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«Security» in industrial frying processes

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SUMMARY

«Security» in industrial frying processes.

It is well known that equipment design features can have a profound effect on the working life of a frying oil, and consequently on secure/safe operation of the industrial deep-frying at high temperatures. The design aspects of the cooker should eliminate known factors of heat degradation/oxidation in the frying oil while maintaining outputs of products of consistent quality. For instance, the pro-oxidant catalyst copper or brass valves/fittings must not be employed. Continuous removal of debris/sediment and the maintenance of uniform oil temperatures leads to the development of FFAs at a lower rate, better taste, colour and appearance of the product. Security thermostats are fitted to each heating element in many modern, small-scale catering fryers. These are designed to trip out if the primary thermostat fails to function. Also the current isolation switch cuts off the electrical supply if the element head is not placed correctly in the fryer. In both catering and industrial frying operations, smoke haze can be a problem. The volatile break-down products such as FFAs, etc. formed in the oil being heated at high temperatures give rise to smoke, which if not controlled can enhance fire hazards due to their lower flash point. The smoke point is of most benefit in assessing the quality of a frying oil, since it is mainly the FFAs produced in the frying operation which contribute to the smoke haze. Commercial frying oils as well as the entire frying installation including cooker design, must meet strict quality and safety requirements. These features become extremely important, especially in the industrial flash frying operation when the frying oil is heated to a higher temperature of 200°C. High oil quality and high smoke/flash point frying oils are essential characteristics of the flash frying operation. These days, two important features namely carbon dioxide blanketing system and a waste air cleaning system have become standard design items for secure and environmental friendly operation of multi-purpose industrial fryers. This paper will highlight various safety and design features of many modern, industrial frying operations.

KEY-WORDS: Design features – Frying equipment – Safety – Security.

INTRODUCTION

A wide range of fried food products have been developed successfully, over the last 20 years, to meet the ever-growing demands of modern world. These products include potato crisps with various flavours, expanded snack products based on corn/maize, rice, wheat or gram flour with different shapes and textures, nuts, potato chips, convenience foods such as chicken and fish products, doughnuts and banana chips. Different types of equipment and frying operations are employed to produce such a wide range of impulse products. The design aspects of equipment can have a profound effect on the working life of a frying oil and consequently on safe operation of both catering and industrial frying at high temperatures. Inevitably, the elevated temperature used in the frying operation brings about some chemical changes in the oil. The design features should eliminate known factors of heat degradation/oxidation in the oil while maintaining outputs of fried products of consistent quality. For example, pro-oxidant catalyst copper or brass valve fittings must not be employed. Continuous removal of debris and maintenance of uniform oil temperature lead to lower rate of free fatty acids (FFAs) development, better taste, colour and appearance of the product.

In many developing countries snack food products are deep-fried at street stalls or in restaurants/hotels at small scale. In Indian sub-continent countries more than 60 fried snack products are prepared in the shops where stringent safety procedures are followed to less extent. Of course, there are few exceptions such as in fast-food chain outlets established in big cities, comparatively safer frying operations are performed. In contrast, frying oils and cooker design as well as the entire frying installation must meet strict quality and safety requirements in the developed countries. The design features become extremely important, especially in the industrial flash frying operation when the frying oil is heated to a higher temperature of 200°C. High quality and high smoke/flash point frying oils are essential characteristics of flash frying operation. This chapter discusses design features and safety/security aspects in catering, small to medium-sized fast food outlets and industrial frying operations.

SAFETY ASPECTS AND OIL PERFORMANCE INDICATORS

There are a number of safety aspects which are required to be observed during a deep-fat frying operation at high temperatures 180-200°C. Hot oil is always a potential hazard and must be treated with a great care. For instant, if excessive foaming occurs for any reason the heating source must be switched off to reduce the risk of fire. Excessive foaming may be caused by one or a combination of several factors such as oil breakdown, heating up too rapidly, contact with copper or brass, frying of foods with excessive moisture, and presence of soap or detergent residue after cleaning the fryer. In both catering and industrial frying operations, smoke haze can be a problem. The volatile break-down products such as FFAs formed in the oil being heated at higher temperature give rise to smoke, which if not controlled, can enhance fire hazard due to their lower flash point.

