1 Sulfolane Aromatic Extraction Special Technical Manual

Scope of Application

Global refineries, petrochemical engineering companies, refining procurement buyers from the Middle East & Southeast Asia, chemical trading groups

Compilation Basis

2026 industrial operation standards; applicable to BTX separation of reformate and hydrocracked gasoline; covers mainstream liquid-liquid extraction processes; directly usable for unit design, annual operation & maintenance budgeting, solvent procurement bidding

Core Catalog

1. Process Principle & Core Industrial Advantages of Sulfolane Solvent (Overseas Refinery Model Comparison)
2. Complete Full Process Flow for BTX Liquid-Liquid Extraction (Extraction Unit + Stripping & Recovery + Solvent Regeneration + Aromatics Distillation)
3. Complete Operation Protocol for Solvent Regeneration System (In-line Purification + Vacuum Deep Regeneration + Ion Exchange Refining)
4. Full-Plant Energy Consumption Optimization System (Heat Integration, Parameter Tuning, Waste Heat Recovery; Special Solutions for High-Temperature Refineries in the Middle East)
5. Graded Control of Sulfolane Solvent Loss
6. Graded Material Selection & Operation Protection Plan for Full-Plant Anti-Corrosion Equipment
7. Differentiated Operation SOP for Refineries in the Middle East & Southeast Asia
8. Solvent Procurement Selection & Long-Term Inventory Management Guide
9. Quick Troubleshooting Comparison Table

Appendix: Supporting Technical Documents Delivered to Overseas Clients

1 Process Principle & Core Industrial Advantages of Sulfolane Solvent

1.1 Separation Mechanism

Sulfolane (CAS 126-33-0) is a high-polarity aprotic solvent with far higher solubility for benzene, toluene and xylene (BTX) than alkanes and cycloalkanes. Multi-stage countercurrent liquid-liquid extraction is adopted to separate aromatics from non-aromatics, followed by vacuum distillation to desorb solvent from aromatics, and final distillation to separate individual BTX products.

1.2 Core Advantages of Sulfolane vs NFM / Tetraethylene Glycol Ether for Overseas Refineries

1. Ultra-high aromatic selectivity; BTX purity ≥99.95%, benzene crystallization point ≥5.4°C, meeting petrochemical feed standards of Europe and Southeast Asia
2. Wide thermal stability window: stable for long-term operation below 180°C; obvious decomposition occurs above 230°C, compatible with high-temperature vacuum recovery
3. Boiling point: 285°C, extremely low vapor pressure; volatile loss is far lower than NFM, cutting long-term solvent procurement consumption by over 30%
4. Controllable water solubility; solvent recovery via water washing is simple, solvent residue in wastewater <10 ppm, complying with environmental discharge standards of the Middle East and EU
5. Non-hazardous chemical; no hazardous cargo declaration for sea and land transportation, reducing customs clearance costs at global ports
6. Sufficient supply of domestic high-purity raw materials; landed procurement cost is only 1/3 of European and American original products, suitable for 10,000-ton annual procurement by large refineries

1.3 Mandatory Acceptance Standards for Incoming Sulfolane Solvent

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Test Item	**Industrial Refining Grade**	**Electronic/High Polymer Grade**
Sulfolane Purity (GC)	≥99.5 wt%	≥99.99 wt%
Water Content	≤50 ppm	≤10 ppm
Color (APHA)	≤10	≤5
Free Acidity (Calculated as H_2SO_4)	≤0.001%	≤0.0004%
Metal Ions (Na/Fe/Ca/K)	≤10 ppb	≤1 ppb
Solidification Point	25.5~26.5°C	25.8~26.2°C

2 Complete BTX Sulfolane Liquid-Liquid Extraction Process

The whole plant consists of four units, applicable to 100,000 ~ 1,200,000 tons/year aromatic plants.

2.1 Unit 1: Multi-Stage Countercurrent Extraction in Extraction Column (Core Separation Section)

1. Feedstock: Pentane-stripped reformate / hydrocracked C6~C8 distillate, nitrogen-blanketed feed tank to control dissolved oxygen ≤1 μg/g, fed from the lower part of extraction column
2. Lean solvent: Cooled clean sulfolane at 40~60°C sprayed from column top, countercurrent contact with upward hydrocarbon stream
3. Backwash reflux aromatics: Light aromatics from stripper top return to column bottom to displace non-aromatics entrained in rich solvent and improve product purity
4. Two outlet streams
    - Column overhead: Raffinate (alkanes/cycloalkanes with trace solvent) → Raffinate water wash tower for solvent recovery, then sent to gasoline blending pool
    - Column bottom: Rich solvent (sulfolane + total BTX) → Preheated via lean/rich solvent heat exchanger, then fed to stripper

