COALESCING CLARIFIER FOR CRUDE PALM OIL CLARIFICATION

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NEW DEVELOPMENTS IN PALM OIL MILLING TECHNOLOGY

- Sterilization
  - Vertical sterilizer with FFB conveying system
  - Continuous sterilizer with FFB crusher and conveying system
  - Tilted sterilizer with conveying system
  - Spherical sterilizer with conveying system
- Boiler with automated fuel-steam management
- Oil clarification
  - New 2-phase decanter based clarification system (Westfalia, Alfa-Laval, IHI)
  - Coalescing clarifier operating without oil purifier
- Effluent Management
  - Modern biogas plant (complete mixed, baffle reactor, CIGAR)
  - Tertiary/polishing plant (SBR, CAS, MBR, Trickling filter)
  - Integrated anaerobic-aerobic with resource recovery

DRIVERS FOR NEW DEVELOPMENTS

- Process efficiency requirements
  - Reduce cost of production
  - Improve oil and kernel recovery
  - Efficient steam management
- Oil quality improvements
  - Low FFA oil
  - Low PV, high DOBI
- Sustainability and environmental issues
  - Carbon footprint, LCA, BOD 20 mg/l effluent discharge
- Quality system certification requirements
  - ISO quality management
  - RSPO certification
  - Code of Good Milling Practices for palm oil mill
  - Food safety certification

STOKES SETTLING – THE BASIC

- When two liquids are immiscible, or non-soluble in one another, they can form either an emulsion or a colloidal suspension
- In either of these mixtures, the dispersed liquid forms droplets in the continuous phase. In suspension, the droplets are less than one micron in diameter and the liquids cannot readily be separated with the conventional clarifier/separator
- Traditionally, gravity separators were used to handle emulsions before the use of coalescing media became applicable
- In this equipment, differences in densities of the two liquids cause droplets to rise or fall by their buoyancy. The greater the difference in densities, the easier the separation becomes
- Rising (or falling) droplets are slowed by frictional forces from viscous effects of the opposing liquid.

STOKES SETTLING – THE BASIC

- When the stream is not flowing and the opposing forces of buoyancy and viscous drag balance, the droplet has achieved its *Terminal Settling Velocity*
- This vertical velocity is constant because there are no net forces acting upon the droplet. This mechanism of separating liquids by gravity is called *Stokes Settling*
- The size of gravity settler is derived from 1) the terminal settling velocity of a minimum sized droplet and 2) the inertial force imparted to the droplet due to the velocity of the emulsion through the vessel. At these conditions, all droplets larger than a minimum will be removed at a quicker rate
- Typical minimum droplet size is between 75 to 300 µm
- In order to settle fine droplets and ensure laminar flow, large vessels and long residence times are required. It may take ten, twenty or even hours to make a separation, depending on the physical properties of the stream

PARTICLE SETTLING (STOKES' LAW)

- Settling velocity is when fluid drag force equals gravitational force (terminal velocity)

$$v = gd^2(\rho_s - \rho_l)/18\mu$$

- For small particles and low terminal velocity, fluid flow around particle is laminar → Stokes' Law applies
- V = terminal velocity (cm/s), g = acceleration due to gravity (981 cm/s^2), d = particle diameter (cm), μ = viscosity of liquid (g/cm-s),

  ρ_s, ρ_l = density of solid particle and liquid (g/cm^3)

Note: assuming flow is laminar

FUNDAMENTAL

Terminal velocity, cm/s

Oil particle diameter

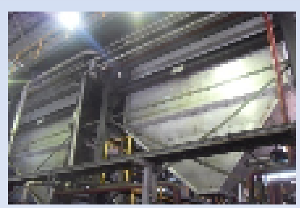
Viscosity, depends on temperature

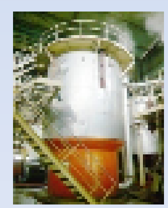
$$v = gd^2(\rho_s - \rho_l)/18\mu$$

Increase g

What makes oil particle diameter increases

- create shearing force to combine small particles
- preventing excessive emulsion formation – choose the right pump
- use coalescer plates – increases particle diameter






PARTICLE SETTLING
(Reynold's Number)

- To validate the assumption of laminar flow, calculate Reynold's Number (Re)

$$R_e = \rho dv/\mu$$

- P is density of the liquid (g/cm^3)
- Re < 0.2 → fluid is laminar (Stokes' Law is valid)

