DETECTION OF LEAKS IN THE REGENERATION SECTION OF EGG PASTEURIZERS

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ABSTRACT

A method is proposed for the detection of leaks in the heat transfer surface of the regeneration section of an egg pasteurizer. When the unit is not in use, the raw side of this section is pressurized with a fluorocarbon refrigerant gas and air on the pasteurized side is then checked with a halogen leak detector for the presence of fluorocarbon. Laboratory tests indicate that presence of a hole too small for any flow of egg white under normal conditions can be detected. Some information is given on the flow of egg whites, air, and fluorocarbon gas through small holes. The problem of assuring that holes will not be plugged when tests are made was extensively investigated. Conditions required to use the method, based on laboratory tests, are indicated. The test method appears to offer a positive and practical means to determine presence of leaks in the regeneration section that might permit flow of raw to pasteurized product.

In the usual egg pasteurization unit the heat exchanger contains 3 parts: a heating section, a cooling section, and a regeneration section. In the latter, part of the heat in the pasteurized egg product coming from the holding tube is transferred to the incoming cold raw material. A positive displacement pump moves the product consecutively through one side of the regeneration section, the heating section, the holding tube, the other side of the regeneration section, and then the cooling section. On the first side of heat transfer plates in the regeneration section there is non-pasteurized material that may contain pathogenic bacteria; on the other side is a pasteurized product. With flow following the pattern described, pressure on the non-pasteurized side is higher than on the pasteurized side. If a leak occurs between these two sides, there will be flow from the non-pasteurized into the pasteurized product and the latter will be contaminated. The frequency of such leaks is apparently extremely low, but the possibility of such leaks and the resulting contaminated products has been of serious concern to people in the industry and to health and regulatory agencies.

The milk pasteurization industry has met the same problem since the same type of heat exchange equipment is used for milk. Their solution has been to use different pumping arrangements and to regulate the pressures on the two sides of the regeneration section so that the pasteurized product is always at a higher pressure than the raw material. If there is a leak in the heat transfer surface of the regeneration section of a milk pasteurizer, flow will be from pasteurized into raw product and the pasteurized product will not become contaminated. Two pumping arrangements are commonly used to accomplish this pressure relationship. If a single pump is used, it is located after the raw product side of the regeneration section so that the raw product is drawn through that side and is below atmospheric pressure. The rest of the system is under positive pressure. If a 2-pump system is used, the first pump precedes the raw product side of the regeneration section and a second pump follows. The first is a centrifugal, developing a limited pressure; the second is a positive displacement unit capable of greater pressure. Pressure regulating equipment is added to assure desired relative pressures. Certain other refinements of the system are necessary for control when starting operations and in the event of power failure.

The method used by the dairy industry has not been used by the egg industry. Egg products are more difficult to pump because of the wide range of viscosities and the presence of dissolved and entrained gases. High viscosities of some cold products result in large pressure drops across the raw side of the regeneration section. For these reasons suction is an impractical way to move egg products. A single pump placed after the raw side of the regeneration section, as used by the dairy industry, has not been feasible. The 2-pump system with pressure regulating equipment may be feasible, but to our knowledge, has not been tested on the various egg products. There may be a serious problem with pressure regulation because of pressure fluctuations and the range of pressures to be covered. Sudden pressure changes have been observed in egg pumping systems, possibly caused by gases that have separated from the liquid product and that go through the pumps as bubbles or foam. We now have a unit in a commercial egg pasteurization plant that is being altered so that problems of using a 2-pump system can be studied.

Until more is known about the feasibility of using pressure control in meeting the problem of possible leaks in the regeneration section of egg pasteurizers, other methods are needed. As described in the *Egg Pasteurization Manual* (3) current practice in plants operating under continuous United States Depart-

