TECHNICAL ARTICLE

Clay Treatment vs. Regenerative Clay Polishing

A technical comparison of conventional Batch Clay Treatment and semi-continuous Regenerative Clay Polishing for re-refined base-oil finishing.

BALAJI CONSULTANTS | KNOWLEDGE CENTRE

CORE SPECIALISATION: USED-OIL RE-REFINING

01 / INTRODUCTION

Two approaches to adsorptive product finishing

Both Batch Clay Treatment and regenerative clay polishing use selective adsorption—but they differ significantly in operating philosophy, adsorbent handling and lifecycle economics.

Adsorbent finishing is widely used to improve the colour, appearance and stability of re-refined base-oil products after distillation or extraction. The adsorbent removes residual polar compounds, oxidation products, colour bodies and other trace contaminants that remain after upstream separation.

In Batch Clay Treatment, fresh adsorbent is contacted with the oil and is ultimately removed from service as spent material. In a regenerative system, the adsorbent is periodically restored by controlled thermal regeneration and returned to service, reducing fresh adsorbent consumption and waste generation.

Technology hierarchy note: This article compares two adsorption-based finishing routes. Where higher and more consistent re-refined base-oil quality is the primary objective, solvent extraction is a separate and generally stronger upgrading technology, particularly for continuous re-refining plants. Clay-based systems remain valuable where adsorption polishing is technically and commercially appropriate.

The two systems solve the same finishing problem differently.

Conventional clay treatment is simple and familiar, but creates a continuous spent-adsorbent stream. Regenerative polishing requires a more integrated process and regeneration section, but can reduce disposal, adsorbent replacement and batch-handling requirements.

Simple, established and highly dependent on consumable adsorbent

The conventional route relies on fresh clay or another adsorbent for each treatment cycle.

In a typical batch configuration, the oil is heated and mixed with a measured quantity of activated clay or adsorbent in a contact vessel. After sufficient residence time, the treated oil is separated from the clay through filtration.

Typical process sequence

- Oil heating
- Clay dosing
- Agitated contact
- Adsorption residence time
- Filtration
- Finished-oil transfer
- Spent-clay discharge and disposal

Advantages

- Simple process configuration
- Low initial investment and relatively simple equipment configuration
- Easy to understand and operate
- Suitable for small capacities or intermittent production
- Flexible dosage for changing product quality
- Straightforward batch operation and easy capacity turndown
- Suitable where clay is inexpensive and spent-clay disposal is manageable

Limitations

- Continuous fresh-clay consumption and recurring clay cost
- Spent-clay disposal, storage and regulatory handling issues
- Product / oil losses retained in spent filter cake
- Batch cycle time can limit throughput
- Filtration equipment, filter media and maintenance requirement
- Higher manual handling, housekeeping and operator involvement
- Disposal cost increases with plant capacity and clay dosage
- Product quality can vary with clay dosage, contact time and filtration consistency

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Semi-continuous adsorption with on-site adsorbent regeneration

Regenerative systems treat the adsorbent as a reusable process medium rather than a single-use consumable.

In a regenerative polishing system, the product passes through one or more adsorbent beds or contact stages. As the adsorbent becomes loaded with contaminants, it is taken out of polishing service and regenerated—typically by controlled heating and removal of the retained hydrocarbons and adsorbed species.

Typical operating cycle

- Online adsorption / polishing
- Bed changeover or controlled transfer
- Drainage of retained oil
- Thermal regeneration
- Cooling / conditioning
- Return of adsorbent to service

Semi-continuous operation is the key advantage.

One adsorption section can remain in service while another bed or adsorbent inventory is being regenerated. This reduces the process interruptions associated with traditional batch clay contact and filtration.

Potential benefits

- Reduced fresh-adsorbent consumption
- Lower routine spent-clay disposal
- Can produce an odourless product with good colour under appropriate feed and operating conditions
- Improved operating continuity
- Lower product loss with discarded adsorbent
- More consistent polishing conditions
- Reduced manual clay handling and cleaner operation
- Adsorbent can be reused through repeated regeneration cycles

Important design trade-offs

Regenerative polishing provides strong operating and product-quality advantages, but it is more equipment-intensive than batch clay treatment. For a given plant capacity, a higher number of polishing columns or beds may be required so that adsorption, changeover and regeneration can occur without interrupting production.

