DECEMBER 2019

Application Solutions Guide

THE GLOBAL PALM OIL INDUSTRY LANDSCAPE

Experience In Motion

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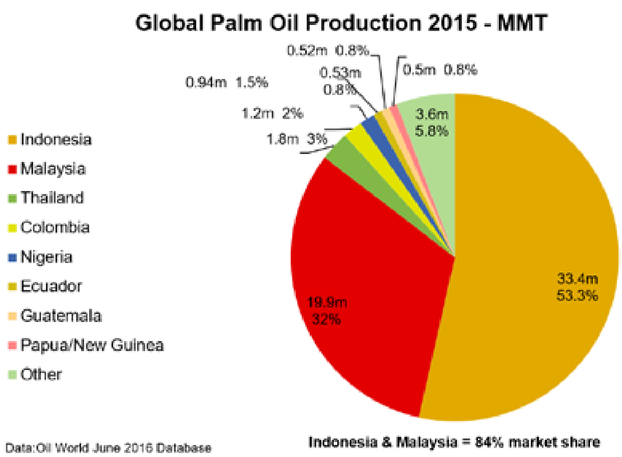
THE GLOBAL PALM OIL INDUSTRY LANDSCAPE

Palm oil, one of the world's most widely produced and consumed oils, is a tropical oil, growing only within 10 degrees north or south of the equator. These growing regions house vast areas of tropical rainforest rich in biodiversity on the continents of Asia (such as Indonesia and Malaysia, global palm oil production countries), Africa and South America due to their warm temperatures, abundant sunshine, and plenty of rain suitable for maximizing plantation yield and production.



This cheap, production-efficient and highly stable oil is used in a wide variety of food, cosmetic and hygiene products. It can also be used as a source for bio-fuel (or biodiesel), one of the key factors driving the growth of the palm oil market in the world. Some noteworthy trends such as expanding global population, growing economy and developments within this industry are increasing demand for sustainable palm and red palm oil. However, the market growth and development are limited by changing global weather conditions, market price volatility, impacts on the environment, and loss of critical habitat for endangered species due to land clearance activities for palm oil plantation.

Palm oil is obtained from the reddish pulp of the fruit of a palm oil seed from the oil palm tree. Through a series of processes, it can produce two different types of oil, i.e., **palm oil** and **palm kernel oil**, which are used in products to treat several medical conditions such as: vitamin A deficiency; cancer; brain disease; as well as malaria; high blood pressure; and high cholesterol.

- Palm oil, referring to the oil extracted from the fruits of the palm oil tree, is an edible plant oil that is naturally reddish, as it contains high amounts of beta-carotene (antioxidant).
- The palm oil tree has an average productive lifespan of about 25 to 30 years. It can reach a height of up to 30 feet (9 m) and produces fruit bunches from three years of age after field planting.
- In each productive year, a palm oil tree may produce between 8 to 12 bunches of fruit.
- Each bunch weighs between 10–25 kg (22–55 lb) and contains between 1000 and 3000 fruitlets.

- Loose fruits are ripe fruitlets which have fallen from a ripe bunch. They are often used as an indication to measure bunch ripeness.
- These fruits are the ripest in the bunch, and therefore contain the highest amount of oil.
- The palm oil fruit is almost spherical in shape. It consists of a hard seed **(kernel)** enclosed in a shell **(endocarp)** which is surrounded by fleshy husk **(mesocarp)**.
- Palm oil is extracted from the mesocarp.
- Palm kernel oil is derived from the kernel after being separated from the mesocarp.

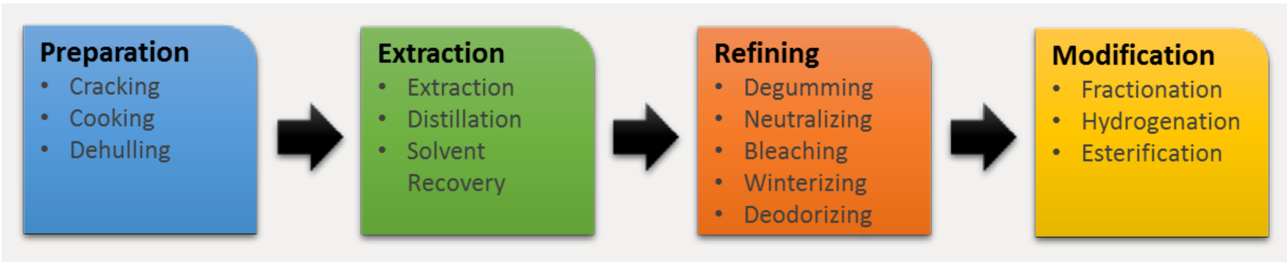
Harvested year-round, palm oil trees produce on average 10 tons (22 050 lb) of fruit per hectare — far more than soya, rapeseed and sunflower crops. This is an effective use of the land, as palm oil requires 10 times less land than the other three major oil-producing crops. In addition to a generally accepted industry standard or rule of yielding 3.74 tons (8250 lb) of palm oil per hectare, 0.4 tons (880 lb) of palm kernel oil and 0.4 tons (880 lb) of palm kernel expeller/cake are also produced from the fresh fruit bunches (FFB).

Palm kernel oil, conversely, is a raw material used in the production of non-food products such as soaps, toiletries and candles. Palm kernel expeller is used extensively in the energy and animal feed sector. Palm kernel oil is a widely used ingredient in the personal care market.

Although a variety of oils remain available apart from palm oil, the many advantages palm oil possesses allows it to remain the most consumed oil globally. The above introductory section of this application selling guide provides a brief summary of global palm oil production, consumption and its regional markets for a basic understanding of the palm oil industry.

A Closer Look at Palm Oil Processing and Technologies

Palm Oil Fundamental Processes



Preparation — *Cleaning, cracking and cooking to get raw oil seed or fruit*

Seedlings are raised in the nursery for about 12 months prior to transplanting in the field. After 24 to 30 months, the oil palm starts to yield fruit in compact bunches called fresh fruit bunches (FFB). Harvesting involves manually cutting ripe bunches using a chisel or sickle. Collection of harvested fruits is either done manually, sometimes with a wheelbarrow, or mechanically using a tractor-mounted grabber with trailer.

Extraction — *Separation of oil from fruit or seed by mechanical, chemical or mechanical/chemical processes*

To preserve the freshness and quality of palm oil, the FFB are preferably sent to the mill for extraction within 24 hours of being harvested. They are steamed under high pressure to sterilize, loosen and soften the fruits before they are stripped from their stalks and mechanically pressed to extract the oil. No solvents are used to express the oil.

Refining — *The goal of refining is to remove undesirable components while retaining the product.*

The extracted oil from the mill is called Crude Palm Oil (CPO). CPO is sent to a refinery where impurities, colors (by bleaching) and odors (by deodorizing) are removed. The refinery would also separate the solid (palm stearin) and liquid (palm olein) fractions of oil to cater to a wide range of uses.

Modification — *Provide the oil with the desired functionality (hardness, crystallization and oxidative stability)*

Interesterification (synonym of *transesterification*) — *Mixing the methanol with a catalyst to form fatty acid methyl esters (FAME)*

Fat modification processes provide opportunities to offer an array of products, reach out to new customer groups and provide increased revenue for businesses. Strategic advantages to be gained from modifying these fats include moving from the basic processing of bulk oils and fats and focusing on a wider market spread and reach. This in turn allows the plant to better handle the impact of seasonal demand, market volatilities and the global commoditization of basic agricultural products.

Fat modification techniques like *fractionation*, *interesterification* (chemical or enzymatic) and *hydrogenation* allow proposing a large range of new fatty products.

The simplest and cheapest fractional crystallization technique of fats and oils (i.e., no chemicals, effluent or losses) is by far dry fractionation. The oil processing industry uses this technique to extend the application of a variety of fatty matters as well as to replace, whether fully or partially, the chemical modifications. Due to the continuous improvements and developments of the dry fractionation process, a gamut of products normally produced by solvent fractionation can now be obtained with a high degree of selectivity with dry fractionation.

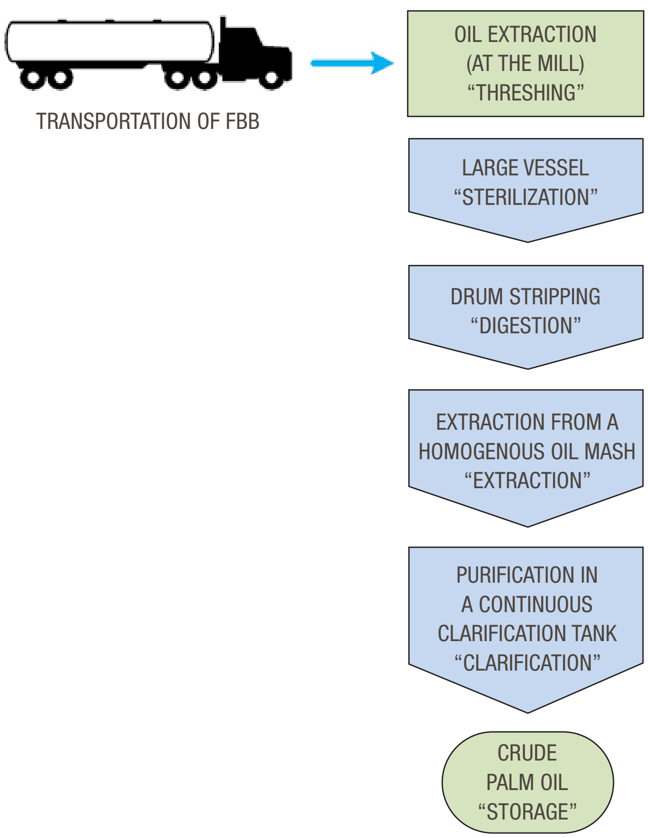
Palm Oil Mill (Oil Extraction)

Reception of Fresh Fruit Bunches (FFB)

Fresh fruit arrives from the field as bunches or loose fruit. It is normally emptied into wooden boxes suitable for weighing on a scale so that quantities of fruit arriving at the processing site may be checked. Large installations use weighbridges to weigh materials in trucks.