TABLE 1. DATA ON HOLES TESTED

Hole Number	Maximum air flow rate —	Equivalent diameter —	Pressure at start of flow —	Flow of egg white before plugging[a]	
				Average	Range
	(ml/min)	(Inches)	(psi)	(ml)	(ml)
A	630	.0065	.5	18	.2 to 39
B	540	.0060	.5	7.3	.5 to 29
C	500	.0058	.4	32	0 to 89
D	408	.0053	.5	21.	.06 to 44
E	346	.0048	.9	1.	.1 to 2.0
F	260	.0042	1.0	.5	.03 to 1.3
G	252	.0041	.5	27.	.5 to 73
H	164	.0033	1.1	.75	0 to 2.3
I	146	.0031	.9	.5	.2 to 1.2
J	104	.0027	.9	1.	.4 to 1.8
K	78	.0023	1.2	.1	0 to .4
L	67	.0021	1.3	.06	0 to .2
M	52	.0019	2.2	.02	0 to .03
N	44	.0017	1.2	.01	0 to .03
O	22	.0012	5.8	.01	0 to .01
P	21	.0012	2.6	.01	.01
Q	.50	.00018	19.	0	0
R	.25	.00013	47.	0	0

[a]For 12 trials on holes A through N, for 4 trials on holes O through R.

ment of Agriculture inspection is to depend on visual observations to prevent occurrence of leaks. The inspector checks all regenerative heat exchanger plates before each run not only for cleanliness but also for evidence of etching, corrosion, or cracking that might lead to leakage. Any suspected plates should be removed. The adequacy of this method of finding leaks has been questioned. The method proposed in this paper is a supplement to visual inspection and offers a sensitive and positive method of finding actual leaks of any type.

The heat exchanger is assembled and connections made so that the raw product side of the regeneration section can be pressurized with a fluorocarbon gas. R-12 (CCl_2F_2) and R-22 ($CHClF_2$), which are the most commonly used refrigerants, work very well. A slow moving air stream at atmospheric pressure is swept through the pasteurized side of the regeneration section and checked for the presence of the fluorocarbon to see if a leak exists. A sensitive halogen leak detector of a type commonly found in the refrigeration industry is used. Two problems appear with this test when applied to a commercial unit: *(a)* sensitivity of the test and *(b)* keeping holes in the transfer system from being temporarily plugged with egg or other material when the test is made.

LABORATORY EQUIPMENT AND PROCEDURES

To conduct the necessary laboratory tests of the proposed detection method various size holes that corresponded to what might be found in commercial pasteurizers were needed. Attempts to make these holes in 20-gage, 304 stainless steel by corrosion were abandoned because of the slow corrosion rates. Holes could be made by this method in aluminum but the resulting sizes were unpredictable. In addition aluminum would be further corroded by the cleaning compounds used in some of the subsequent testing.

The following method of making holes was finally adopted. Discs of 1-1/8 inch diameter were punched from 20-gage, 304 stainless steel. A hole 3/32 inch diameter was drilled in the center of each disk until an appreciable dimple showed on the opposite side but not so far as to break through. A disk with the dimple facing out was then connected on the end of a 1 inch sanitary elbow leading from a flexible air line. Air pressure was applied and the disk placed under water in a pan. The dimple was gently ground down with a fine motor-driven emery wheel, such as is found in hobby kits. Air bubbles showed when the hole broke through. With practice the size of the hole could be roughly judged by the rate of air flow which could then be measured by displacing water in an inverted graduated cylinder.

After some exploratory tests the set of 18 disks listed in Table 1 was assembled. Larger holes were eliminated as they did not offer any problems not encountered with the small sizes. The last 4 disks were added part way through the study to give experience with very small holes.

The primary purpose of testing so many holes was to experiment with various treatments to unplug them. Non-pasteurized egg white that had passed through the filter screen following the egg breakers in a commercial plant was run through the holes at 20 psi and room temperature until the holes were completely plugged. Table 2 lists 21 consecutive treatments which the first 14 holes of Table 1 were given in studying the problem of plugging. After each of the indicated treatments the rates at which air (at 20 psi and room temperature) flowed through the holes were determined. The holes were kept wet between the time of the treatment and the determination of air flow rates unless drying was indicated. When the holes were dry, air flow was started before they were submerged to determine the air flow rates.