■ Higher number of columns / beds for a given capacity	■ Larger valve, piping and switching arrangement
■ Higher initial investment than simple batch clay treatment	■ More instrumentation, controls and regeneration equipment

How the two systems differ in operation

Factor	Batch Clay Treatment	Regenerative Clay Polishing
Operating mode	Typically batch contact followed by filtration.	Semi-continuous or cyclic polishing with regeneration.
Adsorbent use	Fresh adsorbent added regularly.	Adsorbent reused over multiple cycles.
Waste generation	Spent clay generated after treatment.	Substantially lower routine spent-adsorbent generation.
Oil loss	Oil retained in filter cake can be significant.	Lower recurring product loss with disposed adsorbent.
Filtration load	High; filtration is central to each batch.	Much lower dependence on batch filtration.
Labour	Clay charging, filter handling and cake disposal require labour.	More automated handling, but regeneration requires controlled operation.
Capital cost	Low initial investment; simple contact vessel, clay handling and filtration system.	Higher initial investment due to multiple polishing columns / beds, switching valves and regeneration equipment.
Operating cost	Driven by fresh clay purchase, filtration, product loss, labour and spent-clay disposal.	Driven by regeneration energy, maintenance and periodic adsorbent make-up; routine clay-disposal burden is much lower.
Product quality	Can achieve good colour, but consistency depends on clay dosage, contact conditions and filtration.	Key advantage: produces an odourless product with good colour and consistent polishing when properly operated.
Equipment / columns	Relatively few major vessels; compact and simple batch arrangement.	Higher number of polishing columns / beds is typically required for a given capacity to permit online service, changeover and regeneration.
Footprint / complexity	Lower equipment count and simpler piping.	Higher equipment count, switching valves, piping, controls and regeneration integration.

Adsorption performance depends on feed quality and finishing target

Neither system can compensate indefinitely for poor upstream separation.

Clay polishing is most effective as a finishing step after the majority of water, light ends, heavy degradation products and suspended contaminants have already been removed. If the feed to the clay section contains excessive unstable material, the adsorbent will load rapidly and operating cost will increase.

Typical properties influenced by polishing

- Colour and visual appearance
- Residual polar compounds
- Oxidation products
- Trace degradation products
- Certain odour-causing species
- Product stability

Adsorption capacity is finite.

Whether the adsorbent is disposable or regenerative, the polishing section should be sized around the contaminant load—not only the oil flow rate. Upstream distillation, extraction and feed quality directly influence adsorbent life.

Consistency of operation

A regenerative system can provide more repeatable operating conditions when bed loading, regeneration and changeover are controlled systematically. A key advantage is the production of an odourless product with good colour, while maintaining consistent polishing over extended operation. Conventional batch treatment can also produce good-quality product, but the result depends more directly on clay dosage, contact time, temperature and filtration consistency.

What makes regenerative polishing technically different

Successful regeneration requires removal of retained oil and adsorbed contaminants without damaging the adsorbent structure.

Key regeneration considerations

- Controlled heating rate
- Removal of retained hydrocarbons
- Off-gas and vapour handling
- Regeneration cycle time
- Maximum adsorbent temperature
- Air / inert-gas management as applicable
- Cooling before return to service
- Adsorbent attrition and fines generation

The regeneration philosophy must be developed together with the adsorbent chemistry. Excessive temperature can reduce adsorbent performance or create unwanted coke formation, while insufficient regeneration may leave the media partially loaded and shorten the next polishing cycle.

Regeneration is not simply 'burning the clay clean'.

A well-designed system controls temperature, residence time, gas flow and hydrocarbon removal so that adsorbent activity is restored without excessive attrition, sintering or thermal damage.

CAPEX versus recurring consumable and disposal cost

The economic comparison should consider the complete lifecycle, not only the purchase price of the polishing equipment.

Conventional treatment cost drivers

- Fresh clay purchase
- Clay transport and storage
- Filter elements / consumables
- Spent-clay handling
- Disposal or hazardous-waste charges
- Oil retained in filter cake
- Labour and housekeeping

Regenerative system cost drivers

- Regeneration equipment
- Heating energy
- Instrumentation and controls
- Mechanical maintenance
- Adsorbent attrition replacement
- Off-gas treatment
- Periodic shutdown inspection

The higher the throughput, the more important recurring adsorbent cost becomes.

At small or intermittent capacities, Batch Clay Treatment may remain economical because of its low initial complexity. As throughput and operating hours increase, the cumulative cost of fresh clay, product loss and disposal can make regeneration increasingly attractive.

Waste reduction can become a major project driver

Spent adsorbent is not only a cost issue; it can also create storage, handling and regulatory challenges.

Conventional spent-clay issues

- Residual hydrocarbons in discarded cake
- Transport to disposal facility
- Odour and housekeeping
- Fire and storage considerations
- Regulatory classification
- Ongoing disposal documentation

Regenerative system considerations

- Lower routine solid-waste generation
- Reduced clay transport and warehouse demand
- Need for thermal and off-gas safety systems
- Controlled recovery or destruction of retained hydrocarbons
- Higher process integration
- More instrumentation and operator training

Waste minimisation must be evaluated together with energy use.

