN $t/D = \frac{2.25}{3} = .75$

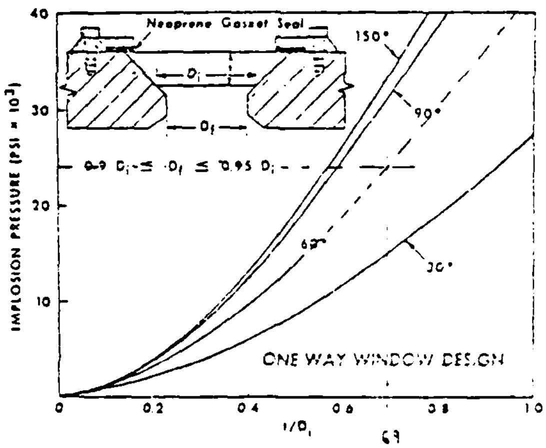

Fig. 1. Catastrophic failure of conical acrylic windows in viewports of hyperbaric chambers under short-term pressure loading.

SINCE $.9 D_i < D_s < .95\ D_i$
USING $D_i = 3$

$2.7 < D_s < 2.85$ CHOOSE $D_s = 2.75''$

MFG'R TOLERANCE FOR $2\frac{1}{4}''$ THICK MTL = -.166 (REF FEDERAL SPEC L-P-391 C)

∴ MIN $t/D_i = \frac{2.25 - .166}{3} = .69+$

∴ MIN IMPLOSION PRESSURE ≅ 24000   C [illegible] = 16

NO EXPERIMENTAL EVALUATION IS CONSIDERED NECESSARY

APPENDIX C:

PROCEDURAL CHECKLIST (COMPRESSED BREATHING GAS)

APPENDIX C:

PROCEDURAL CHECKLIST
(Compressed Breathing Gas)

Compressed gas cylinders are built to withstand normal hard use, but they must not be subjected to abuse. Serious accidents connected with their handling, use, and storage have been due to abuse or mishandling. The safety precautions outlined in this section must be followed to prevent serious mishaps and injury to operational personnel (6)*.

PRECAUTIONS IN HANDLING CYLINDERS:

a. Always close valves and replace caps when cylinders are not in use.

b. Handle cylinders carefully. Rough handling, knocks, or falls may damage the cylinders, valve, or safety devices and cause leakage. A more serious consequence could be a broken valve, which could impart a rocket-like thrust to the cylinder by the rapidly escaping gas.

c. Never use cylinders for rollers, supports, or for any other purpose than to contain gas.

d. Before making a connection to the cylinder valve, open the valve slightly and close immediately. This action, called cracking, clears the valve of particles of dust or dirt that otherwise might enter the connection.

e. Never place hands or any part of the body in the path of the escaping airstream.

f. If a valve is difficult to open, point the valve opening away from the body, and use greater manual force. Do not use a wrench or hammer. The average man can exert enough pressure with his hand to open or close the valve.

g. Do not tamper with safety devices in valves or cylinders.

h. Never force connections that do not fit.

i. Do not attempt to repair or alter cylinder or valves. Such repairs must be made by personnel who are trained for this purpose.

j. If a leak is discovered around a valve outlet, stem, or safety device, move the cylinder outdoors, open the valve, allow the gas to escape slowly, and keep personnel away. The valve will be tagged as defective and returned for repair.

k. When cylinders are placed in an upright position, take precautions to prevent them from being tipped over.

*EDITOR'S NOTE: The reference numbers cited in Appendix C are derived from the list of "References" on p.20.

l. Do not permit oil, grease, paint, or other readily combustible substances to come in contact with cylinders, valves, connections, and fittings.

m. Never lubricate gas valves, regulators, gages, or fittings with oil or grease.

n. Do not handle cylinders, valves, or connections with oily hands or gloves.

o. Do not permit cylinders to come in contact with any source of electricity.