The smoke, flash and fire points of oils and fats are a measure of thermal stability when heated in contact with air. The smoke point is defined as the temperature at which the sample starts to smoke when tested under the specified conditions of the test. The flash point is the temperature at which volatile products are evolved in sufficient quantity to allow instantaneous ignition. The fire point is the temperature at which the production of the volatile products is sufficient to support continuous combustion. The smoke point is of most benefit in assessing the quality of a frying oil, since it is mainly FFAs produced in the frying operation which contribute to the smoke haze. The relationship between smoke, flash and fire points and FFAs presented in Figure 1 indicates that free fatty acid content of an oil has a considerable effect on its smoke point (Meara, 1978).

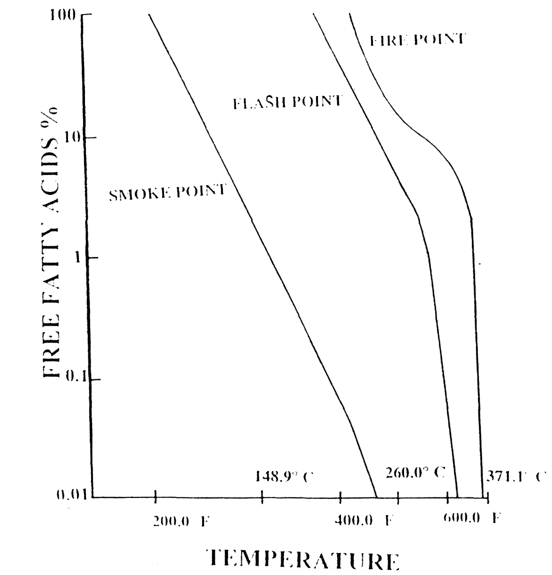


Figure 1
Relationship between smoke, flash and fire points and free fatty acid content

It is well known that the essential attributes of deep-fat frying process are the raw materials, the fryer/cooker, the fat or oil, and the quantity of the product conveyed through the fryer. The quality status of oil at the time of frying is perhaps the most important factor influencing product quality in terms of appearance, texture and flavour. This also contributes significantly to the product shelf-life, as between 5% and 40% of the final product is the oil from the frying process. The key elements of a good frying oil are bland flavour, pale colour, good oxidative stability, and good thermal stability during the frying process. While providing adequate resistance to oxidation/degradation during continuous use in a fryer, the frying oils or shortenings should have minimum smoke point of 210°C. Therefore, if unrefined butter oil, olive oil or animal fat is employed in a frying process, its smoke point will be quite low even when the fat or oil is fresh (e.g. smoke point of virgin olive oil is 169°C). The usage of such fats and of lauric-rich oils will lead to unsatisfactory frying at elevated temperatures, 180-200°C. Over the last 20 years, the traditional use of groundnut oil has become rare, special or too expensive. Now in the UK and other European countries, alternative vegetable oils namely palm oil, palm olein, double olein, sunflower seed oil, or semi-liquid blend of vegetable oils are employed for large-scale production of savoury snacks and convenience food products. For instance, the data of smoke point, flash point, and FFAs of palm olein, given in Table I, show its good performance as a frying medium (Bracco *et al.* 1981). Typical specifications of palm olein for high-qualityfrying purposes are listed in Table II. Some oil suppliers/refiners also include colour (Lovibond 5.25 inch cell) 3.0 R max, 30 Y max, moisture & impurity 0.1% max, peroxide value, < 0.5 mEq/kg of oxygen, and flash point 320-325°C in the specifications data sheet. Other quality assessment parameters such as iodine value, fatty acid composition, slip point, tocopherols content, % solid fat content, any permitted antioxidants / anti-foam agent e.g. E900 added specially into oils for catering purposes, etc. are provided, on request, to individual users of frying fats.

