

Design Feed Washing and Filtration Skid for Vacuum Gas Oil

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Background

Vacuum Gas Oil (VGO) is a heavy intermediate feedstock used in fluid catalytic crackers and hydrocrackers to produce high-value fuels. However, raw VGO often contains salts, solids, and metals that can cause corrosion, fouling and catalyst deactivation.

Problem Statement:

The goal is to design washing and filtration skid for R&D centers and pilot plants to remove impurities like salts, particulates from VGO to protect downstream equipment.

Final Target Specifications

1

Settling time
10-15 mins

2

Recycled
water ≥ 95%

3

0.5 L/s
capacity

4

Salts removal
≥ 95%

5

Remove
particles up to
5-10 microns

6

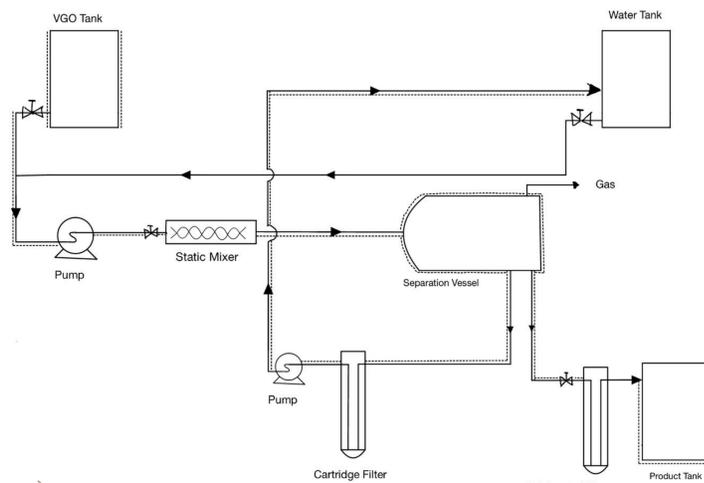
Solid
particles
removal ≥
90%

Project Constraints

- VGO Temperature ~ 80°C
- Water Temperature < 90°C
- Waste-water < 10%

Prototype Design

Process Flow Diagram (PFD)

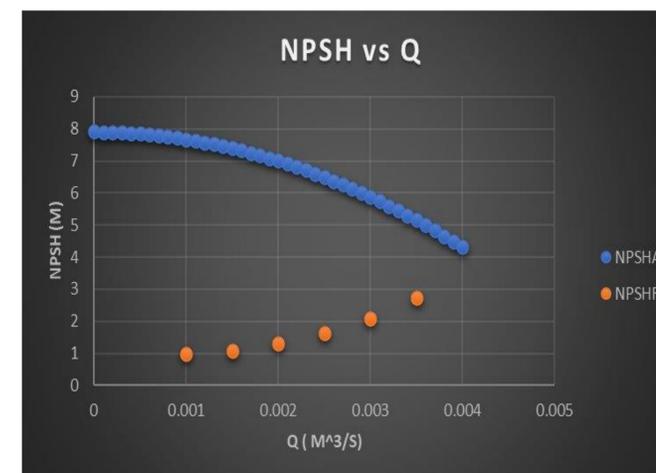


Process Description

This PFD shows a pilot-scale VGO Washing and Filtration Skid. VGO and wash water are mixed, then separated in a vessel where impurities settle. The cleaned VGO passes through a fine filter to the product tank. Separated water is filtered and recycled; pumps and valves manage flow.

Testing / Validation

For Cavitation Avoidance:



For Settling Time Specification:

Settling Time Calculation

Stokes' Law for Settling Velocity

$$v_t = \frac{g(\rho_w - \rho_{vgo})D^2}{18\mu_{vgo}}$$

$$v_t = \frac{9.81(1000 - 896)(100 \times 10^{-6})^2}{18(0.004)} = 1.417 \times 10^{-4}$$

The time required for the water droplets to settle through a height is:

$$t = H/v_t = 0.11 / 1.417 \times 10^{-4} = 776 \text{ seconds} = 12.9 \text{ minutes}$$

Settling Time Calculation	
Gravitational acceleration (g)	9.81 m/s ²
Density of water (ρ)	1000 kg/m ³
Density of VGO (ρ)	896 kg/m ³
Droplet diameter (d)	100 × 10 ⁻⁶ m
Viscosity of VGO at 80°C (μ)	0.004 Pa/s

For VGO Temperature ~ 80°C:

Output Parameter	Value
reynolds number	2490.336735
prandtl number	107.1466667
velocity entry length Xh (m)	7.471010204
thermal entry length Xth (m)	800.49384
nusslet number	20.17885875
Thermal Resistance of Pipe Wall (Conduction)	4.79333E-05
Convective heat transfer coefficient hf	50.44714688
Convective Resistance Inside the Pipe	0.010516283
Fluid Temperature [°C]	77.88715672

The system operated effectively at 60 °C, showing stable flow and impurity removal below the 80 °C target. removal at reduced temperatures.

Operation Research (OR)

Weights:

$W(i, k) = \text{Weight of Criteria } k \text{ in Component } i$

$S(i, j, k) = \text{Score for Product } j \text{ of Component } i \text{ in given Criteria } k$

$P(i, j) = \text{Price of Product } j \text{ in component } i$

Decision Variables:

$X(i, j) = 1 \text{ if product } j \text{ from component } i \text{ is selected, } 0 \text{ otherwise}$

Objective Function:

$$\text{Maximize } Z = \sum_{i=1}^6 \sum_{j=1}^3 \sum_{k=1}^5 X(i, j) \times W(i, k) \times S(i, j, k)$$

Constraints:

$$\sum_{i=1}^6 \sum_{j=1}^3 X(i, j) \times P(i, j) \leq 6000 - 1189 \text{ SR}, \sum_{i=1}^6 \sum_{j=1}^3 X(i, j) \times P(i, j) \leq 2500 \text{ SR } \forall i$$

$$\sum_{k=1}^5 W(i, k) \times S(i, j, k) \geq 7.5, \forall i, \forall j$$

$$\sum_{j=1}^3 X(i, j) \leq 1, \forall i, \sum_{j=1}^3 X(i, j) \geq 1, \forall i$$

- Product1: For The Type of Mixers: Static Mixer
- Product2: For The Type of Filters of Water: Cartridge Filter
- Product3: For The Type of Filters of VGO: Stainless Cartridge Filter
- Product4: For The Type of Tanks: Steel tank
- Product5: For The Type of Pipes: Stainless Steel Pipe
- Product6: For The Type of Heating Wires: Heat Trace Cable AC220V

Conclusions

- The skid effectively purified VGO at reduced temperatures, meeting design targets for impurity removal, flow stability, and water recycling.