A Plant Fumigation Chamber Suitable for Forestry Studies

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Mention of commercial products or equipment by name does not imply endorsement by the USDA in preference to other similar items.

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ABSTRACT

A lean-to greenhouse with a volume of 8.4 m^3 is being used to expose potted trees as tall as 2 m to air pollutants. Desired temperature is maintained by an air-conditioner and electric strip heaters. Pneumatic mist nozzles and steam are used to keep relative humidity at specified levels. Sunlight is used for illumination. Phytotoxicants, introduced into the chamber through tubes leading into the air duct system, are monitored with automatic analyzers. Ozone concentrations from 0.0 to 1.0 ppm and sulfur dioxide concentrations from 0.0 to 5.0 ppm can be maintained by manual adjustment of flowmeters or by a recorder-controller. Temperature control can be maintained at ± 1.0 C, and humidity at ± 5%. Humidities near saturation are possible when the air conditioner-compressor is not needed; above 21 C, somewhat lower humidities must be used when cooling is necessary. This chamber differs from similar ones in that it provides, at a relatively small investment, good control of a wide range of temperatures and humidities independent of outside conditions. The chamber is simple to operate and requires little maintenance. Phytopathology 60:1613-1615.

Additional key words: sulfur dioxide, exposure chamber, phytotoxicants, ozone.

Air pollution studies have required specially constructed environment chambers more frequently than other kinds of disease studies. Chambers used have varied widely in design from very simple, inexpensive arrangements of blowers and plastic bags (2) to specially constructed, highly sophisticated chambers with fine control of light, temp, humidity, wind speed, and gas concn such as the one described by Hill (6).

Indeed, only recently have exposure chambers become available commercially. Commercial models are currently in use at the Agricultural Research Service Station at Beltsville, Md. (H. E. Heggestad, 1968, *personal communication*); at Boyce Thompson Institute, Yonkers, N.Y. (J. S. Jacobson, 1969, *personal communication*); and at the Center for Air Environment Studies at The Pennsylvania State University, University Park, Pa. (11). In addition to those already cited, the following authors have described plant exposure chambers representing a variety of designs and a wide range of construction costs: Adams (1); Cantwell (3); Costonis (4); Heck et al. (5); Hitchcock et al. (7); Katz et al. (8); Menser & Heggestad (9); Thomas et al. (10); and Zimmerman & Hitchcock (12). Some of the first controlled sulfur dioxide fumigations of plants were carried out by Thomas et al. (10) in chambers of their design at the American Smelting and Refining Co. in Salt Lake City, Utah. These chambers were large (2 × 2 × 2.3 m estimated), and although temp was not thermostatically controlled, there was sufficient air exchange to maintain temp at ambient levels.

In over-all construction, chambers described by the above authors could be grouped into the following types: (i) small modified greenhouses; (ii) simple plastic enclosures for use in greenhouse or laboratory; (iii) modified plant growth chambers, walk-in cold rooms, etc.; and (iv) plastic chambers designed to fit in and utilize environmental control of a plant growth chamber. Numbers (i) and (ii) rely on daylight for illumination; (iii) and (iv) use artificial light.

Generally, two basic systems of airflow have been employed to handle air and gas mixtures: recirculating, where only a small amount of "makeup" air is added; and single-pass, particularly useful with fluoride studies in which corrosion and surface adsorption may be a problem. Better control can be obtained with the recirculating system; it is usually used when gas mixtures are not particularly corrosive and continuous gas analyzers can be used for control and monitoring. Most chambers could be designed to operate with either a slightly positive or slightly negative internal pressure. Generally, however, a chamber designed for positive pressure is easier to construct because it will not become contaminated if small leaks occur. Costonis' use (4) of positive pressure in a portable field chamber not only allowed better control of the internal environment but also eliminated the need for structural support.

Materials and Methods.—The chamber described herein is designed for positive pressure and recirculating air. It is a modified lean-to greenhouse (Everlite Model B-3, Aluminum Greenhouses, Inc., Cleveland, Ohio) attached to a small building that serves as an equipment and control shed (Fig. 1). It is of moderate cost, can be built by semiskilled labor and local contractors, is comparatively large in size (ca. 8.4 m^3), and is readily controllable with respect to temp, relative humidity, and phytotoxicant concn. No attempt was made to incorporate provisions for controlling air velocity or light. The air-conditioner fan, which runs continuously, is used to circulate air by means of duct work (Fig. 2) through the chamber from top to bottom (Fig. 3) at a constant rate, providing the equivalent of three air changes/min. Although artificial light could easily be added, daylight is the only source of illumination. Light levels, therefore, are approximately the same as in nearby greenhouses.

