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AN ABSORBER FOR THE REMOVAL OF CARBON DIOXIDE FROM CONTROLLED-ATMOSPHERE STORAGE

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AN ABSORBER for the efficient removal of the excess carbon dioxide produced by fruit in controlled-atmosphere storage has been designed, constructed and field-tested. The absorber, designated as the M.S.U. absorber, utilizes the recirculating principle of the barrel absorber developed by Smock and VanDoren,[2] and the open type reservoir used in conjunction with the brine-spray absorption system commonly employed in the Hudson Valley area of New York state.[3]

The M.S.U. absorber, which operates independently of the refrigeration system of the storage room, has several unique features: a packed absorption column, a high rate of absorption fluid flow, and a low rate of airflow. These features give a high rate of carbon dioxide absorption relative to the physical size of the unit and a high efficiency of materials and power.

The absorber, although designed for a storage room capacity of 10,000 bushels of McIntosh apples stored under 5 percent CO_2 and 3 percent O_2 at 38° F., can be used satisfactorily with larger and smaller rooms. A schematic diagram of the complete absorption system, which includes the absorption tower, reservoir tank, circulating pump, airblower and connecting piping, is illustrated in Fig. 1.

[1]The authors acknowledge and thank Dr. C. M. Cooper of the chemical engineering department, and Pio Angelini and Glenn Shiffer of the agricultural engineering department, Michigan State University; and the following fruit storage operators: Vernon Bull, W. A. Schaefer, John Schaefer, Erwin Klenk and Ralph Succop for their interest, assistance and cooperation in this project.

[2]Smock, R. M., and A. VanDoren (1941). Controlled-atmosphere storage of apples. Cornell Univ. Agr. Expt. Sta. Bul. 762. 45 pp.

[3]Kedenberg, Frank, Jr., (1953). This CO_2 control cuts apple storage costs. Food Engineering 25 (3): 126-127.

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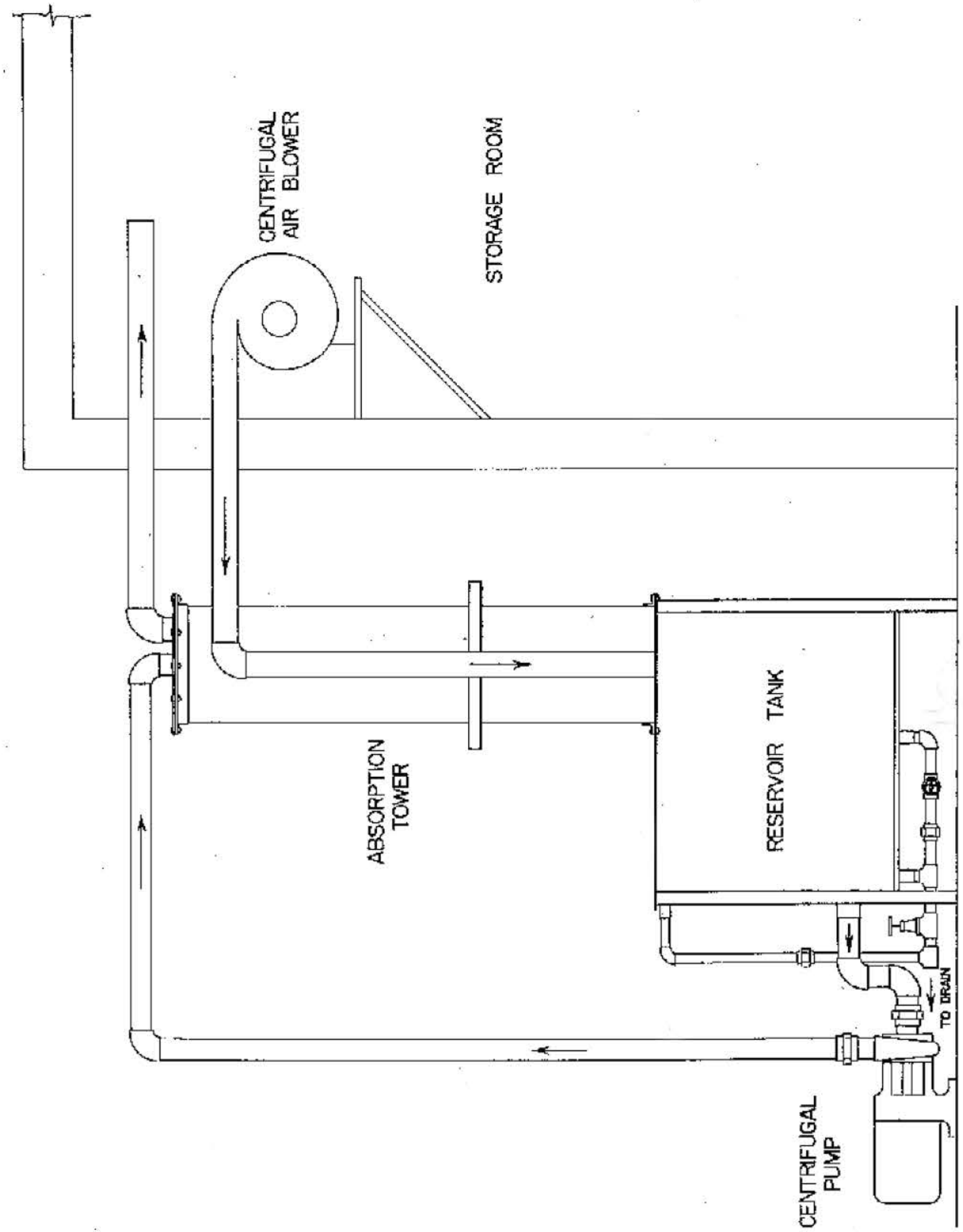

