

INCREASING THE FLASH POINT TEMPERATURE OF DCO OIL PRODUCTS TO MEET THE FO (FP) BASELINE STANDARD OF DUNG QUAT REFINERY

**Nguyen Hoang Tri, Nguyen Chanh Quoc, Huynh Cong Vinh, Bui Anh Khanh, Ho Quang Xuan Nhan
Nguyen Huu Trung, Bui Van Vuot, Nguyen Thanh Bong**

Binh Son Refining and Petrochemical Joint Stock Company

Email: Trinh@bsr.com.vn

<https://doi.org/10.47800/PVSI.2025.06-06>

Summary

The flash point temperature of decanted oil (DCO) has been consistently low since the Dung Quat refinery commenced operations in 2009. This issue is attributed to the absorption of trace amounts of light gases such as H₂, CH₄, and C₂H₆ by the liquid stream at the bottom of the tower. These gases cannot be effectively separated through distillation at T-1501, and neither modifications to hardware nor adjustments to the angle of the fifth packing layer have proven effective. The separation of these light gases can only be achieved by applying the stripping method to the DCO product stream emanating from the bottom of the tower and at D-1515. This method must ensure no alterations to existing hardware and utilize current equipment solely. The technique involves injecting N₂ directly into the liquid drum to remove light gases by reducing the partial pressure of hydrocarbons. This solution successfully increased the DCO flash point temperature from 49°C to 84°C in July 2018, and has been maintained to date. Furthermore, the flash point temperature can be regulated by the N₂ stream to exceed 100°C, thereby meeting and surpassing the technical requirement of 66°C.

Key words: DCO, flash point (FP), stripping, BSR, fuel oil, result, light component.

1. Introduction

The RFCC unit at the Dung Quat refinery, operated by Binh Son Refining and Petrochemical Joint Stock Company, is a key unit that converts residue fractions from the crude distillation unit (CDU) or the atmospheric distillation unit into lower-boiling point and higher-economic value products through catalytic cracking process.

The products of the RFCC unit include:

Primary products:

- LPG;
- Naphtha;
- Light cycle oil (LCO).

Secondary products:

- Fuel gas;
- Clarified oil (CLO) (or decanted oil (DCO));
- Coke.

The reactor effluent from the disengager in the reaction section is sent to the main fractionator T-1501. The bottom slurry pumparound is circulated by pumps P-1519A/B/C, the residual heat from this recycle stream is utilized to heat the feedstock stream and generate medium- and high-pressure steam. Most of this cooled slurry pumparound is returned to the grid section (Bed #5), where the reactor effluent is desuperheated and the bottom slurry product is condensed. Part of the cooled slurry is returned to the bottom of the column to quench the temperature and minimize coking.

The slurry product stream is drawn and sent to drum D-1515. The slurry product is then pumped and cooled in the low-pressure steam generator before being routed to separator X-1504 to remove fine catalyst particles. Decanted oil (DCO) exiting the separator is again cooled before being transferred to the storage tank.

Since the RFCC unit was commissioned in April 2009, the flash point temperature of DCO has failed to reach the design value of 100°C. In numerous instances, it even fell below the standard value of 49°C in storage tanks. Specifically, at the end of June 2018, this value dropped