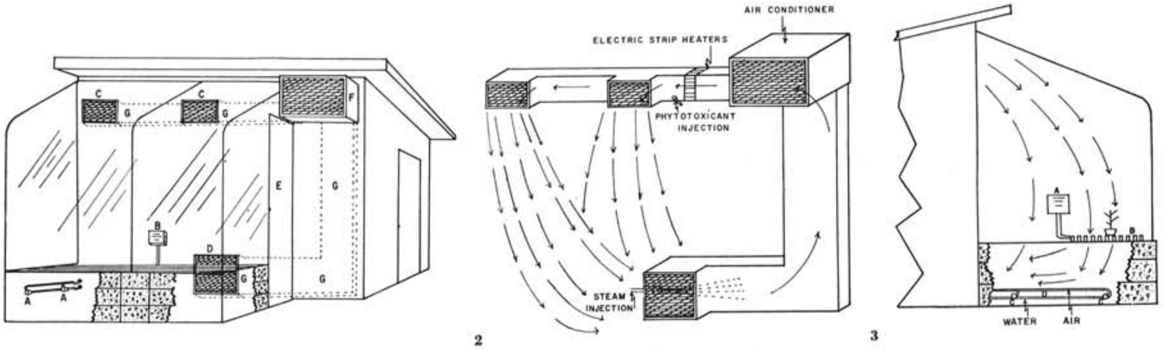

Fig. 1-3. 1) Fumigation chamber: (A) pneumatic nozzles; (B) instrument shelter containing wet- and dry-bulb thermostats; (C) air inlet ports; (D) air exit port; (E) entrance to chamber; (F) air-conditioner; (G) air ducts. **2)** Arrangement of air duct system to the chamber. **3)** Side view of chamber: (A) instrument shelter; (B) bench; (C) pneumatic nozzles; and (D) air and water supply lines. Arrows indicate airflow.

Temperature control.—Two electric strip heaters, each rated at 660 w, are located in the air duct (Fig. 2). These have adequately maintained inside temp at 27 C when ambient temp were as low as −4 C. Heaters are controlled by mercury-in-glass thermostats placed in an aspirated louvered shelter (Fig. 1, 3). Temperature as measured by thermistors can be controlled to ± 1.0 C within the range of about 16 to 35 C or higher. Thermostats and necessary relays for both temp and humidity control were obtained from the H-B Instrument Co., Inc., Philadelphia, Pa.

When temp in the chamber rises above the desired level because of high ambient temp or high solar radiation, the air conditioner-compressor is automatically turned on by an electronic controller activated by a thermistor taped to the inside surface of the glass roof. The air conditioner-compressor, rated at 6 kcal (24,000 BTU), runs continuously while strip heaters cycle on and off until the sun goes down or ambient temp falls.

Humidity control.—Two methods of maintaining high humidity are used. One is by injection of steam supplied from a central source or an auxiliary steam generator into the air ducts. Steam control is accomplished by a "wet-bulb" mercury-in-glass thermostat which opens a solenoid valve in the steamline when the wet-bulb temp falls below the required level. The wet-bulb thermostat, also from the H-B Instrument Co., is located near the dry-bulb thermostat in the aspirated louvered shelter (Fig. 3). The desired relative humidity is obtained by selecting a thermostat that will give the appropriate depression below the dry-bulb temp. When the air conditioner-compressor is running, the resultant drying of air makes additional humidification necessary. This moisture is provided by two pneumatic nozzles (manufactured by The Bahnson Co., Winston-Salem, N.C.) which discharge mist at the rate of 2.7 kg/hr when connected with a source of air compressed at 1,761 g/cm^2 (25 psi) and water pressurized at 1,833 g/cm^2 (26 psi). Mist from these nozzles is directed horizontally about 30.48 cm above the floor in the chamber (Fig. 3).

Humidity control of ± 5% can be attained at ranges of approximately 30% to near saturation at any selected temp when cooling by the air-conditioner is not needed. When cooling is required, humidification is more difficult, but relative humidities as high as 80% can be attained readily at 27 C. Flexibility over a wide range of temp and humidity combinations in a chamber such as this depends greatly on cooling capacity of the air-conditioner. The air-conditioner used here has sufficient capacity to counteract the abnormally high summer temp and humidities that occur occasionally in this area. For more moderate conditions, however, such as occur on warm fall, winter, and spring days, a smaller air-conditioner would suffice and permit somewhat easier control of relative humidity. It should also be mentioned that more efficient humidification could be obtained if steam or mist were added after the air had passed through both the air conditioner and heaters. The arrangement used in this facility, though somewhat less efficient, permitted a more simplified arrangement of plumbing and air ducts.

Phytotoxicant control.—Sulfur dioxide and ozone are the only fumigants that have been used to date in this chamber. Concentrations may be controlled manually by adjustment of flowmeters or automatically by a microswitch controller attached to a strip chart recorder; i.e., a recorder-controller (Fig. 4). With this method a microswitch is situated so it can be opened or closed by a recorder pen. The switch in turn activates a solenoid valve regulating the flow of phytotoxicant into the air duct. Controllers similar to this have been used in other chambers (2, 4, 6) and have proven to be completely satisfactory as well as inexpensive. Concentrations of either gas from 2 or 3 pphm to 1.0 ppm ± about 10% can be maintained.

