TECHNICAL ARTICLE

Solvent Extraction in Used-Oil Re-Refining

Understanding when solvent extraction adds value to recovered base-oil quality, consistency and process performance.

BALAJI CONSULTANTS | KNOWLEDGE CENTRE

CORE SPECIALISATION: USED-OIL RE-REFINING

When distillation alone is not enough

Vacuum distillation and WFE recover the lube-range fractions; solvent extraction can then upgrade their composition and finished-product quality.

Used-oil re-refining begins by removing water, light hydrocarbons, heavy residue and other non-distillable contaminants. Batch vacuum distillation, Wiped Film Evaporation and continuous high-vacuum separation are highly effective for recovering valuable lubricating-oil fractions.

However, boiling-range separation alone does not remove every undesirable aromatic, polar, oxidised or colour-forming component present in the recovered distillate. Where a higher and more consistent base-oil quality is required, solvent extraction can provide a deeper compositional upgrading step.

What solvent extraction changes

Distillation separates mainly by volatility. Solvent extraction separates by selective chemical affinity, allowing undesirable components to move preferentially into a solvent-rich phase while the more desirable lubricating-oil fraction remains in the raffinate.

Potential improvements

- Improved viscosity index and compositional quality
- Improved oxidation stability
- Greater consistency between production campaigns
- Reduced undesirable aromatic and polar material
- Improved colour, clarity and odour
- Reduced dependence on clay as the principal upgrading stage

Where solvent extraction fits in re-refining

Extraction is normally applied after recovery of usable lube-range distillates and before final conditioning or storage.

The extraction section does not replace dehydration, vacuum distillation or WFE. Its role is to upgrade selected base-oil distillates after the recoverable hydrocarbon fractions have already been separated from water, light ends and heavy residue.

Typical functional sequence

Feed preparation → Vacuum distillation / WFE recovery → Solvent extraction → Solvent recovery & recycle → Final conditioning / storage

The exact process route depends on the feedstock, desired base-oil cuts and finished-product specification.

Integration with Balaji process configurations

- Batch plants: batch distillate can be accumulated in intermediate tanks and fed to the extraction section in campaigns.
- Semi-continuous plants: WFE-produced distillate can feed extraction continuously or through intermediate storage.
- Continuous plants: solvent extraction integrates naturally into a steady-state process train.
- Revamps: extraction may be added downstream of an existing distillation or WFE section where higher product quality is required.

Selective upgrading by chemical affinity

The objective is to separate desirable base-oil molecules from components that reduce viscosity index, stability, colour or overall product quality.

The recovered lube distillate is contacted with a selective solvent under controlled temperature and solvent-to-oil ratio. Certain aromatic, polar, oxidised and other undesirable components preferentially migrate into the solvent-rich phase.

After sufficient contact and phase separation, two principal streams are produced: the raffinate, containing the upgraded base oil, and the extract, containing the solvent together with the rejected components.

Raffinate stream

- Upgraded lubricating-oil fraction
- Lower concentration of undesirable extractable components
- Directed to solvent stripping, final conditioning and storage

Extract stream

- Solvent-rich stream containing the rejected components
- Processed through solvent-recovery equipment
- Recovered solvent is returned to the extraction loop
- Concentrated extract is handled as a by-product or downstream stream

Solvent recovery is integral to the technology

A commercially viable extraction plant must recover and recycle the solvent efficiently. The extraction column cannot be evaluated separately from the solvent-recovery, stripping, drying and recycle system.

The quality of the incoming distillate determines extraction duty

Extraction performs best when the upstream recovery section is already stable and properly controlled.

Consideration	What It Means	Process Implication
Water	Can interfere with phase behaviour and solvent selectivity.	Feed and recycle solvent should be controlled to the required moisture level.
Light ends	Increase vapour load and may disturb extraction conditions.	Should normally be removed upstream.
Heavy residue / solids	Can cause fouling and poor phase separation.	Should not be carried into the extraction section.
Distillate composition	Determines how much undesirable material must be extracted.	Influences solvent ratio, temperature and expected raffinate yield.
Viscosity / density	Affects hydraulics and phase separation.	Used in extraction-column and pump design.
Product target	Defines required upgrading severity.	Determines extraction conditions and whether additional finishing is required.

Extraction cannot correct poor upstream separation indefinitely.

If heavy residue, water or unstable material is allowed to enter the extraction section, solvent circulation and recovery duties increase and product consistency may deteriorate.

What determines extraction performance

The process must balance product quality, raffinate yield, solvent circulation and energy consumption.

Key variables

- Solvent-to-oil ratio
- Feed temperature
- Number of effective contact stages
- Raffinate quality target
- Solvent purity and moisture
- Extraction temperature
- Column hydraulic loading
- Phase-settling behaviour
- Extract loading
- Solvent-recovery efficiency

Increasing extraction severity can improve the quality of the raffinate but may reduce the quantity of oil retained in the raffinate phase. The optimum operating point is therefore a commercial balance between quality improvement and product recovery.

Higher quality and higher yield are not always maximised at the same operating condition.

The design basis should define the finished-product requirement first, then establish the solvent ratio, temperature and contact duty required to achieve it economically.

Column configuration and phase-contacting options

The contacting device is selected around capacity, phase behaviour, pressure drop, controllability and maintenance requirements.

Typical contacting arrangements

- Extraction columns
- Packed or staged contactors
- Mixer-settler arrangements where appropriate
- Other liquid-liquid contacting systems selected for the specific duty

Supporting equipment

- Feed and solvent preheaters
- Raffinate and extract receivers
- Solvent strippers
- Condensers and reboilers
- Storage and surge tanks
- Solvent circulation pumps
- Phase separators
- Solvent recovery columns
- Drying / purification equipment where required
- Instrumentation and PLC/SCADA controls

There is no universal extraction column design.