PRECAUTIONS IN STORING CYLINDERS:

a. Protect cylinders against excessive rise or fall of temperature.

b. Cylinders may be stored in the open; but, in such case, protect them from extremes of weather and from the ground beneath to prevent rusting. During winter, protect cylinders stored in the open against accumulation of ice or snow. In summer, protect cylinders stored in the open from the continuous rays of the sun. Provide ventilation to keep temperature below 125^{O}F.

c. Never store cylinders near flammable materials, especially fuels and oils.

d. Be careful to protect cylinders from any object that on contact could produce a cut, dent, or gouge in the cylinders.

e. Do not store cylinders in locations where heavy moving objects may strike them or fall on them.

f. Do not expose cylinders to continuous dampness.

g. Never store cylinders near sources of electricity.

h. Always segregate EMPTY cylinders from full cylinders.

i. If valve protection caps become frozen, thaw them out in a warm room. Never use a heat source for quick thawing, because safety plugs may be melted.

j. Prohibit smoking wherever cylinders are stored.

PRECAUTIONS IN TRANSFERRING CYLINDERS:

a. Always close the cylinder valves and replace valve caps before moving cylinders.

b. Provide suitable hand trucks for moving cylinders, and assure that they are held securely in position on the hand trucks.

c. When necessary to move cylinders without a hand truck, always move the cylinders by tilting and rolling them on their bottom edges--never drag or slide a cylinder.

d. Protect all cylinders from being knocked over or falling to the ground.

e. Do not use bars under valves or valve caps to pry cylinders loose when frozen or fixed to the ground.

f. Do not use an electric magnet or a sling to lift cylinders.

g. When transported in trucks, railroad cars, and aircraft, the cylinders must be secured to prevent overturning or movement.

OPERATIONAL CHECKLIST FOR BREATHING GAS MANIFOLD:

The oxygen manifold system consists of two banks of cylinders with three cylinders for each bank (5). Several general precautions should be observed when operating the oxygen system:

a. Never allow oil to come in contact with any part of the oxygen system.

b. Open all valves slowly, so that buildup of pressure on the down side of the valve is gradual.

c. Never put more than 450 psi in the supply line in order to prevent possible damage to the in-line regulator diaphragm.

d. Remove cylinders for refill when the pressure reaches 100-150 psi. Never let them fall below 100 psi.

e. Use a standard oxygen cylinder wrench to loosen a tight valve.

NORMAL OPERATION CHECKLIST FOR TURNING SYSTEM "ON":

a. Close all valves on the breathing gas control panel (Figs. C-1 and C-2), and relieve the tension on the C-1 pressure reduction regulator.

b. Open all the valves on the high pressure cylinders.

c. Open the high pressure supply valves on the manifold.

d. Select the breathing gas control bank with the lowest pressure as the "in-use" bank.

e. Adjust the C-1 regulator on the "in-use" bank to 200 psi.