Sulfur dioxide (commercial grade 1% mixture, The Matheson Co., Inc., East Rutherford, N.J.) is metered into the air ducts through a solenoid valve and flowmeters and 3.2-mm stainless steel tubing. Ozone is obtained by passing commercial grade oxygen through a 10-cm-diam glass tube containing an ultraviolet lamp (Ultraviolet Sterilamp G-37 T6 VH, Atlantic Ultraviolet Corp., Long Island City, N.Y.). Ozone is also metered into the air ducts through a solenoid valve, flowmeter, and stainless steel tubing.

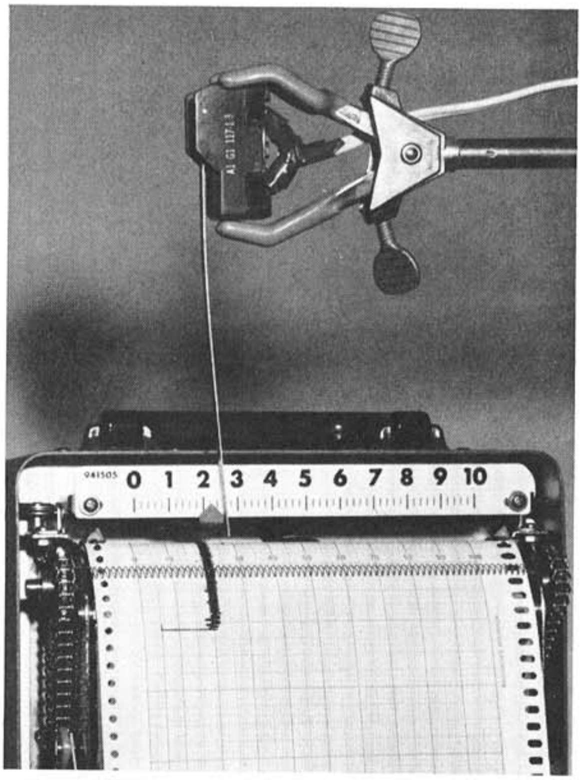

Fig. 4. Microswitch used to control concn of ozone and sulfur dioxide by activating a solenoid valve. Here ozone is being controlled at the 20 pphm level by a Varian recorder.

Contamination.—A blower (Barnebey-Cheney Co., Columbus, Ohio) with a capacity of 14.0 m^3/min (500 cfm) supplies charcoal-filtered air as makeup and provides a slight positive pressure, thereby preventing ambient air from diffusing into the system.

Although the system is recirculating, or closed in design, in reality there are spaces, particularly around the door, where chamber air can escape slowly, resulting in a gradual replacement of all air in the chamber. This replacement is not fast enough to affect gas concn, temp, or humidity control, but is believed adequate to prevent buildup of terpenes or any volatiles that might inadvertently be introduced. Carbon-filtered makeup air is first introduced in the control shed, thereby assuring the operator a supply of uncontaminated air. A loose-fitting window which separates the control shed from the chamber provides for a gradient of pressure between these two areas. The end result, however, is a slight positive pressure in the fumigation chamber and a somewhat higher positive pressure in the control shed.

DISCUSSION.—A plant fumigation chamber in use at the Bent Creek Experimental Forest near Asheville, N.C., is described. The chamber is a modified lean-to greenhouse with a volume of 8.4 m^3, large enough to accommodate trees up to 2 m tall, but equally suitable for fumigation of small plants. Temperatures from 16 to 35 C can be selected and maintained by electric strip heaters alone or in conjunction with an air conditioner. The air conditioner fan is operated full time to recirculate chamber air, and only the compressor is turned off when cooling is not needed. A circulation rate equal to three air changes/minute is afforded. Humidity is raised by use of steam and pneumatic mists or lowered by dehumidification with the air conditioner's cooling coils. Both wet- and dry-bulb temp are controlled by mercury-in-glass thermostats, the wet-bulb thermostat being fitted with a wick. Desired humidities up to near saturation are possible when cooling is not needed. When cooling is needed, somewhat less than saturation must be used above 21 C. Relative humidity of 80% at 27 C is readily obtainable even when cooling is required. Ozone concn from 0.0 to 1.0 ppm and sulfur dioxide concn from 0.0 to 5.0 ppm can be maintained either by manual adjustment of flowmeters or by a recorder-controller. Other gaseous phytotoxicants may also be used if available in compressed form, providing a suitable automatic analyzer-recorder is available. The chamber can be constructed by local contractors at a cost of about $5,000. All equipment except gas handling equipment, mercury-in-glass thermostats with appropriate relays, and gas analyzers and recorders should be available in most localities.

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