The quality standard achieved is initially dependent on the quality of bunches arriving at the mill. The mill cannot improve upon this quality but can prevent or minimize further deterioration.

Palm Oil Mill (Oil Extraction)



The field factors that affect the composition and final quality of palm oil are genetics, age of the tree, agronomic, environmental, harvesting technique, handling and transport. Many of these factors are beyond the control of a small-scale processor. Some control may be exercised over harvesting technique as well as post-harvest transport and handling.

Threshing (removal of fruit from the bunches)

The FFB consists of fruit embedded in spikelets growing on a main stem. Manual threshing occurs by cutting the fruit-laden spikelets from the bunch stem with an axe or machete and then separating the fruit from the spikelets by hand.

In a mechanized system, a rotating drum or a fixed drum equipped with rotary beater bars detaches the fruit from the bunch, leaving the spikelets on the stem.

Most small-scale processors do not have the capacity to generate steam for sterilization. Therefore, the threshed fruits are cooked in water. Whole bunches, which include spikelets, absorb a lot of water in the cooking process. High-pressure steam is more effective in heating bunches without losing much water. Therefore, most small-scale operations thresh bunches before the fruits are cooked, while high-pressure sterilization systems thresh bunches after heating to loosen the fruits.

Small-scale operators use the bunch waste (empty bunches) as cooking fuel. In larger mills, the bunch waste is incinerated and the ash, a rich source of potassium, is returned to the plantation as fertilizer.

Sterilization of Bunches

Sterilization or cooking means the use of high-temperature, wet-heat treatment of loose fruit. Cooking normally uses hot water; *sterilization uses pressurized steam.* Cooking serves several purposes:

- Heat treatment destroys oil-splitting enzymes and arrests hydrolysis and autoxidation.
- For large-scale installations, where bunches are cooked whole, the wet heat weakens the fruit stem and makes it easy to remove the fruit from bunches in the threshing machine.
- Heat helps to solidify proteins in which the oil-bearing cells are microscopically dispersed. The protein solidification (coagulation) allows the oil-bearing cells to come together and flow more easily on pressure application.
- Fruit cooking weakens the pulp structure, softening it and making it easier to detach the fibrous material and its contents during the digestion process. The high heat is enough to partially disrupt the oil-containing cells in the mesocarp and permits oil to be released more readily.
- The moisture introduced by the steam acts chemically to break down gums and resins. The gums and resins cause the oil to foam during frying. Some of the gums and resins are soluble in water. Others can be made soluble in water, when broken down by wet steam (hydrolysis), so that they can be removed during oil clarification. Starches present in the fruit are hydrolyzed (i.e., broken down by chemical reaction with water) and removed in this way.
- When high-pressure steam is used for sterilization, the heat causes the moisture in the nuts to expand. When the pressure is reduced, the contraction of the nut leads to the detachment of the kernel from the shell wall, thus loosening the kernels within their shells. The detachment of the kernel from the shell wall greatly facilitates later nut cracking operations. It is obvious that sterilization (cooking) is one of the most important operations in oil processing, ensuring the success of several other phases.
- However, it is important to ensure evacuation of air from the sterilizer during sterilization. Air not only acts as a barrier to heat transfer, but oil oxidation increases considerably at high temperatures; hence, oxidation risks are high during sterilization. Over-sterilization can also lead to poor bleach ability of the resultant oil. Sterilization is also the chief factor responsible for the discoloration of palm kernels, leading to poor bleach ability of the extracted oil and reduction of the protein value of the press cake.

Digestion of the Fruit

Digestion is the process of releasing the palm oil in the fruit through the rupture or breaking down of the oil-bearing cells. The digester commonly used consists of a steam-heated cylindrical vessel fitted with a central rotating shaft carrying a number of beater (stirring) arms. The fruit is pounded by the rotating beater arms. Pounding, or digesting the fruit at a high temperature, helps to reduce the viscosity of the oil, destroys the fruit's outer covering, and completes the disruption of the oil cells which had begun in the sterilization phase.

Contamination from iron is greatest during digestion when the highest rate of metal wear is encountered in the milling process. Iron contamination increases the risk of oil oxidation and the onset of oil rancidity.

Pressing (extracting the palm oil)

There are two distinct methods of extracting oil from the digested material:

- **Dry method** — uses mechanical presses
- **Wet method** — uses hot water to leach out the oil

In the dry method, the objective of the extraction stage is to squeeze the oil out of a mixture of oil, moisture, fiber and nuts by applying mechanical pressure on the digested mash. There are several different types of presses, but the principle of operation is similar for each. The presses may be designed for batch or continuous operations.

Batch Presses

In batch operations, material is placed in a heavy metal cage, and a metal plunger is used to press the material.

The main differences in batch press designs are as follows:

- Method used to move the plunger and apply the pressure
- Amount of pressure in the press
- Size of the cage

The plunger can be moved manually or by a motor. The motorized method is faster but more expensive to operate.

Different designs use either a screw thread (mechanical press) or a hydraulic system (hydraulic press) to move the plunger. Higher pressures may be attained using the hydraulic system, but be aware to ensure that hydraulic fluid does not contaminate the oil or raw material. Hydraulic fluid can absorb moisture from the air and lose its effectiveness, and the plungers wear out and need frequent replacement. Spindle press screw threads are made from hard steel and held by softer steel nuts, so the nuts wear out faster than the screw. These are, however, easier and cheaper to replace than the screw.

The size of the cage varies from 5 to 30 kg (11 to 66 lb), with an average size of 15 kg (33 lb). The pressure should be increased gradually to allow time for the oil to escape. If the depth of material is too great, oil will be trapped in the center. To prevent this, heavy plates can be inserted into the raw material. The production rate of batch presses depends on the size of the cage and the time needed to fill, press and empty each batch.

Hydraulic presses are faster than spindle screw type, and powered presses are faster than manual type: *ease of operations with increased productivity.*

Continuous Systems

The early centrifuges and hydraulic presses have slowly been replaced with specially designed screw presses. These consist of a cylindrical perforated cage with a closely fitting screw running through it. Digested fruit is continuously conveyed through the cage toward an outlet restricted by a cone, which creates the pressure to expel the oil through the cage perforations (drilled holes). Oil-bearing cells that are not ruptured in the digester will remain unopened if a hydraulic or centrifugal extraction system is employed. Screw presses, due to the turbulence and kneading action exerted on the fruit mass in the press cage, can effectively break open the unopened oil cells and release more oil. These presses act as an additional digester and are efficient in oil extraction.

Moderate metal wear occurs during the pressing operation, creating a source of iron contamination. The rate of wear depends on the type of press, method of pressing, nut-to-fiber ratio, etc. High pressing pressures are reported to have an adverse effect on the bleach ability and oxidative conservation of the extracted oil.

Clarification and Drying of Oil

The main purpose of clarification is to separate oil from its entrained impurities. The fluid coming out of the press is a mixture of palm oil, water, cell debris, fibrous material and "non-oily solids". Because of the non-oily solids, the mixture is very thick (viscous). Hot water is therefore added to the press output mixture to thin it. The dilution with the addition of water provides a barrier, causing the heavy solids to fall to the bottom of the container while the lighter oil droplets flow through the watery mixture to the top when heat is applied to break the emulsion (oil suspended in water with the aid of gums and resins). Water is added in a proportional ratio of 3:1.

The diluted mixture is passed through a screen to remove coarse fiber. The screened mixture is boiled for one or two hours and then allowed to settle by gravity in the large tank so that the palm oil, which is lighter than water, will separate and rise to the top. The clear oil is decanted into a reception tank. This clarified oil still contains traces of water and dirt. To prevent increasing FFA through autocatalytic hydrolysis of the oil, the moisture content of the oil must be reduced to 0.15 to 0.25%. Re-heating the decanted oil in a cooking pot and carefully skimming off the dried oil from any engrained dirt removes any residual moisture. Continuous clarifiers consist of three compartments to treat the crude mixture, dry decanted oil and finished oil in an outer shell as a heat exchanger.

The wastewater from the clarifier is drained off into nearby sludge pits dug for this purpose. No further treatment of the sludge is undertaken in small mills. The accumulated sludge is often collected in buckets and used to kill weeds in the processing area.

Oil Storage

In large-scale mills, the purified and dried oil is transferred to a tank for storage prior to dispatch from the mill. Since the rate of oxidation of the oil increases with the storage temperature, the oil is normally maintained around 50°C (122°F), using hot water or low-pressure, steam-heating coils to prevent solidification and fractionation. Iron contamination from the storage tank may occur if the tank is not lined with a suitable protective coating.

Small-scale mills simply pack the dried oil in used petroleum oil or plastic drums and store them at ambient temperature.

Kernel Recovery

The residue from the press consists of a mixture of fiber and palm nuts. The nuts are separated from the fiber by hand in small-scale operations. The sorted fiber is covered and allowed to heat, using its own internal exothermic reactions, for about two or three days. The fiber is then pressed in spindle presses to recover a second-grade (technical) oil that is used normally in soap making. The nuts are usually dried and can be sold to other operators who then process them into palm kernel oil.

Large-scale mills use the recovered fiber and nutshells to fire the steam boilers. The super-heated steam is then used to drive turbines to generate electricity for the mill. For this reason, it makes economic sense to recover the fiber and shell the palm nuts. In the large-scale kernel recovery process, the nuts contained in the press cake are separated from the fiber in a depericarper. They are then dried and cracked in centrifugal crackers to release the kernels. The kernels are normally separated from the shells using a combination of winnowing and hydro cyclones. The kernels are then dried in silos to a moisture content of about 7% before packing.