      Key operating parameters: Column temperature 45~70°C (lower temperature delivers higher selectivity); solvent-to-feed mass ratio 3.0~4.5, adjustable up to 5.0 under high load

2.2 Unit 2: Stripper + Solvent Recovery Tower (Aromatic Desorption)

1. Stripper: Rich solvent fed at mid-column; low-pressure steam stripping removes light non-aromatics and partial aromatics; condensed overhead liquid separates into oil phase (reflux to extraction column) and water phase (sent to water stripper for hydrocarbon removal)
2. Solvent recovery tower (vacuum operation): Vacuum -45~-60 kPa to lower solvent boiling point and avoid thermal decomposition; high-temperature lean sulfolane extracted from tower bottom, heat exchanged with cold rich solvent first, then water-cooled for recycle to extraction column
3. Overhead distillate: Mixed BTX, sent to clay tower for olefin removal before aromatic distillation section

2.3 Unit 3: Aromatic Distillation & Separation

Mixed aromatics → Clay finishing tower (160~200°C liquid-phase olefin adsorption) → Benzene column (side draw of 99.95% pure benzene) → Toluene column (overhead high-purity toluene) → Xylene column (side draw of C8 aromatics)

2.4 Closed Material Flow Diagram for Overseas Refinery Engineering

Feed tank → Extraction Column → Rich solvent → Lean/Rich Heat Exchanger → Stripper → Solvent Recovery Tower → Cooled Lean Solvent (Recycle)
Raffinate → Water Wash Tower → Gasoline Blending
Recovery Tower Overhead Mixed Aromatics → Clay Treatment → Benzene/Toluene/Xylene Finished Products
Aged Solvent → Regeneration Tower / Ion Exchange Unit → Recycle after Purification
Wastewater → Water Stripper (Solvent Recovery) → Biochemical Treatment

3 Complete Operation Protocol for Solvent Regeneration System

Long-term circulation of sulfolane generates sulfonic acid, sulfuric acid and polymer tar due to oxygen ingress and local overheating, lowering pH value, accelerating equipment corrosion and reducing extraction efficiency. Two parallel regeneration systems are applied: on-line continuous purification and vacuum deep regeneration.

3.1 On-Line Continuous Ion Exchange Purification (Daily Primary Regeneration, No Shutdown Required)

1. 3%~6% of total circulating solvent passes through strong base anion exchange resin tower at 40~60°C, space velocity 1.5~9 h^{-1}
2. Removes sulfonate, chloride and acidic degradation products, maintaining solvent pH at 6.5~7.5
3. Two towers in one-operation-one-standby mode; resin regenerated with dilute alkali after saturation, service life 3~5 years
4. Benefit: Reduces full plant energy consumption by 9%~13% and annual solvent loss by 40% by cutting operation load of high-load deep regeneration tower

3.2 Vacuum Deep Regeneration Tower (Activated for Quarterly Overhaul or Severe Solvent Degradation)

1. Operating conditions: Vacuum -70 kPa, tower bottom temperature ≤180°C (strictly forbidden to exceed 200°C), heated by low-pressure superheated steam
2. Separation products: Purified fresh sulfolane from tower overhead for recycle; tar and iron salt polymer residues discharged from tower bottom for hazardous waste incineration
3. Operation control: Single regeneration cycle ≤72 h; tower bottom pump equipped with double mechanical seals to isolate air

3.3 Auxiliary Purification Supporting Equipment

1. Multi-stage precision filters (10μm + 1μm in series) to remove solid suspended matters and prevent blockage of heat exchangers and trays
2. Continuous monoethanolamine (MEA) dosing system to neutralize transient acidic degradation products and stabilize pH fluctuation

4 Full-Plant Energy Consumption Optimization System (Special Cost-Reduction Solutions for High-Temperature Refineries in the Middle East)

70% of sulfolane extraction energy consumption comes from reboiler steam of solvent recovery tower; energy saving is realized via heat integration, vacuum optimization, heat exchanger upgrade and refined operation parameter adjustment.

4.1 Multi-Stage Heat Integration of Lean & Rich Solvent (Core Energy-Saving Measure)

1. High-temperature lean solvent (>170°C) preheats cold rich solvent in two stages to eliminate independent steam preheaters
2. Waste heat of aromatic overhead vapor from recovery tower preheats feedstock and reduces cooling water load
3. After reconstruction, reboiler steam consumption drops by 18%~25%, and energy consumption per ton of aromatics decreases from 84 kg standard oil to 68 kg standard oil

4.2 Vacuum System Optimization

1. Dry vacuum unit replaces water ring vacuum pump to reduce solvent hydrolysis and acid generation
2. Stabilize recovery tower vacuum at -50~-60 kPa; tower bottom temperature drops by 15~20°C with identical separation effect, cutting steam consumption by 12%
3. High-temperature cooling equipment added in Middle East refineries to avoid vacuum drop in summer