Date of receipt: 24/9/2025

Date of review and editing: 24/9 - 6/11/2025

Date of approval: 6/11/2025

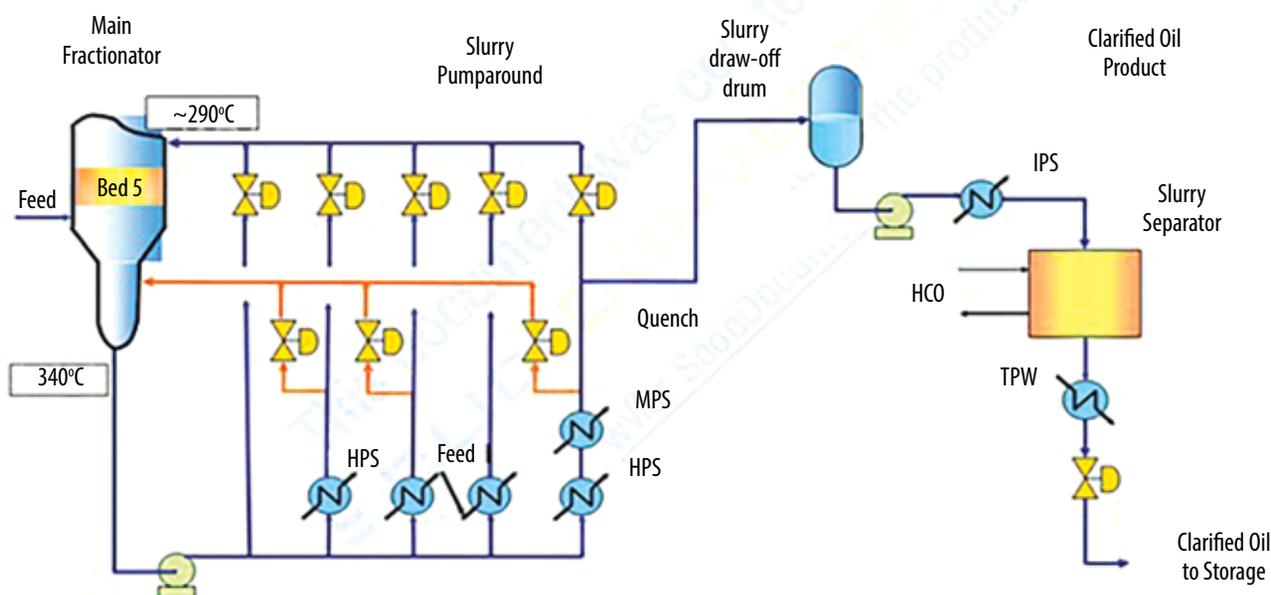


Figure 1. The main fractionator bottom T-1501.

below 46°C. To ensure the safe storage of DCO in product tanks (P3) and to meet the commercial standards, high-flash point residue has to be blended to increase the flash point of the FO product. Nevertheless, blending high-value residue into DCO to produce FO and selling it at a lower price reduces the economic efficiency of the refinery. Various solutions were evaluated, including technological parameter adjustments, replacement of the #5 packing layer, and change of the packing arrangement angle as recommended by the vendor in 2014, to enhance light fraction separation efficiency. However, the flash point did not improve. Most recently, the technology licensor was requested to design and install a steam ring at the bottom of the tower, but the licensor's assessment indicated that the effectiveness was uncertain and did not recommend its use.

In response to this urgent issue, the authors have researched, evaluated, and proposed a solution to increase the flash point temperature of fuel oil (FO) products. This is to ensure operational safety, meet FO sale standards, and reduce the cost of blending high-value products, while utilizing existing equipment and minimizing major changes to the equipment.

2. Theoretical framework/methods

2.1. Mechanism of separating light fractions from the liquid in the current configuration

The stripping process is a physical separation method in which one or more components are removed from the

liquid stream by a vapor stream. In industrial applications, the liquid and vapor streams can flow concurrently or counter-currently, and the stripping process is typically carried out in packed or tray tower structures. Inert gases, steam, and hydrocarbon gases are commonly used as the stripping media to remove unwanted light components from the liquid stream based on reducing partial pressure as light gases absorb heat from the liquid and evaporate from the liquid stream.

In practice, D-1515 drum, containing liquid which is the DCO product, is an empty vessel without any internal structure. Therefore, converting this D-1515 into a light-fraction separation tower equipped with a tray or packed structure is extremely complex. The downstream equipment of vessel D-1515 is the X-1504 separator, which operates at approximately 35 kV to remove solid catalyst particles from the DCO stream, ensuring compliance with the ash content specification of 100 ppm wt maximum. Therefore, steam cannot be used as the stripping medium. Additionally, pump P-1504 transfers liquid from D-1515 at an operating temperature of nearly 200°C. If steam were used, any condensation during the stripping process may cause cavitation in the pump.

Due to these constraints, the authors applied nitrogen gas directly into the liquid in D-1515 vessel to separate the absorbed light fractions from the DCO product. This solution ensures the use of existing equipment and safe operation while being effective.