During the nut cracking process, some of the kernels are broken. The rate of FFA increase is much faster in broken kernels than in whole kernels. Breakage of kernels should therefore be kept as low as possible, given other processing considerations.

Refining Process – Physical Steam and Alkali Chemical

Key actions of transferring the **CPO** from the mill to the refinery include:

- Transfer from refinery tank to plant
- Drying of CPO at 95°C (203°F) and 100 mbar (1.45 psi)
- Degumming using phosphoric acid
- Bleaching using 3% bleaching earth at 180°C (356°F) and 100 mbar (1.45 psi)
- Removal of bleaching earth
- Deodorizing oil using nickel catalyst at 240°C (464°F) and 4 mbar (0.06 psi)
- Output product → **RBD palm oil**

It is important to have a proper **refining process** to produce high-quality, finished products with a specified quality range and meet user requirements. There are two basic types of refining technology available for palm oil:

(a) **Physical steam refining**

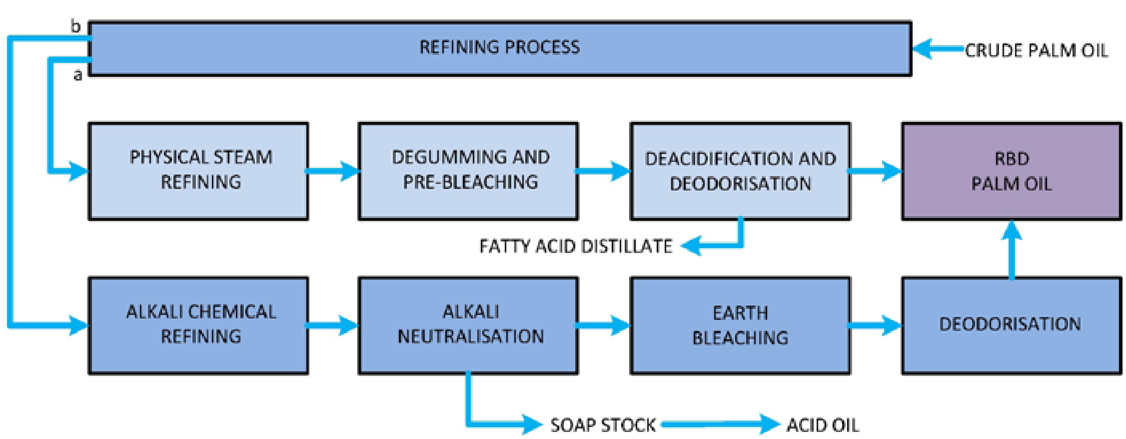
(b) **Alkali chemical refining**

The differences between these two types are based on the types of chemicals used and method of FFA removal. CPO gets processed into refined oil by removing impurities such as fatty acid, gums, dirt, trace metal and moisture.

In its early years of inception, the palm oil refining industry in Malaysia and Indonesia was mainly based on alkali chemical refining. Alkali chemical refining then was the more established process for edible oil. It was not until the late 1970s that physical steam refining of palm oil started to emerge as a more viable alternative to alkali chemical refining in many ways.

As the industry progressed over the years, physical steam refining has proved to be very successful for palm oil, and modern refineries primarily opted to implement it. Physical steam refining appears to practically replace the use of alkali chemical refining in palm oil as the consequence of high-acidity content in chemically refined oil. The de-acidification (deodorization) process stage in physical steam refining can overcome such a situation. Other than that, this method is preferred because it is acknowledged to be suitable for low-content phosphatide vegetable oils such as palm oil. Thus, physical steam refining is proven to have a higher efficiency, fewer losses, lower operating cost, less capital input and less influent to handle.

In general, chemical refining requires more processing stages, equipment and chemicals compared to physical refining. The processing routes for chemical and physical refining are thus summed up as per the illustration below.



Fractionation

Fractionation is a separation process in which crude palm oil is divided into liquid (palm olein) and solid (palm stearin) during a phase transition into smaller quantities (fractions) in which the composition varies per a gradient.

A simplified **process of fractionation** starts with:

- CPO (a mixture of various types of oil)
- Separation of the high-melting stearin and low-melting olein, where the mixture of CPO in the crystallizer tower is cooled
- Stearin crystals will then be separated from CPO and grow into crystals
- The stearin are then filtered via the membrane filter

Palm olein is the liquid oil obtained from palm oil refining. The refined oil is cooled to low temperatures by crystallization. The crystals will then be filtered into liquid palm olein and solid palm stearin products.

Palm stearin is the solid oil from the palm oil refining process. It can be used to blend with other vegetable oils to obtain suitable functional products such as margarine fats, shortenings, vanaspati (hydrogenated vegetable cooking oil) and others.

Palm stearin is also a useful natural hard stock for making trans-free fats.

In addition to edible products usage, it also is suitable for industrial usage such as making soaps and formulating animal feeds.

Physical Properties of CPO

Palm Olein

- Melting Temperature: 5°C
- Iodine Value: 63

Palm Stearin

- Melting Temperature: 27°C
- Iodine Value: 49

Iodine values are often used to determine the amount of unsaturation in fatty acids.

PALM OIL INDUSTRY PROJECT MODEL

Route to Market (RTM)

Palm oil is one of the key commodities within the Asia-Pacific market. Many palm oil processing plants in Indonesia and Malaysia were built under very cost-competitive models and involved many different stakeholders and key decision makers, including owners, licensors and the contractors who were awarded to build the plants.

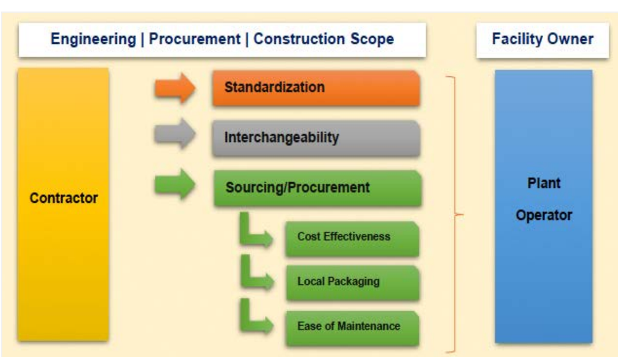
There are three typical scenarios of business ownership models:

1. Plantation owners with their own mill

2. Mill ownership by other business investors

3. Cooperation between mills and plantation owners

Against the above market setting, the currently most established route-to-market (RTM) is often via the following key stakeholders:



Business Model — Fixed EPC Projects

- **Engineering, procurement and construction (EPC)/Original equipment manufacturers (OEM)** — EPC will typically provide their respective niche expert engineering/technological advances and knowhow to the plants that they help to build.
- **Key business owners** — typical agribusiness groups like Wilmar International and Cargill with their own trading operations team
- **Mill owners** — with their own set of specifications and requirements that they can implement via the EPC contractor who is awarded the job.

The palm oil market is highly competitive and price sensitive among the EPC contractors as they strive to bid for any new project or newly built process plant.

THE PALM OIL INDUSTRY — FLOWSERVE INTERFACE

Business Impact and Focus Areas

The Big Picture

In the pumps/valves/seals general industry, there is no singular market data available in place due to the diverse nature of the classification. However, for the purpose of this application solutions guide, palm oil is classified under the broad category of Global Food/Biofuels/Vegetable Oils as per the published 2016 data available from EIF (European Industrial Forecasting Ltd, a market database information service provider).

Special Note: Outside of the main process plants, namely the mills and refineries (i.e., OSBL), there are off-site pump opportunities like the boiler feed water pumps in power generation units as well as engine-driven firewater pump packages that can greatly enhance pump opportunities for us.

The Flowserve Fit in the Palm Oil Industry

Flowserve, through our global presence and food and beverage capabilities, has the distinct advantage of being a single-source supplier of process equipment for the palm oil industry. We have the unique opportunity to provide an array of products and services ranging from pumps and precision mechanical seals to control and manual valves.

Competition in the palm oil market is extremely steep and challenging, with critical success factors linked to price, quick response to field service requests, and short delivery supported by the right level of inventories as primary requirements to support the fast turnaround requisite.

Our presence in this market is mainly through the strong and proven range of SIHI® products for the various services needed in mills and refineries. Our target plant size is in the 100- and 200-ton per day refining capacity. This is further complemented with the other heritage Flowserve products available to the general industry through the Industrial Product Operations (IPO).

For more details on specific pump applications, please refer to the section on “Flowserve Opportunities in the Palm Oil Industry” from page 18 onward.

Products for the Palm Oil Industry — at a Glance

There are many different processes and project scales for a palm oil mill. The products in which Flowserve and SIHI caters to for palm oil mill projects will vary accordingly. At a high level, Flowserve products and service offerings for the palm oil application can be categorized as follows:

Pumps

A variety of pumps and pumping applications can be found in the palm oil industries, including the production process, cooling water, and water and wastewater treatment. Therefore, you will find a wide range of high-quality pumps to cater to almost every need in the palm oil industries. Key among them are:

Liquid Pumps

- Horizontal, overhung pumps (ZLND, DBS, Mark 3™ ISO and ANSI, MEN)
- Side channel pumps (CEH)
- Multi-stage pumps (HEGA)

Vacuum Pumps

- Liquid ring vacuum pumps (LPH, LEM)

Valves

In the palm oil mill and refining process lines, some of the most commonly used valves are:

- Ball valves
- Butterfly valves
- Non-return valves

Additionally, for the **sterilizer** system, there is the need for high-performance butterfly valves.