TABLE 2. TREATMENT OF HOLES PRIOR TO DETERMINATION OF AIR FLOW RATES

	Per cent open	
	Average	Range
1. Holes ground through under water.	83	51 to 100
2. Washed with direct jets in test tube washer at 180 F for 3 minutes with TSP, (trisodium phosphate).	78	38 to 97
3. Holes plugged with egg white at 20 psi at room temperature, washed as above	48	0 to 85
4. Same as 3.	61	1 to 95
5. Same as 3.	76	25 to 100
6. Same as 3.	83	44 to 95
7. Holes plugged with egg white, washed under water tap without direct impact on holes.	10	0 to 45
8. Dried 18 hours at room temperature.	10	1 to 69
9. Washed at 160 F for 10 minutes with 0.5 ounce/gallon TSP flowing 1.75 feet/second.	42	0 to 88
10. Same as 9.	54	4 to 95
11. Same as 2.	86	28 to 100
12. Holes plugged with egg white, washed at 160 F for 30 minutes with 1 ounce/gallon TSP flowing 1.75 feet/second.	71	20 to 97
13. Same as 12.	61	16 to 100
14. Same as 12.	56	13 to 95
15. Washed at 160 F for 30 minutes with phosphoric acid wash 1 quart/25 gallons flowing 1.75 feet/second.	50	12 to 81
16. Washed at 160 F for 60 minutes with 2% caustic flowing 2 feet/second.	94	73 to 100
17. Holes plugged with egg white, washed same as 16.	97	83 to 100
18. Same as 17.	95	90 to 100
19. Dried for 48 hours at room temperature.	93	81 to 100
20. Same as 17.	94	83 to 100
21. Same as 17.	95	79 to 100

In order to check the sensitivity of the proposed leak detection method, a plate pasteurizer was set up to make the necessary tests. The unit contained 21 plates with the flow arranged to correspond to a regeneration section in an egg pasteurizer. To provide leaks in the unit 2 plates near the center were modified as shown in Fig. 1. By use of the various disks listed in Table 1 the desired size of leak could be obtained for the heat exchanger. A tank of R-22 was connected with valves and pressure gages to one side of the plates. This side was provided with a vent valve at the opposite end from the R-22 inlet so that at the start of a test the air in that side could be displaced with the fluorocarbon gas. The other side of the heat exchanger was closed with rubber stoppers until a test for the presence of fluorocarbon was made. At that time the stoppers were removed and a plastic bag containing about 5 ft^3 of air was temporarily attached to one end. By gently squeezing the bag, air could be swept through the air side of the heat exchanger at the desired rate. The air stream flowing from the unit was checked with a halogen detector for the presence of fluorocarbon to see if a leak occurred.

The detector *(2)* used in this work contained a probe through which air was drawn by a small vacuum pump in the unit. This air passed between two electrodes. If a halogen compound such as a fluorocarbon refrigerant was present in the air, the current between the electrodes was increased. This current was amplified causing a small neon light in the probe to flash. For testing refrigeration systems the unit was rated as capable of picking up a leak of 0.1 ounce/year. Use of the unit was improved by putting a pointer and chart on the balance control adjustment.

In making a test, a disk with the desired size leak was placed in the heat exchanger. Stopcock grease was used on the "O" ring to keep it and the disk in place while the heat exchanger was being closed. The valve on the fluorocarbon tank was opened until the pressure in the unit was 15 psi. This valve was then closed and the vent valve opened briefly so that air was displaced from the fluorocarbon side of the heat exchanger. The pressure was then raised, usually to 5 psi and maintained at this level for the test. After elapse of the desired length of time, air was swept through the air side of the heat exchanger and the exit stream checked for fluorocarbon.

Flurocarbon pressure of 5 psi was used because first, it was roughly the amount needed to induce gas flow through any wet hole that permits significant leakage of egg white (Table 1), and second, low fluorocarbon pressure in the heat exchanger was desirable to reduce leakage by the gaskets to the air surrounding the unit. The unit was tightened manually as much as possible but specific gasket areas gave leak signals even at 5 psi. When the air around the unit became contaminated with fluorocarbon, use of the leak detector became more difficult.

A 12-inch fan was operated continuously to keep fresh air in the work area. Care was needed to keep out fluorocarbon from the air used to fill the plastic bag. With these precautions leakage to the outside air gave no problems in testing for internal leaks. Tightness of the "O" ring seal on the perforated plate was checked by tests of 1 hr duration using a disk without a hole.

