TECHNICAL ARTICLE

WFE Selection Considerations

Understanding when high-vacuum wiped-film evaporation is the appropriate choice for a used-oil feedstock and required base-oil product.

BALAJI CONSULTANTS | KNOWLEDGE CENTRE

CORE SPECIALISATION: USED-OIL RE-REFINING

01 / INTRODUCTION

What a Wiped Film Evaporator actually solves

WFE technology is most valuable when high boiling range, increasing viscosity, thermal sensitivity and the need for deep-vacuum recovery occur together.

A Wiped Film Evaporator (WFE) is a mechanically agitated thin-film evaporator. Feed is continuously distributed as a thin film over a heated surface while a rotating wiper system continuously renews the film and moves the increasingly heavy material toward the residue outlet.

The combination of thin-film heat transfer, deep vacuum and short residence time allows valuable lube-range hydrocarbons to be recovered at lower bulk temperatures than would be practical in many conventional batch vessels or reboiler systems. This is particularly important in used-oil re-refining, where excessive thermal exposure can increase colour formation, cracking and coke generation.

WFE is a separation stage, not a complete re-refining plant.

In Balaji semi-continuous technology, dehydration and degassing are performed batchwise. The conditioned oil is transferred to a buffer tank, preheated and then fed continuously to one or more WFEs. The WFE must therefore be selected together with feed preparation, heating, vacuum, condensation, residue handling and downstream finishing.

The Balaji semi-continuous process architecture

Batch conditioning protects the continuous high-vacuum section while the buffer tank stabilises WFE feed.

Batch dehydration & degassing → Buffer tank → Feed preheater → WFE / WFEs → Condensation & product collection → Finishing

This configuration combines feed flexibility at the front end with continuous, short-residence-time base-oil recovery downstream.

The buffer tank is critical because it decouples the batch front-end operation from the continuously running WFE section. While one dehydration batch is being prepared, conditioned oil from the buffer can continue feeding the evaporator at a controlled rate.

Why this matters

- Stable WFE feed rate and temperature
- Reduced vacuum fluctuations
- Improved utilisation of high-value WFE equipment
- Better control of evaporation duty
- Ability to retain existing batch dehydration equipment during brownfield revamps
- A practical pathway from batch distillation to semi-continuous WFE recovery

Conditions that favour wiped-film evaporation

Consideration	Why It Matters	Selection Implication
High boiling range	Conventional distillation requires excessive temperature.	Deep-vacuum WFE lowers effective boiling temperature.
High viscosity	Circulation and heat transfer deteriorate as residue becomes heavier.	Mechanical film spreading maintains effective heat transfer.
Thermal sensitivity	Long residence time promotes cracking, colour formation and coke.	Short residence time reduces thermal exposure.
High residue concentration	Bottoms become progressively difficult to circulate.	WFE can continue evaporation at high residue concentration.
Fouling tendency	Stagnant heated surfaces accumulate degraded material.	Wiper action continuously renews the liquid film.
Revamp requirement	Existing batch still cannot provide desired throughput or recovery.	A downstream WFE section can often be added while retaining useful front-end equipment.

WFE is not automatically the best choice.

If the separation can be achieved economically in a conventional vacuum still without excessive residence time or wall temperature, adding a WFE may not create sufficient value to justify the additional capital and mechanical complexity.

Feed characteristics that must be reviewed before WFE sizing

Consideration	Why It Matters	Selection Implication
Viscosity vs temperature	Controls pumping, film formation and rotor loading.	Defines preheat temperature and operating window.
Distillation profile	Shows recoverable lube-range fractions.	Defines evaporation duty, product cuts and WFE staging.
Water & light ends	Create excessive vapour load at deep vacuum.	Should be removed during upstream dehydration and degassing.
Ash & metals	Concentrate in the non-volatile residue.	Influence residue viscosity and final discharge design.
Solids / sediment	Can interfere with film formation and mechanical parts.	May require settling, filtration or robust feed handling.
Carbon residue	Indicates heavy degraded material and coke tendency.	Limits practical recovery and allowable thermal severity.
Foaming tendency	Can cause entrainment into distillate.	Affects feed rate, vapour disengagement and internal design.
Thermal stability	Defines acceptable temperature-time exposure.	Supports selection of wall temperature, vacuum and number of stages.

The product slate determines the evaporator configuration

A WFE train should be configured around the cuts required—not simply around total feed capacity.

Single WFE configuration

Where the objective is to recover one combined base-oil fraction, a single WFE may separate the recoverable distillate from the heavy non-volatile residue. This provides a comparatively simple semi-continuous configuration with lower equipment count.

Multiple WFE configuration

Where light, medium and heavier base-oil fractions are required separately, two or more WFEs may be arranged in series or another suitable process configuration. Each stage can operate at a different temperature and vacuum condition so that progressively heavier fractions are recovered.

Series and parallel arrangements solve different problems.

Series WFEs are primarily used for staged recovery or different product cuts. Parallel WFEs are primarily used to increase throughput, provide turndown flexibility or share duty while producing a similar cut.

Questions to define first

- One combined base-oil cut or multiple grades?
- Target viscosity range of each cut?
- Expected distillate recovery from each stage?
- Final residue quantity and handling route?
- Downstream finishing requirement for each cut?

Vacuum performance is part of WFE performance

The useful pressure at the evaporation surface matters more than the nominal vacuum-pump specification.

As absolute pressure is reduced, the boiling temperature of heavy hydrocarbons falls. This reduces thermal severity, but very low pressure becomes progressively harder to maintain because vapour load, non-condensables, leakage, pressure drop and condenser temperature all become important.