TABLE I

Performance of palm olein during frying operations

Frying Time (Hours)	Smoke point (°C)	Flash point (°C)	FFAs (%)
0	222	325	0.03
24	218	323	0.11
49	198	320	0.19
82	182	315	0.32
104	180	310	0.54
124	172	304	0.70

TABLE II
Typical specifications of palm olein

FFAs (%)	0.02-0.05
SMOKE POINT	230-240°C
INDUCTION PERIOD AT 120 °C	12-16 hours
FLAVOUR	BLAND

FRYING EQUIPMENT FEATURES AND SAFETY ASPECTS

These days the most modern manufacturing and the finest materials are used in the production of fryers, where a range of products are subjected to frying at elevated temperatures ranging from 160 to 200°C. The stringent quality control practices used by the leading food equipment manufacturers ensure their superior design quality and reliability, safe and secure operation at high temperatures. Two important features of non-domestic frying equipment are the scale/quantity and the nature of actual frying operation. Basically, the frying operations are categorised into two groups:

I. Small (static) batch frying operations used by the catering/ fast-foods/restaurant outlets.

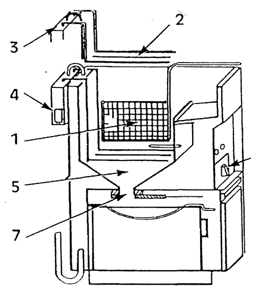
II. Large (continuous) frying operations used on the industrial scale to produce high volumes of the individual end-products. Because of a number of differences between the batch and industrial frying operations including safety and security level involved, these processes are discussed separately.

Batch-scale frying operations:

Frying oil capacity of pans used in the catering industry is in the range of 5 to 25 litres. Typical design features of modern catering fryers are: they are constructed with high-grade stainless steel (including heating elements), no copper or brass valve fittings, accurate thermostatic temperature control, and easy to clean. The auxiliary equipment for automatic frying include automatic basket lift, and built-in pump filtration unit for the removal of debris. Over the period, the sediments/debris, if not removed can cause smoking, charring, darkening, and off-flavour development in the oil, which would affect the product quality adversely. Therefore, for safe operation, periodic removal of any floating material and filtration of the oil on a daily basis is essential practice carried out by a good operator.

The usual frying temperature employed in the catering / fast- food outlets is in the region of 165-190°C. This implies that minimum smoke point, 210°C, of a fresh unused oil, mentioned earlier, is at least 20°C higher than the highest temperature employed. This would provide a good safety margin for secure and quality frying for catering purposes.

In the United Kingdom, over the last 40 years, Valentine Equipment Ltd has been supplying electric fryers to the catering industry. The needs of to-day's caterers –speed, reliability, safety and cost– are met with the latest Zenith series of fryers. The details of Maxi Valentine batch-fryer are presented in Figure 2. All new Valentine Zenith-Dialogue fryers are constructed with high-grade stainless steel. The highly efficient and long heating element (with large surface area limited to 4 watts per square cm) made entirely from stainless steel heats the oil carefully without burning it. The element surface temperature is limited to 250°C. The oil temperature, ± 1°C, is controlled by a most sensitive and accurate electronic thermostat with LED display for the operator.



MAXI

1. BASKET WITH QUANTITY LEVELS
2. STAINLESS STEEL ELEMENTS
3. ELEMENTS LIFT AND SWIVEL
4. SECURITY THERMOSTATS
5. LARGE AND DEEP COOL ZONE
6. UNIQUE FRY INDICATOR
7. DRAIN VALVE

Figure 2
Valentine «Maxi» Zenith series batch fryer

Thus, executing the frying at the correct temperature prolongs life of the oil and secures the operation.

The most important design feature of Zenith fryers is that each element is fitted with secondary security thermostat. These security thermostats are designed to trip out if primary thermostat fails. They also get activated if oil level is too low or the oil is drained too hot. Also the current isolator switch, fitted to the elements, cuts the electrical supply to the element head if it is not seated correctly in the frying pan. These security-guard systems prevent the frying oil overheating or even reaching flash point. The unique, green signal lamp, fry indicator informs the operator of exactly the right moment to introduce food in the fryer. This moment is 30-40 seconds before the thermostat cuts out and thus the output is increased by 20%. In other words, the fryer heats continually at peak times and gives maximum output, while in quiet periods it maintains temperature with only one third of the power, thus saving oil and electricity.