Regeneration reduces solid waste but requires thermal energy. The environmental advantage should therefore be assessed on a complete process basis including fuel, off-gas handling, clay transport, product loss and disposal.

The simpler route can remain the right route

Regeneration should be justified by operating scale and project conditions.

- Small plant capacity
- Intermittent or campaign operation
- Low local clay cost
- Low or manageable spent-clay disposal cost
- Highly variable products requiring frequent dosage changes
- Limited operator skill or maintenance infrastructure
- Projects where low initial capital is the overriding priority

A well-designed conventional system can still be effective

Conventional batch clay treatment remains attractive because of its low initial investment, simple equipment and straightforward operation. However, lifecycle cost is strongly influenced by recurring clay consumption, filtration, oil retained in the filter cake, labour and spent-clay disposal. Good control of contact temperature, dosage, mixing and filtration can improve economics, but the spent-clay disposal stream remains inherent to the process.

Technology selection should remain project-specific.

A regenerative system is not automatically superior for every plant. The process must be evaluated against capacity, clay price, disposal cost, operating hours, product specifications and available utilities.

Conditions that strengthen the case for regeneration

The strongest applications are usually continuous or semi-continuous plants with significant recurring adsorbent consumption.

- Medium to high throughput
- High annual operating hours
- Expensive imported adsorbent
- High spent-clay disposal cost
- Restricted disposal options
- Desire to reduce manual clay handling
- Need for more continuous production
- Brownfield plant with clay-treatment bottleneck
- Need to reduce product losses with spent filter cake
- Environmental targets focused on waste minimisation
- Requirement for an odourless finished product with good colour under appropriate feed and operating conditions
- Preference for cleaner operation with reduced routine clay disposal

Brownfield revamps

Regenerative polishing can be particularly attractive in existing re-refining plants where batch clay contact and filtration have become production bottlenecks. A carefully designed revamp can retain useful existing tanks, utilities and transfer systems while replacing the clay-contact and filtration cycle with semi-continuous polishing and regeneration.

A revamp should begin with an operating audit.

Existing product quality, clay dosage, filtration cycle, waste generation, energy consumption and shutdown constraints should be quantified before selecting the new configuration.

Information required for a meaningful comparison

- Plant throughput and annual operating hours
- Upstream distillation / extraction configuration
- Clay type and purchase cost
- Spent-clay disposal method and cost
- Desired product colour and stability
- Utilities available for regeneration
- Environmental restrictions
- Automation philosophy
- Feed to polishing section
- Current clay dosage
- Existing filtration system
- Oil loss in filter cake
- Current batch cycle time
- Fuel / thermic-fluid cost
- Available plot area
- Existing equipment suitable for reuse

The decision should be based on lifecycle cost per unit of finished product.

CAPEX, clay consumption, product loss, disposal, labour, energy, maintenance, uptime and product-quality consistency should all be included in the evaluation.

Choose the finishing route around operating economics and plant philosophy

Conventional batch clay treatment remains a proven and practical finishing method where plant capacity is modest, operation is intermittent, or low initial investment is the principal project priority. Its simplicity is an advantage, but recurring fresh-clay consumption, filtration, product loss in filter cake and spent-clay disposal must be accepted as continuing operating costs.

Regenerative clay polishing becomes increasingly attractive when plants operate continuously or semi-continuously, adsorbent consumption is significant, waste disposal is costly, or the product requirement includes an odourless product with good colour. Its principal trade-off is greater equipment complexity: for a given capacity, more polishing columns / beds, valves, piping and regeneration equipment are generally required.

The regenerative route requires higher initial investment, greater process integration, thermal control and automation, but it converts clay from a recurring consumable into a reusable process medium and substantially reduces routine spent-clay generation. For medium and larger plants, this can provide strong lifecycle benefits despite the higher number of columns and more complex operating sequence.

The correct question is not whether regenerative clay is newer technology. The question is whether regeneration improves the technical and lifecycle economics of the specific plant.

Balaji Consultants is a specialist used-oil re-refining technology company and supplier of complete re-refining plants. We develop both Batch Clay Treatment and Regenerative Clay Polishing configurations where adsorption finishing is appropriate, while also integrating solvent extraction where higher and more consistent base-oil upgrading is required. For new plants and revamps, the finishing route is selected together with feed quality, product specification, plant capacity, operating philosophy, clay consumption, waste handling, available utilities and lifecycle economics.