

Rag Layers in Electrostatic Desalters: Causes, Diagnosis and Control

Technical report for crude-oil desalting and dehydration service

Scope	Interfacial emulsion (“rag”) layers in refinery desalters and upstream electrostatic dehydrators
Prepared	October 2026
Basis	Published research, operating literature and engineering synthesis

Central finding

A rag layer is an inventory: it grows whenever interfacial material arrives faster than the vessel can resolve or remove it. Persistent rag usually combines a stabiliser (asphaltene films, partially oil-wet fine solids, naphthenates or excess chemical) with a condition that slows drainage and coalescence, such as low temperature, over-mixing or recycled emulsion. Control starts with knowing what the rag is made of and where it comes from, not with more voltage, more demulsifier or more draw-off.

Engineering note

This is a mechanism-based report, not a substitute for the desalter vendor’s operating envelope, site process-safety review or crude-specific laboratory testing.

Executive summary

A rag layer (interface emulsion) is the zone between clean oil and free water where emulsified water, solids and interfacially active material collect, typically as droplets and solids suspended in a continuous oil phase [1]. Conventional vessels are designed with additional volume to allow for some rag [2], but a thick layer can turn a two-phase separation into a three-phase one and significantly reduce oil, water and solids separation efficiency [3].

The rag-specific literature, much of it from oil-sands froth treatment, identifies two recurring mechanisms: slow coalescence of emulsified water, and the trapping of fine solids of intermediate wettability, with asphaltene solvency modifying both [1,4,5]. Broader field studies agree: across a wide range of crudes, inorganic solids content was the most descriptive single variable for emulsion stability [6].

Rag should therefore be diagnosed as a material balance (what arrives, what resolves and what leaves) using interface profiles, rag samples and synchronised operating data; control then targets the source, the stabiliser and the removal route. This report complements our study on the impact of asphaltenes, sulphur and calcium on electrostatic coalescer performance, which treats interfacial chemistry and calcium naphthenates in more depth.

Table 1. Rag-layer contributors and impact

Contributor	Mechanism	Typical rag signature	Overall judgement
Asphaltene/resin interfacial films	Rigid films resist drainage and rupture; poor solvency increases asphaltene segregation at the interface [4,7]	Fine, persistent droplets; rag thickens after blend changes	High direct risk
Fine solids: clays, sand, iron sulphide, scale, corrosion products	Partially oil-wet particles adsorb at the interface, more strongly when coated by asphaltenes or organic acids [5,8,9]	Dense, solids-rich rag; oily solids in brine	High; often dominant
Naphthenates	Interfacially active soaps; calcium naphthenate gels and deposits (see our study on the impact of asphaltenes, sulphur and calcium)	Rag or deposits on high-acid crudes; pH sensitivity	High when present
Demulsifier under- or over-dosing, or wrong chemistry	Under-dosing leaves films intact; overdosing a flocculating chemistry degrades separation [10]; excess chemicals occur in field rag [2]	Dose response plateaus or reverses; good water drop but poor interface	Medium-high; controllable
Low temperature / high viscosity	Slower film drainage, settling and oil drainage from the rag [4,7]	Rag grows in cold periods or with heavier feed	Medium-high
Over-mixing / high mixing-valve ΔP	Smaller droplets form a more stable emulsion [11]	Rag and carryover rise with ΔP	Medium; controllable
Crude blend incompatibility	Blending can push asphaltenes towards incipient precipitation, where particle stabilisation is favoured [8,12]	Sudden growth after a blend or blend-order change	High near instability
Slop/recycled oil and recovered streams	Return aged emulsion, fines and chemicals; drawn-off rag is often recirculated to the vessel [2]	Growth coinciding with slop injection	Medium-high; often underestimated
Wash-water quality	Alkaline pH, tramp amines/ammonia, metals and solids promote rag [13]; pH and brine composition affect films [7]	Rag or oily brine after a source change	Medium; site-specific

Source: engineering synthesis from the references cited. Judgements describe mechanism potential, not universal thresholds.

