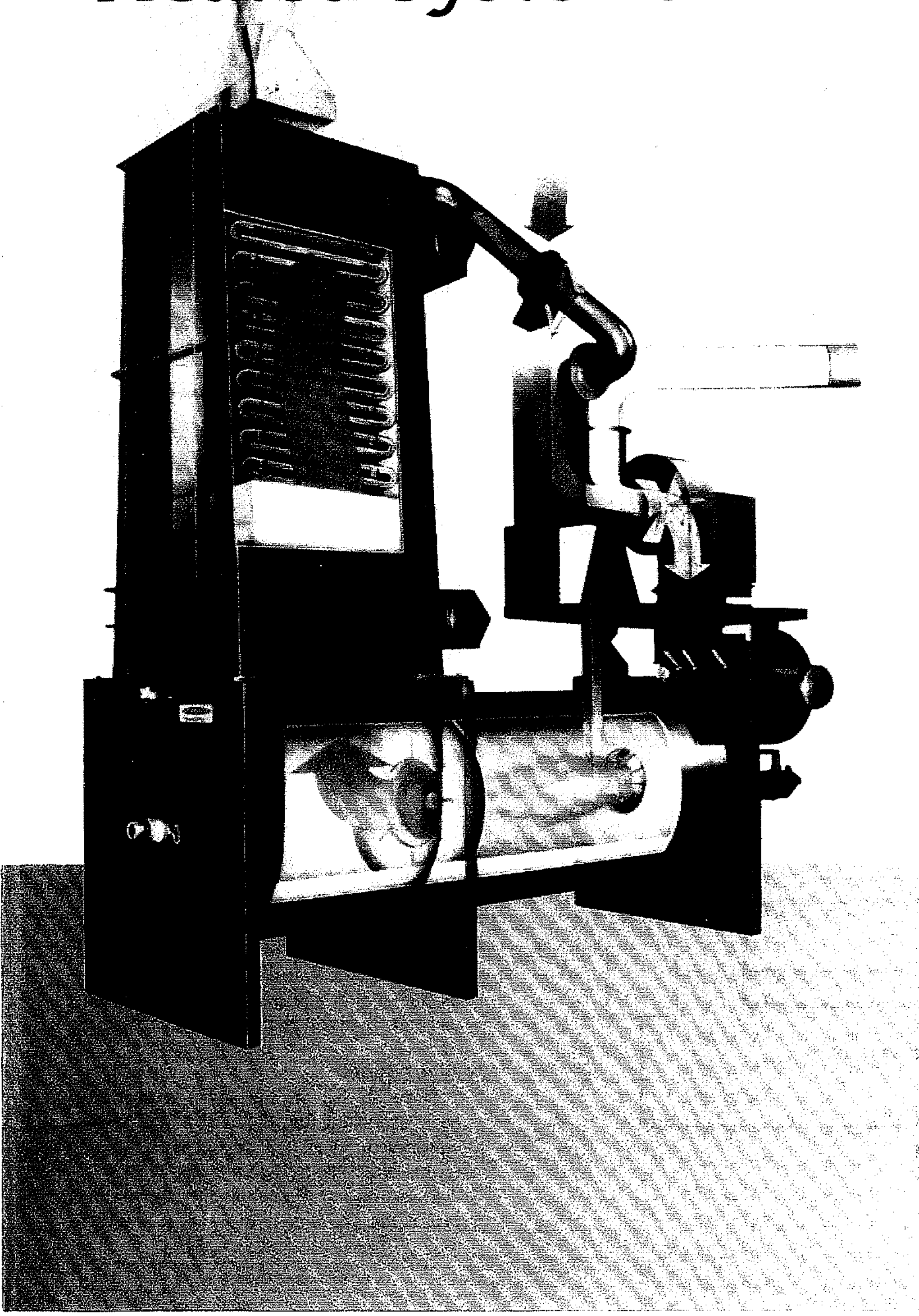
Fryer Systems Technology: Direct- and Indirect-Heated Systems



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Why fry? Considering consumer interest in healthy foods and the introduction of so many nonfried products, one would anticipate a declining market for fried foods. Sales figures, however, prove just the opposite. The multibillion dollar fried food industry continues to enjoy steady growth because, whether it's chicken nuggets, egg rolls, taco shells, or potato chips, fried foods taste good.