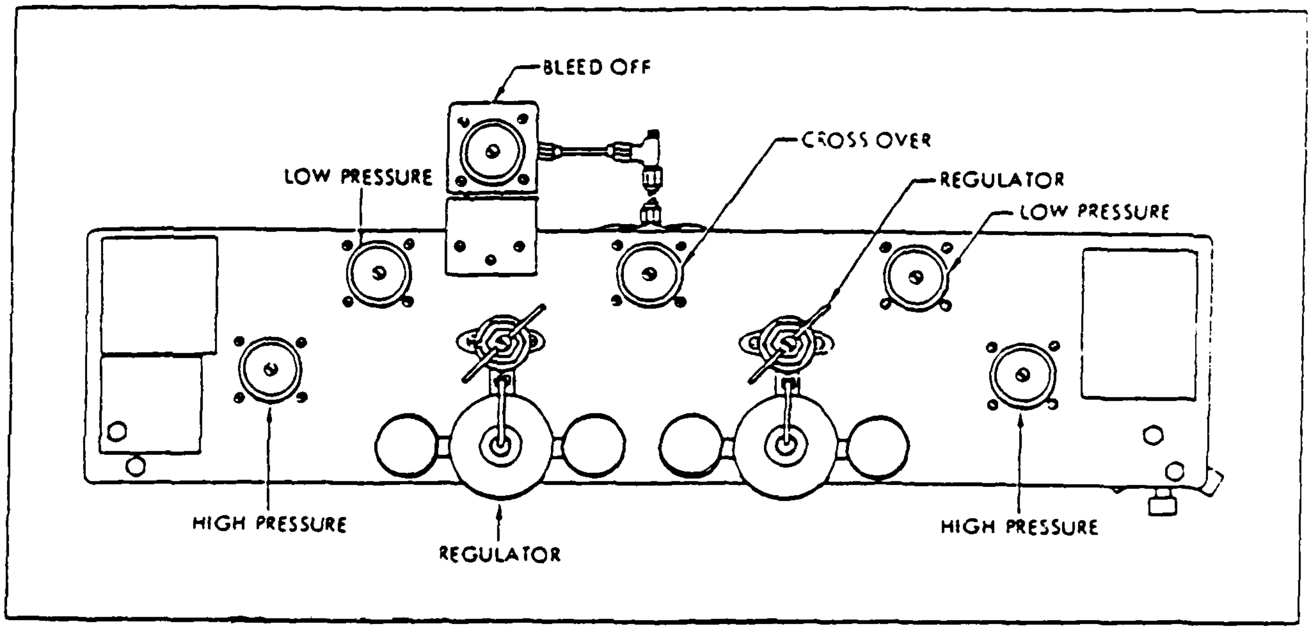

Figure C-1. Oxygen supply control panel—front view.

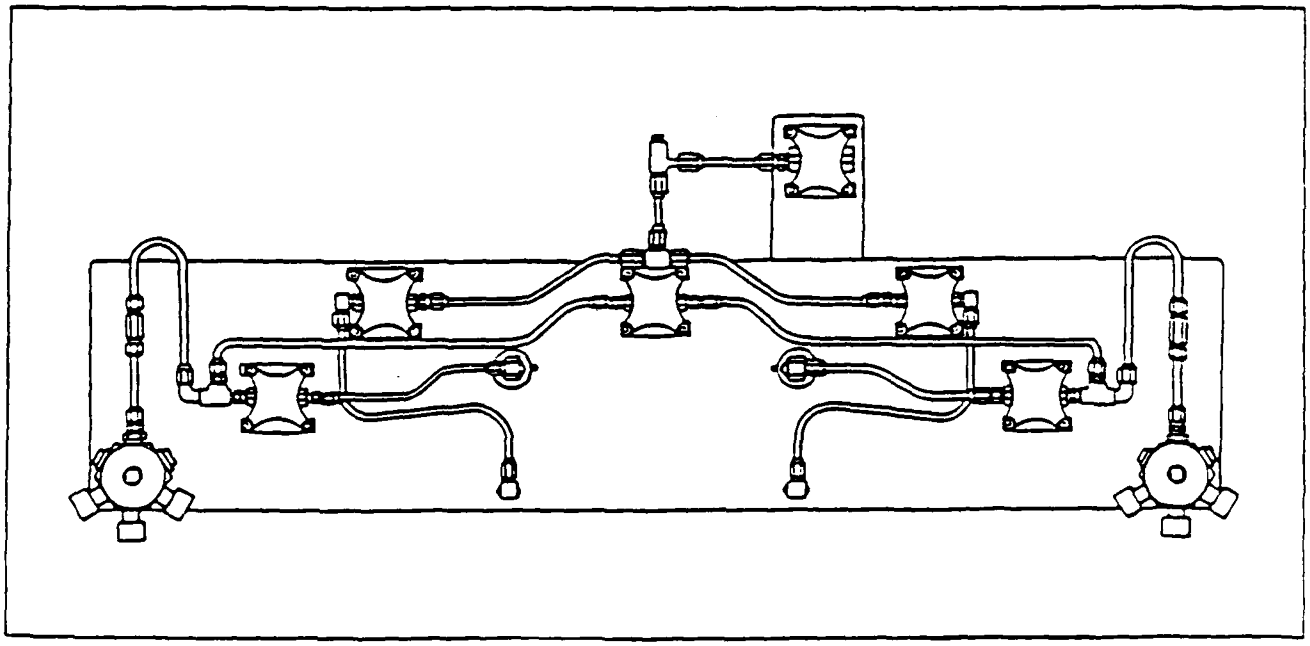

Figure C-2. Oxygen supply control panel--rear view.

f. Adjust the C-1 regulator on the "standby" bank to 150 psi.

g. Open the low pressure valves on the manifold.

h. Open the shutoff valve to the chamber supply line.