Fig. 1. Schematic diagram of the M.S.U. absorption system.

PRINCIPLE OF OPERATION

The atmosphere of the CA-room is forced by an air-circulating blower through the absorption tower. It enters the tower beneath the packing at a point just above the liquid level of the filled reservoir and returns to the room from the top of the tower. The liquid is pumped from the bottom of the reservoir into the top of the tower, where it flows over the packing in contact with the room atmosphere and drains into the reservoir. The carbon dioxide of the storage room air is absorbed upon contact with the liquid charged with caustic soda.

ABSORBER DESIGN

Absorption Tower: The component parts of the absorption tower are shown in Fig. 2. The absorber body, with dimensions of 14 by 14 by 84 inches, is made from 12-gauge sheet steel. It has a flange at the top for securing the cover and an air inlet on the side below the level of the packing basket. The tower cover, made of quarter-inch steel plate, serves as the mounting unit for the liquid header and the air outlet.

The tower packing basket is a separate unit in order to simplify the tower construction. The basket is made by welding the preformed expanded metal basket to the steel frame. The tower contains 5 cubic feet of 1-inch Interlox[4] saddle packing with about 350 square feet of surface area. The absorber tower is supported by three sides of the reservoir.

Reservoir: The absorbing fluid reservoir is 24 inches wide, 36 inches long, and 36 inches high; it has a capacity of 100 gallons. The frame of the reservoir is made from 1½- by 1½- by ¼-inch angle iron; the sides, ends and bottom are made from 12-gauge sheet steel. The reservoir has a baffle 6 inches high that divides the bottom of the tank into two 24- by 18-inch areas.

The absorption tower is located in the section opposite the location of the circulating pump inlet (Fig. 1). The baffle holds 6 inches of liquid to assure a positive seal of the bottom of the absorption tower. Both sections of the reservoir contain drain connections; however, in normal operation, the section that serves as a trap for the absorption tower is not drained. The reservoir is also equipped with an overflow.

[4]United States Stoneware Company, Akron, Ohio.

