PETROVIETNAM SCIENCE, TECHNOLOGY & INNOVATION PETROVIETNAM

PARAFFIN TREATMENT OF CRUDE OIL PRODUCED FROM THE CENTRAL OF RONG AND NAM RONG - DOI MOI FIELDS DURING TRANSPORTATION THROUGH UNINSULATED SUBSEA PIPELINES

Chu Van Luong[1], Tran Duy Hai[2], Pham Thanh Vinh[2], A.G. Alberta[2], Nguyen Huu Nhan[2], Doan Tien Lu[2]
Chau Nhat Bang[2], Le Thi Doan Trang[2], Tran Thi Thanh Huyen[2], Vu Hong Khuong[2]
[1]Vietsovpetro Joint Venture
[2]Science Research and Engineering Institute, Vietsovpetro Joint Venture
Email: vinhpt.rd@vietsov.com.vn
https://doi.org/10.47800/PVSI.2024.06-06

Summary

Due to being developed in the early stages, several major oil subsea pipelines in Vietsovpetro Joint Venture are not equipped with insulation systems, causing significant difficulties in transporting high-paraffin crude oil. Specifically, the lack of insulation leads to intensive heat loss through pipeline walls, resulting in paraffin deposition on the pipe surface. Additionally, the temperature drop significantly increases oil viscosity, leading to high pressure losses during transportation.

This article analyses the difficulties in crude oil transportation through the uninsulated RP-1 → FSO-3 pipeline, the major route from Central of Rong, Nam Rong - Doi Moi fields to FSO-3 and presents the technical solutions that Vietsovpetro has researched and implemented to successfully resolve these problems.

Key words: High-paraffin crude oil, uninsulated subsea pipeline, pour point depressant (PPD), Central of Rong field, Nam Rong - Doi Moi field.

1. Introduction

Crude oil produced in the Central of Rong and Nam Rong - Doi Moi fields has high-paraffin content, ranging from 13.8% to 23% by mass. The asphaltene-resin content ranges from 3.69% to 18.8% by mass. The oil density varies between 832 kg/m^3 and 890 kg/m^3. The pour points temperatures of the produced oils range from 30°C to 36°C. The main properties of crude oil from Rong field are presented in Table 1.

The high-paraffin and asphaltene-resin contents result in complex rheological properties of the produced crude oil. When the crude oil temperature approaches its pour point (< 37°C), wax deposits form intensively in both the tubing and the gathering-transportation system, leading to reduced pipeline internal diameter and increased pressure losses.

Date of receipt: 22/10/2024.
Date of review and editing: 22/10 - 23/11/2024.
Date of approval: 23/11/2024.

2. Pipeline system connected to RP-1 platform

Initially, Vietsovpetro's crude oil gathering, processing and transportation system was constructed following field development model in Caspian sea. According to this model, pipelines were laid on the seabed without burial or insulation. After 1998, Vietsovpetro began insulating its subsea pipelines with composite or foam materials.

Nam Rong - Doi Moi fields have the main platform RP-1 and satellite platforms of RC-DM, RC-4, and RC-5. Crude oil from RC-DM, RC-4, RC-5 is transported to RP-1 as gas-saturated oil, while the one from RC-6 is transported to RP-1 as a gas-oil mixture. The combined oil stream from

Table 1. *Main properties of crude oil from Nam Rong - Doi Moi fields*

Parameters	Values
Gravity at 20°C (kg/m^3)	832 - 890
Paraffin content (% mass)	19 - 23
Asphaltene (% mass)	3.69 - 18.8
Viscosity at 50°C (mm^2/s)	5.6 - 27
Pour point (°C)	30 - 36
WAT (°C)	55 - 60