NORMAL OPERATION CHECKLIST FOR TURNING SYSTEM "OFF":

a. Close all valves on the high pressure cylinders.

b. Open the manifold vent valve to relieve pressure in the system. Close the valve.

c. Close the manifold high pressure valves.

d. Back-off the C-1 regulator in a counterclockwise direction to relieve the internal pressure on the diaphragm.

e. Close the manifold low pressure valves.

REPLACING EMPTY CYLINDERS:

a. After shutting off the oxygen system, as just described, loosen the fittings on each cylinder to relieve excess pressure. Remove and replace one cylinder at a time.

b. Remove the flex line from the cylinder, and replace the safety cap. Remove the empty cylinder from the manifold rack, tag as "EMPTY," move to storage area, and secure.

c. Place a "FULL" cylinder in the manifold rack and secure. Remove the safety cap.

d. Briefly crack open each cylinder to clear debris from the port, close immediately, and attach the flex lines.

e. Open the cylinder valve slowly.

f. Open the manifold high pressure valve and adjust the C-1 regulator to a desired pressure.

g. Open the manifold low pressure valve.

APPENDIX D:

HAZARDS AND SAFETY PRECAUTIONS FOR ATC OPERATION

APPENDIX D:

HAZARDS AND SAFETY PRECAUTIONS FOR ATC OPERATION

In any hyperbaric chamber operation, safety must be a major concern. The most serious aspects of hyperbaric chamber safety are: maintaining pressure integrity, pressurization and breathing gas system, fire prevention, and operating procedures.

PRESSURE INTEGRITY:

a. Pressure and leak-rate checks must be performed periodically to insure that chamber pressure integrity is intact (refer to section on "Plumbing Facilities").

b. To protect the chamber, it should be kept clean and dry after each use. The chamber should be inspected periodically for corrosion and surface cracks, particularly around welds.

c. Window seals and door gaskets should be kept clean, and inspected regularly.

d. Window ports should be protected from intense heat from external light sources. External lights should be placed a minimum of 6 in. from the window surface to prevent overheating and rupture. Inspect all window ports for cracks and deep scratches. If these are present, all chamber operations should cease and the window port(s) should be replaced, as required.

e. The ATC chamber is built to withstand 300 fsw; however, for safety purposes and to avoid a mishap, a pop-off valve is installed to depressurize the chamber when it exceeds 185 fsw. The pop-off valve can also be tested manually by pressurizing the chamber to about 5-10 fsw and pulling its lever to assure that the valve is functioning properly. Both methods of inspection should be done on a routine basis.

PRESSURIZATION AND BREATHING GAS SYSTEM:

a. Compressed gas, serving as both the breathing medium and the supply source to pressurize the chamber, is supplied in high pressure (2000-psi) cylinders and attached to separate breathing gas manifolds. A continuous quality control surveillance is required throughout storage, handling, transfer, and servicing this equipment.

b. Compressed gas cylinders should be sampled before initial use and after any major repairs. During extended periods of non-use, the system should be sampled and tested once every 45 days. Each set of cylinders charged on the same manifold, at the same time, can constitute a lot. Gas samples can be taken either at the chamber gas sample port, or from the cylinder valve with an attached regulator.

c. Recommended emergency and continuous exposure limits for various gas components, as provided by the Committee on Toxicology, National Research

Council, Washington D.C., are exposure limits based on a standard atmospheric pressure environment (14 psi, 1 ATA at 15°C/59°F). The physiological significance of individual gases under hyperbaric conditions must be considered.

d. Pure oxygen breathing should never be used at pressures greater than 3 ATA because of the toxic effects on the central nervous system.

e. Oil, grease, and other hydrocarbon contaminants should be restricted from the oxygen system to prevent fire or explosion. Components may be viewed under ultraviolet (black) light to detect hydrocarbons by fluorescence.

f. Oxygen equipment maintenance should be performed by qualified persons with clean, grease-free clothing, hands, and static-free tools. All parts of the oxygen piping system should be properly cleaned before use (ref. 7: Ch 13).*

(1) Mechanically clean all parts by, first, removing chips, burrs, fillings, dirt, and most of the grease and oil.