Table III lists oil capacity, French fries (chips) per hour output, and other features of Zenith series. These fryers are fully interlocking and a suitable combination of them can be employed to produce fast/convenience foods for medium-sized outlets at peak times.

The element control panel of each fryer is equipped with lift and swivel mechanism for easy cleaning of the pan. On daily basis i.e. at the end of the day, the cool oil (at least half hour after last operation) can be easily drained through filter and into the stainless steel bucket, simply by switching on the pump mode automatically. The sediments on the filter are removed and the filter is washed only with very hot water. The bucket is wiped out clean and the filter is replaced. The use of detergent for cleaning filter is not recommended. A comprehensive check list for safe operation of batch frying is presented in Table IV.

TABLE III
Some valentine fryers of zenith series

	PENSION 1	CANTINE	MAXI
French fries per hour	20 kg	45 kg	65 kg
Oil capacity	8	15.5	25
Basket lift	x	✓	✓
Heat boost	x	✓	✓
Built-in-filtration	x	✓	✓

TABLE IV
Check list for safe/secure frying operation

1	NEVER SWITCH ON FRYER WITHOUT OIL
2	USE CORRECT OIL LEVEL
3	HEAT COLD OIL USING LOWEST TEMPERATURE SETTING
4	DON'T OVERFILL THE BASKET
5	FRY FOODS AT THE CORRECT TEMPERATURES
6	ALWAYS FRY HIGH WATER CONTENT/CRUMBED FOODS SEPARATELY
7	DON'T SALT FOOD OVER THE OIL
8	KEEP THE LID ON WHEN THE FRYER IS NOT IN USE
9	CHECK THERMOSTATS ARE WORKING CORRECTLY
10	FILTER OIL REGULARLY
11	CLEAN FRYER REGULARLY
12	NEVER LEAVE WATER IN THE FRYER AFTER CLEANING

Large-scale (industrial) frying operation:

Industrial deep-fat frying is a quite a complex operation. Over the past 25 years, several food equipment manufacturers are improving continually the design features of frying systems so as to meet modern demands of better quality product, producing new exotic products, higher efficiency, lower production cost, secure and environmentally safe operation. Two types of products are commonly deep fried on large scale installations.

Type I: many convenience foods such as various battered and bread-crumbed chicken portions and fish products, and blanched or pre-fried potato chips which are frozen rapidly after frying and re-heated or cooked in an another oil before consumption.

Type II: potato crisps with different flavours, snacks based on corn, wheat flour or potato solids, and nut products which are fried, packed into suitable packaging, stored at ambient temperatures and then consumed before the end of shelf-life. In both cases, there should not be any development of objectionable/ adverse, off-flavour during the expected storage period i.e. the best before date. Although many products have their own flavours or added flavouring, probably the most important requirement for secure industrial operation is that the security of oil quality is maintained during the course of frying process.

Typical industrial fryers have oil capacities ranging from 200 to 1000 kg and production capacities i.e. input rate to the fryer from 250 to 2000 kg. In fact, depending upon the type and the quantity of food product fried, the fryer is designed and constructed specifically to achieve optimum frying operation. Figure 3 presents basic diagram of a continuous industrial fryer. The conveyors, heating system, hood cover, and other parts of the equipment are not illustrated here. The oil level in the frying tank is maintained continuously by adding controlled amount of fresh oil. Depending upon the product type, the sediments/debris are discharged as necessary.

