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A VERSATILE EXPERIMENTAL HYPOTHERMIC-HYPERBARIC OXYGEN CHAMBER FOR WHOLE ORGAN PRESERVATION

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A VERSATILE EXPERIMENTAL HYPOTHERMIC-HYPERBARIC OXYGEN CHAMBER FOR WHOLE ORGAN PRESERVATION

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The advent of whole organ transplantation demands the necessity of having an organ available for implantation when the recipient is prepared. In order to accomplish this it is necessary to have the organ readily available in a viable sterile condition.

Hearts have been preserved up to seven hours in iced saline and re-implanted with long term function (Lower, Stofer, Hurly, Dong, Cohn, and Shumway, 1962). Lungs have been transplanted after two hours of preservation by hypothermia and oxygen (Hardy, Webb, Dalton, and Walker, 1963). Other investigators (Barsamian, Jacob, Collins, and Owen, 1960) have preserved cells and tissue for a longer period of time utilizing dehydration and hypothermia. With the reintroduction of hyperbaric oxygen as a medical tool by Boerema (1961) investigations of whole organ preservation have been carried out by combining high pressures to lower the freezing point and hypothermia (Robertson, Deshpande, Slegal and and Jacob, 1964) as well as hyperbaric oxygen and hypothermia to prolong the viability of whole organs for implantation (Eyal, Manax, Bloch, and Lillehei, 1965).

A hypothermic-hyperbaric oxygen chamber was needed for investigations in this field. A unit was designed and built which is low in cost, safe, and is versatile in controlling pressure, temperature, nutrient solution exchange, sterility, physiological lead components and visibility.

MATERIALS

Standard commercially available parts were used in construction.

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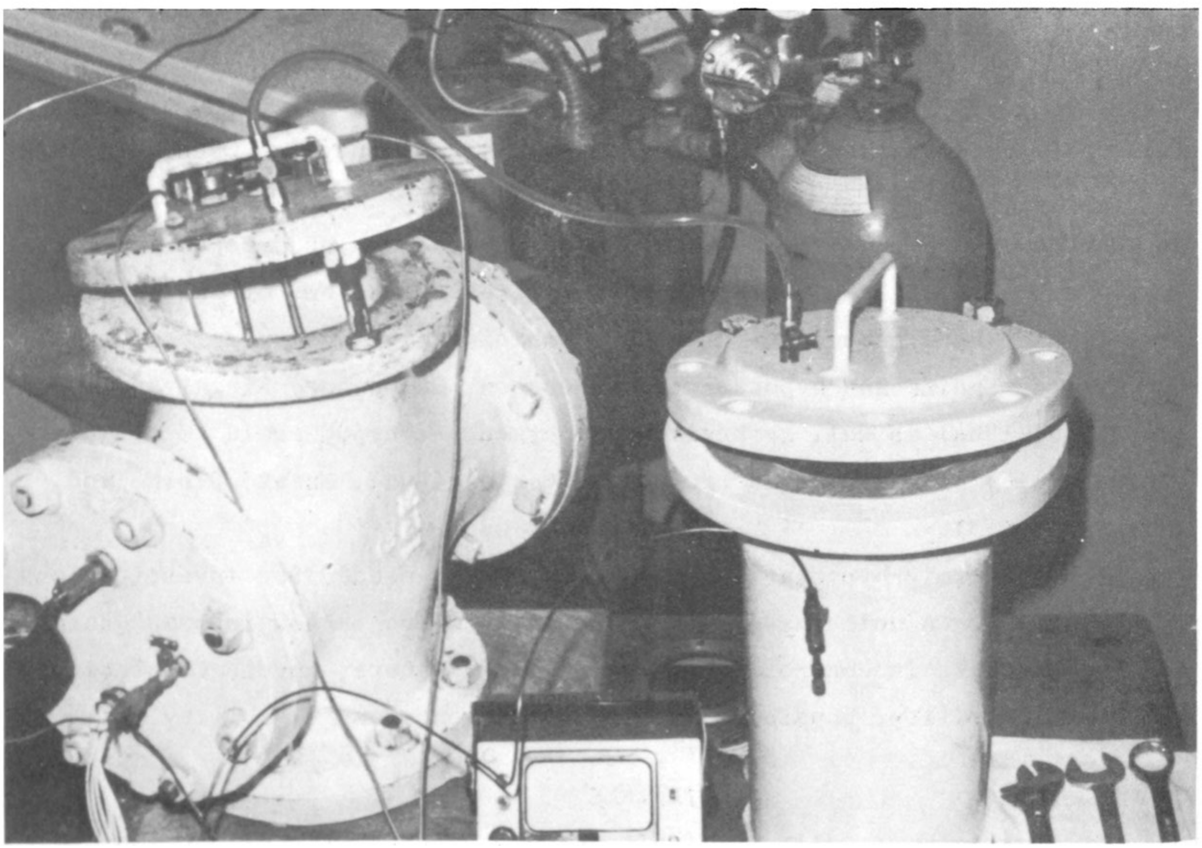
A cast flanged pipe cross 8 inches in diameter was chosen as the basic pressure vessel. It was in stock locally, conservatively rated at 125 psi gauge pressure and had 4 large access holes. A pyrex pipette washing jar of 7.5 inches outside diameter serves as a removable glass liner to contain the organs and nutrient solution.