(2) Remove all hydrocarbons.

(a) Fluorinated hydrocarbons such as trichlorotrifluorethane (Freon TF), Freon PCA, or Freon 113 may be used, but thoroughly dried of solvent.

(b) Anionic detergents containing wetting and sequestering agents, such as alconox or trisodium phosphate solution, may be used. An ultrasonic cleaning bath or trisodium phosphate is every effective for small parts. Piping systems must be repeatedly flushed with hot water to remove the detergent. The piping system should then be dried with compressed air or nitrogen.

(3) If nonmetallic parts are incompatible with the solvent being used, they should be removed before oxygen cleaning.

(4) All solvent should be thoroughly removed to leave a clean dry system. Once the solvent is drained or the detergents are rinsed away with clean water, the system should be dried with a dry nitrogen purge.

g. Low pressure (below 500 psi) oxygen piping can be either copper or aluminum, and may be fitted with flange and threaded fittings. No lubricants other than oxygen antiseize and sealing compounds (such as oxylube, fluorocarbons, or molybdenum disulfide) should be used. These compounds should be applied sparingly to pipe threads, to avoid getting the lubricant inside the line. Teflon tape may be used for tapered pipe threads. The

*EDITOR'S NOTE: The reference numbers cited in Appendix D are derived from the list of "References" on p.20.

Teflon tape should be procured and kept in special dispensers to prevent contamination before application (ref. 7: Ch 13).

h. All gas cylinders must be fastened securely to the walls below the pressure manifolds for the chamber, to insure that they will not be accidentally knocked over to the ground. All empty cylinders should also be secured to the wall, with their valves tightly closed and their valve protective caps in place.

FIRE PROTECTION:

a. Fire prevention involves controlling the oxygen concentration, the amount of burnable materials available, and the potential ignition sources. Materials which are nonflammable or noncombustible under normal atmospheric conditions may become flammable or combustible under increased partial pressures of oxygen, even when the percentage of oxygen in the gas mixture remains constant.

b. The oxygen concentration should never be allowed to exceed 25% (unless experimental design calls for 100% oxygen), in order to decrease the potential for a fire. If adequate purging gas is available, a maximum level of 23% oxygen is recommended. The oxygen concentration can be controlled by venting the chamber. An oxygen analyzer should continuously monitor chamber air when oxygen is used.

c. When oxygen is used to compress the chamber, special attention must be given to the chamber contents, including the animals, for 5-10 min after being removed from the chamber following a dive. Any absorbant material, including animal fur, will be saturated with oxygen and extremely susceptible to fire ignition.

d. Smoking is not permitted within 50 ft of the chamber in operation, as well as the breathing gas cylinders when operational or not.

e. No electrical equipment is permitted inside the chamber, except that designed for usage in 155% oxygen at 3 ATA pressure. Any equipment with defective cords or faulty electrical components must be removed from service and repaired or replaced.

f. Suggested procedures to follow in event of fire in the ATC chamber:

(1) For fires within the hyperbaric facility not involving the chamber--

(a) Activate the building fire alarm.

(b) Don emergency breathing mask.

(c) Turn off oxygen source to the chamber.

*(d) Decompress the chamber and remove the animals.

(e) Evacuate the area.

(2) For fire within the chamber--

*(a) Turn off oxygen source to the chamber and isolate it form any remaining chambers.

(b) Turn off the overboard exhaust valve.

(c) Stand by with an emergency breathing mask.

(d) Stand by to activate the building fire alarm and notify appropriate personnel.

(e) When the fire is extinguished in the chamber through depletion of chamber oxygen, vent the chamber to the atmosphere outside the building.

(f) Purge the affected chamber with an inert gas (helium) to eliminate any remaining fire hazard before decompressing the chamber.

(g) Decompress the chamber and remove the animals.