BASIC DESIGN CONCEPTS – The emulsion

- In selecting and designing a coalescer, it is important to understand and characterize the emulsion that has to be treated. The finer the droplets dispersed in an emulsion, the more stable it is, because buoyancy force diminishes in magnitude as the diameter decreases
- The manner in which the mixture is created effects the droplet size distribution
- Centrifugal pumps shear liquid droplets much more severely than progressive cavity pump, thereby creating finer droplets
- It is important to construct the droplet size distribution curve by plotting the droplet diameters against the volume or mass fraction at the differential diameter. The shape of the distribution is affected by the manner in which the emulsion was formed, and its age

BASIC DESIGN CONCEPT – Operating Principles of a Coalescer

- Liquid-liquid coalescers are used to accelerate the merging of many droplets to form a lesser number of droplets, but with greater diameter
- This increases the buoyant forces in the Stokes Law equation
- Settling of the larger droplets downstream of the coalescer element then requires considerably less residence time
- Coalescers exhibit a three-step method of operation:
  - Collection of individual droplets
  - Combining of several small droplets into larger ones
  - Rise/fall of the enlarged droplets by gravity
- Coalescers work better in laminar flow for several reasons:
  - Droplets will stay in the streamlines around a media
  - High fluid velocities overcome surface tension forces and strip droplets out of the coalescer medium
  - Slower velocities result in greater residence time in the media and therefore more time for droplet-to-target impact, droplet-to-droplet collosion, and intra-media Stoke Settling

BASIS FOR SIZING AND SELECTION

- For liquid-liquid coalescers, as with any process equipment, successful sizing and selection is always a combination of empirical observation/experience and analytical modeling
- Of the three steps in coalescing – droplet capture, combining of the collected droplets, and gravity separation of the enlarged droplets – the first and the last can be modeled with good accuracy and repeatability. The modeling the middle and the actual coalescing step is a complex function of surface tension and viscous effects, droplet momentum, and the dynamics of sizes of the droplets in the dispersion

CRUDE PALM OIL CLARIFIER

Current Oil Clarifier

New Oil Clarifier

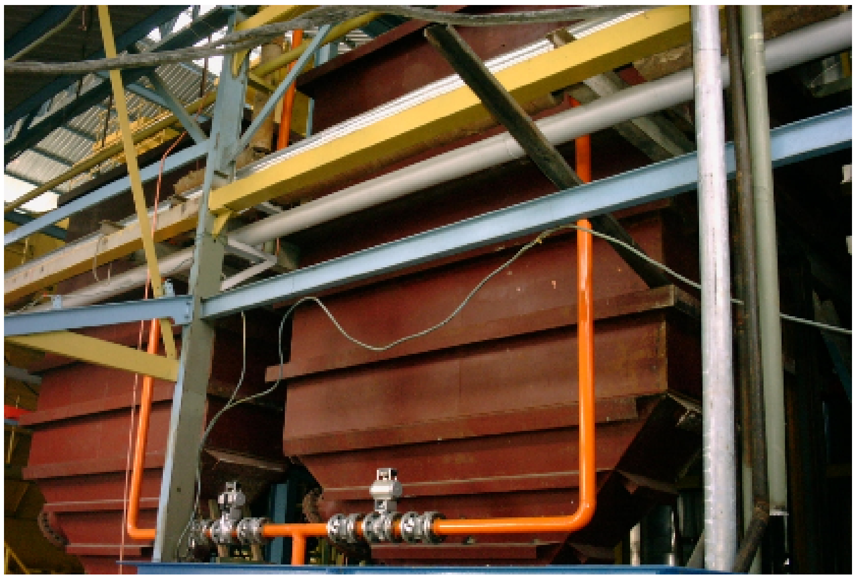
Vertical clarifier

Eco-D decanter - two phase without dilution

Coalescing clarifier (Oilsep) without purifier

OIL PURIFIER	
YES	NO

COALESCING CLARIFIER (OILSEP) – 1ST GENERATION (INDONESIA)