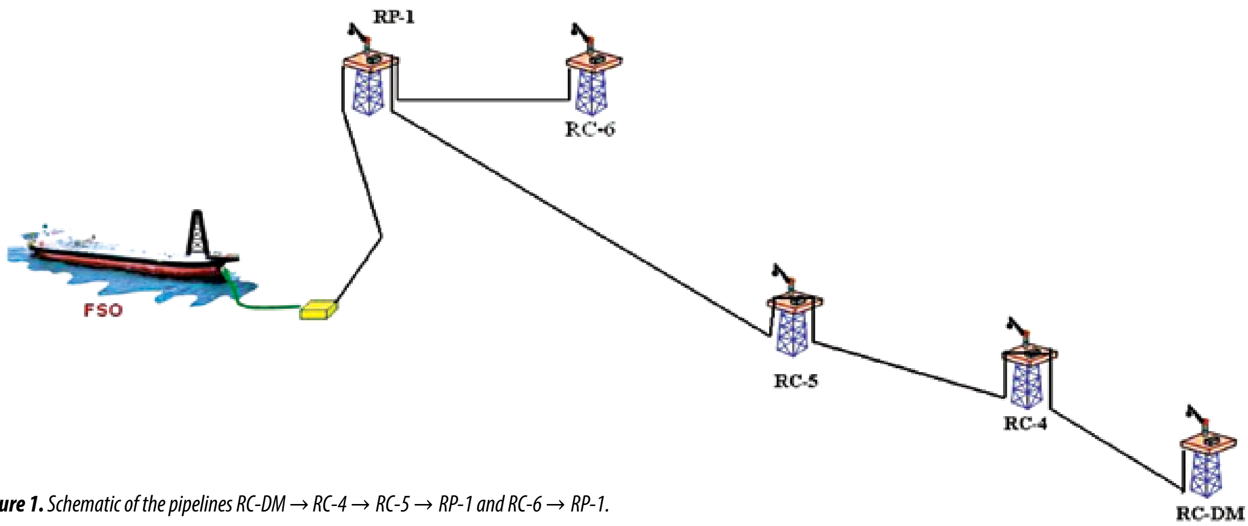

Figure 1. *Schematic of the pipelines RC-DM → RC-4 → RC-5 → RP-1 and RC-6 → RP-1.*

these satellite platforms is then transported to FSO-3 for processing to meet commercial specifications (Figure 1).

As mentioned above, the pipeline from platform RP-1 to FSO-3 is uninsulated, while other subsea pipelines from RC-DM, RC-4, RC-5, and RC-6 platforms are insulated with composite or foam materials.

Therefore, the most critical problem for the Nam Rong - Doi Moi field's transportation pipeline system is to maintain flow assurance in the uninsulated section RP-1→ FSO-3. This is the sole pipeline transporting oil from this field to FSO-3.

3. Challenges in high-paraffin crude oil transportation through uninsulated pipeline RP-1 → FSO-3

The seabed water temperature ranges from 22°C to 28°C. Crude oil produced from RC-DM, RC-4, RC-5, RC-6 and RP-1 platforms has high content of paraffin, asphaltene and resin. The pour points of the produced oils range from 30°C to 36°C. The transportation of crude oil through RP-1 → FSO-3 pipeline faces the following risks:

- Paraffin crystallization: Wax crystal deposit on the internal pipeline walls, reducing the internal diameter and increasing pressure loss;

- High transport pressure: Required due increased oil viscosity when the temperature approaches the pour point.

Simulation results indicate that in the uninsulated pipeline RP-1 → FSO-3, paraffin deposits can form a layer approximately 40 mm thick. While this solid wax layer acts as a natural insulation, reducing heat loss to the surrounding environment, it also causes significant pressure increase.

Table 2. *Dependence of incoming liquid FSO-3 on seabed temperature*

Seabed temperature (°C)	Temperature of incoming liquid FSO-3 (°C)
23	32,2
24	32,4
25	33,0
26	33,4
27	34,0
28	34,2
29	34,5

As the seabed water temperature decreases, the oil temperature in the pipe drops rapidly, causing the transported oil's viscosity to increase significantly and leading to high pressure drops. Depending on the seabed water temperature, the oil temperature at FSO-3 fluctuates from 32 - 35°C if pumped from RP-1 at 37 - 40°C. The treated crude oil has a pour point of approximately 32°C. When seabed water temperature falls below 23°C, the temperature of crude oil arriving at FSO-3 approaches its pour point. In these conditions, the averaged pump pressure increases to 25 - 35 bar, creating high risks for the transportation system.

4. Optimization of high-paraffin crude oil transportation via uninsulated RP-1 → FSO-3 pipeline

The study focused on improving crude oil treatment using pour point depressants in combination with demulsifier to achieve maximum efficiency in lowering the pour point and viscosity of the oil mixture.

In general, chemical treatment efficiency depends on multiple factors: chemical dosage, product temperature, water content, produced water form in the product, among which product temperature plays the most crucial role. To maximize the effectiveness of pour point depressant (PPD), Vietsovpetro implemented a method of injecting PPDs through capillary tubes at 2,000 - 2,500 m depth, where the crude oil temperature exceeds its wax appearance temperature.

At the Central of Rong and Nam Rong - Doi Moi satellite platforms, chemical dosage has been uniform across all oil wells, without considering well-specific parameters such as crude oil properties, product temperature at pump locations, water content, and individual well production rates. This highlighted the critical need for a study to determine optimal dosage for each oil well.