4.3 Refined Operation Parameter Tuning

1. Dynamic control of solvent circulation ratio: 4.2~4.5 under high aromatic load, 3.0 under low load to eliminate invalid solvent circulation
2. Strictly control reboiler wall temperature ≤180°C to avoid local overheating and coking
3. Cascade utilization of low-pressure steam for water stripper and raffinate wash tower; waste heat heats deaerated water of plant area

4.4 Differentiated Energy-Saving Plans for Global Regions

- Middle East refineries (high ambient temp, cheap natural gas): Expand lean/rich heat exchange area, install air coolers to replace water coolers and cut water pump power consumption

- Southeast Asia refineries (high electricity & steam cost): Match waste heat boiler to recover latent heat of aromatic overhead vapor for self-produced low-pressure steam
- European refineries (CBAM carbon tariff): Long-term operation of ion exchange unit to lower steam consumption and CO_2 emission

5 Graded Control of Sulfolane Solvent Loss

Benchmark annual solvent loss: 0.12 kg/t feed without control measures; ≤0.06~0.08 kg/t feed after full implementation of control solutions, reducing fresh solvent procurement by dozens of tons per year for 10,000-ton scale refineries. Loss is categorized into four sources with targeted control strategies.

5.1 Category 1: Volatile Loss via Gas Phase

1. Control measures: Nitrogen blanketing for all solvent tanks and reflux drums, system oxygen content <0.1%; strict liquid level control of oil-water separator in water wash tower with 100% solvent recovery from wastewater; activated carbon adsorption of trace solvent in vent gas
2. Benefit: Gas-phase loss reduced by 65%

5.2 Category 2: Thermal Oxidation & Hydrolysis Degradation (Hidden Maximum Loss)

Degradation trigger factors: oxygen ingress, temperature >180°C, excessive free water in system

1. Full-plant LDAR leak detection and repair, all leakage points of flanges and pump seals repaired within 48 h
2. Regeneration tower temperature capped at 180°C, overheating prohibited
3. Deep dehydration of feedstock, system water content controlled ≤200 ppm
4. Continuous neutralization of acidic products via on-line ion exchange to slow down solvent ring-opening degradation
5. Continuous micro-dosing of anti-oxidant stabilizer

5.3 Category 3: Mechanical Leakage

1. All solvent pumps adopt double mechanical seals, packing pumps forbidden
2. Metal wound gaskets for high-temperature solvent pipelines, regular hydraulic pressure leak test
3. Closed collection of regeneration residues and filter cake, solvent recovery via water washing

4. Closed discharging for IBC drums and storage tanks, open operation banned

5.4 Category 4: Waste Solvent Recycling

1. Thermal extraction of sulfolane from regeneration tower tar residue with recovery rate ≥90%
2. Centralized collection of degraded waste solvent, third-party distillation refining to recover solvent up to 99.5% purity for reuse
3. Membrane separation pre-treatment matched in large refineries; waste solvent regeneration cost only 25% of fresh solvent purchase price

6 Graded Material Selection & Anti-Corrosion Operation Protection Plan for Full-Plant Equipment

6.1 Corrosion Mechanism

Sulfolane decomposes under high temperature and oxygen to generate sulfonic acid, H_2S and sulfuric acid; accumulated chloride ion accelerates stress corrosion cracking of stainless steel, with highest corrosion rate in high-temperature heat exchange equipment.

6.2 Graded Material Selection List for Overseas Refineries

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Equipment Zone	**Working Condition**	**Recommended Material (Overseas Standard)**	**Forbidden Material**
Extraction Tower & Water Wash Tower (40~70°C Low Temp)	Neutral, low acid	Carbon steel shell (3 mm corrosion allowance); 304 trays	Ordinary cast iron
Lean/Rich Heat Exchanger & Recovery Tower Reboiler (160~180°C High Temp)	High acid, chloride ion rich	316L / 2205 duplex stainless steel tube, clad tube sheet	Carbon steel, 304 under high chloride condition
Solvent Regeneration Tower & Bottom Pump (Severest Corrosion)	High acid, polymer	Carbon steel lined with 0Cr13; 2205 duplex stainless steel internals & pump body	304 austenitic stainless steel
High-Temperature Solvent Piping & Regeneration Overhead Piping	>150°C acidic medium	304/316L seamless stainless steel	Carbon steel (short-term perforation)

Equipment Zone	Working Condition	Recommended Material (Overseas Standard)	Forbidden Material
Storage Tanks & Ambient Lean Solvent Piping	Ambient temp, low acid	Carbon steel with solvent-resistant epoxy coating	None