Priority actions

1. Sample and analyse the rag itself (water, solids, mineralogy and wettability, asphaltenes, metals and microscopy) before changing chemistry or operation.
- (2) Trend rag thickness against crude blend, slop injection, wash-water source, mixing ΔP , temperature, demulsifier dose and electrical load.
- (3) Give drawn-off rag a defined treatment route that does not return it untreated to the same desalter.
- (4) Change one variable at a time under management of change and within the vendor envelope.

Conclusions at a glance

- **Rag is an inventory balance:** it grows when interfacial material arrives faster than it resolves or is removed.
- **Solids are frequently decisive:** fine, partially oil-wet particles, notably organically coated clays and iron minerals, have been identified as rag formers and can sustain rag despite demulsifier.
- **More chemical is not always better:** overdosing can worsen separation, so interface quality must be an explicit test criterion.
- **Recycle loops matter:** returning slop, recovered oil or drawn-off rag to the desalter can sustain the very rag that draw-off was meant to remove.
- **Instruments shape control:** a level device that cannot see emulsion misleads operators and control loops alike.

1. What a rag layer is and why it matters

Rag composition varies widely between systems; in diluted oil-sands froth experiments, for example, rag layers contained roughly 32–46 wt% water and 7–15 wt% solids [1], figures that should not be read across to refinery desalters. Rag in dehydrators and desalters is described as containing excess chemicals, fine solids, scale and iron sulphides in addition to oil and water [2], and its density can be close to that of water [13]. Consequences include:

- **Water and salt carryover:** rag occupies settling height and brings unresolved emulsion closer to the electrodes; more droplets leave with the crude.
- **Oil undercarry into brine:** lowering the interface to keep rag away from the electrodes can draw rag and oil into the brine outlet.
- **Electrical instability:** water-rich rag is far more conductive than dehydrated crude; as it approaches the grids, current can rise and voltage fall, in severe cases to the point of trips (engineering inference, not a published threshold).
- **Level-control problems:** an emulsion layer disturbs displacer readings and cannot be resolved by differential-pressure measurement [14], so the controlled “interface” may not be where the rag is.
- **Effluent upsets:** uncontrolled undercarry or rag dumping sends oil, solids and chemicals to wastewater treatment.

Indicator	What to trend	Failure signature suggesting rag
Rag inventory	Thickness from profiler or try-cock profile, versus time	Steady growth, or a step change after a feed event
Desalted crude	BS&W, salt	Rising water and salt at constant feed
Brine	Oil and grease, suspended solids	Oily or solids-rich brine; intermittent slugs

Indicator	What to trend	Failure signature suggesting rag
Electrical	kV, current, power, trips	Current rise, voltage sag or trips coinciding with a high interface
Level control	Controller output; instrument versus sampled interface	Hunting, frequent manual intervention, instrument disagreeing with samples

Source: conventional operating framework; align with site and vendor specifications.

2. Formation mechanisms

Rag forms when droplets and particles reach the interface faster than they coalesce or pass through, and something stabilises them there.

2.1 Slow coalescence of emulsified water

Crude-oil emulsions are stabilised by rigid interfacial films that form a “skin” on water droplets. Film stability depends on heavy components (asphaltenes, resins, waxes), on solids (clays, scales, corrosion products) and on temperature, droplet-size distribution, pH and oil and brine composition [7]. In staged centrifugation of froths, rag volume beyond the hindered-settling stage was governed by the coalescence rate of emulsified water, and adding emulsified water enlarged the rag [1]. Rag is therefore partly a queue of droplets waiting to coalesce; anything that slows film drainage, including the asphaltene film ageing described in our companion study, lengthens the queue.

2.2 Solids at the interface

Small inorganic particles strongly enhance water-in-crude emulsion stability when interaction with asphaltenes promotes their adsorption at the interface; smaller particles and higher concentrations increase stability [8]. In diluted bitumen, near-complete separation was achieved with demulsifier in the absence of clays, but a rag layer persisted when clays were present. The organic content of the clays decreased from the oil layer through the rag to the water layer, consistent with rag solids of intermediate wettability [5]. Solids from a rag-forming stream in an oil-sands froth-treatment plant were enriched in iron minerals, including pyrite (an iron sulphide) and siderite; organic matter bound to them through carboxylic acid groups made their surfaces hydrophobic [9].