Typical Flowserve valves used in the different stream of the palm oil process include critical and general services applications such as the following:

- **Control valves**
  - Globe (Valtek® GSV and Mark One™)
  - Eccentric plug (Valtek MaxFlo 4™)
  - Segmented ball (Valtek ShearStream™)
  - High-performance butterfly (Valtek Valdisk™)
- **On-off manual valves**
  - Ball (Flowserve®)
  - Butterfly (Serck Audco™ and FX)

Seals

For general applications, slurry and hot oil services:

Shaft sealing mechanical seal recommendations for palm oil mills and refineries along with the appropriate flushing plans are designed to enable longer and trouble-free operations or mean time between failure (MTBF)/or planned maintenance (MTBPM). Some standard mechanical seals in use are:

- Single pusher seals (Pac-Seal® and RO)
- Standard cartridge seals (ISC2 and P50)
- Metal bellow seals (BX)
- Custom design (GNZ balanced seal by Desmet Ballestra)

FLOWSERVE OPPORTUNITIES IN THE PALM OIL INDUSTRY

Flowserve Products and Capabilities in Palm Oil Mill

Overview

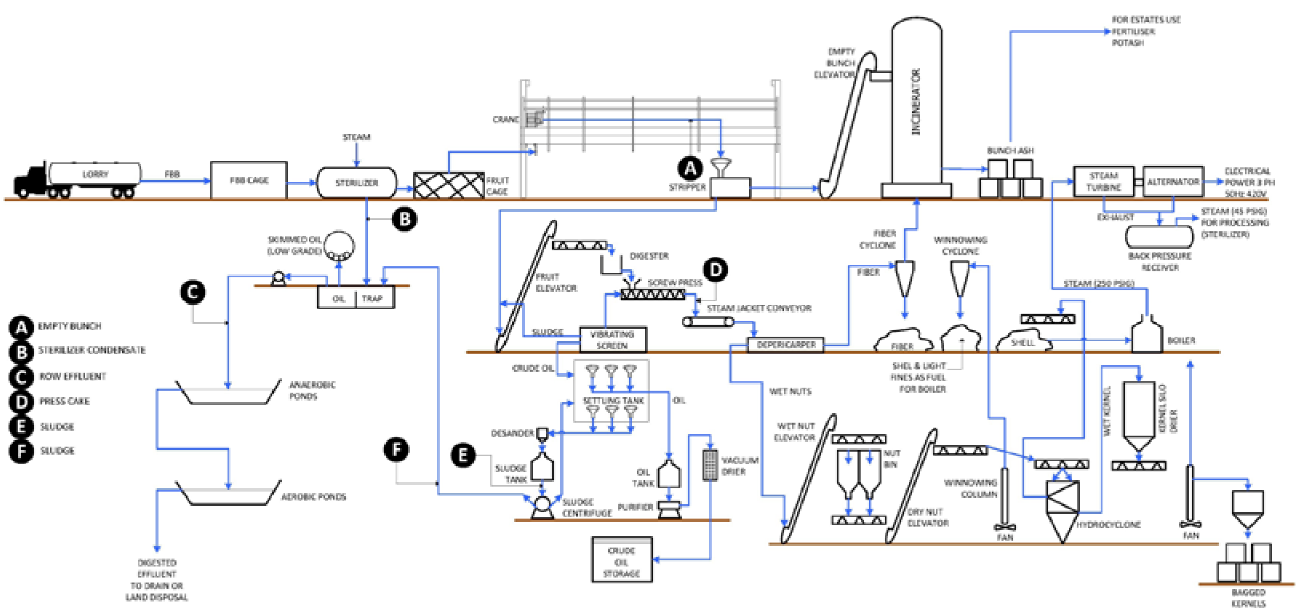
In general, the basics of a palm oil mill (POM) process have been broadly explained in a previous section. The yield derived from a given palm oil mill can now be summarized in a general timeline as follows:

- Palm fresh fruit spikelets are usually harvested in the third year of planting the seedlings.
- Each tree will normally produce one to three fruit bunches in a month.
- Harvesting of the fruit bunches will then be possible throughout the year thereafter.

After the FFB harvest, the oil extraction process shall begin and can be described in a few basic processes, starting with:

- Sterilization began in large fruit cages.
  - FFB are first loaded onto buggies which will then be pushed into the sterilizer.
  - It will then be cooked for about two hours using waste steam from the turbine at 45 psi (5 bar) until the fibrous parts become soft.
- Stripping the fibers from bunches and nuts follows in rotating drums.
- CPO are then extracted from fibers using the screw press.
- Purification in clarification tank will be the next process, with the removal of solids and water using centrifuges.
- Drying of CPO follows, using the vacuum process.
- Finally, the CPO is transferred to tanks for storage.

The overall palm oil mill extraction can now be summarized in a simple process flow diagram, as shown in the chart below.



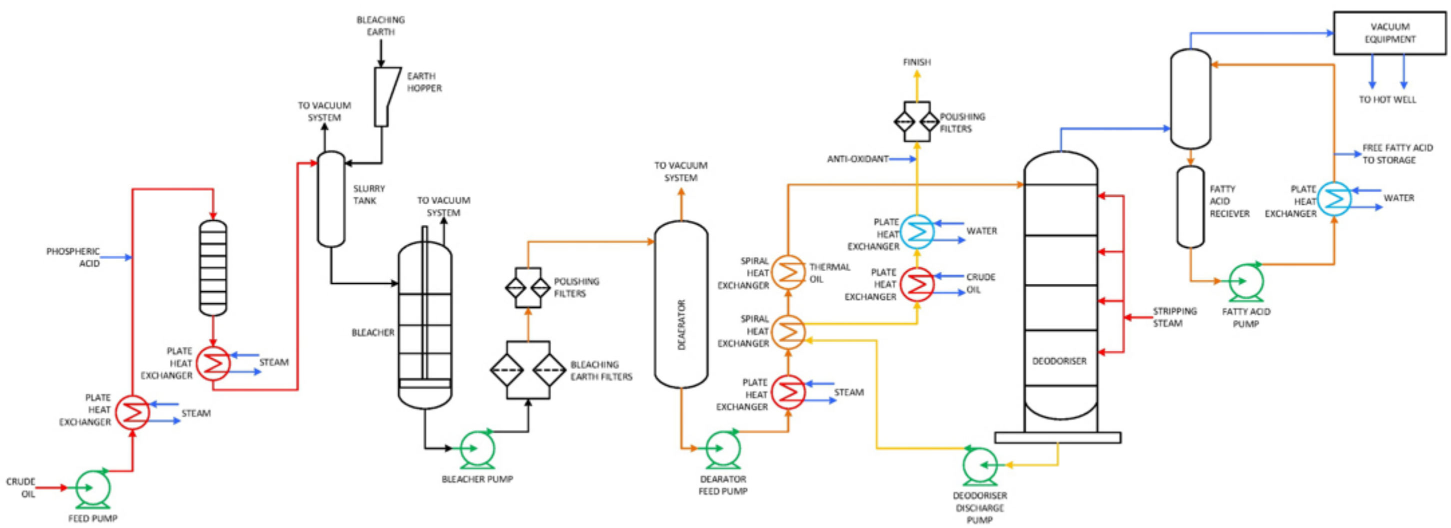
Products

A common range of pumps used in a POM include the following services:

- Clean water pump
- Sludge pump
- Clarifier pump
- Clean oil transfer pump
- Water transfer pump
- Deaerator pump
- Boiler feed pump
- Effluent pump

Flowserve Products and Capabilities in Palm Oil Refining

Overview



The following table shows typical pump selections for a 100 and 200 metric ton per day (MTD) capacity refinery based on SIHI Pumps selection:

Plant: 100 MTD Refinery		
Tag No	Services	Qty
PT 501	CPO Feed Pump	2
P622	Bleacher Pump	2
P802	Phosphoric Acid Pump	1
P682A	Recovered Oil Pump	2
P682B	Deodoriser Feed Pump	1
P850/81AG	Cooling Water Pump	1
P880	Deodoriser Discharge pump	2
P814AG	Fatty Acid Circulation/Distillate Pump	2
P5613C	Cooling Water Pump	2
P5613D	Cooling Water Pump	2
	Vacuum Pump for Steam Ejector	2
31	Boiler Feed Pump	2
32	Thermal Deaerator Pump	2
33	Vacuum Pump	2
34	Dried Oil Transfer Pump	2

Plant: 200 MTD Refinery		
Tag No	Services	Qty
PT 501	CPO Feed Pump	2
P622	Bleacher Pump	2
P802	Phosphoric Acid Pump	1
P682A	Recovered Oil Pump	2
P682B	Deodoriser Feed pump	1
P850/81AG	Cooling Water Pump	1
P880	Deodoriser Discharge pump	2
P814AG	Fatty Acid Circulation/Distillate Pump	2
P5613C	Cooling Water Pump	2
P5613D	Cooling Water Pump	2
	Vacuum Pump for Steam Ejector	2
31	Boiler Feed pump	2
32	Thermal Deaerator Pump	2
33	Vacuum Pump	2
34	Dried Oil Transfer Pump	2

The next table shows typical pump selections for a 50 to 300 MTD capacity refinery based on Flowserve Pumps selection:

