DYNAMIC SYSTEM FOR NITROGEN ANOXIA OF LARGE MUSEUM OBJECTS: A PEST ERADICATION CASE STUDY

Gordon Hanlon, Vinod Daniel, Nancie Ravenel and Shin Maekawa

Abstract: Exposure to an oxygen atmosphere containing less than 0.1% is known to cause 100% mortality of the most commonly found museum pests in a few days. This paper will describe a dynamic system in which a continuous flow of nitrogen can be used to maintain a low oxygen concentration inside a sealed bag for insect anoxia with large museum objects.

1 INTRODUCTION

In the past, various toxic gases such as ethylene oxide and methyl bromide have been extensively used to eliminate pest infestation. However, in addition to the serious health and safety implications of such gases, several papers have reported damage to objects by these chemical fumigants [1,2].

A number of investigators have discussed the effects of low oxygen atmospheres on the mortality of several insect species [3-10]. In a collaborative project between the Getty Conservation Institute and the Entomology Department of University of California at Riverside has found that in a less than 0.1% oxygen atmosphere all stages of the ten species of insects studied had a 100% mortality in less than 8 days [7,8]. Such a low oxygen concentration can be obtained either by continuously purging with an inert gas, such as nitrogen, or by the use of an oxygen scavenger, such as Ageless™ [10-11].

Previous investigators have successfully used this method of anoxia for relatively small objects. We were interested in testing the practicality of maintaining low oxygen atmospheres in high volume bags enclosing large museum objects. We present the results of our anoxia experiment on an Italian armchair, c.1730-40 infected with the furniture beetle (Anobium punctatum). The anoxia treatment of the chair is shown in figure 1.

2 EXPERIMENTAL

A number of variations in protocol and materials had to be considered in effecting anoxia of insects in a museum piece using a large plastic bag, though the basic procedure is a simple one of displacement of almost all oxygen in the bag. First, there is the choice of a dynamic versus a static process. In the dynamic anoxia technique, the inert gas is used to flush all air out of the bag by an initial rapid flow rate and then, when a level of around 0.1% oxygen is reached, the flow is reduced to that required to maintain the low-oxygen atmosphere *for* two weeks. In the static technique, after a 0.1% oxygen level is achieved by a rapid flow of inert gas through the bag, an oxygen scavenger is quickly inserted, the gas flow stopped and the bag sealed for the required time period. This paper reports our work with the dynamic process. (We are beginning investigations of the static technique and the results will be presented when that development is completed).

2.1 Bag Construction

Plastic films vary in their permeability to oxygen. standard polyethylene sheet is ten to a hundred times more “porous” to oxygen than other commercial oxygen barrier films. Thus, in a very large polyethylene bag, a rapid nitrogen flow would have to be maintained to insure a low-oxygen atmosphere because of the oxygen that would leak through the plastic. To minimize nitrogen use, we selected an Aclar (polychloroflu oroethylene) composite film with a leak rate of 9 ml. of oxygen/24 hr./atm. Other plastic composites have lower oxygen leak rates but are either very expensive or unavailable in one meter and larger widths.

The bag was fabricated by joining large sheets of plastic to yield a form conforming to the shape of the object. The seals were made by a heated hand-held rolling sealer. Precise circular holes were cut for the Swagelok fittings with a punch. The approximate volume of the bag was 1500 liters.

2.2 Relative humidity control.

To avoid possible hygrometric shock to a museum object undergoing anoxic treatment in the plastic bag, the dry nitrogen from the cylinder was humidified to the object's optimal RH before being allowed to flow into the bag. The system is shown schematically in figure 2. The system involved splitting the gas flow from the nitrogen cylinder into two valve-controlled lines via a tee. One line bubbled the nitrogen through water in a stout polypropylene bottle; exiting the bottle the moist nitrogen joined the other (dry) flow of nitrogen in a mixing chamber, which flowed to a third bottle containing an RH sensor. By controlling the needle valves on the two lines, the ratio of wet to dry nitrogen was varied to achieve the desired RH in the combined nitrogen stream which subsequently went to the plastic bag containing the object.

To minimize the influx of oxygen, all fittings from the nitrogen cylinder to the entrance of the bag used 1/2 inch brass Swagelok fittings. Polypropylene tubing (1/2 inch) led to a-ring sealed fittings in holes that had been precisely drilled in the humidification bottles. A tee fitting with an on/off valve was attached between the sensor bottle and the bag. This allowed any nitrogen whose RH was being varied prior to achieving a final RH value to be exhausted to the room atmosphere.