As later discussion indicates, it was found best to conduct the tests with the disks dry so that no water was in the holes. For laboratory tests, drying could readily be done by allowing the disks to remain exposed to normal room conditions overnight. For commercial pasteurizers, a similar procedure may at times be inadequate because of low temperatures and high humidities that may occur. Various other methods of drying may be feasible; namely, forced circulation of room air over open plates by an oscillating fan, circulation of heated air over open plates with an electric air heat-

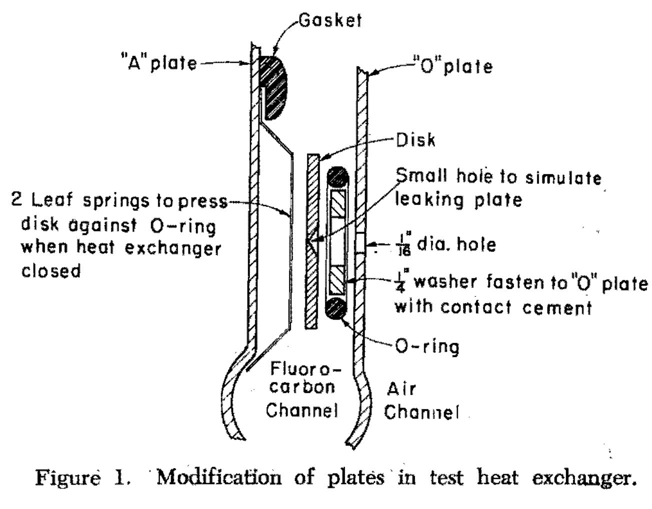

Figure 1. Modification of plates in test heat exchanger.

er which contains a fan, and blowing heated air through the closed heat exchanger. The latter seems preferable, based on some exploratory testing in the laboratory. It provides more uniform drying conditions for all heat transfer surfaces and overcomes the problem of slow drying, if low temperatures and high humidity occur in the pasteurizing rooms.

An expedient method in the laboratory for forcing heated air through the heat exchanger was to use a household canister type vacuum cleaner as a blower. This particular unit was rated at 1.25 horsepower, and after leaks were sealed it delivered 15 ft^3/min of air at 1 psi with a temperature rise of about 30 F or 75 ft^3/min at 0.1 psi with a temperature rise of 25 F.

RESULTS AND DISCUSSION

As an indication of the size of each hole, an "equivalent diameter" was calculated. The following orifice formula for critical flow of air *(4)* was used for the calculation assuming the coefficient of discharge was 1, even though the holes were not shaped like orifices nor were they similar to each other in shape. Microscopic examination showed the holes to be quite irregular in shape. The maximum air flow rate (Table 1) at any time was assumed to be the rate for the hole when completely open and it was used as the basis for the calculations.

$$w = \frac{.533\ CAp}{\sqrt{T}}$$

where w = flow rate, pound/second
C = coefficient of discharge
A = area of throat, square foot
p = upstream pressure, pound/square foot
T = upstream temperature, 460 + F

The above formula can be converted to the following for the conditions of our tests.

$$d = 2.6\sqrt{V} \times 10^{-4}$$

where d = equivalent diameter, inches
V = volume of flow, ml/min measured at atmospheric pressure and saturated at 70 F

Table 1 shows the equivalent diameters calculated by this formula range from .00013 inch to .0065 inch. Some preliminary testing included holes slightly larger than .01 inch. Plugging of such holes with egg white took a long time and the larger holes provided the same information as the smaller holes. Comparative trials with the fluorocarbon gas, R-22 gave volumetric flow rates about 40% of those for air.

While the air flow rates through the holes were being measured, it was observed that a significant pressure was required to initiate air flow through the holes when they were wet. The required pressures varied from test to test and were quite high for the smaller holes (Table 1). Tests with fluorocarbon gas, R-22, required similar pressures. Table 1 also gives some information on the amount of egg white required to plug the holes. Quantities under 0.1 ml are estimated. A drop of egg white is about 0.06 ml. When a fraction of a drop came through, the quantity was visually estimated down to 0.01 ml. If the quantity was insufficient to be observed on the metal disk but showed as a small spot on a fingertip after touching the hole, it was called 0.01 ml. For the small flows, plugging commonly occurred within 1 min. For the large flows, the times were as long as 1 hr or more. As anticipated, the results were quite variable, probably because of the variability in the occurrence and amount of suspended material in the egg white. Some smaller holes never showed any indication that egg white had flowed through even when the pressure was raised to 40 psi.