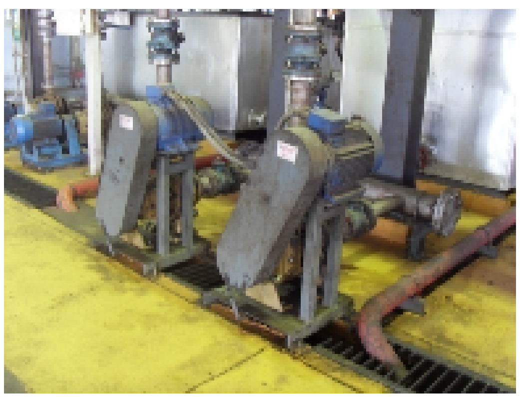



2 units designed for 60 tonnes FFB/hr operating as primary clarifier.
Matererial of construction: SS316 inserts and mild steel casing with Insulation, temperature control and flow control

COALENCING CLARIFIER (OILSEP) AT VICHITBHAN OIL MILL

Topside view

Bottom view



Feed pump

Control valve

Bottom view

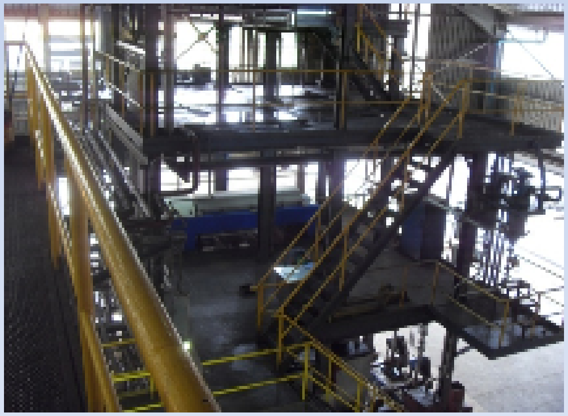
COALESCING CLARIFIER (OILSEP) AT VICHITBHAN OIL MILL

Top view

Top view

Oil skimmer

Top view – two units