2.3 Instrumentation

The temperature and relative humidity inside the bag were monitored with a Vaisala HMP 133Y sensor. The oxygen concentration was monitored both by a GC Industries oxygen monitor, Model GC 502 with Model 33-475 sensor which was sensitive and accurate to 0.1% oxygen, and a trace oxygen analyzer, Teledyne Model 316, sensitive and accurate to a few parts per million. All sensors were interfaced to a Campbell Scientific 21X data logger in which data was collected every second, averaged over a 60 minute period, and stored. These data were transferred to a personal computer for analysis and graphing. Schematics of our experimental setup are shown in figure 3.

2.4 Experimental procedure.

The bag encapsulating the Italian armchair was initially purged with a high flow rate (7 slpm) of nitrogen conditioned at 55% RH for 40 hours and the oxygen concentration, relative humidity, and temperature monitored. The flow rate should be selected such that the bag does not become over pressurized which could split the heat seals.

After establishing a stable oxygen concentration of 0.1%, the nitrogen supply was turned off and the inlet and outlet valves to the bag closed. This static setup was maintained for four days to assess the leak rate of the bag. After this period the nitrogen supply was resumed for 2 days at 7 slpm to purge the bag back to 0.1% oxygen concentration. The nitrogen flow rate was then reduced to 0.5 slpm for 5 days. At this point the nitrogen tank was replaced and the flow rate was increased from 0.5 to 2.0 slpm for the next 9 days to assess the effect of increasing the flow rate on the oxygen concentration.

3 RESULTS

3.1 Leak rate of bag

The oxygen concentration within the bag increased from 0.04% to 0.24% over a period of 4 days (Fig. 4). The leak rate evaluated in the first 24 hours was 0.022% O_2 per day and the leak rate over the next 72 hours was 0.049% 2 per day. The leak rate over the first 24 hours was lower probably due to the fact

that the bag was under pressure due to initial nitrogen flushing. with the nitrogen supply turned off, the pressure within the bag drops to the same as atmospheric pressure. The oxygen leak rate was therefore calculated to be 0.049% O_2 per day, on the latter data, when the pressure inside and outside the bag were the same. The continuous low flow rate of nitrogen that we used can compensate for this slow leak rate and hence the oxygen concentration was maintained at less than 0.1% (Fig. 5).

3.2 Oxygen Concentration

After ascertaining the leak rate of the bag, the oxygen concentration was purged back down to below 0.1% using a nitrogen flow rate of 7 slpm. This was achieved over a two and a half day period. The nitrogen flow rate was then decreased and the exit valve closed in order to compensate for oxygen permeating into the bag from the outside. At a very low flow rate, of approximately 0.5 slpm, the oxygen concentration remained fairly constant, increasing only 0.01% over five days.

When the nitrogen tank was replaced and the flow rate increased to 2.0 slpm, the oxygen concentration initially dropped rather quickly over three days, and then continued to decrease at a much lower rate. The oxygen concentration as a function of elapsed time is shown in figure 5.

Moving the oxygen sensor vertically within the chamber provided an indication of the stratification of the oxygen concentration in the bag. At a constant nitrogen flow rate there was 0.01% difference in oxygen concentration when the sensor was moved from a height of 80 cm. to 30 cm. from the floor, hence there was no significant oxygen stratification inside the bag.

3.3 Relative Humidity & temperature

Temperature and relative humidity within the bag were continuously monitored and the temperature remained constant at 22.5°C ± 0.2 throughout the experiment. The humidification setup described in section 2.2 and illustrated in figure 2, maintained the desired humidity for the inlet nitrogen. But as a safety consideration it is recommended that a buffer should be added to the encapsulating bag to help maintain a stable RH.

4 ANOXIA EXPERIMENTS ON OTHER OBJECTS

Previously, two smaller objects, a French fire screen and a French console table, infested with wood boring insects were subjected to dynamic nitrogen anoxia. Each object was placed in an Aclar bag using the procedure described above. The oxygen concentration was monitored visually to be 0.1% during the 14 days of the treatment using a GC Industries oxygen monitor (Model GC 502). The Aclar bag used on the fire screen was re-used for the console table and successfully maintained the necessary low oxygen atmosphere.

5 CONCLUSIONS

A dynamic system with a continuous nitrogen flow into a large Aclar plastic bag can maintain an oxygen concentration of 0.1% for the desired duration of the treatment and therefore meets the conditions required for anoxia pest eradication.

All three objects treated using this method are frequently reexamined. No evidence of subsequent infestation has been observed.