OPERATING PROCEDURES:

a. Research animals breathing extremely dry air, over an extended period of time, may experience pulmonary discomfort and pain. Insure the ATC chamber is humidified above 28% to avoid fire and to prevent static discharge from an animal's fur. Place a flat tray of water in the chamber bottom. The water should be absorbed in a paper towel or sponge. If the walls of the chamber sweat, or if the window ports tend to fog while in use, the water tray can be eliminated.

b. Equipment and supplies that contain closed air spaces may be crushed unless they are vented or constructed to withstand the mechanical effects of pressure change. These items should be tested before use, especially if any question exists about their ability to withstand pressure.

c. If the chamber exhaust line is routed to a fume hood or to a location exterior to the building, a fire suppression sprinkler system will not be

*Author's Note: Animal occupants of the ATC chamber are considered expendable when operating personnel (or animals in adjacent chambers) might be exposed to any risk.

required for the ATC vessel. If the exhaust line is vented to the interior of the building, a fire suppression system will be mandatory, based on NFPA fire safety standards for class "C" chambers.

d. During a compression dive, the ATC vessel must be periodically vented to meet oxygen, carbon dioxide, and humidity requirements, as well as to maintain a uniform gaseous environment throughout the dive profile. CO_2 concentrations should not exceed 3.8 mmHg (surface equivalent) concentration. Concentrations of oxygen and humidity have been previously discussed.

e. The ATC vessel has been painted with an epoxy paint and should be reasonably resistant to corrosion. However, after each dive, the chamber should be cleaned with a warm mild liquid detergent to remove all animal waste matter. The chamber should be thoroughly rinsed, drained, and dried internally to prevent corrosion (refer to section on "Post - Dive Procedures" in "Chamber Operation").

f. When the chamber is not in use, relieve the pressure in all lines and regulators.

APPENDIX E:

OPERATIONAL CHECKLIST FOR ATC SYSTEM

APPENDIX E:

OPERATIONAL CHECKLISTS FOR ATC SYSTEM

Each user organization should develop specific checklists to insure that ATC chamber operations are conducted safely. The following sample checklists, for the ATC system, are used at the USAF School of Aerospace Medicine, Hyperbaric Medicine Division.

PRE-DIVE CHECKLIST:

a. Breathing Gas System:

____ Connect inlet supply line to breathing gas manifold.
____ Close all valves on breathing gas manifold.
____ Back-off C-1 regulator (counterclockwise direction) on the "standby" bank to 150 psi.
____ Open the manifold low pressure valves.
____ Open the manifold shut-off valve to the chamber inlet supply line.

b. Ancillary Equipment:

Calibration of all ancillary monitoring equipment is based on guidelines established by the user organization.

c. ATC chamber:

____ Clock(s)/stopwatch(es) available and set?
____ An adequate supply of forms and pencils at recorder station?
____ A complete set of diving tables at recorder station?
____ Depth gauge reading "zero"?
____ Fire extinguisher next to chamber door?
____ Main power cord to chamber electrical box "plugged in"?
____ Thermostat control switch "ON" and set between 65°F and 100°F?
____ Humidifier polycarbonate bowl filled with water?
____ Humidifier drain port closed?
____ All chamber supply and exhaust valves closed?
____ Petcock valve for chamber external drain port closed?
____ Viewports checked for scratches, cracks, or any suspected damage?
____ External chamber lights turned on?
____ Chamber interior clean?
____ All hazardous materials and equipment removed from the chamber?
____ Water tray placed at bottom of chamber for humidity control?
____ Animals placed in chamber?
____ 'O'-ring door seal free of dirt, grease, etc.?
____ Door closed and secured with "T" clamps and door hex lugs?