Column diameter, internals, contact height and operating conditions must be developed from the actual distillate and solvent system, not selected from a standard package.

The extraction loop must minimise solvent loss

Extraction economics depend heavily on efficient recovery and reuse of the solvent.

Both the raffinate and extract streams leave the contactor carrying solvent. That solvent must be separated, condensed and returned to the circulation system.

Typical recovery functions

- Raffinate solvent stripping
- Condensation and solvent collection
- Solvent storage and surge capacity
- Make-up solvent addition
- Extract solvent recovery
- Drying or purification where necessary
- Controlled recycle to the extraction section
- Containment and loss monitoring

Why recovery efficiency matters

- Reduces recurring solvent consumption
- Improves plant economics
- Maintains stable extraction conditions
- Reduces solvent carryover into products and by-products
- Reduces environmental and handling losses

A solvent extraction plant is a closed process loop.

The extraction column is only one part of the system. Proper heat integration, solvent recovery, drying, containment and recycle control are essential to long-term operating performance.

When solvent extraction justifies the additional process complexity

The technology is most attractive when the market value of improved base-oil quality supports the capital and operating cost.

Advantages

- Deeper compositional upgrading than adsorption polishing alone
- Improved viscosity index potential
- Improved oxidation stability
- Improved colour and odour characteristics
- Continuous or semi-continuous integration
- Reduced routine clay consumption where extraction becomes the main upgrading step
- Greater product consistency when feed and operation are controlled

Trade-offs

- Higher capital investment
- Additional solvent-recovery equipment
- Greater instrumentation and control requirements
- Solvent containment and safety considerations
- Energy consumption for solvent recovery
- Need for disciplined operating and maintenance procedures

Solvent extraction should be selected for a defined product-quality objective.

It should not be added simply because it is a more sophisticated technology. The required improvement in base-oil quality must justify the additional equipment, solvent loop and utility demand.

The finishing technology should match the overall process architecture

Batch re-refining

Batch high-vacuum distillation can produce one or more base-oil cuts that are accumulated in intermediate tanks. Selected cuts can then be processed through extraction in campaigns. This arrangement preserves batch flexibility while providing a higher-quality upgrading route.

Semi-continuous re-refining

In the Balaji semi-continuous process, dehydration and degassing are performed batchwise, followed by buffer storage, preheating and continuous WFE/WFEs. The recovered WFE distillates can then be fed to solvent extraction continuously or from intermediate product tanks.

Continuous re-refining

A fully continuous plant can integrate extraction and solvent recovery directly into the steady-state process train, allowing continuous product upgrading and automated operating control.

Brownfield revamps

Existing distillation and WFE facilities may be upgraded by adding an extraction and solvent-recovery section when the client's market requires improved base-oil quality without replacement of the upstream recovery plant.

Different technologies for different upgrading objectives

Consideration	What It Means	Process Implication
Primary mechanism	Selective liquid-liquid extraction by chemical affinity.	Adsorption of residual colour bodies, polar material and trace contaminants.
Depth of upgrading	Can materially change distillate composition.	Primarily a polishing step.
Typical objective	Higher and more consistent base-oil quality.	Colour, odour and final appearance improvement.
Operating mode	Well suited to continuous or semi-continuous operation.	Batch clay is batchwise; regenerative clay can operate semi-continuously.
Consumables	Solvent is largely recovered and recycled; make-up is required.	Fresh clay is consumed in batch treatment; regenerative media is reused over cycles.
Plant complexity	Higher due to extraction and solvent-recovery loop.	Lower for conventional batch clay; higher for regenerative polishing.

The technologies are not mutually exclusive.

Depending on the product target, solvent extraction may be followed by a final polishing step. The correct sequence is determined by the incoming distillate quality and the finished-base-oil specification.

Information required before recommending solvent extraction

- Representative distillate analysis
- Viscosity index target
- Oxidation stability requirement
- Plant capacity and operating hours
- Available utilities
- Existing downstream finishing equipment
- Space available for extraction and solvent recovery
- Required finished base-oil specification
- Colour and odour requirement
- Distillate cut or cuts to be treated
- Batch, semi-continuous or continuous process architecture
- Solvent-handling and hazardous-area requirements
- Target product recovery / raffinate yield
- Automation philosophy

Questions the process designer must answer

- How much upgrading is actually required?
- What quality can the feed distillate realistically achieve?
- What extraction severity gives the best quality-yield balance?
- How should the solvent be recovered and recycled?
- Is extraction economically justified compared with alternative finishing routes?

Use solvent extraction when the product-quality objective demands it

Solvent extraction can be one of the most effective upgrading technologies in used-oil re-refining when the objective is to improve the composition, viscosity index, stability, colour, odour and consistency of recovered base-oil distillates.

Its value is greatest when it is integrated with a properly engineered upstream recovery process and an efficient solvent-recovery loop. The technology should therefore be selected as part of the complete re-refining route—not as an isolated equipment package.

Process technology first. Engineering throughout. Built for operation.

Balaji Consultants evaluates the feedstock, recovered distillate quality, required product specification, plant architecture and lifecycle economics before recommending solvent extraction.

Balaji Consultants develops solvent-extraction systems as part of complete used-oil re-refining plants, plant upgrades and technology revamps. Our scope can include process design, extraction and solvent-recovery engineering, heat integration, equipment specification, detailed engineering, automation, commissioning and performance optimisation.