Vacuum design must consider

- Residual water and light-end carryover
- Condenser temperature and available cooling medium
- Air leakage through seals, flanges and instruments
- Vacuum-pump operating range
- Total vapour generation at design feed rate
- Pressure drop in vapour piping and demisters
- Non-condensable load
- Start-up, shutdown and upset conditions

Upstream dehydration protects the WFE vacuum system.

Removing water, dissolved gases and volatile contaminants before the buffer tank prevents the WFE vacuum package from being used as the primary dehydration system. This improves vacuum stability and available capacity for lube-oil evaporation.

Heating surface alone does not determine WFE capacity

Throughput depends on heat transfer, vacuum, viscosity, rotor mechanics and required evaporation percentage.

Thermal considerations

- Feed inlet temperature
- WFE wall temperature
- Available temperature driving force
- Heat flux and local overheating risk
- Startup and turndown conditions
- Preheater duty
- Thermic-fluid temperature
- Overall heat-transfer coefficient
- Distillate condensation duty

Mechanical considerations

- Rotor and wiper configuration
- Handling of increasing residue viscosity
- Feed distributor design
- Residue outlet design
- Inspection and maintenance access
- Rotor speed
- Solids tolerance
- Vapour disengagement area
- Seal arrangement and vacuum integrity

Higher wall temperature is not always higher useful capacity.

Beyond the optimum operating range, increasing wall temperature may accelerate colour formation, cracking or coke deposition instead of producing commercially useful additional recovery.

Define the separation objective before sizing the machine

- Required base-oil cut or cuts
- Expected percentage recovery
- Flash point requirement
- Allowable heavy carryover
- Target viscosity of each distillate
- Maximum acceptable residue generation
- Colour and thermal-stability requirement
- Downstream clay, regenerative clay or solvent-extraction finishing
- Desired turndown range

The WFE should not be selected on feed rate alone. A 2 TPH WFE duty recovering a light fraction is not equivalent to a 2 TPH duty attempting much deeper evaporation into a highly viscous residue. The required evaporation percentage and product boiling range materially affect area, vacuum and heating duty.

Recovery, product quality and thermal severity must be balanced.

The process target is not maximum evaporation at any cost. It is the highest commercially useful recovery that can be achieved while maintaining acceptable distillate quality, residue handling and long-term operating reliability.

One of the strongest applications for semi-continuous technology

Existing batch dehydration assets can often be retained while the main distillation section is modernised.

A brownfield WFE retrofit can be attractive where an existing batch plant has useful dehydration and degassing equipment but the high-vacuum distillation stage has become a bottleneck, has excessive residence time or cannot provide the desired recovery.

Typical retrofit additions

- Buffer storage
- Feed preheater
- Deep-vacuum package
- Continuous residue handling
- Continuous feed pump
- WFE or multiple WFEs
- Distillate condensers and receivers
- Instrumentation and control integration

Existing infrastructure should be audited before design freeze.

Tie-in locations, available heating duty, cooling capacity, vacuum-system condition, product storage, structure, plot space and shutdown window all influence the retrofit configuration.

Technology selection should remain process-driven

- Low-viscosity feed that distils satisfactorily in a conventional batch or vacuum system
- Products that tolerate longer residence time without degradation
- Separation dominated by sharp fractionation between close-boiling components
- Very small evaporation duty where WFE capital and maintenance are not justified
- Feeds containing excessive coarse solids that cannot be adequately pretreated
- Projects where the desired product can be recovered economically with simpler equipment

WFE is primarily an evaporation and high-vacuum recovery device.

Where the dominant requirement is sharp fractionation between close-boiling components, a fractionation column or hybrid distillation configuration may be more appropriate than relying on WFE alone.

Information required before specifying the WFE section

- Representative feed analysis
- Distillation / boiling-range profile
- Density
- Carbon residue
- Required base-oil cut or cuts
- Maximum acceptable residue
- Cooling conditions
- Vacuum-system constraints
- Existing equipment to be retained in a revamp
- Water and light-end content after dehydration
- Viscosity versus temperature
- Ash, metals and solids
- Expected feed rate and turndown
- Target distillate recovery
- Available heating medium and temperature
- Required operating pressure
- Downstream finishing requirement
- Maintenance and cleaning philosophy

Pilot or laboratory work can reduce scale-up risk.

Where the feed is unusual, heavily contaminated or thermally unstable, representative vacuum-distillation or evaporation trials can provide valuable information on yield, residue behaviour, fouling tendency and achievable product quality.

Select the complete WFE process—not an isolated evaporator

Wiped Film Evaporation is particularly effective when used-oil re-refining combines high boiling temperatures, rising viscosity, thermal sensitivity and a requirement for high recovery under deep vacuum.

Within the Balaji semi-continuous process, the WFE operates downstream of batch dehydration and degassing, buffer storage and feed preheating. One WFE may be used for a combined base-oil cut, while multiple WFEs may recover progressively heavier fractions where the product slate requires it.

The best WFE is the configuration that achieves the required product recovery and quality with the lowest practical thermal severity and lifecycle cost.

Feed characterisation, product cuts, preheating, vacuum generation, condensation, rotor mechanics, residue handling and downstream finishing must all be engineered together.

Balaji Consultants develops WFE-based process configurations for new used-oil re-refining plants, semi-continuous plants, modular capacity additions and brownfield revamps. The evaporator is selected as part of the complete re-refining technology rather than as an isolated equipment item.