We can compare the degree of contamination caused by a small leak in a commercial pasteurizer with that remaining after pasteurization. Assuming that a leak with a total flow of 0.01 ml is diluted with 5 min of production in a plant running 3,000 pounds/hr, the degree of contamination of the pasteurized product is 1×10^{-7} of that of the raw product. Pasteurization requirements for killing *Salmonella* give a similar order of reduction (holding time = 3.5 min; decimal reduction time = 0.4 min; holding tube efficiency, 74%). From a comparison of equivalent diameters and flow of egg white in Table 1 and the above discussion, it appears that a method capable of detecting leaks with an equivalent diameter of 0.001 inch or smaller is needed. The average pressure required to initiate flow of gas through this size hole when it is wet is about 5 psi.

Table 2 indicates the size (per cent open) of the first 14 holes of Table 1 after each treatment. These figures show some completely plugged and many partially plugged until the cleaning method listed in treatment 16 was used. This method is similar to a recommended washing procedure for the cleaning-in-place of egg pasteurizers *(1)*. In this laboratory, disks were placed in a rack that could be inserted in a 1.5 inch sanitary pipe for washing. The face of the disks was parallel to the line of flow. A 2% caustic solution containing some additional cleaning agents was pumped through the pipe with the indicated conditions. It may be assumed from the data of preceding trials that there were some thoroughly cooked-on egg solids in the holes at the start of this cleaning operation. Opening of holes in any commercial unit should not be any more difficult. In subsequent tests the same methods showed equally good results in opening holes. It is believed that if any holes exist in the plates of an egg pasteurizer, they will be open after proper cleaning.

Tests conducted with hole R indicate the sensitivity of using the fluorocarbon testing method for leaks.

The equivalent diameter of .00013 inch for this hole (Table 1) is based on the maximum air flow at any time which occurred immediately after it was ground and probably before the hole became wet. This diameter is of an order of magnitude of one-tenth that which permits flow of egg white in any significant amount. After this hole was ground and the initial air flow determined it never again, while wet, permitted any gas flow at 20 psi. It never permitted any detectable flow of egg white. After treatments 16 through 21, the air flow through this hole while wet was .075 ml/min at 60 psi. The hole was then dried overnight at room temperature and tested for leakage in the heat exchanger. On consecutive tests at 5 psi R-22 pressure and with the air side closed for the indicated length of time the following results were obtained: 2 min-weak signal; 5 min-strong signal; 2 min-no signal; and 5 min-strong signal.

Holes with equivalent diameters of .002 inch to .003 inch when dry always gave strong signals at 5 psi in 1 to 2 min. Some tests as low as 1 psi gave equivalent results. Hole R, when wet, never gave a positive signal with pressures up to 20 psi. The larger holes, when wet, gave inconsistent results for various pressures. While the figures cited in Table 1 for the pressures required to start flow of gases varied appreciably, the tests conducted in the heat exchanger varied more. Because of the inconsistency of tests on wet holes, but primarily because of the much greater sensitivity of those on dry holes, we believe it is better to use dry heat transfer surfaces than to try to overcome the effect of wetness.

For drying a commercial plate heat exchanger we propose the following procedure. *(a)* After the surfaces are thoroughly cleaned, the open plates should be rinsed with hot water and promptly dried with a sponge or towel so that no visible drops of water remain. *(b)* The exchanger is then closed and warm air is forced through each side of the section to be tested for 30 min. If either side is more open to flow, that side should be dried first to produce more uniform temperatures through the exchanger. Air leaving the unit at the end of the drying period should be at least 15 F warmer than the room air.

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Reference to a company or product name does not imply approval or recommendation of the product by the U. S. Department of Agriculture to the exclusion of others that may be suitable.

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