Automatic Remote Heating Cures Frying Faults

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Consulting Engineer, Richmond, Va., and Vice-President of Engineering, H. W. Lay & Co., Atlanta, Ga., respectively

Reprinted from
FOOD ENGINEERING
March 1955, pp. 60, 61, 62, 205
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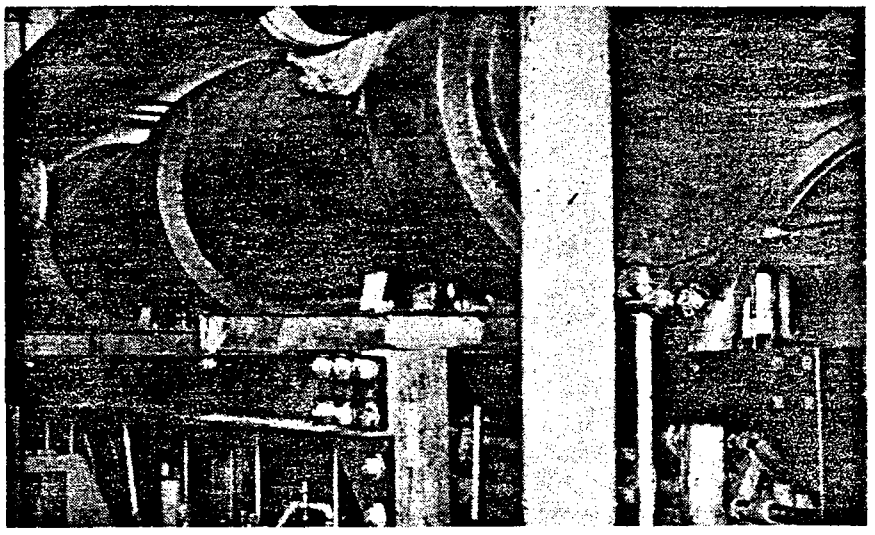
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Heat Generated Here **Transferred to Oil in This Unit**



FURNACE fired with gas heats liquid heat-exchange medium as it flows through boiler-like tubes.



HEAT EXCHANGER transfers Btu.'s from hot liquid medium to oil used in deep-fat cooker. Employed is insulated exchanger of shell-and-tube type, with cooking oil circulating through the tubes.

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By means of a radically different deep-frying process, big strides have been taken in quality, capacity, safety, and efficiency in potato chip production. In this process, the cooking oil is heated by a remote furnace and heat-exchanger system, and its temperature in the fryer is closely controlled.

Here is a continuous process involving food engineering principles of wide importance.

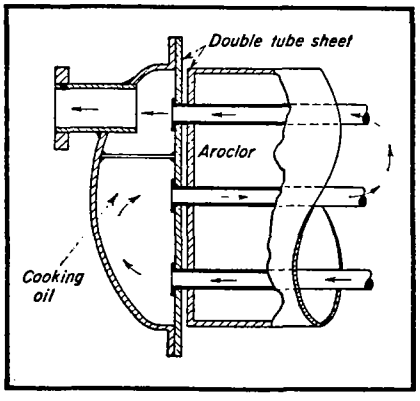
Used since June to fry potato chips in one of the Atlanta plants of H. W. Lay Co., the process has performed so well that it has just been installed in Lay's expanded Jacksonville, Fla., chip factory.

The principle is simple, if ingenious. The engineering which makes it work so well, with so many fundamental food-factory plus values, is a longer story.

Basically, the operation involves "low-temperature" heating of the frying oil by circulating it from the fryer, through a heat exchanger, and back into the fryer again continuously, under instrument control. The low-temperature liquid medium that heats the oil in the heat exchanger is, in turn, circulated through the tubes of a gas-fired furnace.

As can be seen, the high-temperature gas flames that supply the frying heat are doubly removed from the oil itself, and therein lies many of the advantages of the system.

It is because of this arrangement, plus automatic continuous operation, that these benefits result:



SAFEGUARD against contamination of oil or heat-exchange medium in event of a leak is provided by this double tube-sheet construction at ends of heat exchanger.

▶ **Fire Hazard Eliminated**—There is no flame near the cooking oil.