The effect is not uniform: in one study added fines had inconsistent effects, and the authors judged their role unclear [1]. Coarser solids generally settle to the vessel bottom as mud [2] and matter mainly through mud-wash practice.

2.3 Solvency and blending

In solvent-bitumen-water systems, a more paraffinic diluent caused asphaltenes to segregate at the oil-water interface and increased rag formation, whereas a more aromatic diluent reduced both rag stability and the oil lost to the rag [4]. Incompatible crude oils are relatively common, and the proportions and order of blending can determine whether asphaltenes stay in solution [12]. A blend close to its flocculation point is particularly hazardous because, in model emulsions, particle stabilisation required asphaltenes near the point of incipient precipitation [8].

2.4 Chemical, hydraulic and thermal conditions

- **Demulsifier:** one analysis concluded that, where a flocculating chemical is used as demulsifier, overdosing necessarily degrades performance, making dose optimisation and accurate process control essential [10].

Bottle tests report water drop, oil dryness and interface quality as distinct parameters [6]; a chemistry that drops water quickly can still leave a poor interface.

- **Mixing:** higher mixing-valve ΔP improves wash-water contact but produces smaller droplets and a more stable emulsion [11].
- **Temperature:** higher temperature reduced rag formation and oil loss to the rag, attributed to lower oil viscosity and better drainage [4].

2.5 Recycle and wash water

Accumulated rag is conventionally drawn off periodically and either treated outside the vessel or, in most cases, circulated back to it [2]. Slop and recovered oil can return the same aged emulsion, fines and chemicals. On the water side, alkaline pH, tramp amines or ammonia, metals and solids have been reported to promote rag stability and size [13].

3. Monitoring the interface

Interface instruments respond to a physical contrast (density, dielectric properties or conductivity), and an emulsion band blurs each one differently.

Instrument type	Principle	Behaviour with rag
Displacer	Buoyancy; depends on phase densities	Emulsion layer disturbs the reading [14]
Differential pressure	Hydrostatic head	Cannot resolve emulsion; sand or wax can block connections [14]
Single-element capacitance/RF probe	Dielectric contrast	Reports only one interface; needs temperature compensation [14]
Segmented (multi-point) probe	Electrode array along the height	Identifies sharp interfaces; conductive brine is a design challenge [14]
Nuclear density profiler	Gamma attenuation along the height	Shows inter-phase mixing as a density profile; requires radiation-safety controls [14]
Try-cocks / sample lines	Direct samples at fixed elevations	Shows the actual material; discrete points, operator-dependent

Source: [14] and engineering synthesis; verify vendor claims against sample profiles on the actual vessel.

- Define rag thickness consistently (for example, first emulsion to first clean water) and record the method.
- Revalidate instruments against sample profiles as rag conditions change.
- Measure solids at the interface: as rag grows, interface solids rise above the theoretical minimum expected from crude solids, solids removal and wash-water rate [13].
- Sampling is hazardous (hot fluids that may contain H_2S and can flash); follow site procedures.

4. Diagnosis: rag sampling and analysis

Sample across the rag at several elevations, with the oil above, the brine below and synchronised crude, slop and wash-water samples. Record the operating state, and keep samples at temperature or analyse promptly to limit phase redistribution.

Analysis	What it shows	Diagnostic use
Water content	Water fraction	Water-rich, low-solids rag suggests coalescence limitation and conductivity risk
Solids content and size	Loading and fineness	High fines loading points to particle stabilisation [6,8]
Mineralogy and elemental composition	Clays, iron sulphides and oxides, carbonates, scale, sand	Iron minerals were enriched in rag-forming solids [9]; trace their source. Scale suggests water incompatibility
Organic content of solids	Oil-wetness	Rag solids fell between oil-layer and water-layer solids [5]
SARA/asphaltenes, rag versus bulk crude	Enrichment of polar material	In one froth study, rag asphaltenes carried about twice the heteroatoms of bulk asphaltenes [3]; enrichment implicates films and solvency
Metals (Fe, Ca, Na and others)	Corrosion, naphthenate or brine contributions	For calcium with a high acid number, see our companion study
Microscopy	Droplet size, flocs, armoured droplets	Very fine droplets suggest over-shear or under-treatment; armoured droplets suggest solids
Bottle test on the rag	Response to heat, chemical and dilution	Easy resolution points to chemistry or temperature; persistent resistance suggests solids or naphthenates

Select validated methods suitable for emulsions containing solids.