Table 1. N₂ product quality using injection at D-1515

	Analyst	Result	Units
1	Nitrogen	100	mol%
2	Trace oxygen	3.5	ppm vol
3	Carbon dioxide	< 0.2	ppm vol
4	Carbon monoxide	0.2	ppm vol

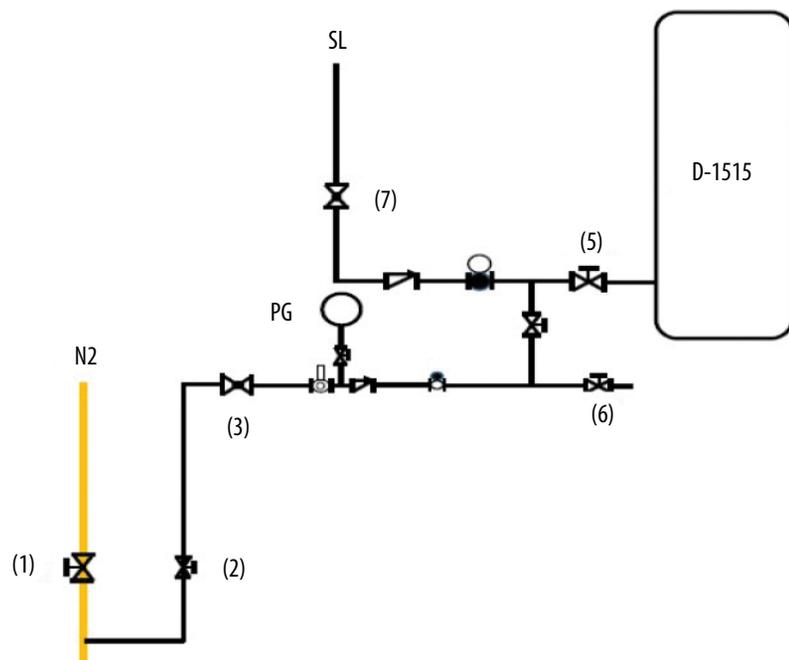


Figure 2. Sketch of the nitrogen injection point into the D-1515 liquid drum.

2.2. Site survey and evaluation of existing equipment system, proposal of the nitrogen injection point, and implementation of the modification

The authors surveyed the existing equipment at BSR to propose a nitrogen injection point that aligns with the goal of utilizing the existing equipment configuration at the lowest cost. After the proposal was approved by the company leadership, the authors issued “028-APR-R&D on Approval for N₂ injection service with flexible”, allowing the installation of flexible hoses to connect and inject nitrogen into the liquid phase in vessel D-1515. This resulted in the flash point temperature of DCO soaring to 84°C, surpassing the product sales standard of 66°C for the first time since the refinery began operation. Based on the high effectiveness of this temporary system in improving the flash point of DCO, the team implemented MOC-15-18-318. After evaluating the equipment condition during the fourth overall maintenance of the Dung Quat refinery in 2020, the system was integrated into the permanent configuration.

3. Results and discussion

3.1. Practical application of the solution

The trial process initially started injecting nitrogen at a point above the liquid surface in vessel D-1515, at a flow rate of approximately 200

m³/hour. However, this approach did not result in any improvement in the flash point of the DCO product. Only when nitrogen was directly injected into the liquid phase of vessel D-1515 did the flash point temperature significantly increase. During the initial phase of the trial, the nitrogen flow rate was set at 200 m³/hour, but subsequent optimization and flash point sampling indicated that a much lower flow rate of approximately 70 m³/hour was sufficient to raise the flash point temperature to meet the DCO product specification.

Since the nitrogen injection system has been operational, it has significantly improved the flash point of DCO, which had previously been unattainable. Additionally, with this system, the flash point temperature can be adjusted as required. Thanks to the installed system, the refinery no longer needs to blend valuable components like residue into DCO to increase the flash point temperature to meet the commercial product sales standard for FO.

The successful handling of the DCO flash point has increased the competitiveness of BSR FO product in the market, while also opening new directions for the production and sale of marine fuel oil (MFO) at higher values.

The operating conditions of vessel D-1515 remain unchanged in the temperature range of 190 - 194°C and with operating pressure maintained at 1.2 - 1.3 kg/cm². When nitrogen is injected into the vessel, the pressure will increase. Since the drum pressure is automatically adjusted by the pressure controller, the valve on the flare line opens wider to maintain stable pressure at the set value of 1.2 - 1.3 kg/cm².