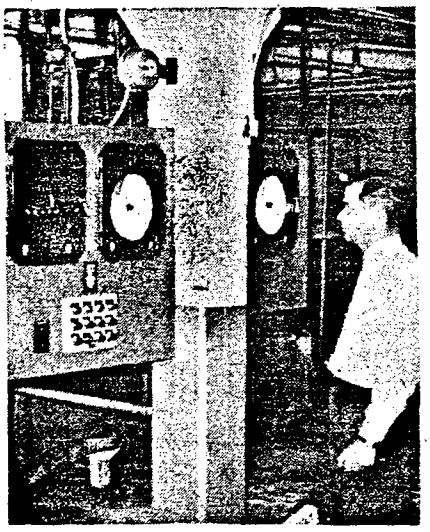
▶ **Oil Damage Avoided**—The oil does not come in contact with any surface that at any time is hotter than 450 deg. F.

▶ **Quality Improved**—Since the oil is not heat-damaged, the product fried in it is of better quality. And automatic control holds the oil tempera-

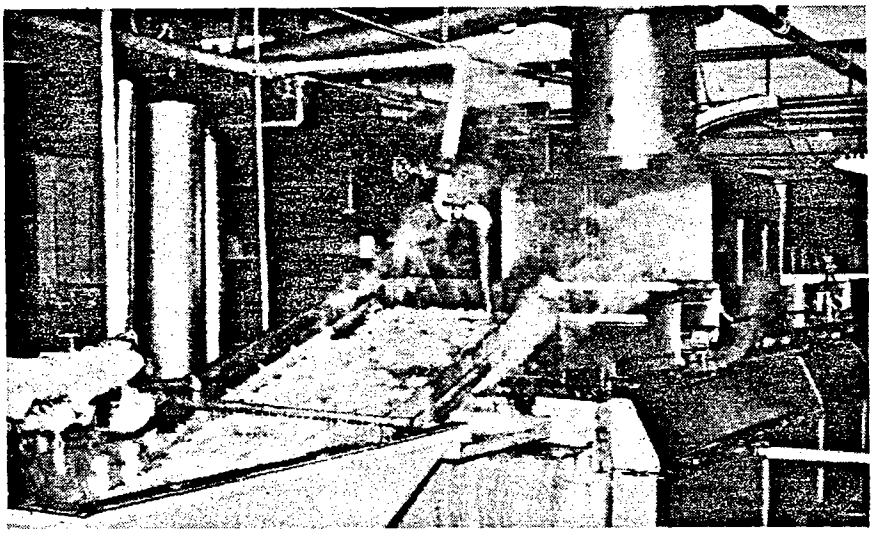
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Controlled And Delivered to Fryer To Cook Chips



CONTROLLERS regulate amount of heat generated and transferred to oil as flow of raw chips fluctuates.



CONTINUOUS FRYER moves chips through hot oil, which is circulated through heat exchanger to pick up Btu.'s from liquid medium heated in remote furnace. Potato chip production capacity is increased 50%.

ture within 2 deg. F. for uniform cooking.

▶ **Fuel Saved**—Efficiency in utilization of fuel is 60%, compared with 35-40% for direct-heated fryers. This is particularly significant in view of the large amount of heat required to evaporate the water entering the fryer on, and in, the raw chips.

▶ **Multiple Operation Possible** – One efficient heat source can handle two or more fryers, yet the fryers can be operated at different temperatures.

▶ **Maintenance Reduced**—Not only is the oil heating and control system designed for low maintenance, but the gentle, uniform heating of the oil reduces burning of chip particles and oil discoloration. As a result the fryers need not be shut down and cleaned out so often, and fewer "spotted" chips are produced.

