GREENHOUSE OXYGEN DEPLETION BY UNVENTED HEATERS

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Many articles have appeared lately that warn of the dangers of using unvented heaters in greenhouses. This is a real danger to both plants and people. Here are some figures on how short a time they can be used in an emergency and how little heat can be safely supplied on a continuing basis.

First, let us restrict our thoughts to a greenhouse of at least 2500 square feet with an average height of eight feet, or a volume of 20,000 cubic feet. The danger of operating unvented heaters increases as the greenhouse size decreases.

Next, let us consider propane as the fuel and adjust our parameters for other fuels later in this paper.

Here are a few guidelines concerning heat requirements.

1. A single glazed polyethylene house or a loose glass house will require about 2 BTU/sq. ft./hour to raise the temperature 1°F.

2. A double poly cover or thermal blanket may decrease the heat requirement 30%; 1.4 BTU/sq. ft./hour is required.

3. Other heat retention practices such as north wall insulation will decrease heat requirements further.

4. The minimum oxygen level for burners to operate properly is considered to be 18.9% O_2 (a 2% depletion). At 18%, modern gas burners are supposed to shut off automatically. At 17%, human discomfort is pronounced.

IT SHOULD NOT BE CONSIDERED SAFE TO BURN 50 BTU/SQ. FT./HR. FOR MORE THAN 2 HOURS WITHOUT VENTILATION.

If 50 BTU/sq. ft./hr. are supplied to provide 25° protection (to keep a single poly house from freezing when the outdoor temperature is above 10°), the oxygen will be depleted to 18.9% in just two hours.

This means that it should be safe to supply 25 BTU/sq. ft./hr. for 4 hours without ventilation and provide at least 12° protection. However, at this rate the air infiltration will provide some oxygen and thus extend the safe time.

Figure 1 shows oxygen depletion at 40 BTU/sq. ft./hr. with various infiltration rates. Note that an air infiltration rate of 1/2 exchange per hour may provide enough oxygen to maintain an adequate oxygen level. But few greenhouse operators know how much air is entering a greenhouse. A tight poly house, poly over glass or lapsealed glass house could quite likely have an exchange rate of less than 1/4 per hour, especially when inside surfaces are frost covered.

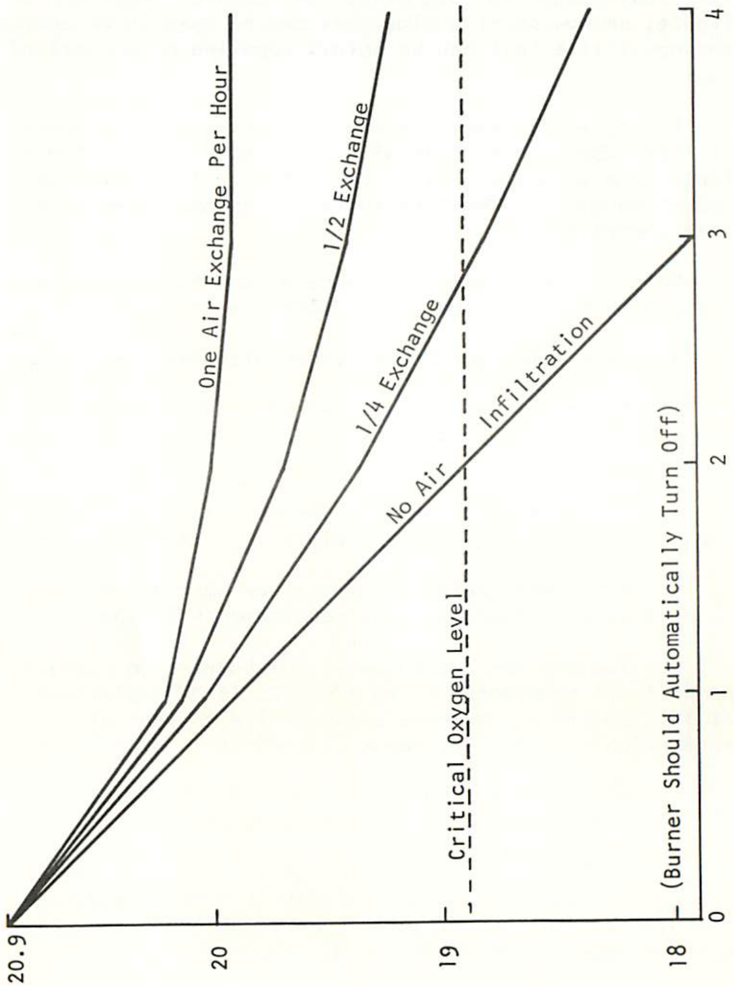

Figure 1. Oxygen depletion by a propane burner providing 50 BTU/sq. ft./hr. as influenced by air infiltration rates.

Do other fuels use up oxygen at the same rate? No. Kerosene or fuel oil requires less O_2, natural gas more O_2 per BTU produced. But oil burners are more sensitive to low oxygen levels and incomplete combustion may occur sooner than with gas.

For safety, provide outdoor air to the burner or use the figures for no air infiltration.