It is well-established in the literature (Thomson, 1990), and can be seen from the data shown in Table V that fast oil «turn-over» maintained satisfactorily the level of FFAs. In this particular example, Indian snack product called «Sev» prepared from gram flour was fried in an industrial fryer charged with 2.5 tonnes of groundnut oil, initial FFAs content 0.6%. With slow «turn-over» there was a continuous increase in FFAs content and also other oil deterioration parameters (Lakshminarayana *et al.* 1979). These data clearly show that the oil turn-over must be kept high in order to maintain high/total oil quality (FFAs 0.2%) during the course of industrial frying. This will, obviously, keep smoke point of the oil, 15 to 25°C, above the actual frying temperature. In general, depending upon on the nature of product and the cooker design, the oil turn-over in the industrial operation is kept between 3 to 8 hours. Several factors relating to fryer design which can have a profound effect on the working life of the oil are listed in Table VI. For example, longer life of the oil is attained by keeping the lower uniform heat input per unit area of heating system, thus eliminating localised hot spots, and by continuous removal of the debris from the oil.

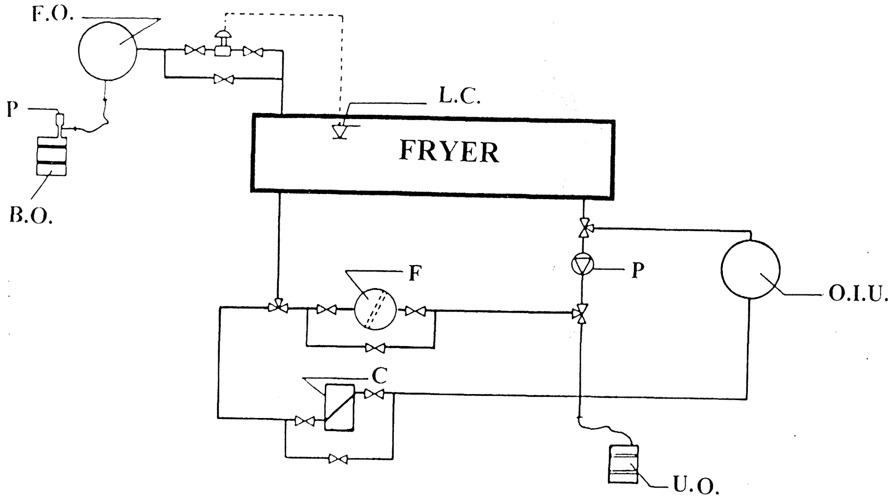


Figure 3
Basic diagram of industrial deep fat fryer

F.O. = fresh oil; P = pump; B.O. = bulk oil; F = filter; C = cooler; L.C. = level controller; U.O. = used oil; O.I.U. = oil in use.

TABLE V
Effect of oil turnover on oil quality in continuous fryer

*SLOW OIL TURNOVER		**FAST OIL TURNOVER	
Frying Time (Hours)	FFAs (%)	Frying Time (Hours)	FFAs (%)
0	0.5	0	0.6
8	0.6	65	0.8
25	1.1	156	0.7
50	2.0	367	0.7
75	3.2	500	0.8

*** Turnover change = 13 hours ** Turnover change = 8 hours**

It is worth mentioning two main frying equipment manufacturers, namely (1) Florigo B.V. The Netherlands, and (2) Cambridge Food Systems Ltd. UK (previously known as Sandvik Jahn), who supply continuous fryers to the snack food industry.

The directly-heated electric fryer, supplied by Cambridge Foods Systems, has a large heat exchanger surface relative to a low oil capacity in the frying tank/kettle. This leads to uniform oil temperature,

TABLE VI
Design features of continuous industrial fryer

* CONSTRUCTED WITH HIGH GRADE STAINLESS STEEL
* COUPLED WITH CLEAN-EASY MECHANICAL SYSTEM
* NO COPPER OR BRASS VALVES/FITTINGS
* OPTIMUN DIMENSIONS FOR OIL SURFACE RATIO TO OIL
* NO «DEAD» OR «HOT» SPOTS
* VERY ACCURATE CONTROL OF FRYING TEMPERATURE AND DURATION
* MAINTENANCE OF EFFECTIVE STEAM BLANKET OVER HOT OIL SURFACE
* CONTINUOUS REMOVAL OF DEBRIS/SEDIMENT
* NO AERATION OF HOT OIL DURING PUMPING
* EFFECTIVE HEAT EXCHANGERS TO RAPIDLY LOWER THE TEMPERATURE OF HOT OIL, IF REQUIRED
* SEPARATE STORAGE TANK FOR «USED» OIL
* TEMPERATURE CONTROL OF BULK OIL
* NO AIR POLLUTION FROM FRYING VAPOURS
* EFFECTIVE RECOVERY OF WASTE HEAT
* MINIMUN INSTALLATION COST, EFFICIENT OPERATIONAL USE & LOW MAINTENANCE CONST I.E. OPTIMUN PRICE-PERFORMANCE RATIO
* NATURE AND QUANTITY OF FRIED FOOD PRODUCT CONVEYED THROUGH FRYER