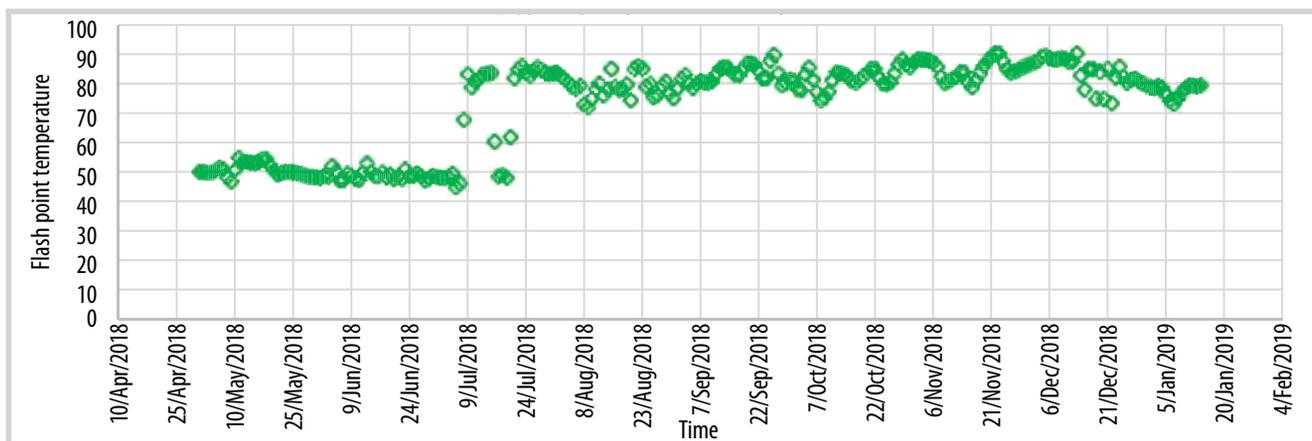


Figure 3. The flash point temperature of DCO has improved since July 2018.

Table 2. Analysis results of the gas sample after performing N₂ stripping

Sample name	Date/time of sample	Component	Method	Unit	Result	Note
Gas from D-1515 to fare	15H00 - 01/09/2021	Hydrogen	UOP539-12	%mol	19.46	
		C ₆ +		%mol	0.69	
		Methane		%mol	2.6	
		Ethane		%mol	1.44	
		Ethylene		%mol	1.32	
		Carbon dioxide		%mol	0.06	
		Propane		%mol	0.7	
		Cyclopropane		%mol	0.0	
		Propylene		%mol	1.59	
		n-Butane		%mol	0.85	
		i-Butane		%mol	0.26	
		Propylene		%mol	0	
		Acetylene		%mol	0	
		Hydrogen Sulfide		%mol	0.42	
		t-2-Butene		%mol	0.3	
		1-Butene		%mol	0	
		i-Butene		%mol	0.43	
		c-2-Butene		%mol	0.32	
		Cyclopropene		%mol	0.01	
		i-Pentane		%mol	0.54	
		n-Pentane		%mol	0.08	
		1,2 Butadiene		%mol	0	
		1,3 Butadiene		%mol	0	
		Methyl Acetylene		%mol	0	
		3-methyl-1-butene		%mol	0.06	
		t-2-Pentene		%mol	0.2	
		2-methyl-2-butene		%mol	0.36	
		1-Pentene		%mol	0.08	
		2-methyl-1-butene		%mol	0.14	
		c-2-Pentene		%mol	0.09	
		Ethyl Acetylene		%mol	0.02	
		Oxygen		%mol	2.84	
Nitrogen	%mol	65.08				
Carbon monoxide	%mol	0.06				

Table 3. Comparison of benefits: N₂ stripping vs. residue blending to achieve required flash point temperature

	Average price index*
BH crude oil price, USD/bbl (C44)	62
BH crude oil price, USD/ton (C45)	= $C44 \times 6.28981/0.825$ = $62 \times 6.28981/0.825 = 472.6^{**}$
FO price, USD/ton (C46)	369.67
FO export VAT, % (C47)	8.2%
FO price (including non-refundable VAT due to export), USD/ton (C48)	= $C46 \times (1 - C47)$ = $369.67 \times (1 - 8.2\%)$ = 339.36
DO price, USD/bbl (C49)	67.44
DO price, USD/ton (C50)	= $C49 \times 6.28981/0.83$ = $67.44 \times 6.28981/0.83$ = 511.1

*From August 1, 2018 to August 10, 2020; ** $1 \text{ m}^3 = 6.28981 \text{ bbl}$

The analysis results of the venting gas stream at the top of D-1515 to the flare after nitrogen injection to separate the light fractions from the liquid are shown in Table 2.

Thus, the issue causing the low flash point of DCO oil is largely due to the amount of hydrogen gas, with a smaller contribution from C1, C4 and C5 gases being absorbed in the liquid. These gases are routed to the flare system for combustion. Any heavier fractions carried over with the gas stream will be stripped and collected in the flare system's knock-out drum, provided such equipment is installed. The process of separating light gases does not affect the liquid yield of DCO oil because these components are not permitted in the DCO product specification and must be removed from the product stream.