Four blind flanges were used to close the 4 access holes. The bottom hole was closed by an unmodified blind flange. The blind flange on the right in the Figure 1 was bored centrally to accept a stock 6 3/4 inch pyrex window rated at 135 psi gauge pressure. The window was mounted on the inside of the blind flange so that increasing pressure seats the window more firmly on its gasket. Normal practice was followed in design of the retaining ring. Viewing area is a circle 5.5 inches in diameter.



Overall View of the Hyperbaric Organ Preservation and Feeding Chambers

Figure 1

The blind flange mounted on the left in the photograph was drilled and tapped to accept the oxygen and instrumentation fittings. Ten shielded leads for EKG or other uses were brought out thru the left flange by use of a hermatically sealed pass-thru insulator. A pressure guage was installed as shown, and provides information up to 9 atmospheres. A safety valve was installed to protect against excessive pressure. The rate at which pressure may be released is much greater than the maximum rate at which oxygen may be introduced. A manual release is incorporated in the safety valve and will rapidly lower the chamber pressure when opened. A standard oxygen pressure regulator was chosen to meter the oxygen. Six feet of 1/8 inch soft copper tubing between the regulator and the chamber provides the necessary flexibility and also serves to restrict the maximum rate of filling.

Only the nutrient solution container is cooled, as this may be more easily controlled than attempting to cool the whole chamber. A cooling coil suspended at the top of the nutrient solution was used so that convection currents would help to prevent temperature stratification. The cooling coil was attached to the lower surface of the upper blind flange and is immersed in the solution when the flange is in place. Chilled ethylene glycol and water from an existing cooler is passed through the flange and circulated in the cooling coil.

The nutrient solution changing system was also incorporated in the upper flange. A stainless steel fitting was designed to pass through the flange. A needle valve was fitted to its upper end, while its lower end was shaped to accept plastic tubing which descends to the bottom of the nutrient solution container. The upper flange was also found to be a convenient location to enter the chamber with two leads of a telethermometer. Packing glands were made from 1/8 inch tubing to 1/8 inch male pipe adaptors by drilling out the center hole just large enough to accept the telethermometer leads. A small rubber washer was used as packing material in compression to effect a seal. A handle was welded to the upper flange to facilitate handling.

The feeding chamber used for nutrient solution exchange is similar to the oxygen chamber. It is 8 inches in diameter, 16 inches high, and has only a safety valve, oxygen connection and nutrient solution connection. An inner vessel is also used to contain the nutrient solution.

SAFETY

Oxidation resistance and safety were considered at every point. Silicone rubber 1/16 inch thick was used for all gaskets because of its oxidation resistance. The needle valves are stainless steel and are packed with Teflon. The safety valve has a metal-to-metal seal with no organic packing. The paint used to improve appearance and visibility was an epoxy. No flammable materials were used in the chamber except the plastic feeding tube, the gaskets, the thermometer leads, and the paint. All of these were chosen for their oxidation resistance, and are not considered to be an explosion hazard. No organic material should be introduced into the chamber during operation which could ignite spontaneously. A rupture disc could have been installed to release any explosive pressure built up, but this was not considered necessary. Leakage of oxygen has been negligible and is not considered hazardous. The volume of oxygen released to the room when depressurizing is not hazardous except at the immediate time and place of release. All component parts used are conservatively rated at 125 psi gauge pressure or above.

METHODS

The nutrient solution container may be sterilized in the normal manner, as may the cooling coil. Quick-disconnect fittings may be used on the cooling coil if desired, although this has not been found necessary as yet. The telethermometer leads are not readily removable, but may be wiped with an antiseptic prior to use. The nutrient solution may be precooled and/or pre-oxygenated as desired. It takes two to three minutes to position the top flange, tighten the eight retaining bolts and build up oxygen pressure to the desired value.

