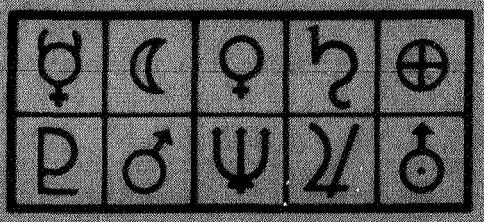

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THE DEVELOPMENT OF TWO CLOSELY CONTROLLED HUMIDITY SYSTEMS

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ABSTRACT

Accurately controlled humidity systems were needed to study the effect of relative humidity on the dry heat and thermoradiation inactivation of microorganisms. Two different systems were developed which provided the degree of control needed. This report describes the components and operation of the systems, as well as some of the factors considered in their design.

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USE OF COMMERCIAL PRODUCTS

Trade names used in this report are for identification only and do not necessarily constitute endorsement of the products.

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THE DEVELOPMENT OF TWO CLOSELY CONTROLLED HUMIDITY SYSTEMS

Introduction

The relative humidity (RH) of the air used in dry heat sterilization studies is known to have some effect on the heat sensitivity of microorganisms. In order to establish definitive relationships between relative humidity and microbial inactivation, it is first necessary to devise a method for closely controlling the RH of the air in the temperature chambers where the experiments are conducted.

Our typical laboratory RH is about 25 to 35 percent. Any variation in normal conditions such as mopping the floor or opening doors to the outside atmosphere will affect the ambient RH temporarily. Laboratory temperature, while thermostatically controlled, will also vary a few degrees F which in turn affects the RH.

The effect on the lethality of dry heat to organisms when room ambient conditions are varied has been demonstrated. The standard NASA test organism, Bacillus subtilis var. niger was used in these experiments. When the RH was varied from 20 to 60 percent, the 105°C dry heat D value* changed from 2.3 hours to 5.3 hours.[1]

This report describes two humidity control systems that were developed for dry heat and thermoradiation sterilization studies at Sandia Laboratories. The first system, designated System A, provides for mixing dry and

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*A "D value" is the time required for a given microbial population to be reduced by 90 percent or one log at a given temperature.

[1]M. C. Reynolds, "The Feasibility of Thermoradiation for Sterilization of Spacecraft-A Preliminary Report," SC-RR-69-857, 1969

moist air to achieve the desired relative humidity. It is a relatively portable system located at the Gamma Irradiation Facility which is in an area remote from our microbiological laboratories. The other system, designated System B, utilizes the principle that a given RH at a given temperature can be attained by saturating the air at a specific temperature. This system is stationary and is located in our laboratory area. It was specifically designed for long-term studies.

System A

Equipment and Operation

The purpose of System A is to provide moisture control for spore inactivation studies using thermoradiation as the inactivating agent. This system normally operates for periods ranging from 6 to 48 hours and is usually attended during operation. Occasional minor adjustments are necessary to maintain close humidity control. A schematic of this system is shown in Figure 1.