STD PHYSICAL REFINERY PLANT		PLANT SIZE	A		B		C		D		E	
			50 MTD		100 MTD		150 MTD		200 MTD		300 MTD	
1	Olein Pump	Flow (m3/hr)/ Head (m)	2.6	74	5.2	74	7.8	74	10.4	74	15.6	74
		Model	2K40-25-250A-OP		2K40-25-250A-OP		2K40-25-250A-OP		2K40-25-250A-OP		65-40MEN250	
		Qty	1		1		1		1		1	
		MOC	CS/CS		CS/CS		CS/CS		CS/CS		CI/CI	
		MKW	7.5		7.5		7.5		11		11	
2	Filtration pump	Flow (m3/hr)/ Head (m)	2.7	59	5.4	59	8.1	59	10.7	59	16.1	59
		Model	1K1.5x1LF-82 M3 LF		1K1.5x1LF-82 M3 LF		1K1.5x1-82OP M3 ST		1K1.5x1-82OP M3 ST		1K1.5x1-82OP M3 ST	
		Qty	1		1		1		1		1	
		MOC	SS316/SS316		SS316/SS316		SS316/SS316		SS316/SS316		SS316/SS316	
		MKW	5.5		5.5		7.5		7.5		7.5	
3	Slop oil pump	Flow (m3/hr)/ Head (m)	1.4	23	3.2	23	4.6	23	6.5	23	8.6	23
		Model	1K40-25-125A-OP		1K40-25-125A-OP		1K40-25-125A-OP		1K40-25-125A-OP		1K40-25-125A-OP	
		Qty	1		1		1		1		1	
		MOC	CS/CS		CS/CS		CS/CS		CS/CS		CS/CS	
		MKW	1.1		1.1		1.1		1.5		1.5	
4	Deaerator Discharge Pump	Flow (m3/hr)/ Head (m)	2.7	82	5.4	82	8.1	82	10.7	82	16.1	82
		Model	2K40-25-250A-OP		2K40-25-250A-OP		2K40-25-250A-OP		2K40-25-250A-OP		65-40MEN250	
		Qty	1		1		1		1		1	
		MOC	CS/CS		CS/CS		CS/CS		CS/CS		CI/CI	
		MKW	7.5		7.5		11		11		11	
5	Fatty Acid Circulation Pump - Palm Oil	Flow (m3/hr)/ Head (m)	15	52	19	52	23	52	27	52	42	52
		Model	1K40-25-200A-OP		1K40-25-200A-OP		1K50-32-200A-OP		1K50-32-200A-OP		1K65-40-200A-OP	
		Qty	1		1		1		1		1	
		MOC	SS316/Duplex		SS316/Duplex		SS316/Duplex		SS316/Duplex		SS316/Duplex	
		MKW	7.5		7.5		7.5		11		15	
6	Fatty Acid Circulation Pump - Seed Oil	Flow (m3/hr)/ Head (m)	19	52	27	52	42	52	54	52	83	52
		Model	1K50-32-200A-OP		1K50-32-200A-OP		1K65-40-200A-OP		1K80-50-200A-OP		1K80-50-200A-OP	
		Qty	1		1		1		1		1	
		MOC	SS316/Duplex		SS316/Duplex		SS316/Duplex		SS316/Duplex		SS316/Duplex	
		MKW	7.5		11		15		15		22	
7	Precoat Pump	Flow (m3/hr)/ Head (m)	4.2	23	9.7	23	13.7	23	19.5	23	25.9	23
		Model	1K40-25-125A-OP		1K50-32-125A-OP		50-32MEN160		50-32MEN160		65-40MEN160	
		Qty	1		1		1		1		1	
		MOC	CS/CS		CS/CS		CI/CI		CI/CI		CI/CI	
		MKW	1.5		2.2		2.2		3		4	

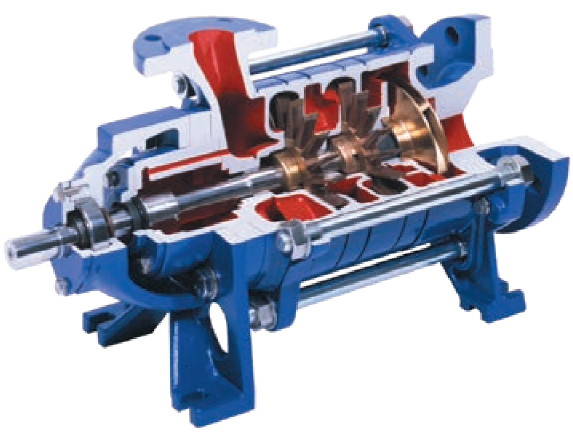
Note: For operating conditions outside these parameters, please consult Commercial Operations for recommendations.

Pumps

ZLND

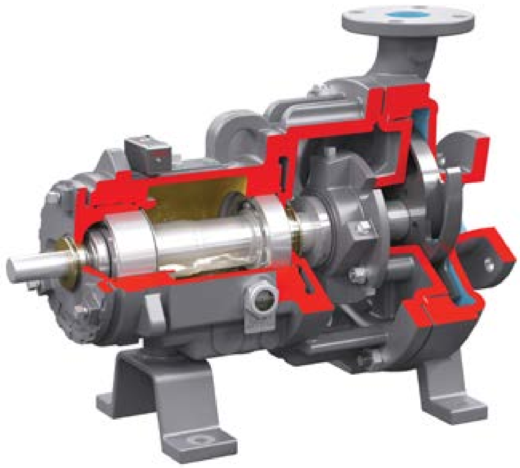
LPH

CEHA

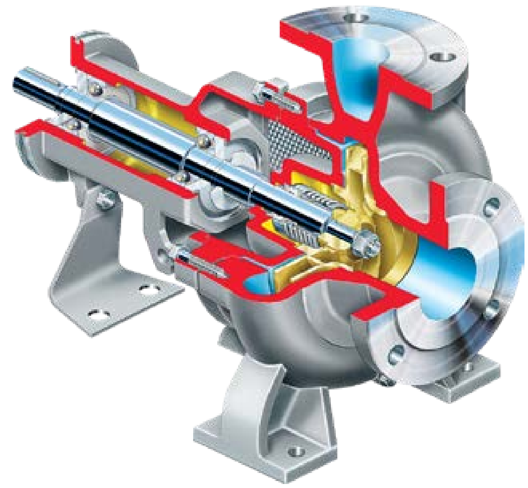


HEGA

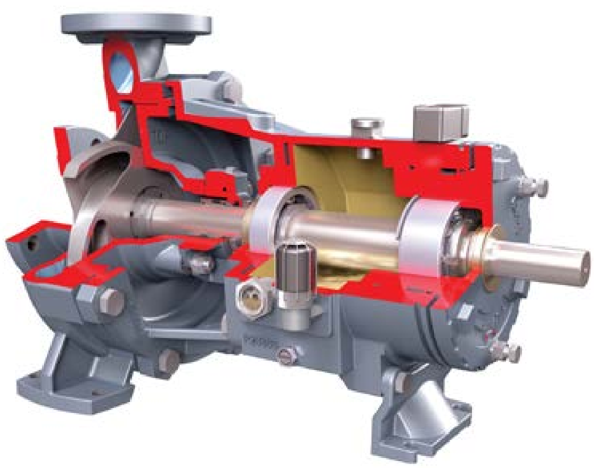
Mark 3 ANSI



MEN



Mark 3 ISO



Total pump selections summary for a 50 to 2000 MTD capacity standard physical refinery:

STD PHYSICAL REFINERY PLANT	PLANT SIZE	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
		50 MTD	100 MTD	150 MTD	200 MTD	300 MTD	400 MTD	500 MTD	600 MTD	700 MTD	800 MTD	900 MTD	1000 MTD	1200 MTD	1500 MTD	2000 MTD	
No	Pump Model	Qty	Qty	Qty	Qty	Qty	Qty	Qty	Qty	Qty	Qty	Qty	Qty	Qty	Qty	Qty	Tot Qty
1	1K40-25-125A-OP	2	1	1	1	1	0	0	0	3	0	0	0	0	0	0	9
2	1K40-25-200A-OP	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3
3	2K40-25-250A-OP	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	8
4	1K50-32-125A-OP	0	1	0	0	0	1	0	0	0	3	0	0	0	0	0	5
5	1K50-32-160A-OP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1K50-32-200A-OP	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	3
7	1K65-40-200A-OP	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	2
8	1K80-50-200A-OP	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	5
9	2K100-65-200A-OP	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	8
10	2K125-100-200A-OP	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	4
11	50-32MEN160	0	0	1	1	0	0	1	1	0	0	1	1	1	1	1	9
12	65-40MEN160	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	2
13	65-40MEN250	0	0	0	0	2	2	1	0	0	0	0	0	0	0	0	5
14	65-50MEN125	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	4
15	65-40MEN250L	0	0	0	0	0	0	1	2	2	2	2	1	0	0	0	10
16	65-50MEN250L	0	0	0	0	0	0	0	0	0	0	0	1	2	1	0	4
17	80-65MEN250L	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3
18	1K1.5x1LF-82 M3 LF	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
19	1K1.5x1-82OP M3 ST			1	1	1	0	0	0	0	0	0	0	0	0	0	3
20	2K3x1.5-10AOP M3 S	0	0	0	0	0	1	1	1	3	3	3	3	4	4	5	28
	Total Pumps	7	7	7	7	7	7	7	7	11	11	7	7	8	8	9	117

Valves

Valtek GSV (Globe)

Value Add

- High-capacity
- High-performance
- Ease of maintenance

Valtek MaxFlo 4 (Eccentric Plug)

- Highest rated C_V
- Precise control
- Reliable shutoff

Valtek Mark One (Globe)

- Heavy top guiding
- High-performance
- Severe service trim Available
  - Noise reduction trim
  - Anti-cavitation trim
- VL Series actuator
  - Field-reversible
  - Double-acting spring return

Valtek ShearStream (Segmented Ball)

- Highest capability and rangeability
- Abrasive, erosive and corrosive fluid
- Slurry, two-phase flow

Valtek Valdisk (Butterfly)

- Jam-lever toggle soft seat
- Single pivot point for actuator to disc connection
- Self-centering seal
- Non-selective disc and shaft for cost reduction

Flowserve Butterfly Valve (Butterfly)

- Seat design options
- Stuffing box packing options
- Primary steam seal plus two optional secondary seals provide triple-leak protection
- Wide range of optional materials includes: D20, DMM, DC2, DC3, DNI and DNIC
- Exceeds shutoff requirements of ASME/FCI 70-2 for all classes