Frying is one of the fastest heat transfer methods available for cooking. It is a simple and commonly used technique for developing flavor, color, and unique product characteristics that cannot be duplicated by any other method.

Frying can be accomplished in a batch or continuous system. This article will focus on continuous frying systems as batch frying capabilities are limited, making that system impractical for large quantity production.

Criteria for Fryer Selection

Regardless of the product type, fryer system selection is critical to producing the desired product.

Product characteristics should be considered when selecting a fryer type. Both coated and noncoated products can be fully cooked or partially fried (also known as par-fried or blanched) for color.

Noncoated products include items such as meatballs and turkey breasts (fried for browning); dough enrobed products, like fruit turnovers and chimichangas; snack foods, like potato chips, tortilla chips; and grain- or meat-based pellets.

Coated products include everything from battered and breaded meats to vegetables. These can have a variety of coatings such as tempura batter, seasoned flours, glazes, and coarse crumbs.

The type of product and the product's sensory qualities and physical dimensions all have to be considered when selecting a frying system.

Desired production rate has to be established to determine the appropriate fryer size. The physical dimensions required to accommodate the expected production rate are determined by the process time and the product loading per square area, better

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know as a belt loading. This belt loading can be expressed in pounds per square foot, pounds per linear foot, pieces per linear foot, etc. If the belt loading were calculated in pounds per square foot, the formula would be as follows:

$$\text{Cook area, ft}^2 = \frac{\text{production rate, lb / min}}{\text{loading, lb / ft}^2 \times \text{process time, min}}$$

For example, if the desired production rate were 50 lb/min, the product loading 1.5 lb/ft^2, and the processing time 1 min, then the required cook area would be 33.3 ft^2.

Heat load of the fryer system has to be designed to deliver the heat necessary to cook the product. This requires a mass heat load balance calculation to be run on the system. The heat balance takes into consideration loss of heat due to the oil, the fryer vessel, the piping, the processing room, the fryer exhaust, ancillary equipment (filters), the thermal efficiency of the heat transfer mechanism, and the product.

One other item must be considered in the equation: the temperature differential (ΔT) of the cooking oil. This is the temperature differential that the oil achieves when heat is given up to the system, including the product. The heat load or requirement is expressed as BTUs required for the fryer system.

Oil pick-up of a product is the result of the product's physical characteristics and process parameters. Most products will absorb the majority of oil during the initial stages of frying. Oil pick-up can be affected by the coating systems, frying temperatures, product flow rates, ΔT of the frying process, and drain time.

It should be noted that there are products in which this does not apply. With some types of noncoated products, such as meatballs, fat is rendered into the cooking oil.

Oil turnover is critical to the success of any product because it determines how frequently used oil is replaced with fresh oil. The oil turnover rate in a fryer system is a function of the amount of oil contained in the system and the rate at which the oil is removed by the oil pick-up of the product. The more frequent the turnover rate the more consistent the product and the better its shelf life. Oil turnover rate is calculated as follows:

$$\text{Turnover rate, hr} = \frac{\text{oil in system, gal}}{\text{pick-up per hour, \%}}$$

For example, if a fryer system contains 400 gal of oil (6.8 lb/gal) and 4,000 lb of product with a 9% pick-up rate were produced on an hourly basis, then the turnover rate would be 7.6 hr.

Fines removal or filtration plays an important role in every frying system. Debris from products left in the fryer will burn and carbonize, and burnt fines are one of the greatest contributors to degrading oil quality. The particle size of the coating, the floating or sinking characteristics of the product, and the flow rate through the system all have to be considered when selecting a fines removal/filtration system.

For example, sinking debris settle on the bottom of the fryer pan, where they are difficult to remove. To prevent fines accumulation, a sludge conveyor or pan wipers are necessary to drag sediment from the pan bottom to a discharge port, where the sludge is removed by an auger, conveyor, or oil flow to a filtration system.