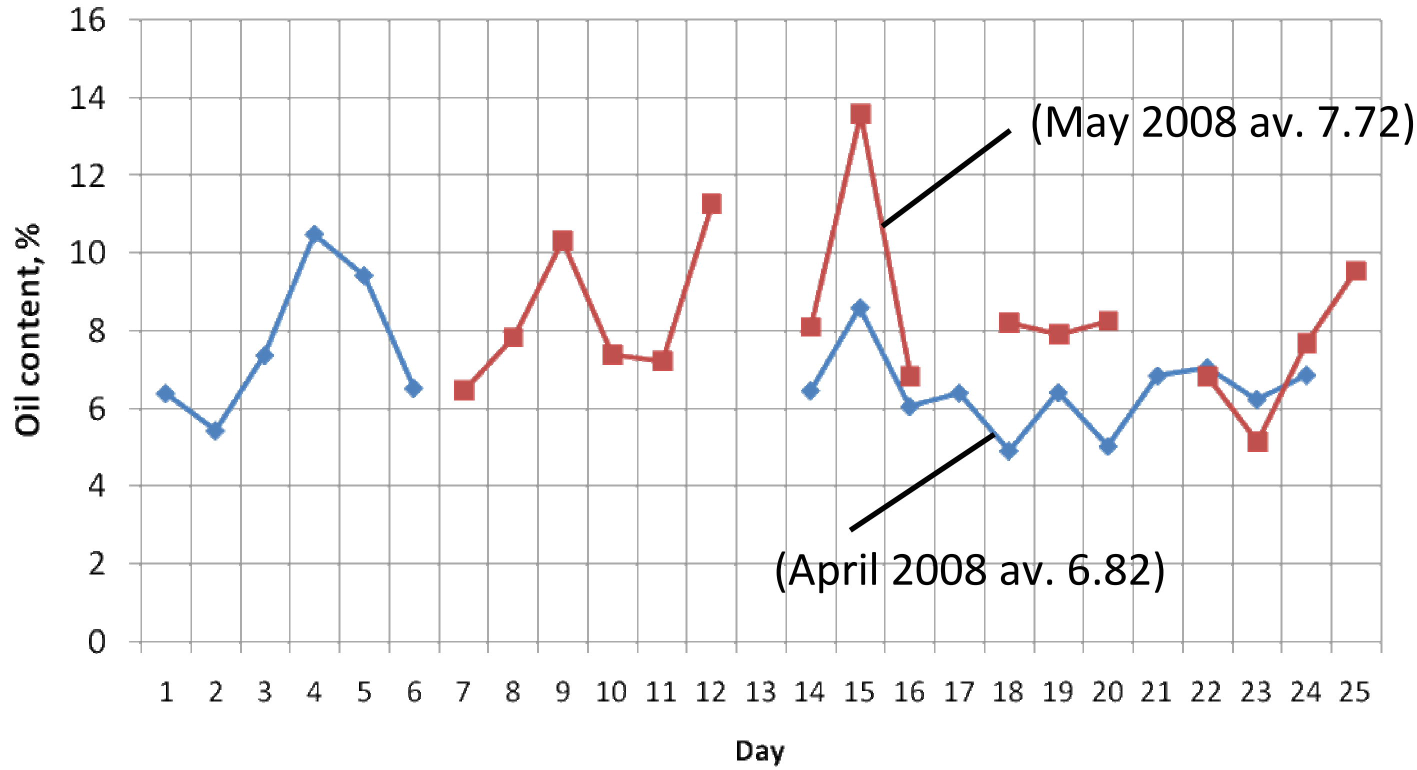
Decanter

Sludge separator

OILSEP CHRONOLOGY

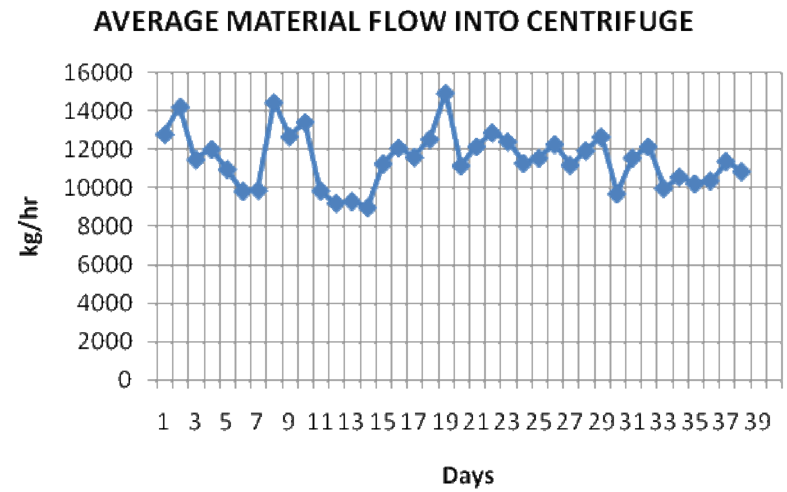
Year	Event
2000	R&D with MPOB. Tested pilot unit at Krau Palm Oil Mill
2002	1st unit installed in a mill in Indonesia. 1st Generation
2005 - 2008	3 units in operation in Thailand
2009	2 unit installed in Thailand for mill upgrading
2009	Discussed with interested parties: UNIVANICH (Thailand), PAPUA NEW GUINEA, KECK SENG (Malaysia), WEST AFRICA
2010	Planning to conduct testing on OILSEP without dilution