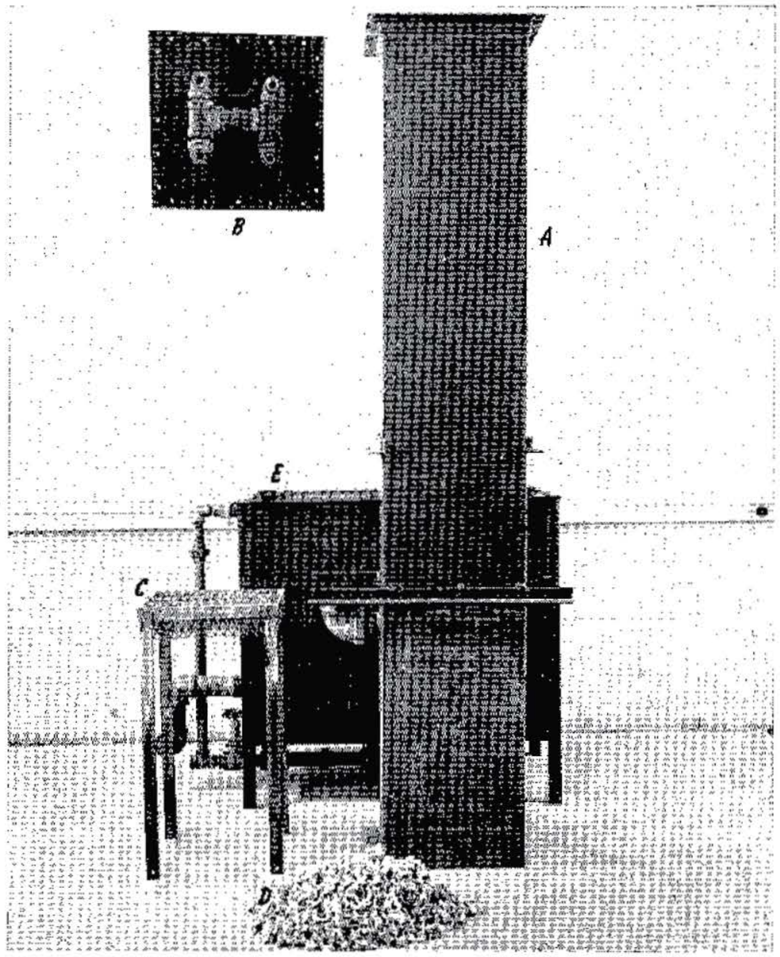

Fig. 2. Absorber components: (A) absorber body (B) tower cover, (C) packing basket, (D) packing, (E) reservoir.

Advantages offered by the open type reservoir are ease of filling and charging, ready inspection, and ease of cleaning.

Circulating Pump: The M.S.U. absorber was designed for an all-iron, one-half horsepower, 1,750-revolutions per minute (r.p.m.) high volume centrifugal pump with a 2-inch suction and a 1½-inch discharge which will normally give a desired flow of 60 gallons per minute (g.p.m.) The electric motor of the pump should be grounded and adequately protected against overload.

Air Blower: The air blower must have pressure-volume characteristics to move a minimum of 60 cubic feet per minute (c.f.m.) against a pressure of 3.50 inches of water gage. There are several commercial units available that meet these requirements; they are called blowers, pressure blowers, or utility pressure blowers. The size required will probably have a ⅛-horsepower motor and operate at 3,450 r.p.m. Selecting a fan that is too large is not economical in original or operating cost, and it may reduce the efficiency of the absorber by unduly cooling the absorbing solution.

Connecting Units: The liquid circuit consists of 2-inch pipe from reservoir to pump and 1½-inch pipe from the pump to the distributing header atop the absorption tower. The four header discharge openings are on 7-inch centers; nozzles are not used since the liquid stream is broken up sufficiently as it flows out through a three-quarter by half-inch n.p.t. reducing coupling.

If an open impeller pump is used, a strainer is not essential since a half-inch diameter particle will move through the pump and piping. The pump inlet is located 6 inches above the bottom of the tank to prevent heavy objects and sediment from being circulated.

The air connections of the CA-room to the absorber must be adequate in size and gas tightness. The use of 2½-inch steel pipe or 3-inch outside diameter (O.D.) steel or copper tubing and 3-inch inside diameter (I. D.) flexible tubing is a satisfactory combination if all air lines are short. The 2½-inch pipe is only 2⅞-inch O. D., but two layers of 2-inch wide vinyl tape will increase the diameter of this pipe to 3 inches. The 3-inch flexible tubing placed over the tape and secured with a hose clamp will make an airtight seal between hose and pipe. When the absorber is located away from the storage room, 4-inch connecting pipe or tubing should be used.

ABSORBER OPERATION

The operating characteristics of three M.S.U. absorbers installed and used commercially during the 1956-57 apple storage season have been extensively studied.

The results of tests on the effect of liquid flow rates of 20, 40, 60 and 80 g.p.m. with airflow rates of about 110, 90, 60 and 30 c.f.m., respectively, and a carbon dioxide level of about 5 percent are shown in Fig. 3. The rate at which carbon dioxide is absorbed is about the same for all four flow rates until the sodium hydroxide has been neutralized to sodium carbonate (50 percent utilization).