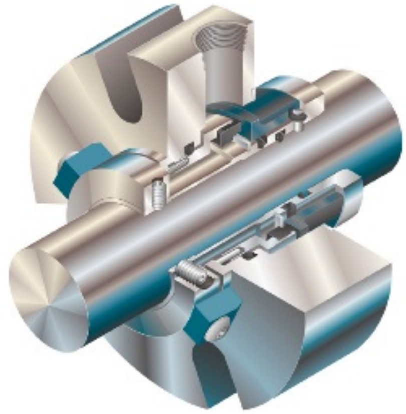
Worcester® and Audco (Ball Valves)

- Wide applications in the oil process lines such as in a biodiesel plant or a dry fractionation plant
- Total ball seat interchangeability
- Fire-safe design
- Low torque
- Bi-directional sealing

Seals

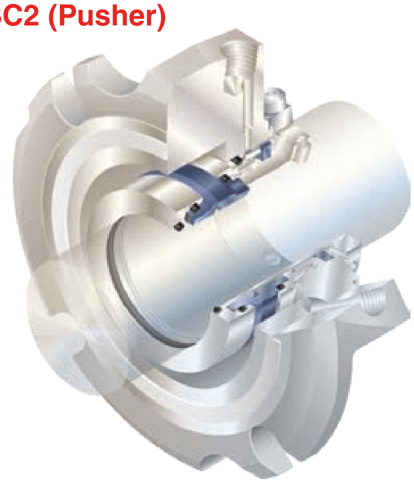
Pac-Seal

P50

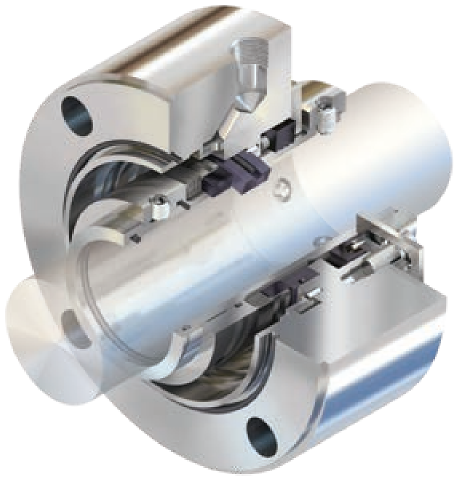


RO

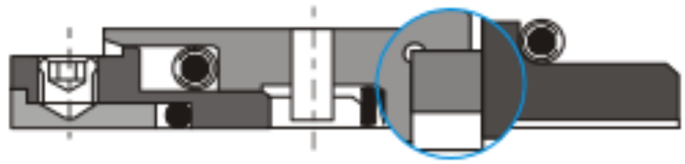
ISC2 (Pusher)



BX



GNZ (cross-sectional view)



Custom design mechanical seal

Type: Single and balanced

Available in code:

- AF3: Q12AEGG
- AFJ: Q12BVGG

GNZ

Flowserve Products and Capabilities in Palm Oil Fractionation

Overview

Typical pumps used in a fractionation plant include:

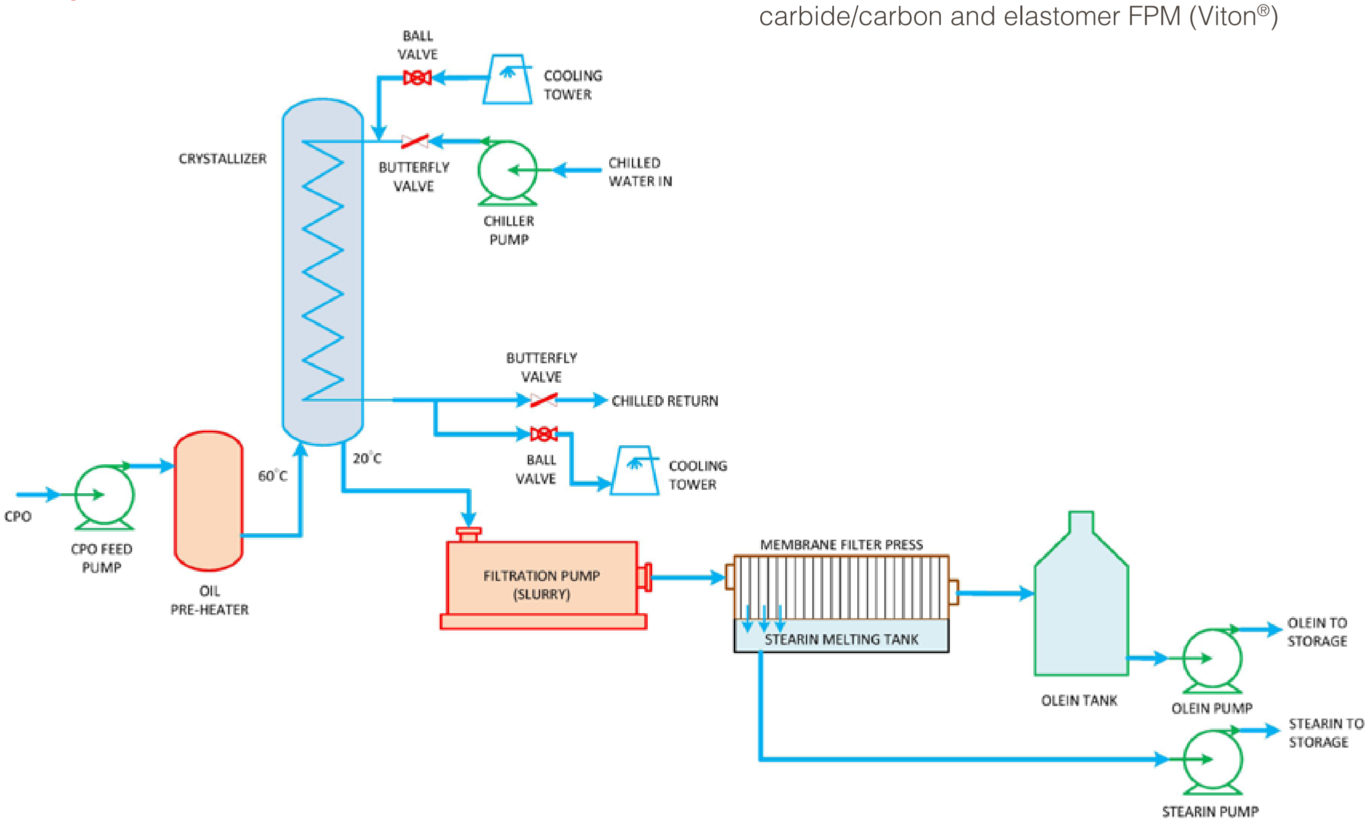
- CPO feed pump
- Chiller pump
- Slurry pump (filtration)
- Clean oil pump (palm olein and palm stearin)

A range of 20 to 50 pumps is normally used in each plant.

In general, the available standard materials of construction are:

- Chiller Pump
  - cast iron and stainless steel
  - Equivalent Flowserve seal to Eagle Burgmann code BJ3 mechanical seal
  - Unbalanced with seal face materials silicon carbide/carbon and elastomer EPDM
- Olein and Stearin Pump
  - Cast iron
  - Equivalent Flowserve seal to Eagleburgmann code BJJ mechanical seal
  - Unbalanced with seal face materials silicon carbide/carbon and elastomer FPM (Viton®)