--APPENDIX E--

NORMAL OPERATION CHECKLIST:

a. Pressurizing the Chamber:

- _____ Select proper treatment or experimental dive profile.
- _____ Open chamber inlet supply valve slowly.
- _____ Adjust system pressure with the Norgren variable pressure control knob to desired chamber depth.
- _____ Adjust supply valve for humidified or non-humidified gas to chamber interior.
- _____ Close chamber inlet supply valve at desired depth.

b. Flushing and Venting the Chamber:

- _____ Simultaneously, open the chamber inlet supply and exhaust valves to maintain chamber depth.
- _____ Continue flush and vent rate for 5-10 min.
- _____ Close chamber supply and exhaust valves.

c. Gas and Humidity Samples at Depth:

- _____ Close chamber supply valves.
- _____ Turn chamber exhaust valve to "SAMPLE."
- _____ Collect gas sample or else monitor gas and humidity by ancillary analyzers/monitors.
- _____ Close chamber exhaust valve.

d. Depressurizing the Chamber:

- _____ Select proper decompression schedule.
- _____ Close chamber supply valves.
- _____ Turn chamber exhaust valve to "DRAIN."
- _____ At surface, open the door hex lugs (counterclockwise direction) to drain all residual pressure inside the chamber, and pull "T" clamps away from door.
- _____ Close chamber exhaust valve.

e. Emergency Ventilation of Chamber:

One of three methods can be used to rapidly depressurize the chamber (Tables E1 and E2)---

- _____ Open the chamber exhaust valve to the full open position; or
- _____ Manually open the chamber pop-off valve; or
- _____ Open both the chamber exhaust valve and the chamber pop-off valve.

TABLE E-1. VENTILATION VOLUME WITH CHAMBER EXHAUST VALVE FULLY OPEN *

D Depth (fsw)	T Ascent time (sec)	A Pressure (ATA)	TA Ascent time X pressure	R Rate = $\frac{25}{TA}$ (ft^3/min)
165	22	6.00	132	0.19
60	63	2.82	177.7	0.14
45	69	2.39	164.9	0.15
30	90	1.91	171.9	0.15

D - Depth (fsw); T = time (sec); A = pressure (ATA); TA = T X A; and R = rate (ft^3/min).
*When the chamber exhaust valve is fully open, approximately 0.15 ft^3/min is vented from the chamber (actual value per depth is indicated by R).

TABLE E-2. VENTILATION VOLUME WITH CHAMBER POP-OFF VALVE FULLY OPEN*

D Depth (fsw)	T Ascent time (sec)	A Pressure (ATA)	TA Ascent time X pressure	R Rate = $\frac{25}{TA}$ (ft^3/min)
165	18	6.00	108	0.23
60	27	2.82	76.1	0.33
45	39	2.39	93.2	0.27
30	54	1.91	103.1	0.24

D = Depth (fsw); T = time (sec); A = pressure (ATA); TA = T X A; and R = rate (ft^3/min).
*When the chamber pop-off valve is fully open, approximately 0.25 ft^3/min is vented from the chamber (actual value per depth is indicated by R).

--APPENDIX E--

POST-DIVE CHECKLIST:

a. Breathing Gas System:

_____ Close high pressure cylinder valves.
_____ Open manifold vent valve to relieve pressure in the system.
_____ Close manifold vent valve.
_____ Close manifold high pressure valves.
_____ Backoff C-1 regulator (counterclockwise direction) to relieve internal pressure on diaphragm.
_____ Close manifold low pressure valves.

b. ATC Chamber:

_____ Open chamber door.
_____ Bleed-off all supply lines to the chamber by opening the humidifier drain port and the supply valve connected directly into the chamber interior.
_____ Close the chamber inlet supply valve.
_____ Thermostat control switch "OFF"?
_____ External chamber lights turned "OFF"?
_____ Main power cord, to chamber electrical box, "unplugged"?
_____ Turn off all ancillary monitoring equipment.
_____ Remove animals from chamber.

c. ATC Chamber Clean-up:

_____ Remove residual food and animal waste from chamber.
_____ Remove water tray placed on bottom of chamber floor.
_____ Clean chamber interior with mild liquid detergent in warm water. Scrub thoroughly.
_____ Rinse chamber interior with clean water from a hand-held hose.
_____ Remove all standing water and residual moisture from the chamber interior:

    ____ (1) Pressurize chamber to 10-15 fsw.
    ____ (2) Open petcock valve on external chamber exhaust drain.
    ____ (3) Decompress chamber to surface.
    ____ (4) Towel dry chamber interior.
    ____ (5) Leave chamber door slightly open.

_____ Remove the humidifier polycarbonate bowl and empty the water. Periodically autoclave the water reservoir to eliminate algae buildup.
_____ Clean the animal cages and restock with fresh food and water.
_____ Perform any minor chamber maintenance.