6 ACKNOWLEDGEMENTS
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AUTHORS' BIOGRAPHIES

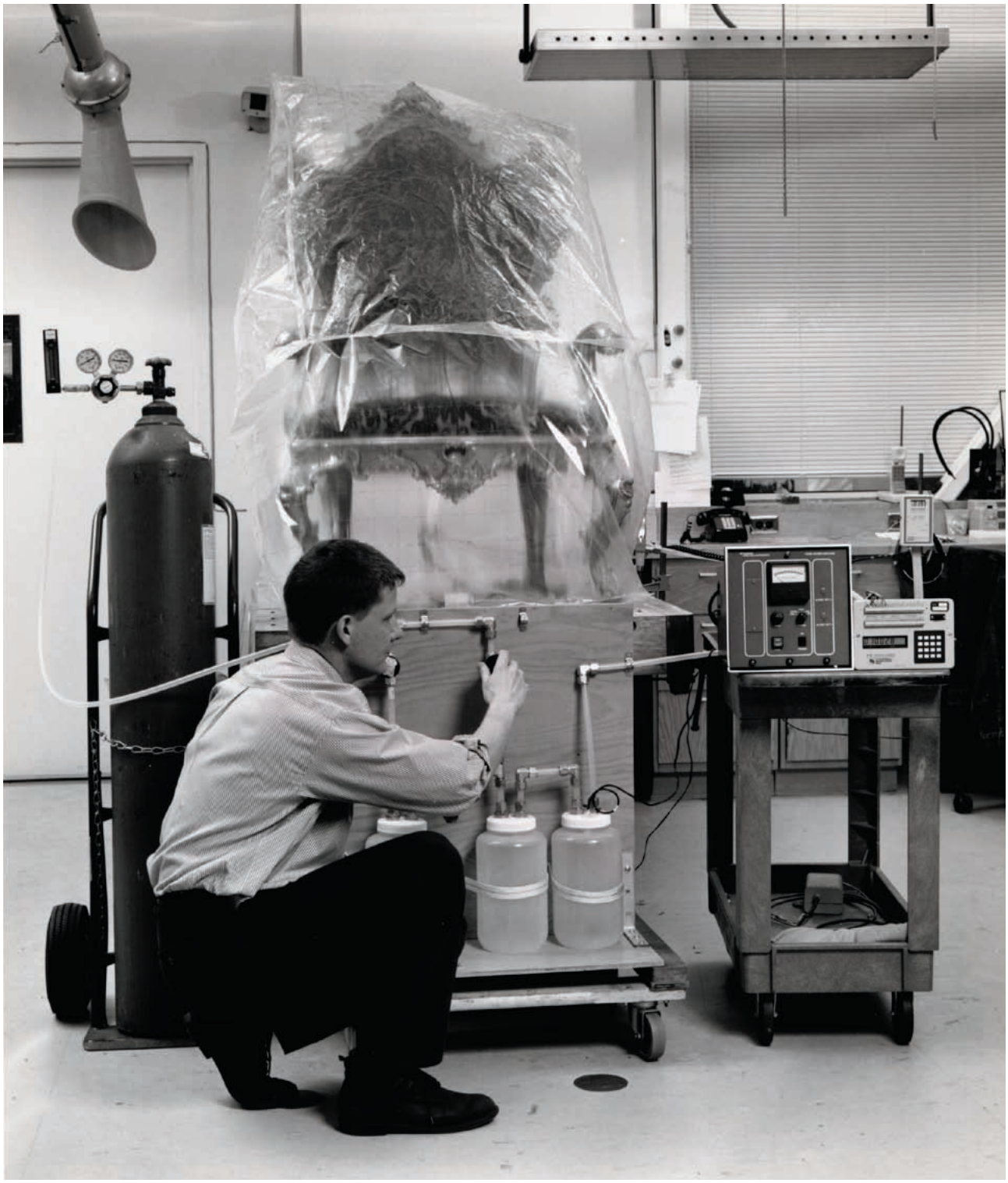
Gordon Hanlon received his B.A. degree in Biology from the University of York, England in 1979. From 1980–1984 he was Assistant Curator of Road Transport and Agricultural Implements at the Museum of Science and Technology, London. In 1984 he started a four year studentship at the Victoria & Albert Museum, London, specializing in the conservation of Furniture and Gilded objects. In 1988 he joined the J. Paul Getty Museum as an intern, and subsequently Assistant Conservator in the Department of Decorative Arts and Sculpture. Author's Address: J. Paul Getty Museum, 17985 Pacific Coast Highway, Malibu, CA 90265.

Vinod Daniel received his M.Tech degree in chemical engineering from Indian Institute of Technology, Madras, India in 1986, where he worked on the rheological characteristics of polymer blends. He also received his M.S degree in physical chemistry from Texas Christian University in 1991, where his thesis was in diffusion in liquids. He is presently working as a Senior Research Fellow in the environmental sciences division at the Getty Conservation Institute. His research involves museum cases, moisture buffers in display cases, non-toxic fumigation, data acquisition. Author's Address: Getty Conservation Institute, 4503 Glencoe Avenue, Marina Del Rey, CA 90292.