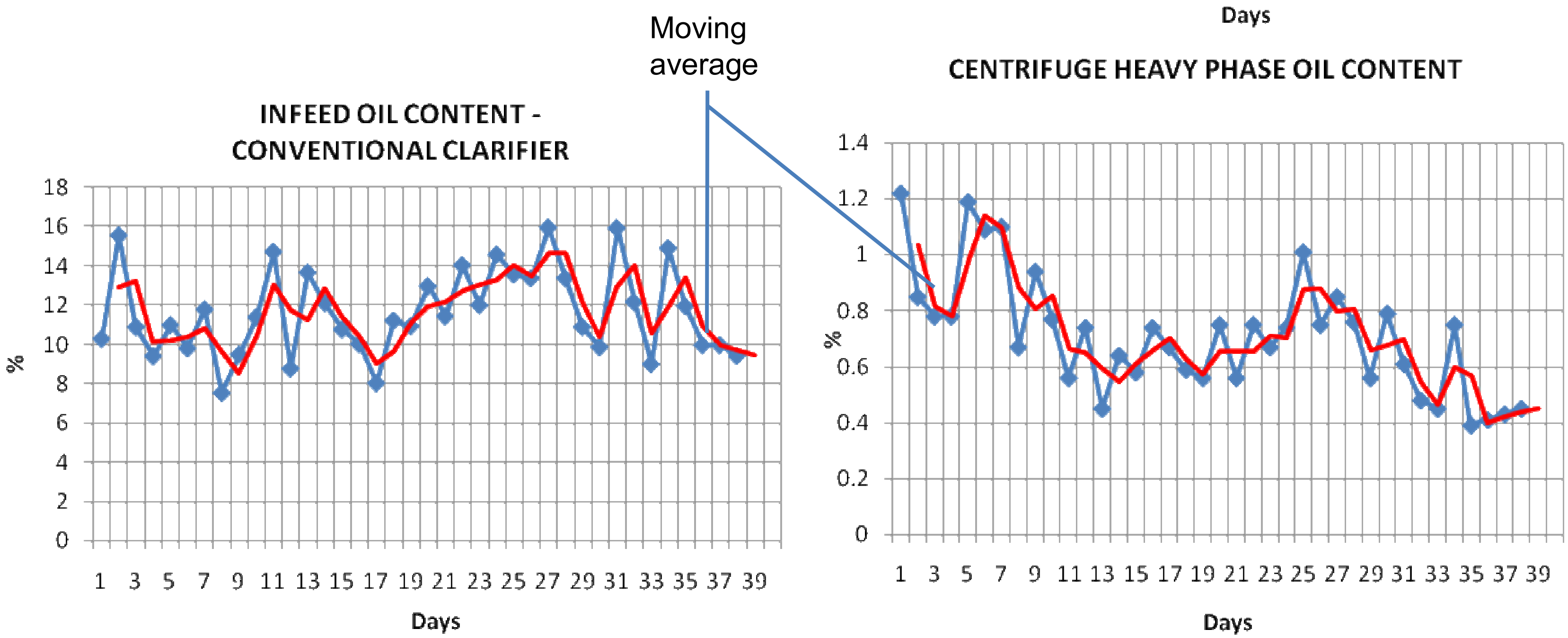
OIL IN UNDERFLOW OF COALESCER CLARIFIER - VICHITBHAN OIL MILL



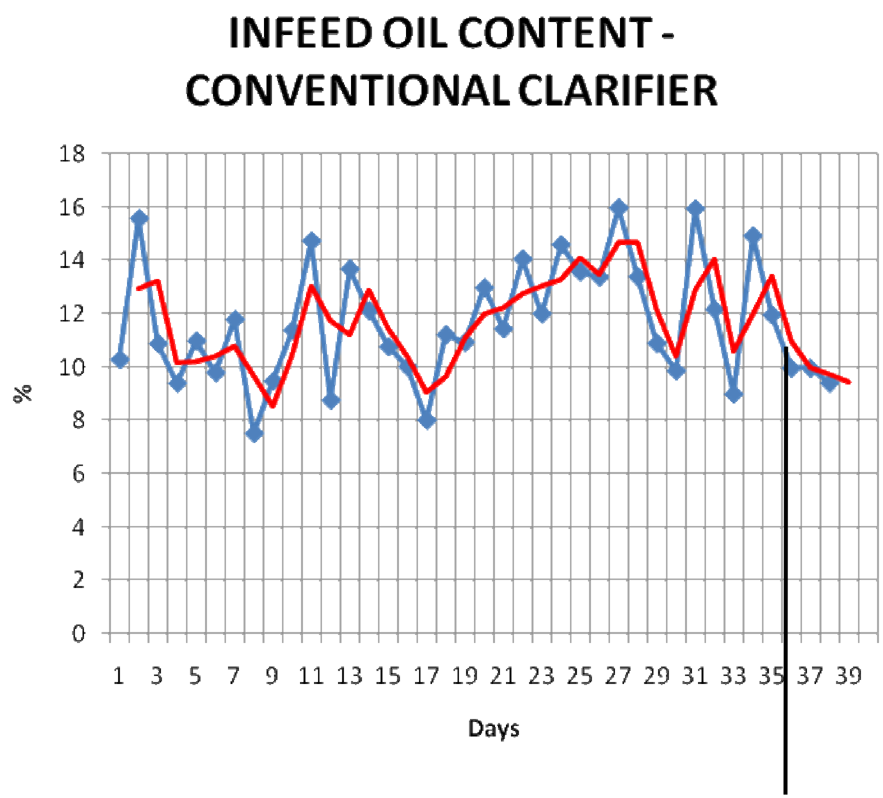
TYPICAL PERFORMANCE OF A SLUDGE SEPARATOR