Product conveyor selection is important when choosing a fryer design. For a buoyant product, a hold down or submerger conveyor is necessary to keep the product fully submerged in the oil. This type of conveyor may also be used to hold a product in place when orientation must be maintained to prevent bonding of product pieces.

To avoid coating damage, some products require a short section of free fry area where there is very little mechanical movement from a conveyor belt. The product is dropped directly into an oil bath and allowed to fry for several seconds. This sets the coating prior to the product settling onto a conveyor belt for system transfers.

Some products with a delicate coating like tempura require a special conveyor known as a "tempura conveyor" or "Teflon in-feed conveyor." This type of conveyor allows a batter coating to begin frying on a belt without developing a belt mark or disturbing the integrity of the coating. Once the coating is set, the product is transferred onto a conventional style stainless steel product conveyor.

Environmental concerns about fryer emissions are on the rise in all parts of the world. By-products of combustion can be minimized, however, by utilizing the best available combustion components and by keeping them properly maintained. Special incinerating systems can also be made a part of the fryer oil heating system to bring emissions into compliance with government air quality standards.

To address these concerns, two types of emissions must be considered: oil-laden exhaust created by the frying process and the by-products of combustion from the fryer's heat source.

Oil-laden exhaust can be dealt with by using an oil mist eliminator or oil de-mister. Air, steam, and oil emitted as exhaust from the fryer hood are drawn through a specially designed stainless steel mesh pad. The mesh pad captures entrained oil droplets, while allowing air and water to pass through. Oil droplets drip back into a catch pan and are discharged outside the fryer.

Fryer Types

Once all the criteria for a fryer have been evaluated, the fryer type has to be considered. There are two basic types of fryers: direct-heated and indirect-heated.

Direct-heated fryers heat the cooking oil *inside* the fryer pan, using heat transfer

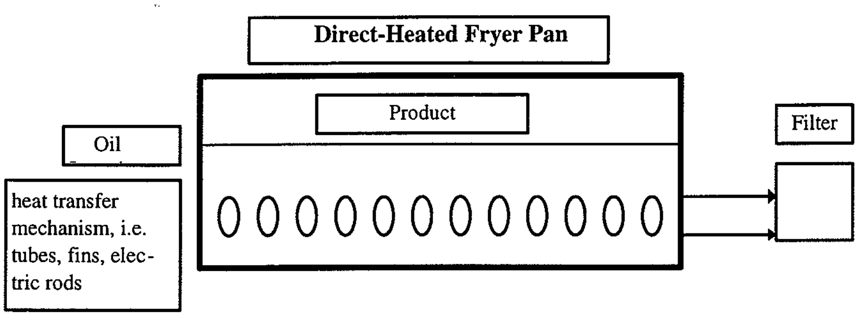

Fig. 1 Diagram of a direct-heated fryer pan.

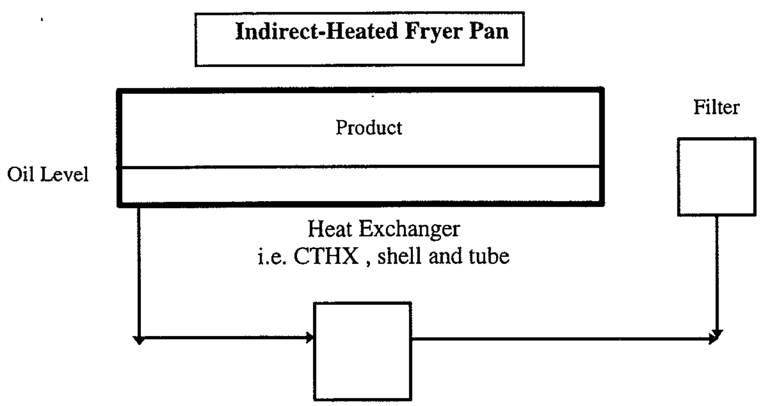

Fig. 2 Diagram of an indirect-heated fryer pan.

mechanisms such as burner tubes, thermal fluid fins, or electric elements (Fig. 1). Indirect-heated fryers heat the cooking oil *outside* the fryer pan by circulating oil through an external fuel-fired, thermal fluid, or steam heat exchanger (Fig. 2).