APPENDIX F:

PROPOSED ATC CHAMBER OPERATION RECORD

APPENDIX F:

PROPOSED ATC CHAMBER OPERATION RECORD (FORMAT)

The chamber operator must maintain accurate dive records for each ATC compression operation. These records can provide vital dive information to be utilized in subsequent reports for clinical and/or experimental investigations. The ATC Chamber Operation Record (Fig. F-1) is a format suggested to record all pertinent dive data per chamber compression. The following abbreviations and their definitions are presented here for clarification, as they are used on the operations record:

1. TBT - Total bottom time of the dive. The time from leaving the surface until leaving maximum depth.

2. TDT - Total decompression time. All time spent in ascending from maximum depth to the surface, including time spent at decompression stops.

3. TTD - Total time of dive. All time from leaving the surface until reaching the surface, the entire exposure time (i.e., TBT + TDT = TTD).

4. MAX DEPTH - Maximum depth attained during the dive.

5. REPET GRP - Repetitive group. A letter designating a level of dissolved nitrogen present in the body at the completion of a specific dive.

6. START - Real time the dive starts.

7. ENDED - Real time the dive ends.

8. TABLE - Decompression table used as chosen in the standard depth and time format.

9. TEMP - Temperature of chamber interior.

10. REL HUM - Relative humidity of chamber interior.

--APPENDIX F--

1.	ATC CHAMBER OPERATION RECORD					
	ANIMAL INFORMATION/DIVE INFORMATION					
ANIMAL TYPE	AGE	WT	SEX	TYPE MEDICATION/DRUGS GIVEN	ANIMAL ID#	PROTOCOL #

	First Treatment (DA, MO, YR)	Total Number of Treatments	Summary of Hyperbaric Treatment	Final Animal Disposition
	Last Treatment (DA, MO, YR)	Total Treatment Time		

2. ANIMAL COMPRESSION RECORD

DATE		RESEARCHER		TIME	TEMP	REL HUM	$\%O_2$	$\%CO_2$
Dive #		Chamber Operator						
Start		Recorder						
TBT		Max Depth						
TDT		Table						
TTD		Repet GRP						
Ended		Type of Gas						

DATE		RESEARCHER		TIME	TEMP	REL HUM	$\%O_2$	$\%CO_2$
Dive #		Chamber Operator						
Start		Recorder						
TBT		Max Depth						
TDT		Table						
TTD		Repet GRP						
Ended		Type of Gas						

DATE		RESEARCHER		TIME	TEMP	REL HUM	$\%O_2$	$\%CO_2$
Dive #		Chamber Operator						
Start		Recorder						
TBT		Max Depth						
TDT		Table						
TTD		Repet GRP						
Ended		Type of Gas						

Figure F-1. Proposed ATC Chamber operation record (format).

ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS AND SYMBOLS

Abbreviations and symbols	*Definitions*
AFP	- Air Force Pamphlet
Amp	- ampere
ASME	- American Society of Mechanical Engineers
ATA	- atmosphere absolute
ATC	- Animal Transfer Chamber
BSC	- Biomedical Science Corps
^{o}C	- degree centigrade or Celsius
ft^3/min	- cubic feet per minute
^{o}F	- degree Fahrenheit
ft^3	- cubic feet
fc	- foot-candle
fsw	- feet sea water
H_2O	- water
HP	- horsepower
Hz	- Hertz
Max. Asc.	- maximum ascent
MIL-STD	- military standard (publication)
min	- minute

(Cont'd. on next page)

ABBREVIATIONS AND SYMBOLS (Cont'd.)

Abbreviations and symbols	*Definitions*
NFPA	- National Fire Protection Association
O_2	- oxygen
ppm	- parts per million
psi	- pounds per square inch
psig	- pounds per square inch gauge
PTC	- pressurized transfer chamber
Rept. Grp.	- repetitive group
RPM	- revolutions per minute
TBT	- total bottom time
TDT	- total decompression time
T.O.	- Technical Order
TTD	- total time of dive
USAF	- United States Air Force
V	- volts

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