The rheological properties of crude oil from each well were analyzed using different dosage of the PPD currently applied in Vietsovpetro's fields. The tested dosage was based on current operational levels. The results are presented in Figures 2 - 5.

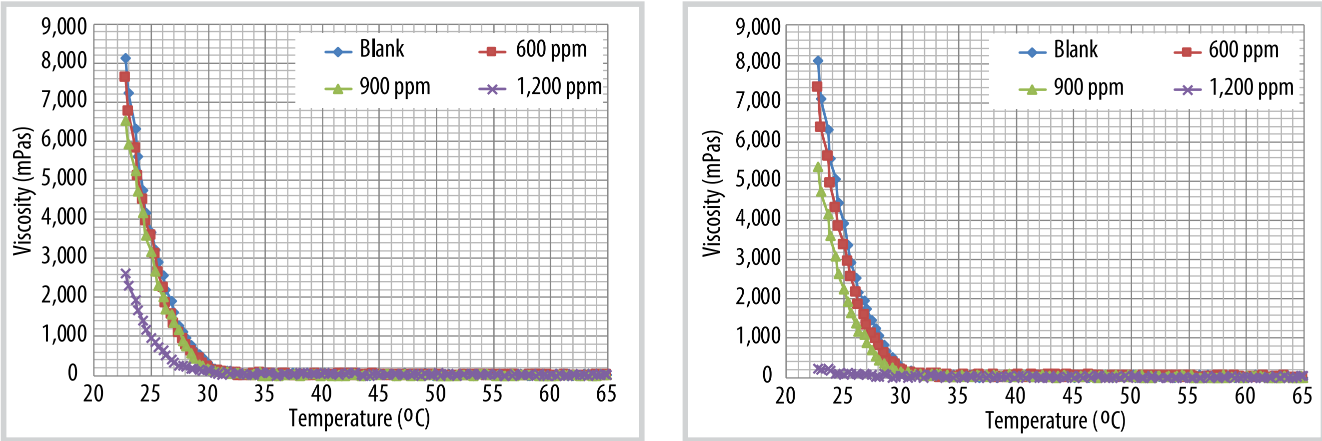

Figure 2. Rheological properties of crude oil of the wells 425, 424 RC-4.

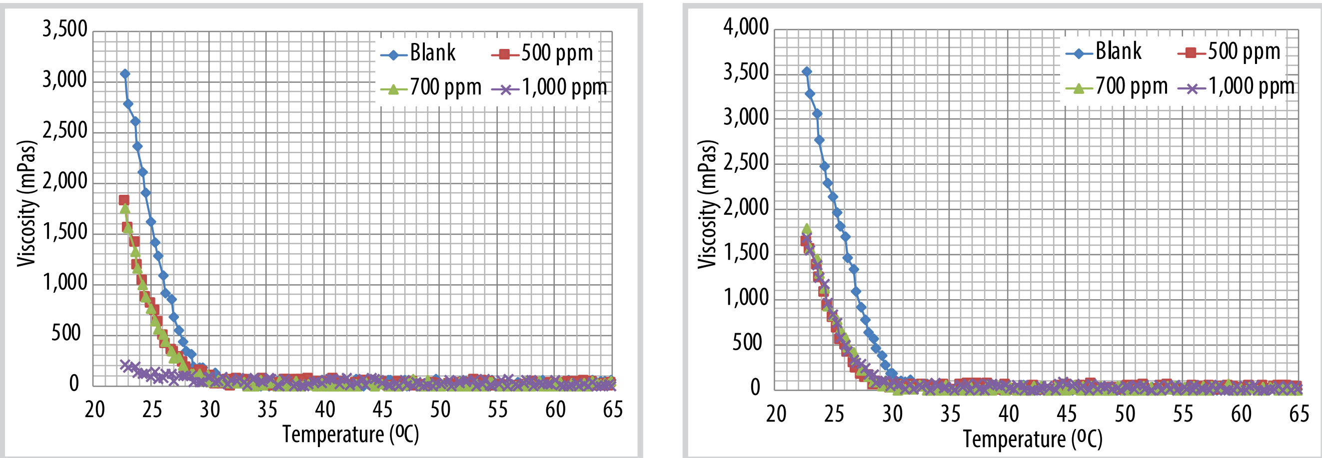

Figure 3. Rheological properties of crude oil of the wells 15, 17 RC-5.