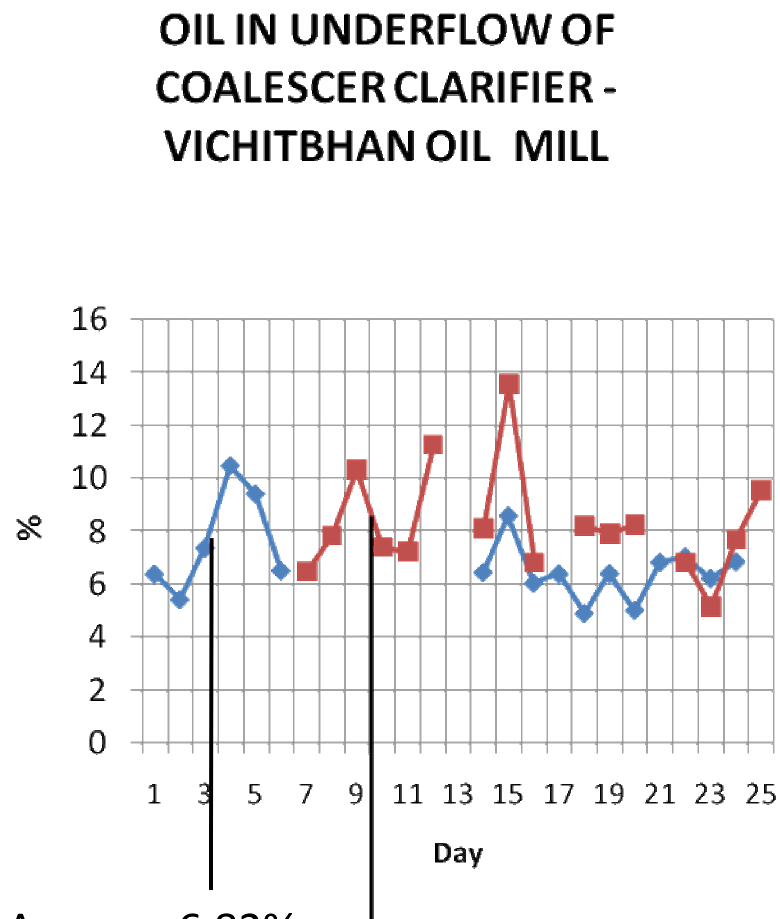
- Average flow rate: 11,800 kg/hr with 1.8 mm nozzle
- Strong correlation between oil content in feed To oil content in centrifuge heavy phase