6.3 Anti-Corrosion Operation Measures

1. On-line pH monitoring, maintain solvent pH at 6.5~7.5; increase MEA dosing and start ion exchange immediately when pH <6.0
2. Full nitrogen blanketing for tanks and reflux drums under micro positive pressure to isolate oxygen
3. Ion exchange dechlorination, solvent Cl^- ≤1 mg/kg to avoid stainless steel stress corrosion
4. Heat exchanger offline hot water cleaning once temperature difference rises by 10°C to remove iron sulfonate scale
5. Corrosion coupon & ultrasonic wall thickness monitoring for high-temperature pipelines and reboilers, re-measurement every quarter

7 Differentiated Operation SOP for Refineries in Middle East & Southeast Asia

7.1 Middle East High-Temperature Refineries (Ambient Temp 40~55°C, Scarce Fresh Water)

1. Air cooling section added for overhead water cooler of extraction tower to prevent solvent overheating and selectivity drop in summer
2. Low-temperature cooling water equipped for vacuum unit to stabilize vacuum degree of recovery tower
3. Sunshade & thermal insulation for solvent storage tanks to avoid solvent oxidation under high tank temperature
4. Closed circulation of wastewater from wash tower to cut water-phase solvent loss

7.2 Southeast Asia High-Humidity & Rainy Refineries

1. Dry nitrogen protection for tank breathing valves to prevent rainwater and air ingress
2. Increased LDAR inspection frequency in rainy season, anti-rust treatment for flange bolts
3. Strict nitrogen blanketing of feed tanks to avoid water and oxygen dissolution from air

8 Sulfolane Procurement Selection & Inventory Management Guide

8.1 Procurement Specification by Refinery Scale

1. Small & medium refineries (<500,000 tons annual processing): Industrial grade 99.5% sulfolane, 200 L galvanized drums for flexible small-batch supply
2. Large integrated refineries (≥1,000,000 tons annual processing): Domestic high-purity grade 99.9%, long-term bulk supply via IBC drums or tankers, cutting annual procurement cost by 15%~20%
3. Integrated plants matched with PEEK/Lithium Battery Downstream: Electronic grade with metal ion ≤1 ppb, independent storage tanks to avoid cross-contamination with industrial grade solvent

8.2 Safety Inventory Benchmark

- Normal stable operation: 1-month total circulating solvent volume
- Annual overhaul & predicted global solvent shortage in 2027: Increase to 2-month inventory
- Middle East sea transportation (40~60 days shipping cycle): Minimum 1.5-month buffer inventory

8.3 Storage Control Requirements

1. Storage temperature ≤30°C, heat tracing with 35°C warm water to prevent crystallization (solidification point 26°C)
2. Continuous nitrogen blanketing, tank lined with solvent-resistant epoxy coating
3. Separate storage of industrial grade and electronic grade with dedicated pipelines, mixing forbidden
4. Shelf life 24 months, FIFO principle; full index testing every quarter (pH, water content, color)

9 Equipment Failure Quick Troubleshooting Comparison Table

表格

Failure Phenomenon	**Root Cause**	**Rapid Disposal Plan**	**Impact on Procurement & Solvent Loss**
Declined BTX purity, excessive non-aromatic impurity	Insufficient solvent circulation ratio / Over-high extraction column temperature	Lower extraction column temperature, increase lean solvent flow, inspect heat exchange efficiency of lean/rich exchanger	Short-term solvent consumption rises, additional fresh solvent required

Failure Phenomenon	Root Cause	Rapid Disposal Plan	Impact on Procurement & Solvent Loss
Rapid solvent pH drop below 5.5, dark color	Air leakage, regeneration tower overheating	Fully open ion exchange tower, increase MEA dosage, repair nitrogen blanketing failure points	Sharp rise in solvent degradation loss, 30% higher annual procurement volume
Sharp drop of heat exchanger efficiency, higher steam consumption	Iron sulfonate scaling	Cut heat exchanger offline for hot cleaning, activate precision filters	Higher energy & steam cost, elevated aromatic processing cost
Corrosion leakage of high-temperature pipelines & reboilers	Excessive chloride ion, low pH	Replace with 316L / duplex steel spare parts, deep dechlorination via ion exchange, stabilize pH	Massive solvent leakage, emergency procurement & shutdown loss
Annual solvent loss >0.12 kg/t feed	Failed gas-phase recovery, multiple mechanical leakage	Activate vent adsorption system, full plant LDAR inspection, optimize regeneration system	Overrun annual procurement budget, recalculate long-term supply volume

Appendix: Supporting Technical Documents Delivered to Overseas Clients

1. Sulfolane TDS & Batch COA, 16-Chapter English SDS
2. Aspen Plus process simulation file & equipment material specification drawing
3. Solvent regeneration operation curve & energy consumption calculation Excel template
4. Global compliance qualification summary (REACH/TSCA/K-REACH)
5. Annual solvent consumption calculation formula adaptable to different refinery capacities