Observed pattern	Most likely class of cause	First checks
Steady growth at constant feed	Solids or emulsion arriving faster than removal	Interface solids versus solids balance; draw-off and mud-wash records
Step growth after crude or blend change	Asphaltene destabilisation, new solids or acids	Blend compatibility; rag SARA and solids; acid number and calcium
Growth when slop is processed	Recycled emulsion, solids or chemicals	Correlation with slop rate; slop analysis; short isolation trial
Rag with rising current or trips	Water-rich rag near the electrodes; interface too high	Instrument versus try-cocks; rag water content; level set point
Rag with oily brine	Undercarry, over-treatment, or oil-wet solids leaving with water	Brine oil; interface position; solids wettability
Growth after a demulsifier increase	Overdosing or flocculation	Controlled step-down; bottle test including interface quality
Growth after a wash-water change	pH, amines/ammonia or solids	Wash-water analysis

Diagnostic matrix; causes are not mutually exclusive. Change one controlled variable at a time where practicable.

5. Control measures

Lever	Measures	Cautions
Chemistry	Select by crude-specific bottle tests judged on water drop, oil dryness and interface quality [6]; map the full dose response, including overdose [10]; review injection point; screen solids-wetting products where solids dominate	Overdosing, brine oil and downstream effects; confirm compatibility with wastewater treatment
Temperature	Raise within the design envelope to lower viscosity and improve drainage [4,7]	Higher crude conductivity and current, vapour pressure and energy use (see companion study)
Mixing	Step mixing-valve ΔP down to find the window between extraction and emulsification [11]	Under-mixing reduces salt removal
Wash water	Control pH and tramp amine/ammonia content and minimise solids [13]; test compatibility with other waters in the system	Source changes affect sour-water and wastewater systems; acidification raises corrosion risk
Solids management	Upstream tank settling and water draining, corrosion control, filtration where justified, mud washing to vendor procedure	Mud washing can disturb the interface and send solids to brine
Rag draw-off/skimming	Use a dedicated interface draw-off where fitted; withdraw at a controlled rate guided by profiles	Oil and chemicals to effluent; hydraulic disturbance; no improvised connections
Handling of drawn-off material	Route to a dedicated treatment step (heating and settling, chemical treatment or mechanical separation) and analyse before any reprocessing	Recirculation to the vessel is common [2] but can sustain the rag; iron-sulphide-bearing solids may be pyrophoric on drying
Slop management	Segregate, characterise and pre-treat slops; inject at a low, steady rate; suspend during desalter upsets	Slop inventory limits; slugs upset the vessel
Level strategy	Set the interface within the vendor's range to balance carryover against undercarry, using profiles rather than a single instrument	High levels risk electrical instability; low levels risk oil undercarry

Any field change requires the site's management-of-change, process-safety and vendor constraints.

6. Interaction and risk matrix

Combination	Mechanism	Operational consequence	Risk
Fine solids + blend near asphaltene instability	Asphaltene-modified particles adsorb and armour droplets [8]	Dense, persistent rag; oily solids	High

Combination	Mechanism	Operational consequence	Risk
Drawn-off rag or slop returned to feed	Recirculation, common for rag [2], closes an accumulation loop	Progressive growth; recurring upsets	High
Flocculating demulsifier overdose + solids	Overdosing degrades dewatering performance [10]	Persistent rag; poor interface quality	Medium-high
Alkaline wash water + high-acid crude	Naphthenate soap formation (see companion study)	Interfacial gels; oily brine	High when present
Water-rich rag + high interface set point	Conductive material near the electrodes	Current rise, voltage loss, trips	High (electrical)
Iron-bearing solids + organic acids	Acid groups bound to iron surfaces make particles hydrophobic, as shown for iron minerals [9]	Iron-rich, persistent rag	Medium-high

Severity must be confirmed with the actual crude, water and operating temperature.