± 2°C, and a low temperature differential between the heating surface of stainless tubes and the surrounding oil. These design features prevent hot spots and generation of burnt deposits on the hot tube surface. A high oil turn-over rate 2-3 hours is obtained by constructing V-shaped cross-section of the frying tank, which reduces the total volume of frying oil in use. Lower operating costs of the electric fryer are claimed to be due to higher heating efficiency 90-100%.

In order to meet the special requirements of a wide range of snack end-products, Florigo B.V. has developed a range of multi-purpose fryers for their production. This is achieved by combining various items of equipment. Figure 4 shows general details of Florigo fryer in open position. Frying process, at extremely uniform rate, is carried out using regulated throughput and good oil circulation coupled with accurate temperature control. The hood and conveyor of stainless steel equipment can be lifted by electro-hydraulic system for easy cleaning. The special feature of the multi-purpose fryer is that it is adaptable to any heating source, which can be by means of internal or external heat exchanger. The heating source can be operated as a direct heater using electricity, gas or fuel oil, or as an indirect heat exchanger for thermal oil or steam. The thermal oil or steam, which can withstand much higher temperature than the frying oil with safety, is heated in a generator and pumped into an exchanger either external or internal to fryer where it transfer heat with accurate and safe control. The frying process equipped with indirect heating system has several advantages such as no hot spots, little oil breakdown, consistence product quality, high heat transfer efficiency, low running and maintenance costs.

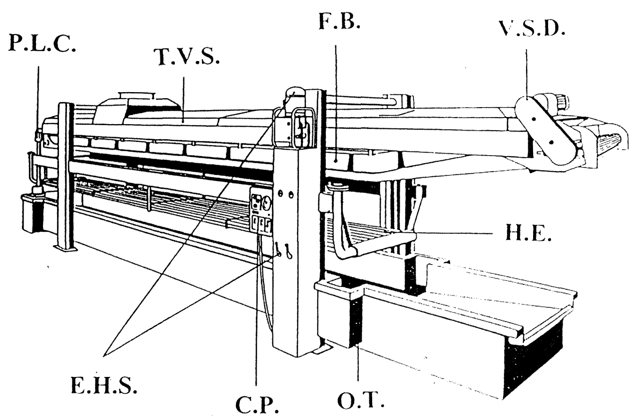


Figure 4
Diagram of Florigo continuous deep fat fryer in open position

P.L.C. = pump & level controller, T.V.S. = telescopic vapour stack; F.B. = frying belt;
O.T. = oil tank; V.S.D. = variable speed drive; C.P. = control panel; H.E. = heat exchanger;
E.H.S. = electro-hydraulic system.

High efficiency, Flow-Therm, heating systems for industrial frying oils are supplied by Flow-Mech Ltd., UK. Figure 5 illustrates details of FTU version heating system with multiple waste energy recovery. At a controlled rate, the frying oil is passed through stainless steel tubes, the outsides of which are heated via heat transfer from pre-heated gases. The required temperature of the oil in the fryer is thus maintained, ±1°C, by continuous circulation of the oil. The FTU heating system, designed for 24 hours operation, can be easily cleaned and maintained, and will operate with 90% efficiency.