Nancie Ravenel held pre-program internships in the National Museum of American History, Washington, DC, 1987-88, and in the Conservation Analytical Laboratory of the Smithsonian Institution, 1988-89. Since 1989 she has been a Fellow in the University of Delaware/Winterthur Museum Art Conservation Program, and is currently completing her studies as a graduate intern at the J. Paul Getty Museum's Department of Decorative Arts and Sculpture Conservation. Author's Address: J. Paul Getty Museum, 17985 Pacific Coast Highway, Malibu, CA 90265.

Shin Maekawa is head of the Environmental Science section of the Getty Conservation Institute. His area of specialization is environmental monitoring and micro environmental research. Author's Address: Getty Conservation Institute, 4503 Glencoe Avenue, Marina Del Rey, CA 90292.

Figure 1. Anoxia setup of Italian armchair. (Photograph)



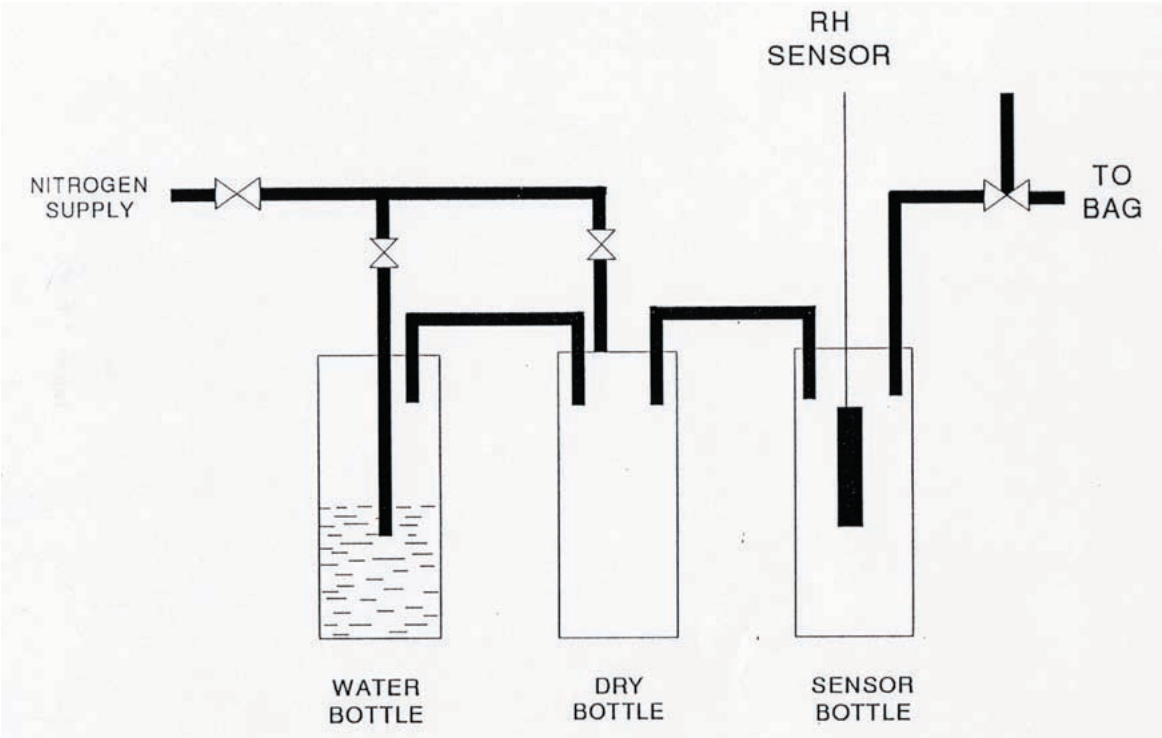
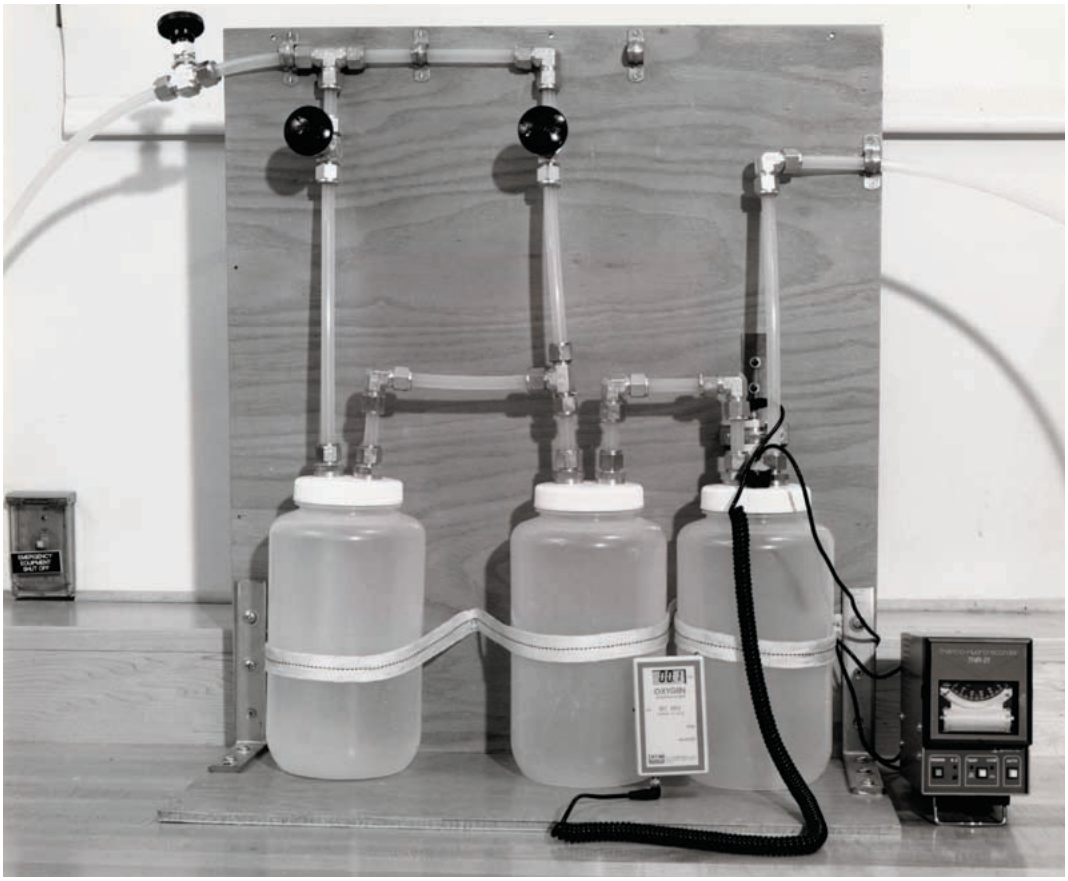
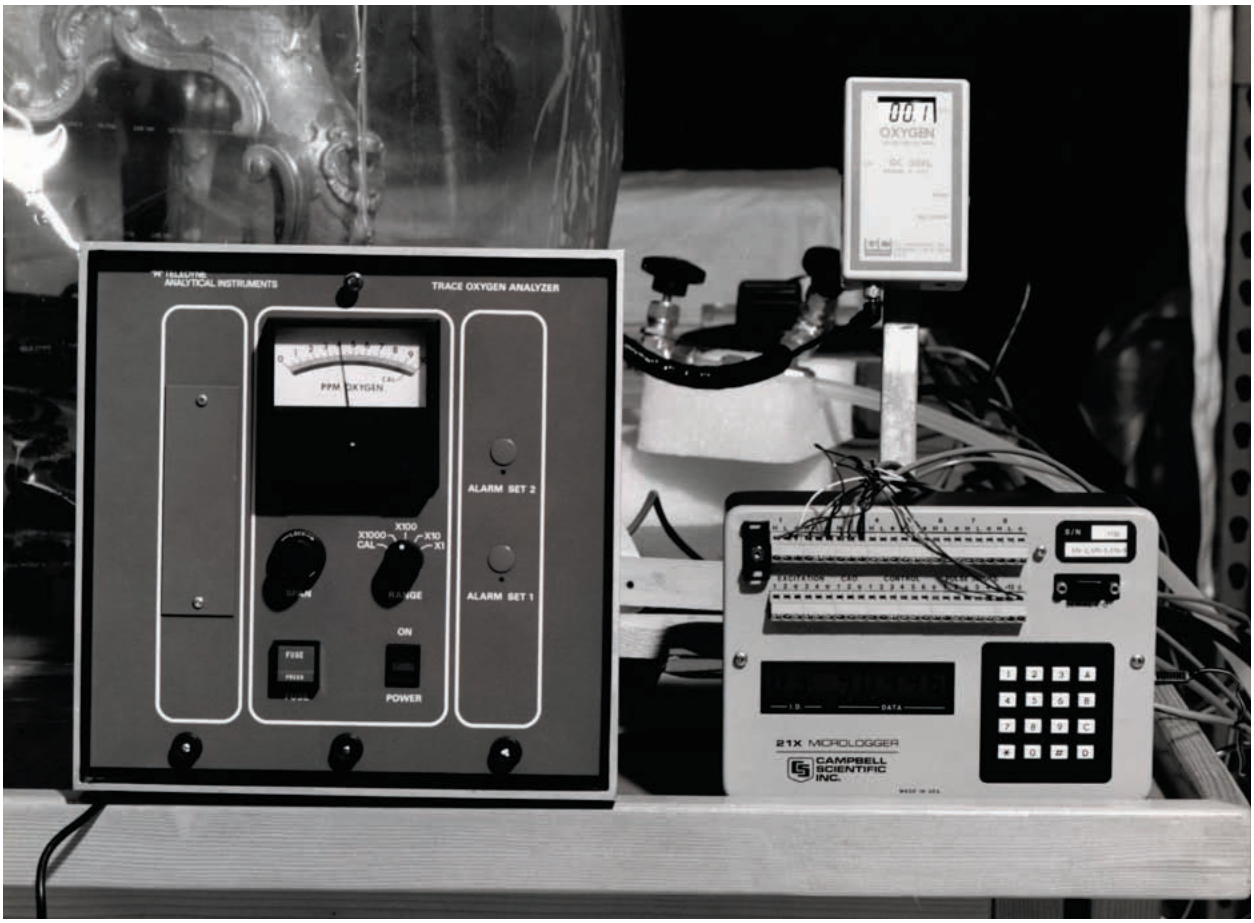