7. Implementation plan

7.1 Baseline and classify

1. Define the rag-thickness metric and profiling frequency, and validate instruments (Section 3).
2. Record feed blend, slop rate, wash-water source, mixing ΔP , temperature, demulsifier dose and electrical data alongside rag thickness.
3. Sample and analyse the rag (Section 4) and classify the regime: coalescence-limited, solids-stabilised, chemistry-limited, hydraulic/level-limited or recycle-driven.

7.2 Laboratory screening

Use the actual crude blend, slop and wash water at process temperature. Screen demulsifier family and dose (including overdose), solids-wetting chemistry, temperature, mixing energy and slop ratio, and test blend compatibility at actual ratios and blending order [12]. Judge results on water drop, oil dryness, interface quality [6] and brine oil.

7.3 Controlled field trial

Trial phase	Controlled change	Acceptance criteria
A. Baseline	No intentional change; establish rag growth rate and variability	Validated rag measurement; stable operating record
B. Source control	Slop isolation or metering; wash-water quality correction	Lower rag growth rate without new upsets
C. Chemistry	Approved demulsifier or solids-wetting change, including a dose step-down	Thinner rag and better interface quality without brine-oil or downstream penalty
D. Operating conditions	One approved temperature or mixing step at a time within the vendor envelope	Less rag and carryover without loss of salt removal or electrical stability

Trial phase	Controlled change	Acceptance criteria
E. Draw-off and handling	Defined draw-off rate and treatment route	Stable rag inventory; no wastewater upset; no untreated recycle
F. Confirmation	Return to baseline or repeat the best condition	Reproducible improvement beyond baseline variation

Do not trial chemistry, high-voltage or draw-off changes outside approved procedures, site management of change and vendor limits.

8. Trade-offs

Control knob	Potential benefit for rag	Principal trade-off
Demulsifier dose	Weaker films; faster coalescence	Overdosing, flocculation, brine oil and cost
Temperature	Lower viscosity; faster drainage	Conductivity and current; vapour pressure; energy
Mixing ΔP (lower)	Larger droplets; less stable emulsion	Poorer salt extraction
Wash-water rate	Dilutes salts; flushes solids	Hydraulic load; more water near the field; effluent volume
Rag draw-off	Removes inventory	Oil to effluent; treatment burden; disturbance
Interface level (lower)	Keeps rag away from the electrodes	Oil undercarry; less water residence time

9. Conclusions

The literature identifies slow coalescence of emulsified water and the trapping of partially oil-wet fine solids as recurring mechanisms, with asphaltene solvency, temperature and chemical dose modifying both. The concentration, fineness, mineralogy and organic coating of the solids often decide whether rag resolves.

Control is a sequence: measure the rag reliably, identify its stabiliser and source, remove the source where possible, optimise chemistry, temperature and mixing, and keep untreated rag out of the desalter feed.

Recommended decision rule

When rag grows, first ask whether arrival has increased or resolution has decreased. If growth follows a feed, slop or wash-water event, control the source before adjusting the desalter. If it follows a chemical, temperature or mixing change, revert or re-optimize that variable. Make permanent changes to chemistry, draw-off or level strategy only after the rag has been sampled and its stabiliser identified, within vendor limits and site management of change.

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Evidence limitations

- Much published rag characterisation comes from oil-sands froth treatment with added diluent. The mechanisms are broadly transferable to refinery desalters; the numbers are not.
- The electrical consequences of rag are inferred from its composition and from operating practice rather than from controlled published studies.
- Peer-reviewed rag studies specific to refinery desalters appear scarce; refinery-specific statements rely partly on a vendor patent and a vendor article [2,13], which describe field practice rather than independent benchmarks.

- The instrument review cited predates several current technologies; installed performance is vessel-specific.