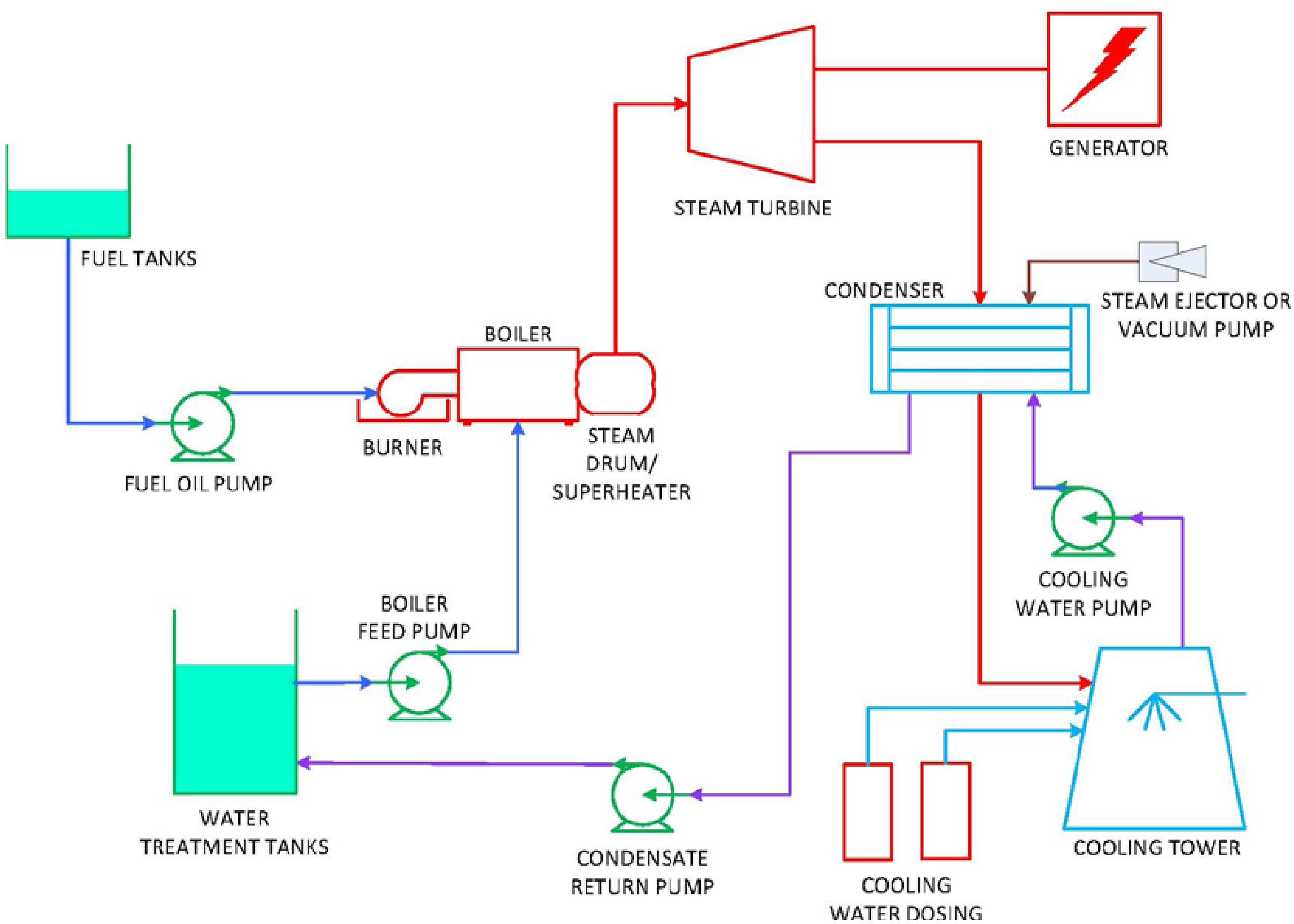
Dry Fractionation Process



Steam and Power System

Within the POM, the steam turbine-driven power generation system can be integrated into the entire plant using some of the waste product from the extraction as feedstock to the boiler system.

A typical steam and power process flow diagram can generally be provided by the various boiler OEMs available in the market where some Flowserve products can also be offered such as vacuum pump, boiler feed pump fitted with mechanical seals and related environmental controls for maximum seal life and operations, as well as the appropriate control valves, steam valves, etc.



Products

The recommended pumps within the SIHI product lines along with the selected materials of construction are tabulated according to the different processes within the POM (along with its integrated steam and power system), refinery and fractionation plant as follows:

PROCESS PUMPS	PUMP TYPES	PUMP EXECUTION	SPECIFICATIONS
Extraction Refining Modification	Centrifugal pump Type ZLN		**Capacity:** Max 1800 m^3/h **Shaft sealing:** Mechanical seal **Materials:** Cast iron, stainless steel
Modification	Centrifugal pump Type CBS (*replaced by Mark 3 ISO and ANSI)		**Capacity:** Max 650 m^3/h **Shaft sealing:** Mechanical seal **Materials:** Ductile iron, stainless steel
Pressing and Preparation	Centrifugal pump Type DBS		**Capacity:** Max 800 m^3/h **Shaft sealing:** Mechanical seal **Materials:** Cast iron, stainless steel
Boiler Feed, Cooking	Multi-stage pump Type HEGA		**Capacity:** Max 190 m^3/h **Shaft sealing:** Mechanical seal **Materials:** Cast iron, stainless steel
Solvent Recovery	Liquid ring vacuum pump Type LPH		**Capacity:** Max 10 700 m^3/h **Shaft sealing:** Mechanical seal **Materials:** Ductile iron, stainless steel
Refining	Side channel pump Type CEH		**Capacity:** Max 35 m^3/h **Shaft sealing:** Mechanical seal **Materials:** Ductile iron, stainless steel

Aftermarket Opportunities

Over the last few decades, Flowserve Quick Response Center (QRC) capabilities have been constantly improved as new technologies were developed. With efficiency and reliability improvements, there is a high potential for upgrading existing installations and helping owners/operations:

- Increase plant efficiency
- Improve plant output
- Reduce emissions output

This can be achieved by overhauling existing equipment with additional reliability features, upgrade hydraulics or other capabilities through APAC Flowserve QRCs.

Flowserve Asia-Pacific QRCs are strategically located within hours of various customers in the palm oil industry. Malaysia, Indonesia and Thailand are the three main tropical countries where palm oil is produced within southeast Asia.

Flowserve QRC facilities for pumps, valves and seals are strategically located in these countries:

- Malaysia
  - Kuala Lumpur
    - pumps (for SIHI) and seals (two separate facilities)
  - Kuantan
    - pumps
- Indonesia
  - Jakarta
    - pumps, valves and seals
- Thailand
  - Rayong
    - pumps, valves and seals
  - Chonburi
    - packaging for SIHI wet and vacuum pumps and vacuum systems

These QRCs are equipped with the necessary engineering, manufacturing and servicing capabilities and equipment to serve customers in the palm oil industry. The vast network of Flowserve QRC Centers in Latin America is also capable to serve all markets and services.

Flowserve Value Proposition in the Palm Oil Industry

Summary

Over the long term, global palm oil demand shows an increasing trend as an expanding global population gives rise to an increased consumption of palm-oil based products. The regions with the highest rates of palm oil consumption are India, Indonesia, European Union and China. Moreover, growth in demand for palm oil is driven by increasing incomes and urbanization, and an associated dietary shift toward processed foods.

However, emissions from tropical deforestation and forest degradation continue to be a major concern, as they are responsible for the bulk of the total global greenhouse gas emissions. With increasing demand of bio-fuel driving the need for palm oil, many major plantation owners are looking toward west and central Africa to expand their plantation business there. These regions will potentially be the next growth regions in the palm oil industry.

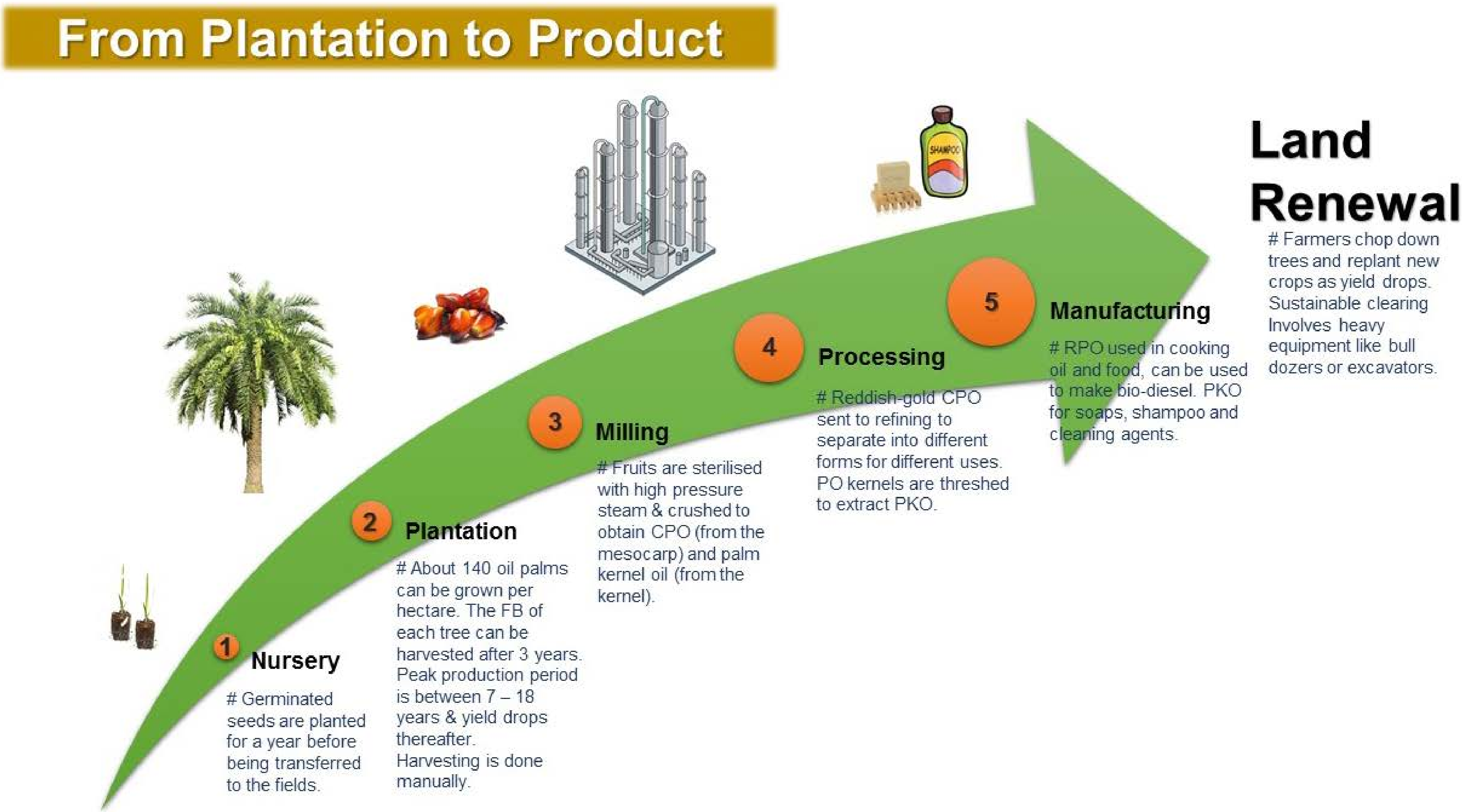
APPENDIX
Installations References

Palm oil mill (in Malaysia)