Figure 2. Schematic of humidification system for nitrogen flow.

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CAMPBELL SCIENTIFIC INC.

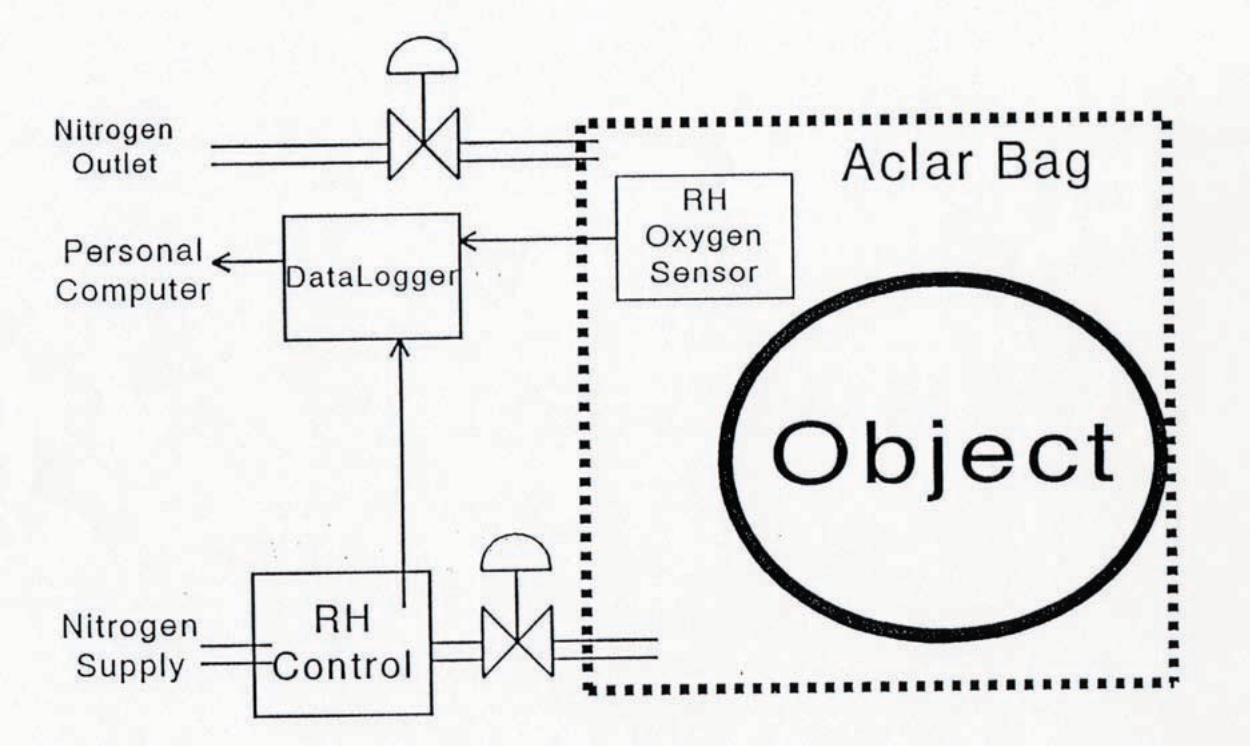
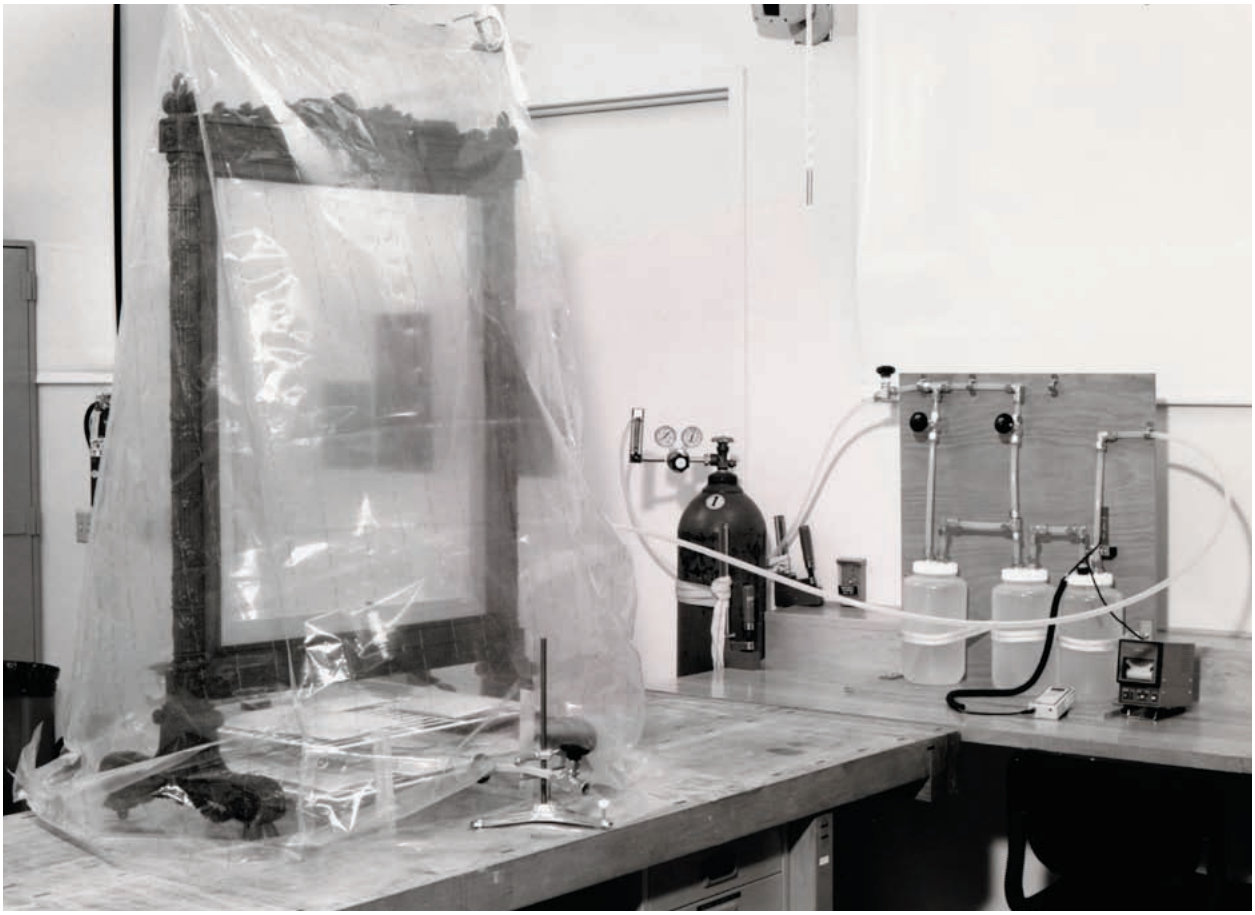