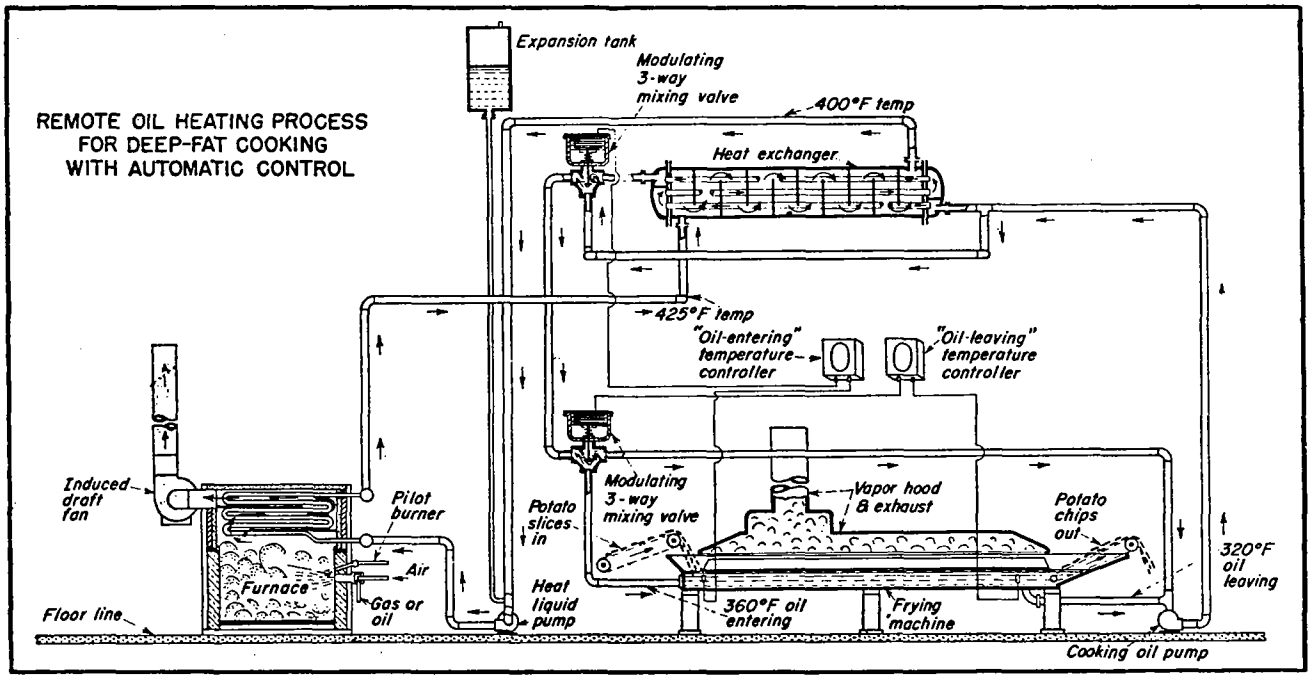
▶ **Capacity Increased**—Because of the controlled high Btu. capacity of the system (2,170,000 Btu. per hr.), output of chips per hour per fryer is increased 50%.

In conventional deep-fat frying, lack of temperature control and damage to the cooking oil are especially serious factors. Let us see why.

Temperature Problem

With a great amount of heat required to vaporize the water in the potato slices, any sudden change in the rate of feeding raw slices to the kettle instantly changes the heat demand in a major way.

If the feed rate of slices is reduced, the temperature of the oil increases



COMPLETE PROCESS schematically shows equipment involved, the circulation of the heat-exchange medium through the furnace and heat exchanger, and the path of the cooking oil through the exchanger and fryer. Automatic control valves and oil-flow bypasses on fryer and exchanger maintain oil temperature within 2 deg. of selected point regardless of big heat-load variations. Two or more fryers can be served by such a system.

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rapidly, because of the low specific heat of oil and the fact that only sensible heat is required to increase its temperature. If the infeed rate of slices is increased, then, of course, the heat input into the oil should be immediately increased in like proportion.

With direct firing under the kettle, it is obviously impossible to secure accurate temperature regulation. A tremendous amount of heat is stored in the refractory furnace lining and this heat is given off for a long time even after the fire is reduced or extinguished.

The radiant energy varies as the fourth power of the absolute temperature. Therefore, a furnace hot-face temperature of 2,000 deg. F. and an assumed emissivity coefficient of 0.8 radiates approximately 50,000 Btu. per hour per sq. ft. And a furnace having 75 sq. ft. of hot-face surface would radiate energy at a rate of over 3,000,000 Btu. per hour. So any adjustment in the rate of firing will have little effect on the rate of heat input into the kettle for many minutes.