Direct-Heated Fryers: Direct-heated fryers use the natural convection current of the heating mechanism to heat the cooking oil. The heating fins, tubes, or rods are fully submerged in the oil bath. Adequate oil is necessary to fully cover the heat source, and a buffer area of oil between the heat transfer mechanism and the product is required because it allows the natural convection currents to rise and have adequate time to uniformly heat the oil. This buffer area prevents hot spots in the fryer that can create nonuniform cooking.

These types of fryers will have some form of sediment or drag conveyor to remove the debris that settles on the bottom of the fryer. Fines are moved to a sump where they are conveyed to a filtration system. Only a portion of the fryer oil volume is filtered at any given time.

Direct-heated fryers are limited to the available heat generated by the surface area of the heat transfer mechanism in the oil. This limits product throughput, even though the fryer's square area can hold more product.

Those direct-heated fryers in which the oil is heated by means of gas-fired tubes or electric heating elements require less floor space than other systems and often cost less for the same square foot area. However, fryers that heat the cooking oil by circulating steam or thermal fluid through coils placed in the pan (also known as direct heat-indirect fired fryers) have floor space and cost requirements similar to those in indirect-heated fryer systems.

Direct-heated fryers are usually used in systems in which oil turnover rate is not a factor, where floor space is a concern, and where lower cost is an issue.

Indirect-Heated Fryers: To transfer heat, indirect-heated fryers circulate oil through an external heat exchanger. The cooking oil is also circulated through the frying pan and a filtration system. This type of frying system has the ability to match the product heat load requirements to the square feet of frying area required by the product.

The indirect system minimizes the oil volume required for cooking. In the frying vessel, only enough oil is needed to cover the product. This usually results in 30–40% less oil volume in the entire system than that in direct-heated fryers of a similar size. Because of the lower oil volume, indirect-heated fryers deliver excellent oil turnover rates.

In indirect heated fryers, oil is filtered in a very short period because it is continuously circulated through the fryer and its components. Product particles are constantly removed from the oil, preventing fines and carbon build-up anywhere in the fryer system.

The indirect-heated fryer system does use some form of external heat exchanger. The most common ones include the CTHX (coil-type heat exchanger) or some type of shell and tube heat exchanger, i.e. thermal fluid or steam. These systems deliver more gentle oil heating than any other design available because the oil flow rate is engineered to maximize heat transfer without thermally degrading (or scorching) the oil.

This fryer can be configured with either inside or outside return conveyors along with tempura in-feeds and free fry area. Oil is introduced to the fryer through single or multiple inlets located at the bottom of the pan. Oil flow can be adjusted at inlet points to match product flow patterns and to minimize temperature drop (ΔT) along the fryer's length. In addition, zone control can be achieved to allow for product profiling, which can affect the product's characteristics.

Cleaning indirect-heated fryers is very simple. These fryers have a built-in, clean-in-place system, and the cleaning solution takes the same path as the cooking oil, ensuring that all areas of the fryer are cleaned using a minimal amount of chemicals in a minimal amount of time.

Indirect-heated fryers are used when reduced oil volumes, minimal thermal degradation, and full oil filtration are required. These systems cost more than a direct-heated system but will guarantee the highest product quality.

Frying Made Simple

The benefit of using frying technology for processing foods is realized in the finished product and is ultimately judged by the consumer. Regardless of the product base, frying is a very viable heat transfer medium, which creates unique product characteristics that cannot be achieved by any other method. Frying can be made simple if you know the product you want, the criteria for selecting a fryer, and the type of system that best suits your needs.

James Padilla

James Padilla, director of product development, Processing Systems Division, has worked for Heat and Control for four years. He is responsible for managing process prepared sales, processing division product development, and the Applications Test Facility at the company. James has 16-years experience in the areas of food product formulation, quality control, process development, and applications along with equipment development. He has a strong background in process technology with an emphasis on thermal transfer techniques, including dehydration and retort technology, conventional and dielectric methods, and coating and frying. Padilla came to equipment manufacturing from the poultry industry, and he holds a patent in radio frequency technology with impingement technology for processing bakery goods (pizza).