Figure 3. Schematic of experimental setup.



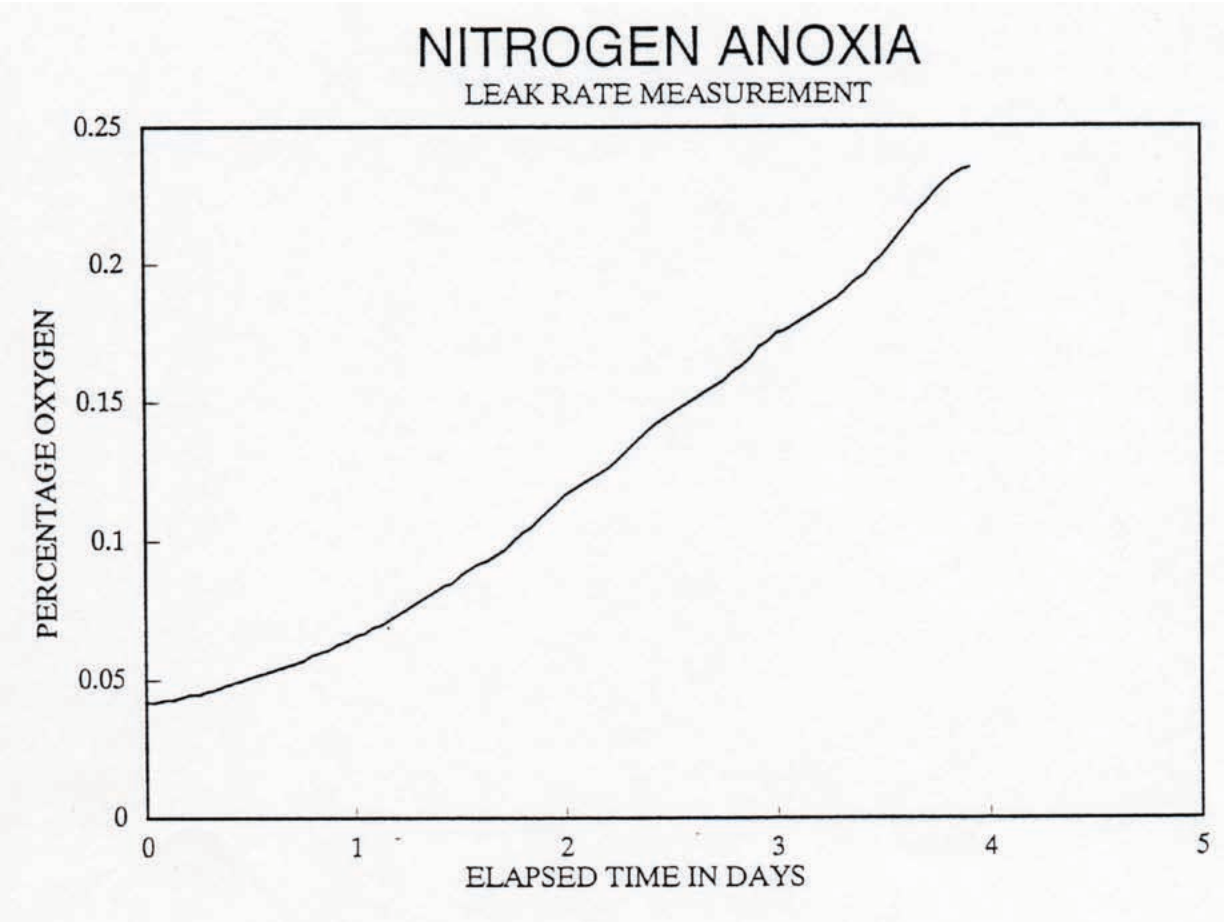


Figure 4. Leak rate experiment.

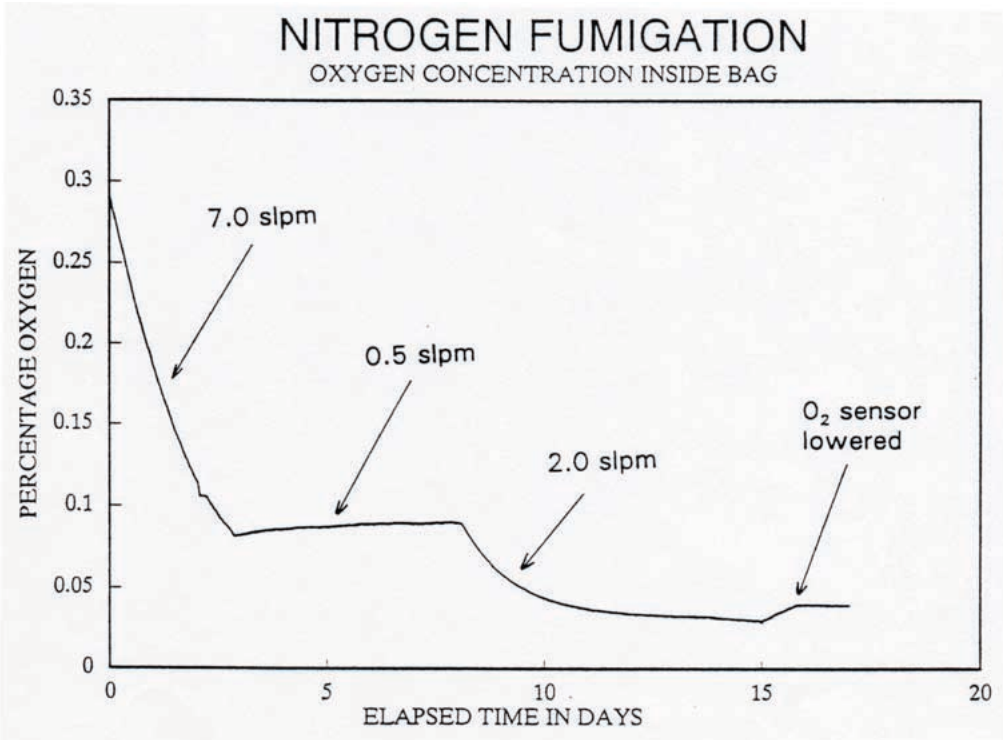


Figure 5. The oxygen concentration inside the bag over the duration of the experiment.