An important point in producing best quality potato chips is the temperature gradient throughout the length of the kettle. A more or less accepted average will be 360 deg. F. at the inlet end of the kettle and 320 deg. F. at the exit. With a dormant or static pool of oil contained in the kettle, and an open furnace under it, accurate control of the temperature gradient is extremely difficult, if not impossible.

Damage To Oil

Vegetable oils suitable for cooking potato chips are usually damaged by excess temperature. The changes that occur in fats or shortening during deep fat frying include hydrolysis, polymerization, and discoloration. Also, foreign material accumulates in the oil, and flavor changes occur.

Hydrolysis involves the splitting of a fat into its component fatty acids and glycerol. Fresh shortenings usually contain less than 0.10% free fatty acid, but if the fat is mistreated, the free fatty acid content may reach 5%, which is very undesirable. As the smoke point of a shortening is inversely proportional to its free fatty acid content, a high acid value causes excessive smoking.

Fats are easily damaged by overheating. Yet a dormant pool of oil is contained in a shallow tank having a thin steel bottom. And the flame temperature immediately under the tank is 2,500 to 3,500 deg. F. So the temperature of the film of oil at the bottom of the tank necessarily reaches very high values.

The cooking oil acts as a carrier of heat from the bottom of the kettle to the individual slices of potato. Heat transfer is by conduction and convection. But cooking oil is a very poor heat conductor. And to transfer heat several inches by conduction requires a big difference in temperature or thermal gradient.

Heat transfer by convection is dependent on vertical circulation. Hot particles of oil rise, giving up their heat to a slice, are cooled, and return to the bottom of the kettle. With a 4- to 6-in. depth of oil from the bottom of the kettle to the center of the mass of potato slices, natural convection circulation in the oil is extremely sluggish.

With a small area of kettle bottom exposed to the furnace, the rate of heat transfer per square foot of kettle area is necessarily high. And as heat is transferred from the dry furnace gases to the dry surface of the bottom of the kettle, the heat transfer coefficient on the furnace side is quite low. This results in very high stack temperatures and very low overall efficiency. Many chip cookers are operating with stack temperature of over 1,500 deg. and an overall fuel efficiency of not more than 35%.

How Problems Were Licked

The process employed by Lay was designed to overcome these problems and to satisfy the requirements for an ideal potato chip process. Called the Smitherm process, it was designed by Horace L. Smith, Jr., with the cooperation of Lay engineers, has been fully covered by pending U. S. patent applications.

The process starts with a boiler built along conventional lines by International Boiler Co. It involves the water-tube principle, and has sufficient combustion volume for efficient utilization of fuel and relatively low hot-face temperatures of the furnace lining.

Instead of using water in the tubes, a liquid having good heat transfer properties is circulated by means of a pump. Sufficient tube area is provided for both radiant heat absorption and convection heat transfer, so that the stack temperatures are low and the overall thermal efficiency is equal to best current boiler design.

The boiler can be placed in any convenient location and the heating liquid pumped to the heat exchanger, which preferably should be located adjacent to the potato chip cooker.

Heat Transfer Liquid

Steam could be used to heat the oil, but to provide steam at 425 deg., it is necessary to operate a boiler at more than 300 psi. gage. This high pressure introduces something of a physical hazard. In some instances it requires the presence of a licensed steam engineer to operate the boiler.

Many industrial processes requiring high temperature utilize the vapor of a high-boiling liquid. But it is practically impossible to operate such a system at exactly atmospheric pressure. And at positive pressures, the low-viscosity vapors are quite difficult to confine. Therefore, leakage can readily occur, and the vapors are very pungent, disagreeable, and toxic.

If a high-boiling liquid heat exchange medium is used under negative pressure, it is quite difficult to prevent inward leakage of air into the system. And the auxiliary equipment needed to keep the system continuously purged of air is intricate and costly.

The Smitherm process uses a heat-transfer liquid in the boiler and keeps it in the liquid phase. The liquid is a low-viscosity chlorinated biphenyl, nonflammable heat-transfer medium suitable for temperatures up to 550 deg. F. or higher.