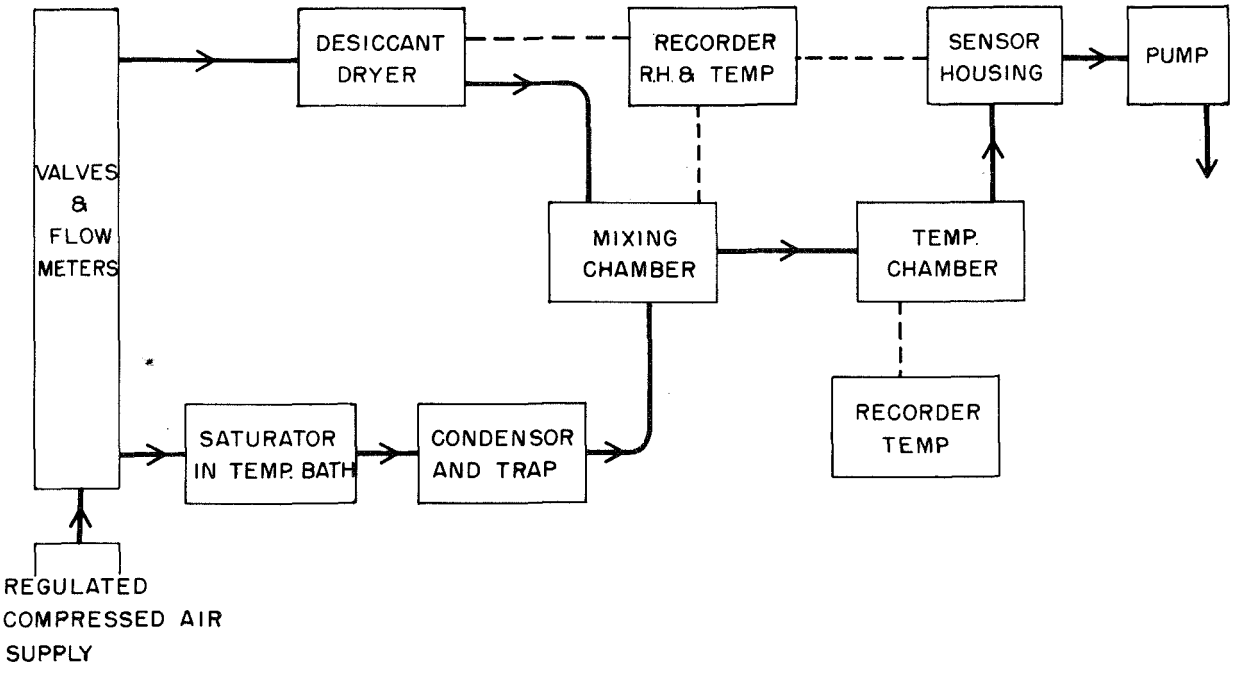

Figure 1. Relative Humidity Control System A

Room air is dried in one leg of the system to less than 1 percent RH by passing it through a desiccant bed. In the second leg of the system, air is saturated at a temperature slightly above room ambient and then cooled to room temperature, with excess moisture being condensed into a trap. The two flows are then mixed to provide a continuous airflow of 1 cfm with controlled relative humidity. The relative humidity is continuously measured and recorded at three different points in the system. Each component of the system, along with its function and operation, is explained below.

Air Supply--The air supply for the system was originally furnished by a small portable compressor but is now taken from the building air supply because this is a more reliable source for long-term experiments. The air pressure is maintained at 10 to 15 psi by a regulator; the airflow is precisely metered through a tapered needle valve, and measured with 1 cfm full flow meters on each leg of the system.

Desiccator--A closed container with about 15 pounds of desiccant suspended in the center section provides air for the dry leg of the system. Air enters the container from the bottom, passes up through the desiccant bed, and out through the top to the mixing chamber.

Saturator--The saturating apparatus consists of a 1-gallon plastic bottle immersed in a constant temperature water bath. Air enters the bottle through a fritted glass gas dispersion tube, is dispersed through water in the bottle thereby increasing its moisture content, and passes out of the bottle into a condensor.

Condensor and Trap--The condensor consists of about 15 feet of 1/4-inch copper tubing formed in a coil and suspended in the ambient air with the lower end connected into the top of a 1/2-gallon plastic bottle. This permits any condensed moisture to gravity flow into the bottle with the air passing out of another connection in the top of the bottle to the mixing chamber.

Mixing Chamber--This is an air-tight container into which air is admitted from both the dry and moist legs of the system, is mixed, and passes on to the temperature chamber.

Temperature Chamber--Although it is not a part of the humidity control system, the temperature chamber is an integral part of the apparatus for the thermoradiation studies. It is located inside the gamma irradiation cell while the controller and recorder are outside the cell. The objective of this entire humidity control system is of course to provide a closely RH-controlled air supply to the temperature chamber.

Air Pump--This small pump provides the suction to draw an air sample of about 0.1 cfm from the temperature chamber through a sensor housing. The air is then exhausted into the ambient from the pump.