3.2. Economic and technical efficiency

By avoiding the installation of a steam ring at the bottom of tower T-1501, approximately USD 300,000 in installation costs and USD 177,390 in annual operating costs are saved.

Operating costs: Steam price: USD 27/ton (refinery steam price); Steam amount: 750 kg/hour (0.75 tonnes/hour); Total steam rate: 18 tonnes/day; Daily cost: 486 USD/day; Yearly cost: 177,390 USD/year; Material, fabrication & installation costs: USD 300,000 (estimated cost of installing a steam ring).

With the DCO flash point above 84°C and without continuous blending of residue to increase the DCO flash point from 1/8/2018 to 10/8/2020, the benefit is approximately USD 11,134,562.

DCO flow rate and flash point:

- DCO flowrate: 28 m³/hour (26.7 tonnes/hour);
- DCO flash point: 50.7°C;
- DCO rundown temperature: 77.7°C;
- DCO flash spec min: 47°C;
- Atmospheric residue density: 0.884 g/cm³.

Blending AR to DCO:

- AR blend ratio to increase 1°C FP: 4%;
- AR blend to reduce FP: 4.11 m³/hour (3.632 tonnes/hour).
- AR, USD/ton = DO, USD/ton (C53) = C50 = 511.1
- Delta AR vs FO, USD/ton (C54) = (C53 - C48) = 511.1 - 339.36 = 171.7
- AR blend cost, USD/hour (D16) = D14 × C54 = 3.632 × 171.7 = 623.6.

Operating Cost:

- N₂ stripping, Nm³/h (D29): 20 m³/h
- N₂ stripping price, USD/Nm³ (D30): 0.021
- N₂ stripping cost, USD/h (D31): = D30 × D29 = 0.021 × 20 = 0.42
- Reducing heating up for storage tank at P3 (D32): = $-(20 \times 37.5) / (10 \times 24 + 20) = -2.9$
- Total operating cost, USD/h (D35): = D32 + D31 = -2.9 + 0.42 = -2.5

Table 4. Overall efficiency compared to AR mixture

Annual price index	Average price index*
Overall efficiency compared to AR mixture, USD/hour (D38)	= D16 - D35 = 623.6 + 2.5 = 626.1
Overall efficiency compared to AR mixture, USD (D39)	= D38 × D40 × 24 = 626.1 × 741 × 24 = 11,134,562
Number of days solution applied (D40)	= 741 days (from August 1, 2018, to August 10, 2020)

* From August 1, 2018 to August 10, 2020

Implementation Funding:

The solution does not require retrofitting and incurs no costs.

Benefits:

- Cost savings from not retrofitting and not blending residue into DCO amount to approximately USD 300,000 + USD 177,390 + USD 11,134,562 = USD 11,611,952.

- It facilitates the plant's ability to produce MFO products from 2020. The estimated production of MFO from 2020 increases the plant's efficiency by approximately USD 19.5 million per year compared to the production of FO 180 cSt.

- The long-standing issue of DCO's flash point temperature is resolved, ensuring stable operation of the T-1501 distillation tower in the RFCC unit.

- DCO flash point temperature can be adjusted by regulating the nitrogen stream in the D-1515.

- DCO flash point is enhanced to meet TCVN/MFO product standards.

4. Conclusion

BSR has implemented a nitrogen injection system to ensure that the flash point of commercial FO consistently exceeds the standard value. This method has proven effective, eliminating the need for blending with high-flash point residues.

Major refineries worldwide, including those operated by Shell, SK, and O&M, as well as facilities licensed by Axens, have encountered persistent challenges with low low or unstable flash points in their DCO. These refineries have invested substantial capital in system retrofits, however, such modifications have generally failed to yield satisfactory results.

In contrast, BSR has successfully addressed this issue through the innovative application of engineering principles, achieving DCO flash point improvements that meet the specifications for commercial FO.

The nitrogen injection system developed by BSR represents a significant technological advancement in flash point control for commercial FO production. This approach not only ensures compliance with safety standards but also offers considerable advantages in terms of cost reduction and operational efficiency compared to conventional blending methods.

References

[1] Norman P. Lieberman, and Elizabeth T. Lieberman, *A working guide to process equipment*. McGraw-Hill, 2014.

[2] Reza Sadeghbeigi, *Fluid catalytic cracking handbook*. Butterworth-Heinemann, 2019.