This liquid involves no fire, corrosion, or toxicity hazard. It has favorable specific heat characteristics, is readily available at low cost, and has high heat stability. It is used in a simple vented arrangement with an expansion tank, similar to a conventional residence hot-water heating system. The liquid can be controlled at any reasonable temperature. For potato chip cooking, a range of 400 to 425 deg. F. appears to be optimum. Called Aroclor, the heat-exchange fluid was developed by Monsanto Chemical Co.

Unique Heat Exchanger

The heat exchanger is of conventional shell-and-tube design. But it has a double tube sheet. If for any reason leakage should occur, either from the heating liquid or from the oil, the leakage would be to atmosphere. No contamination of the other liquid could occur. This is a simple and inexpensive means of insuring complete isolation of the two liquids.

By providing sufficient heat transfer surface in the heat exchanger, relatively low mean effective temperature differences can be maintained for the amount of heat to be transferred.

Bypass Heat Control

Heart and soul of the Smitherm process is the method of controlling temperatures in the cooking kettle. Temperature of the heating liquid is easily controlled within a narrow range by conventional equipment that regulates the burner settings.

Temperature of the cooking oil en-

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tering the fryer is controlled by a three-way mixing valve that varies the relative volumes of oil passing through the heat exchanger and through a bypass around the exchanger. Or the valve may be placed in the heating-liquid line.

The temperature sensing element that operates this valve is located near the inlet end of the kettle.

To maintain a predetermined difference between the temperature of the oil entering the kettle and that of the oil leaving the kettle, a bypass around the kettle is provided with a three-way diversion valve.

An example of the effect of the bypass around the kettle is as follows: Assume that under full load conditions, production is 800 lb. of finished chips per hour from potatoes having 18% solids and 38% oil content. Since 325,000 Btu. is needed to cook 100 lb. of chips, the total heat load is 2,600,000 Btu. per hour. Now, the specific heat of cottonseed oil at 350 deg. F. is 0.57 Btu. per lb., and the specific gravity is 0.81. Therefore, 3.85 Btu. will raise 1 gal. of cottonseed oil 1 deg. F.

Assume temperature conditions of oil entering the kettle at 360 deg. and the exit temperature of 320 deg. Then 1 gal. of oil gives up 154 Btu. (3.85 Btu. per deg. x 40 deg. temperature change). And the total heat load of 2,600,000 Btu. per hour divided by 154 shows that 16,883 gal. of oil must be circulated through the kettle per hour, or 281 gal. per minute.

If the load was decreased to 600 lb. of chips per hour, the volume of oil circulated through the kettle would immediately drop to 211 gpm. Therefore, 70 gpm should be bypassed.

Vapor-Lock Problem

One of the problems that had to be licked in pumping the hot oil is vapor lock. Here is the theory behind this phenomenon. Fine water droplets, driven out of the frying potato slices, are carried in the oil more or less as an emulsion. In the heat exchanger, the higher temperature releases some of this water as vapor. Then more is freed by the action of the pump impeller when the hotter oil from the kettle bypass reaches the pump. The vapor thus freed causes vapor lock unless the pump is designed to handle a certain percentage of gas as well as liquid. The Lay installation uses a LaBour non-priming centrifugal pump.

Amount of vapor released in the oil can be reduced by eliminating the kettle bypass and controlling the amount of oil that flows through the kettle in another way. To be used in Lay's new Jacksonville plant, this method involves passing all of the oil through the kettle and controlling flow by a back-pressure valve. This valve is regulated from a temperature controller with its sensing element at the discharge end of the kettle. As back-pressure increases on a centrifugal pump, the volume of fluid passing through it decreases.

This reduces the vapor lock problem, because no "hot" oil is bypassed directly into the pump suction. All of the oil now flows through the kettle. But there still is an emulsion of water droplets in the oil. And the pump must be able to handle water vapor without becoming vapor locked.

Oil Cooled for Shutdown

No heat is stored in the cooker other than the sensible heat in the cooking oil, plus a small amount of heat in the kettle itself. So at the end of an operation, the oil in the system can be easily and quickly cooled by means of a water-jacketed section of pipe in the oil line. By continuing the operation of the oil-circulating pump and admitting water into the jacket of the heat dissipator, the entire mass of oil can be quickly cooled down to temperatures at which it will not deteriorate rapidly.

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