Humidity and Temperature Sensors--The temperature and RH of the air is continuously monitored at the following points: (1) in the desiccator, (2) in the mixing chamber, and (3) in the sensor housing containing the sample air drawn from the temperature chamber. The lithium chloride sensors are the narrow range type covering a range of about 10 to 15 percent RH and 10^{0}F. Sensors are cable connected to multipoint recorders.

Recorders--The temperature and RH of the air at the three locations mentioned above are recorded on a Honeywell, multipoint, strip chart recorder. The sensors and recorder were calibrated as a system in the Sandia Primary Standards Laboratory. A single-point, Honeywell, strip chart recorder is used to continuously record temperature in the temperature chamber with a thermocouple.

Connecting Tubing--Tygon tubing is used for the connection between the air supply and the mixing chamber. Copper tubing is used from the mixing chamber to the temperature chamber to minimize hygroscopic action in the tube walls.

Results

The system provides RH control of ± 1 percent of the desired value as measured in the air sample drawn from the temperature chamber. This degree of control is considered adequate for the thermoradiation studies.

We found that the RH of the air sample drawn from the temperature chamber will vary from that of the input air (measured in the mixing chamber) to the temperature chamber. Factors which significantly affect RH measurements at both points are:

1. Ambient air temperature changes
2. Variations in air pressure at different points in the system
3. Leakage of ambient air into the system
4. Hygroscopic action of the materials which the air contacts within the system
5. Degree of dryness of the desiccant

When these factors are controlled to reasonably constant levels, the two RH values are constant and there is a minimum of variance between the values at the two measuring points. Under these conditions, the RH value of the input air can be controlled to less than ± 0.5 percent of the desired value. This degree of control was achieved in the range of 10 to 60 percent RH at room temperature. The difference in RH value of the air sample drawn from the temperature chamber is attributed principally to a slight difference in air pressure and leakage of ambient air into the oven.

System B

Equipment and Operation

The purpose of this system is to provide a continuous source of air with controlled and stable RH over periods of time ranging from 24 hours to 30 days. This implies the need for a system which would require no manual adjustments and only a minimum amount of monitoring to assure continuous and reliable operation.

Based on the curves in Figure 2, it is shown that RH can be controlled in a closed system by controlling the temperature at which the air is completely saturated. For example, air which is saturated at $3^{o}C$ will have an RH of 28 percent at $22^{o}C$ and 0.6 percent at $105^{o}C$.

The items of laboratory equipment comprising System B are shown in a schematic (Figure 3). The primary items are a saturator, two temperature baths, humidity sensors, a temperature chamber, and humidity and temperature recorders.

Ambient air under pressure enters the system through a flow meter at the rate of 1 cfm. The air is then directed through a fritted glass gas dispersion tube submerged in a bottle of water which is located in a