There are other dangers to be considered. If your burner is not adjusted to provide an excess of air, undesirable by-products of combustion may occur which will damage plants. If the fuel contains excessive sulfur, plant damage is certain to occur, especially with prolonged usage and particularly if kerosene is the fuel. Be certain to use the kerosene labelled 1-K which contains less than 0.4% sulfur by weight.

Two percent of the oxygen is 40,000 ppm. Burning propane with it is equivalent to 24,000 ppm CO_2. Over 5,000 ppm is considered to be hazardous to humans. Over 3,000 ppm may affect plant growth while 20,000 ppm is reported to cause notable plant injury. This means that high CO_2 levels may well be the most hazardous by-product of the use of unvented heaters in greenhouses.

A paper by Lavagetto and McNeil (1964) reports that CO_2 does not reach high levels under greenhouse conditions. CO_2 is soluble in water and, under their conditions, equilibrium was reached at about 2700 ppm. They found that the soil was absorbing CO_2 and becoming more acid, dropping from a pH of 6.0 down to 5.). Can it be assumed that plant tissue was likewise "supercharged" with CO_2? If so, the stomates would remain closed but photosynthesis would proceed uninhibited by CO_2 insufficiency until much of it had been used by the plant. This would suggest that high CO_2 levels may result in problems but that excessive levels in the atmosphere are not a primary hazard to people.

There is also a danger reported from England that propylene may occur in propane gas and that leaks could cause plant damage. Propylene is detrimental to plant growth, being related chemically to ethylene.

ADDENDUM

The above conclusions are based on the following calculations.

Assume a greenhouse 25 x 100' with an average height of 8'. It will contain 20,000 cu. ft. of air. If covered with single polyethylene, 20 BTU's per sq. ft. per hour should raise the temperature about 10°, enough to provide heat during a spring cold spell or a power failure. This is 50,000 BTU for this 2500 sq. ft. house.

Consider a propane burner with this data:

Propane data

A gallon weighs 4.24 lbs. and provides 92,000 BTU
A pound provides 21,700 BTU, an ounce = 1360 BTU
50,000 BTU will be provided by 36.9 oz. propane
Burning each ounce of propane requires 2.18 oz. oxygen and produces 3 oz. carbon dioxide.

Air data

Air is about 20.9% 0_2 by bolume, about 23% by weight.
At 60°, dry, 1 lb. = 13.2 cu. ft. or 1.212 oz./cu. ft.
1.212 oz. x 23% 0_2 = .28 oz. 0_2/cu. ft. air
A cu. ft. 0_2 = 1.34 oz. (1.43 oz. @ 0°C.)
A cu. ft. 0_2 will provide 622 BTU from propane combustion.

Our greenhouse example contains 20,000 cu. ft. of air which contains (20,000 x 20.9%) 4180 cu. ft. 0_2. If 0_2 weighs 1.34 oz./cu. ft., there will be 5600 oz. 0_2 in the house. If the 50,000 BTU propane burner uses 36.9 oz. propane/hour, it will consume (36.9 x 2.18) 80 oz. 0_2/hour, this is (80 ÷ 1.34) 60 cu. ft. of oxygen.

Assuming that the burner is adjusted to a lean flame and that it will burn properly with a 2% oxygen reduction in the atmosphere, there are [4180 - (4180 x 79.1%)] 400 cu. ft. of oxygen available for burning propane. This is enough oxygen to produce (400 x 622) 248,800 BTU's from burning propane. In a 2500 sq. ft. house, this is 100 BTU/sq. ft. One could therefore have a burner producing 20 BTU/sq. ft./hr. for five hours or 40 BTU/sq. ft. for 2 1/2 hours before the oxygen was depleted by 2%.

Greenhouses are not air tight. Let us assume 1/4 air exchange per hour and that the greenhouse air has been depleted to 18.9% 0_2. There will be (20,000 x 25%) 5000 cu. ft. air entering per hour. It contains (2% of 5000 cu. ft.) 100 cu. ft. more oxygen than the air which exited. It will supply all of the oxygen necessary for combustion to maintain an equilibrium of 18.9% 0_2 in the greenhouse when 62,300 BTU are being produced (25 BTU/sq. ft. in a 2500 sq. ft. greenhouse).

Expanding upon this, 1/2 air exchange per house will support 50 BTU/sq. ft./hr. at 18.9% 0_2 equilibrium. The CO_2 equilibrium will be 24,000 ppm.

Now, suppose that a 100,000 BTU burner is used to provide 40 BTU/sq. ft./hr. in this 2400 sq. ft. greenhouse. Since each 622 BTU's requires a cu. ft. of 0_2, 160 cu. ft.

O_2 per hour will be required. If 1/4 air exchange per hour provides 100 cu. ft. O_2, this air exchange per hour would not provide enough O_2 for continued use. It would be extremely dangerous.

Let us repeat. Unvented heaters are useful for emergency heating. They have very limited capabilities for continuous use. When using such heaters, fresh air supplied by a 4 to 6" pipe to the outside may be necessary to provide the oxygen necessary for complete combustion.

One final suggestion. Grow a tomato in your greenhouse. Tomatoes are sensitive to many forms of air pollution and may serve as an indicator if anything is going wrong.

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