It is during the phase of the absorption cycle when the sodium

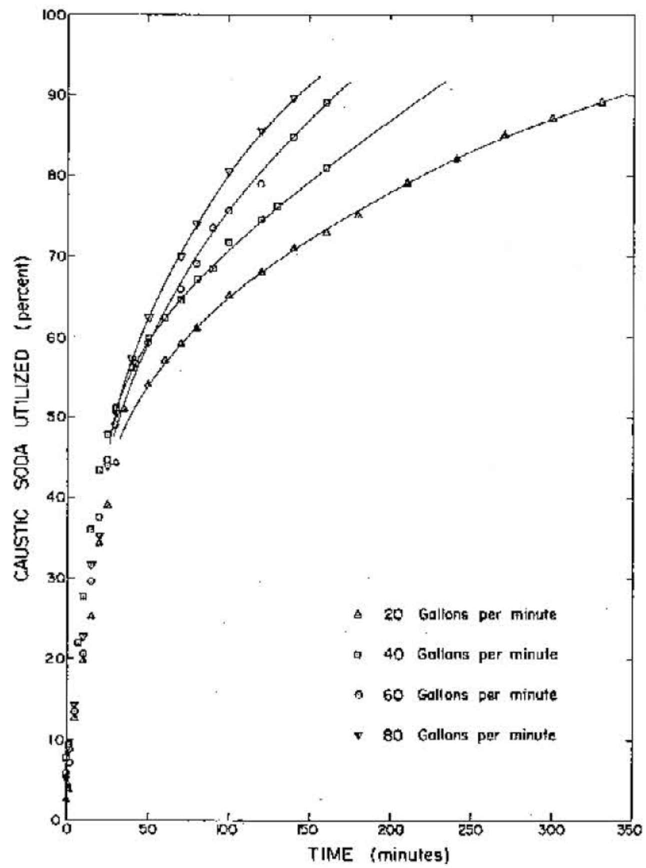

Fig. 3. The effect of the rate of liquid flow on the rate of caustic soda utilization.

carbonate is being neutralized to sodium bicarbonate that the flow rate is critical; increasing the liquid flow rate from 20 g.p.m. to 60 g.p.m. under these conditions more than doubled the rate of carbon dioxide absorption.

The effect of the quantity of caustic soda on the time (minutes-per-pound) to reach the 90 percent utilization point was determined for caustic soda charges of 5, 10, 15 and 20 pounds per 100 gallons of water. The carbon dioxide level in the commercial room was 5 percent, the liquid flow rate 60 g.p.m., and the airflow rate about 60 c.f.m. during these tests.

Concentration appears to have little or no effect since it was found that, regardless of the caustic charge, it required about 18 minutes-per-pound to utilize 90 percent of the caustic. The quantity of caustic soda that is used per charge is limited by the solubility of sodium carbonate which, in turn, varies with temperature.[5] The maximum quantity of caustic soda per 100 gallons of solution that will not form a sodium carbonate precipitate is 75.4 pounds for a solution temperature of 50° F., and 47.2 pounds for a solution at 35° F.

The operating time of the absorber is determined by the caustic loading and the desired degree of caustic utilization. Since the operating cost of the absorbing system is low, it is economical to fully utilize the caustic. Tests show that about 30 minutes (0.5 hour) is required to fully utilize each pound of caustic when a flow rate of 60 g.p.m. and up to 20 pounds of caustic per 100 gallons of water are used. Consequently, when charged with 10 pounds of caustic and operated under these conditions, the absorber should be run for 5 hours (0.5 hr./lb. x 10 lb. = 5 hr.) before draining.

Carbon dioxide should be removed from the CA-storage daily. The absorber reservoir should be filled and recharged each time the absorber is used, and the reservoir should be drained and flushed after using.

The unavoidable presence of drying oils, paint, pipe dope and other materials that react with caustic soda will cause foaming as the solution is circulated through the tower. This difficulty is readily corrected by the addition of 15 milliliters (half a teaspoon) of a commercial defoaming agent each time the absorber is recharged.

SUMMARY

A carbon dioxide absorber, designed for controlled atmosphere storages using dry-type refrigeration evaporators, provided satisfactory removal of the excess carbon dioxide from a 10,000-bushel capacity room of McIntosh apples. The absorber is independent of the refrigeration system and, since its recirculates a minimum quantity of air, it can be located away from the storage room. The packed absorption tower and open reservoir are efficient and compact.

The quantity of caustic soda employed for each charging depends upon the quantity of carbon dioxide to be removed and the temperature of the absorber solution. Each pound of caustic in 100 gallons of water was 90 percent utilized in about 18 minutes of operation; 30 minutes of operation for each pound of caustic soda per 100 gal-

[5]Pflug, I. J., Pio Angelini and D. H. Dewey (1957). Fundamentals of carbon dioxide absorption as they apply to CA-storage. Mich. Agr. Expt. Sta. Quart. Bul. 40: 131-138.

lons of water was needed to fully utilize the caustic when the solution was circulated at 60 g.p.m.

Efficient operation is facilitated by recharging the absorber with water and caustic soda after each charge is spent. Foaming can be prevented by the use of a defoaming agent.

Construction plans for the M.S.U. absorber are available from the agricultural engineering department, Michigan State University.