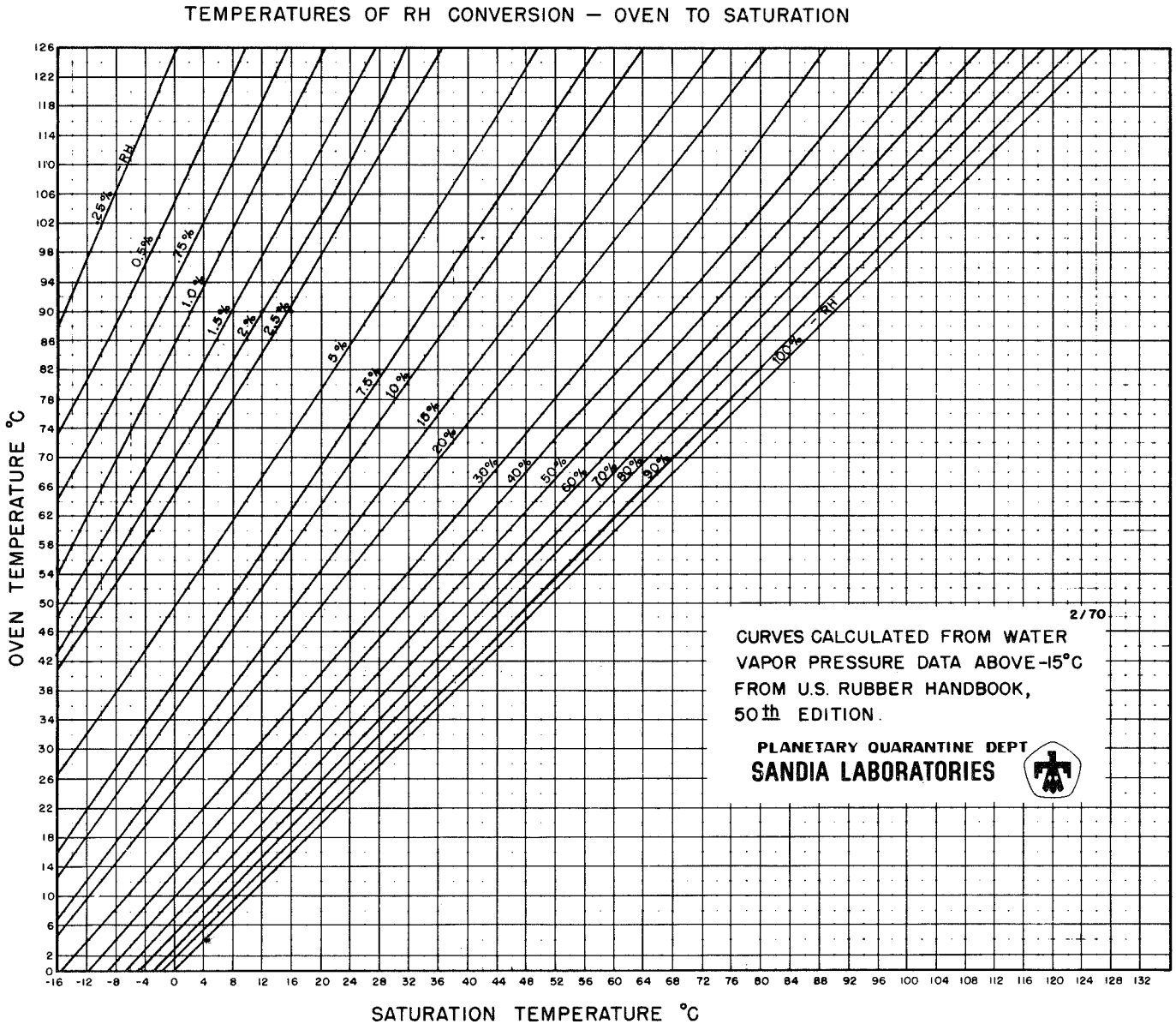

Figure 2. Temperatures of Relative Humidity Conversion

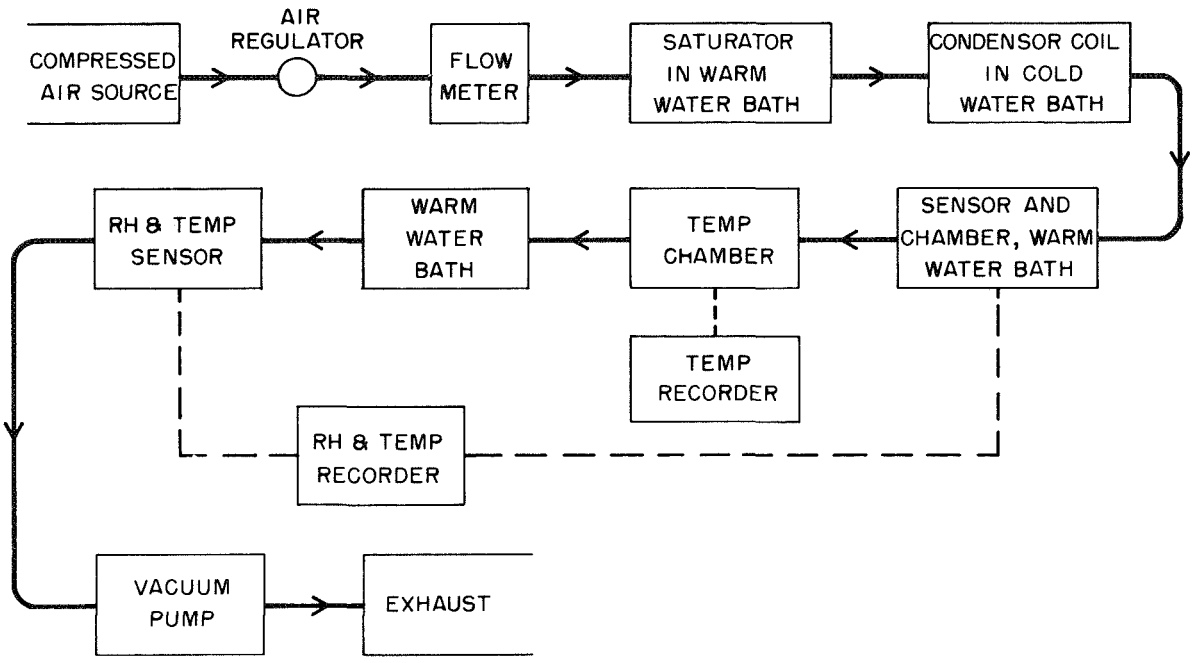

Figure 3. Relative Humidity Control System B

constant temperature water bath at 26°C. This temperature was selected because it is slightly above room ambient and not subject to variations in room temperature. The air then proceeds through coils in a cold constant temperature bath where complete saturation is achieved by reducing the temperature. Excess moisture is condensed into a trap. The large volume (50 gallons) of the cold water bath facilitates maintaining a constant bath temperature to ±0.1°C.

The air is warmed again to 26°C, the relative humidity is measured, and the air is introduced into the temperature chamber where microbial inactivation experiments are conducted. A continuous air sample is withdrawn from the chamber and cooled to 26°C, and the RH is again measured and recorded.

The temperature and RH are measured by specific range LiCl sensors. The sensors and multipoint strip chart recorders are calibrated as a system by Sandia's Primary Standards Laboratory. As a result, RH measurements are accurate to ±1 percent at ambient conditions.

Results

The system has been operated at saturation temperatures (cold water bath) of $3^{o}C$, $6^{o}C$, and $12^{o}C$. With both constant temperature baths operating at the desired temperature, the system equilibrates in about 30 minutes.

No significant deviations from the RH values on the conversion chart have been observed in the input air to the temperature chamber over periods of 24 hours. The RH of this air is held constant to within ± 1 percent at $26^{o}C$.

Some variation was noted between the RH of the input and output air. This difference is attributed principally to leakage of ambient air into the temperature chamber and will vary with the difference between the ambient RH and system air RH. In addition, differences in air pressure at the two measuring points will contribute to differences in RH values. It was determined during our experiments that the output RH varied from the input RH by +0.5 to -2.0 percent at $26^{o}C$. This represents a difference of less than 0.1 percent RH at $105^{o}C$, a temperature which is frequently used for our experiments.

Conclusions

The development of these two humidity control systems has demonstrated that humidity can be closely and predictably controlled in a closed system. It was evident that precise RH control requires accurately calibrated sensing and recording equipment. It was also shown that the ability to achieve and maintain a desired RH at a given temperature is dependent on the ability to eliminate the effects of ambient environmental changes.

Although both systems satisfy the needs of the microbial inactivation studies, a comparison of the two revealed that precise RH control over long time periods can be more easily achieved by controlling air temperature in System B than by controlling air mixing as used in System A.

Continuation of Work

This project is essentially completed since these systems are operating satisfactorily. We anticipate, however, that additional refinements will be made to further improve the systems.

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