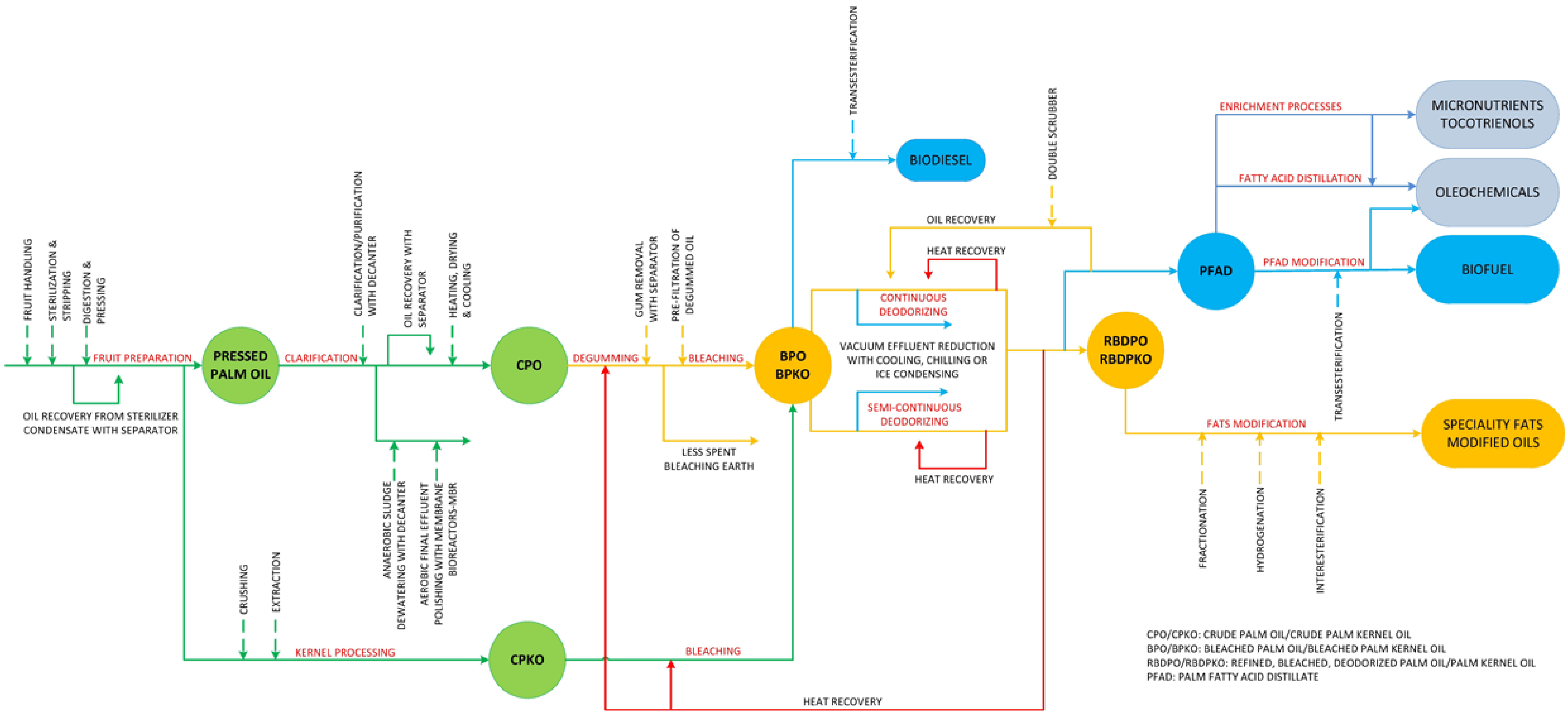
Boiler feed pump (SIHI model HEGA multistage)

Water transfer pump (SIHI model ULNC)

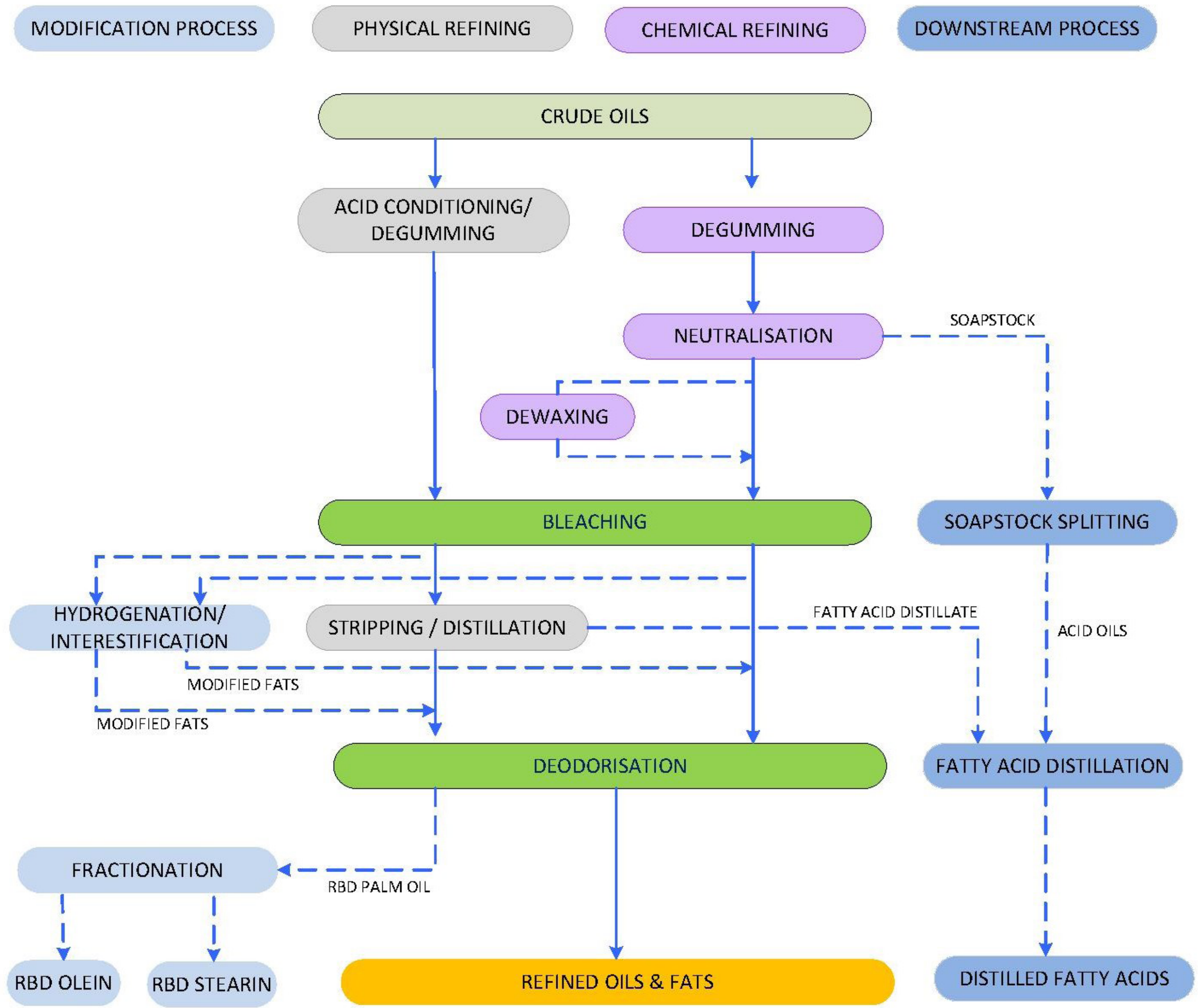
Detailed Schematics of Palm Oil Processes



Typical Palm Oil Solution 1



Typical Palm Oil Solution 2



Pump Sourcing Guide

Pump Family	Primary Market Segment	Pump Model	1-Arnage 2-Pozuelo 3-Chesapeake	Coimbatore	Suzhou
General Service	General Industry	MEN	🟦 1	🟥	🟥
	(Palm Oil)	Mark 3 ISO	🟦 2	🟩	🟥
		Mark 3 ANSI	🟦 3	🟥	🟩

Pump Family	Primary Market Segment	Pump Model	1-Pozuelo 2-Itzehoe 3-Trappes 4-Toltecas	Shanghai	Chonburi & KL
General Service	General Industry	LPH	🟦 2	🟩	🟥
	(Palm Oil)	CEH	🟦 3	🟥	🟥
		ZLND	🟦 1	🟥	🟥
		HEGA	🟦 4	🟥	🟥
		DBS	🟦 1	🟥	🟥

Legend
- 🟦 *Design Center and Primary Manufacturing*
- 🟥 *Packaging or Other Manufacturing*
- 🟩 *Secondary Manufacturing*

Industry Sub-segment Information

Coming from the upstream of the palm oil process flow, which started with the extraction mill, refinery, fractionation plants and for some plants with the steam and power generation plants forming the bulk of the process activities, there are other sub-segments that can also offer attractive opportunities in the downstream side that will include:

- **Oleo chemicals** — one of the end products among a wide variety of palm-based derivatives produced from processing palm oil
- **Bio-diesel** — production of biodiesel that is a relatively straightforward process and usually produced as a by-product through two chemical reactions, esterification and transesterification. This involves inducing a reaction between the palm oils and short-chain alcohols (typically methanol or ethanol).
- **Pulp and paper** — production from oil palm empty fruit bunches (EFBs), an agricultural waste that is available year-round; renewable, abundant and cheap (if not free)

For more information on theses opportunities, please contact your respective regional Commercial Operations team.

GLOSSARY

BPKO	bleached palm kernel oil
BPO	bleached palm oil
CPKO	crude palm kernel oil
CPO	crude palm oil
CSPO	certified sustainable palm oil
EFB	empty fruit bunches
FAME	fatty acid methyl esters
FFA	free fatty acid
FFB	fresh fruit bunches
NBO	neutralized bleached oil
NPO	neutralized palm oil
OSBL	outside battery limits
PFAD	palm fatty acid distillate
PKFAD	palm kernel fatty acid distillate
POM	palm oil mill
RBDPKO	refined, bleached and deodorized palm kernel oil
RBDPO	refined, bleached and deodorized palm oil
RSPO	Roundtable on Sustainable Palm Oil
SAM	serve available market

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Lipico Palm Oil Solutions

– Lipico Technologies

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Latin America

Europe

Middle East

Africa

Asia-Pacific

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