Spent nutrient solution may be drained when the chamber is pressurized by simply opening the needle valve. Fresh nutrient solution may then be introduced from the feeding chamber, when it is pressurized by oxygen to slightly higher than organ chamber pressure. With the needle valve shut, the feeding container may be removed for cleaning. The feeding chamber may be used for periodic batch replacement of the nutrient solution or it may be used for hyperbaric perfusion of the organ. The connections are diagrammed in Figure 2. As an alternative, the two chambers may be used alternately to perfuse organs at one atmosphere with hyperbarically oxygenated solution.

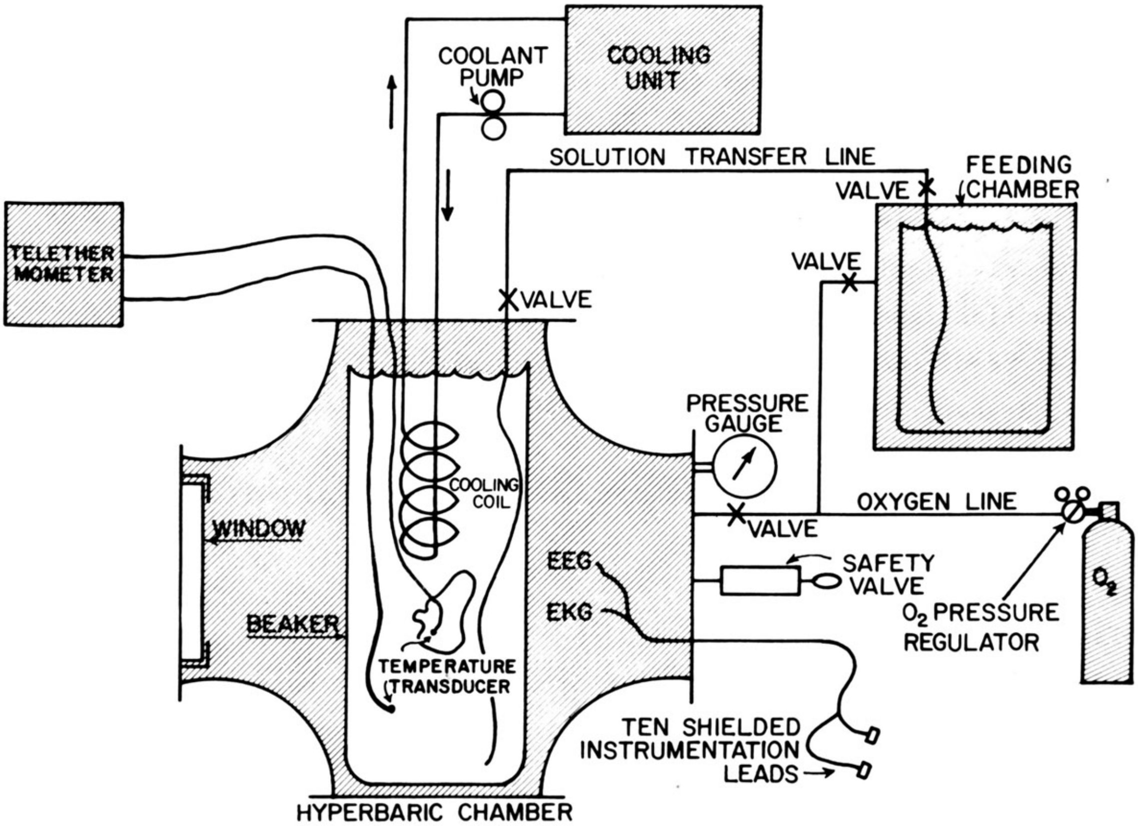


Diagram of Connections for the Hyperbaric Organ Preservation and Reading Chambers.

Figure 2

The useable volume of nutrient solution is an upright cylinder 7 inches in diameter and 12 inches high. This is sufficient for hearts, lungs, kidneys, or a heart-lung preparation of a dog. A smaller inner container has also been used in order to reduce the amount of nutrient solution required. The design may be easily enlarged in the future by adding a length of flanged pipe on the top and/or bottom, which could provide room for organs or limbs of any length. Or as an alternative method, two or more pipe crosses could be stacked to provide both space and visibility. Larger diameter pipe fittings are available if a larger chamber should be needed.

SUMMARY

The hyperbaric chamber described was designed and built in about two weeks. No delays were encountered because of construction or procurement difficulties, and it was economically built from proven, readily-available components. Weighing 402 pounds, it is transportable on a wheeled equipment table. It has been in continuous use since its construction, and has demonstrated its ability to meet or exceed its initial requirements. Results of its use are reported elsewhere (Almond, Anido, Seaber, Young and Mackenzie, 1965).

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