COMPARISON OF OIL CONTENT IN UNDERFLOW OF OIL CLARIFIER



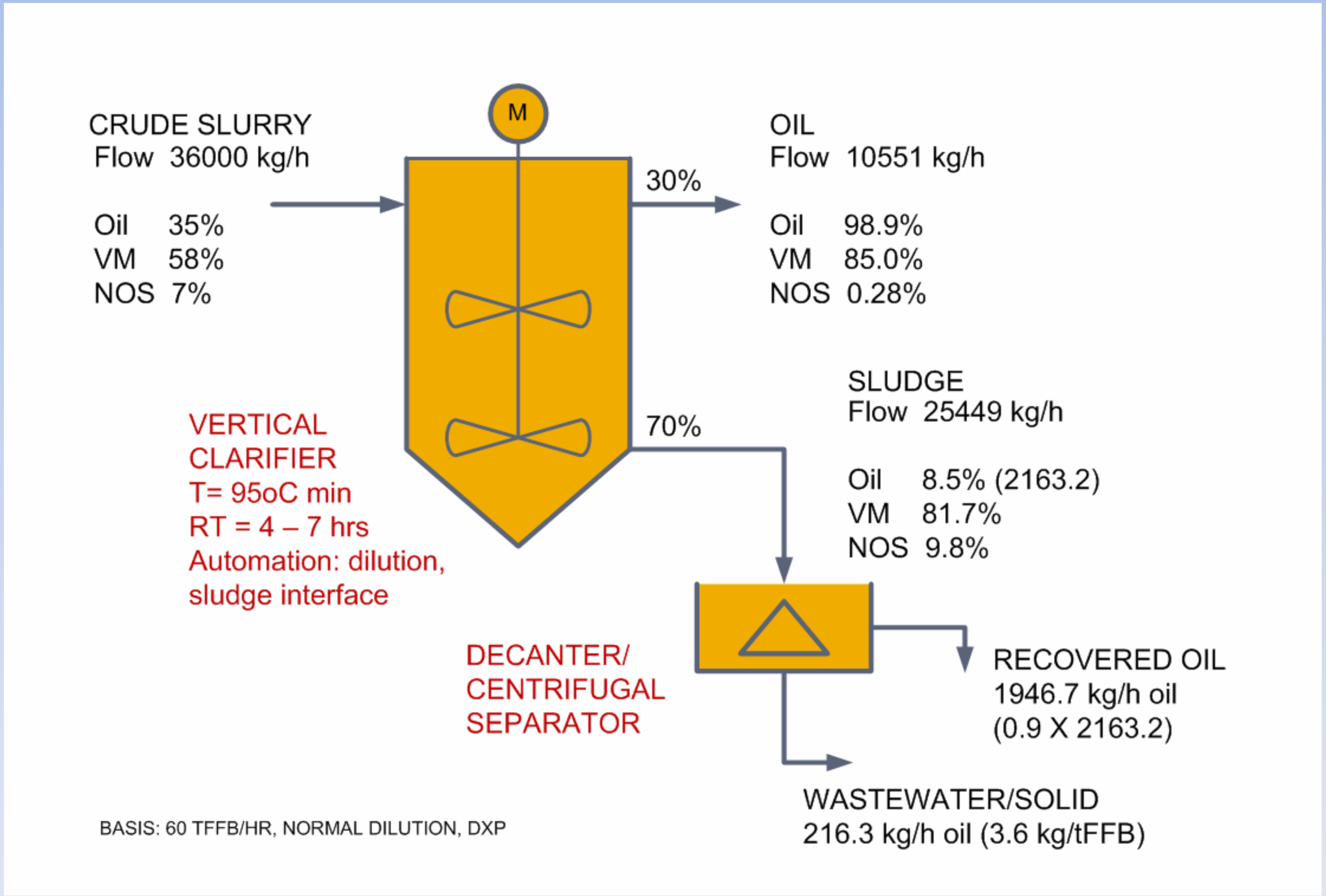


Average 11.7%

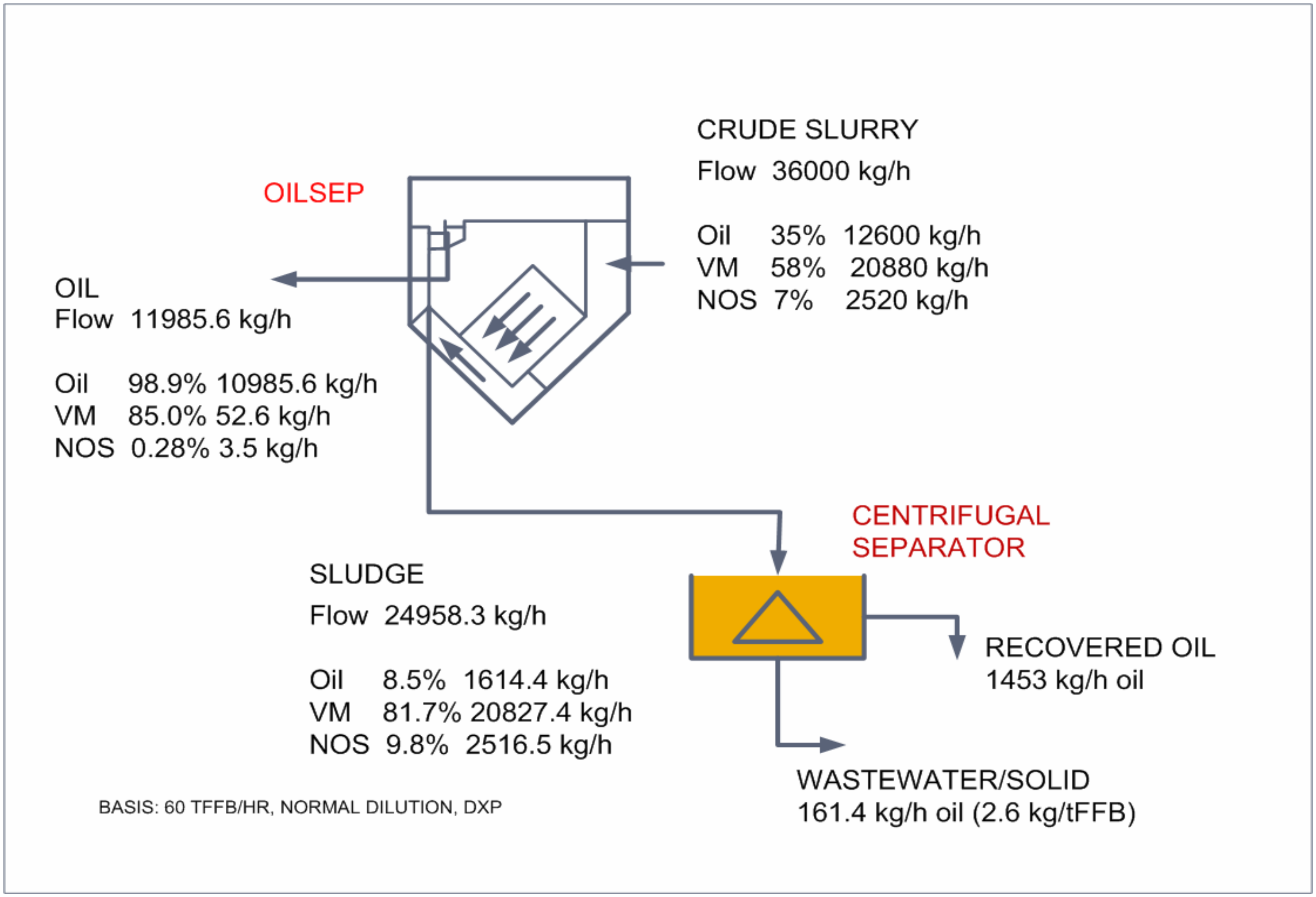
Average 6.82%

Average 7.72%

MATERIAL BALANCE OF CONVENTIONAL CPO CLARIFIER



MATERIAL BALANCE OF COALESCING CLARIFIER (OILSEP)



COMPARISON BETWEEN OILSEP & VERTICAL CLARIFIER

Item	Description	OILSEP	VERTICAL CLARIFIER	REMARKS
1	Oil recovery	12438 kg/h	12383.7 kg/h	54.9 kg/h
2	Oil content (underflow)	5% - 7%	8.0% - 12%	OILSEP very consistent
3	Feeding & temperature control	Automatic 90 ^{o} C ± 2 ^{o} C	Normally non-auto 95 ^{o} C – 98 ^{o} C	Low temperature minimize quality deterioration
4	Oil quality*	DOBI 2.6 – 2.8	DOBI 2.0 – 2.5	Consistent
5	Retention time	1 – 1.5 hrs	4 – 7 hrs	Oil flow out within 45 minutes
6	Foot print for oil room	9 m X 6.5 m X 6 m (H)	Much bigger	Depends on tank size
7	Material of construction	Housing – 304 SS Inserts – 316 SS	304 SS lining	Comply to CoP of milling. Long life

* Depends on FFB Quality

COMPARISON BETWEEN OILSEP & VERTICAL CLARIFIER

Item	Description	OILSEP	VERTICAL CLARIFIER	REMARKS
8	Maintenance and cleaning	Very easy	Time consuming	High pressure water jet for inserts cleaning