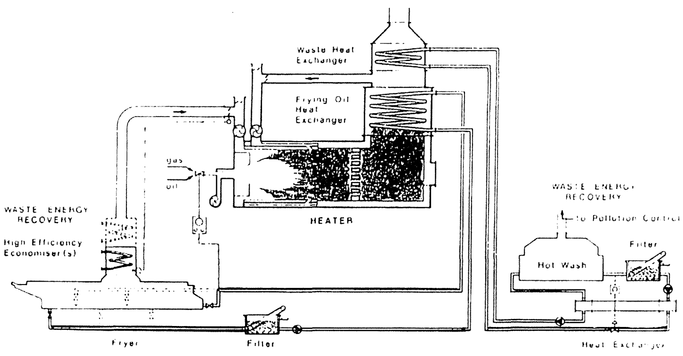


Figure 5
Diagram of F.T.U. high efficiency heating system for frying oil

Pollution control systems:

The frying fumes, primarily made up of moisture and a fine mist of oil/fatty acids, are of great concern to the snack food manufacturers. For health and safety reason, these smelly fumes must be eliminated from the frying operations installed in built-up areas. These days most of industrial frying installations are equipped with pollution control systems to overcome fumes problem. The frying-vapour combustion system can be supplied along the FTU high efficiency heating system (shown in Figure 5). With pollution control and full energy recovery the FTU system will operate up to 88% efficiency. This optional pollution control system assures the complete combustion of the smelling components in the fumes.

An efficient air-cleaning system for controlling the emission of fatty deposits and odours, particularly palm oil vapours, released from convenience food and potato-chip frying industry is supplied by Colt International, UK. Often appearing as a fine mist / smoke, with droplet size about 0.3 micron diameter, is difficult to remove using gas scrubbing equipment. Important features of this waste air-cleaning system are high resistance to fouling, compact installation, easy access for inspection, cleaning and maintenance (Anon, 1995). The design procedure, computer modelling, is used to predict plume dispersion and to assist in the elimination of odour concentrated at ground level.

Fire protection systems:

Carbon dioxide blanketing systems are normally employed in food processing industry, including large-scale frying installations. These days, the latest development in fire protection, the Hi-fog system supplied by Flow-Mech Ltd is gaining market. The fire protection system utilises a mist of very fine water droplets to extinguish and cool fire. The fine mist is produced by a supply of water and nitrogen to the spray heads at a pressure of 210 bar. The mist, droplet size 0.01 mm, absorbs heat from the fire rapidly and the flames are quenched effectively. Any airborne water soluble particles or smoke will also be absorbed by the mist. It is claimed that any major fire down the full length of an industrial fryer would be quenched and extinguished within a period of approximately 10 seconds. In addition, the system can easily be adapted to run at a lower pressure for effective cooling of, for instance, hot frying oil at commencement of shut-down periods. The Hi-fog system has been tested to be electrical safe. No disruptive discharges were observed when tested on 690V AC/DC and 24 kV switch gear. The fire protection system is environmentally safe, as it uses only clean de-ionised water and nitrogen.

Stir-frying equipment:

The extremely rapid cooking of Chinese stir-fry dishes require quick, precise, manual stirring and tossing to fry the product evenly. Stir-frying process requires extremely high temperatures up to 260°C e.g. in the case of puffed rice products. Such high temperatures are needed to shear ingredients to produce crisp and fresh textured product, which must be cooled rapidly to maintain its crispiness.

Blentech has now mechanised the manual stir-frying technique and produced mechanical stir-fryer to prepare Chinese food dishes on large scale (Tetlow, 1996). Temperature in excess of 310°C is achieved by pumping safely hot thermal oil through the jacket of the Versa-Wok. The patented scraper system with «PEEK» scraper blades controls burn-up at these ultra high temperatures. The automatic reversing agitators mix and toss crisp product to keep it frying uniformly. The stir-fried product is then discharged and chilled quickly with carbon dioxide or liquid nitrogen spray in order to lock in its crispness. Within seconds the discharge doors are opened and the product is pushed out of the Versa-Wok for packaging. The discharge and access doors are all safely interlocked. One operator can stir fry 135 kg of Chinese food product from loading to discharge in less than 8 minutes. This unique stir-frying / cooking system is also equipped with a vacuum cooling facilities which can be used to produce improved quality of other ethnic/Asian food products at lower operational costs.

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