9	Purification requirement	Not required	YES	Cleaner oil
10	Automation	Fully auto, flow control, temp control	Partial in some installation	Ensuring laminar flow for better oil coalescing
11	System performance	Dynamic constant shearing of crude slurry	STATIC, no barrier for solid movement	Oilsep is a dynamic system
12	Total surface area	150 m^2 surface for shearing action	No shearing surface	Oilsep surface area is equivalent to 200 MT vertical clarifier

COMPARISON BETWEEN OILSEP & VERTICAL CLARIFIER

Item	Description	OILSEP	VERTICAL CLARIFIER	REMARKS
13	Investment cost	RM 1.4 mil.	RM 600,000	RM 800,000
14	Return on investment	0.86 yrs new mill compared to vertical clarifier 1.52 yrs if installed in existing oil room		Overall oil recover = 54.9 kg/hr or 1098 kg day at 20 hr/d 1098 kg X 350 d/yr = 384.3 t/ yr X RM 2400/t = RM922,320

CONCLUSION

- OILSEP utilizes coalescing principle to enhance Stokes gravity settling. It helps in aggregating small droplets resulted as a results emulsification of crude oil slurry – BETTER OIL RECOVERY IN SHORT RETENTION TIME
- It comply to the requirement of Code of Good Milling Practices for palm oil milling (MPOB) as all parts in contact with oil are made of SS