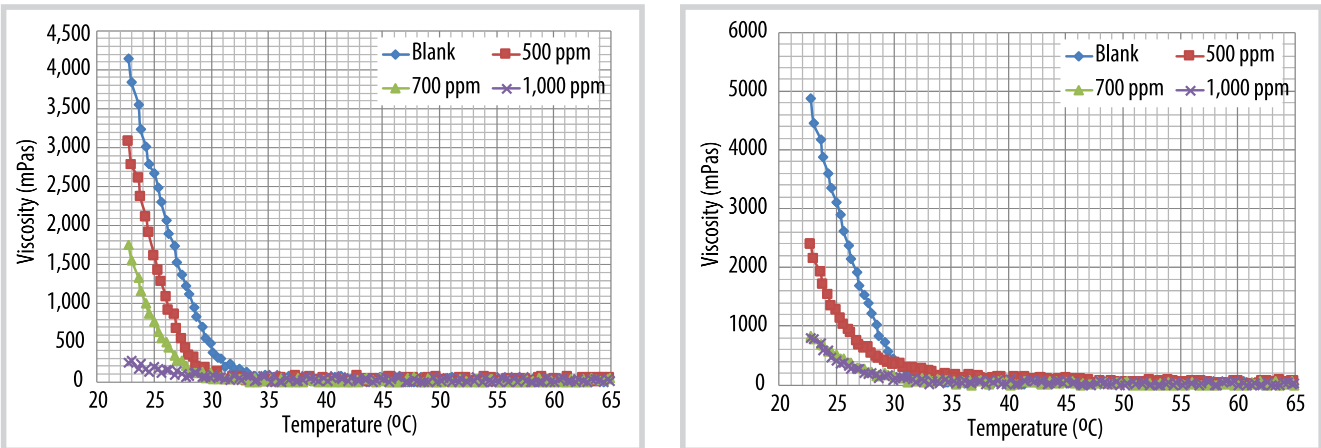

Figure 4. Rheological properties of crude oil of the wells 503, 506 RC-5.

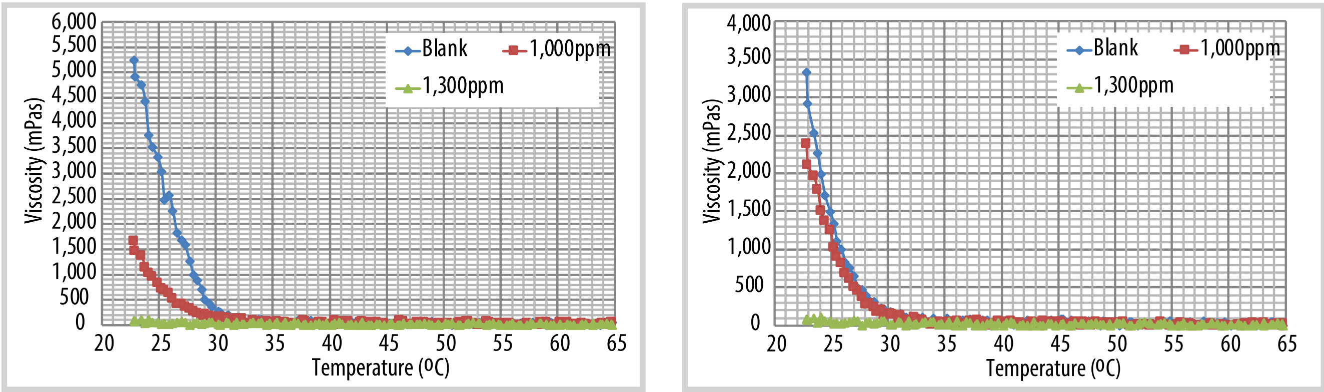

Figure 5. *Rheological properties of crude oil of the wells 410, 407 RC-DM.*

Table 3. *Deposition of paraffin of crude oil RC-DM treated by cold finger method*

Wells	Deposition of paraffin (kg/m²) Temperature of bulk oil at 37°C Temperature of cold finger at 32°C			
	0 ppm	700 ppm	1,000 ppm	1,300 ppm
20	6.75	5.39	3.27	1.75
25	4.59	3.13	2.14	0.65
421Б	7.01	3.80	3.26	1.27
422	7.20	4.81	2.48	2.09
423	6.88	2.53	1.42	1.21
424	8.09	6.76	5.04	2.82
425	8.11	6.55	5.11	5.01
426	8.52	6.86	5.23	2.11

Table 4. *Deposition of paraffin of crude oil RC-4 treated by cold finger method*

Wells	Deposition of paraffin (kg/m²) Temperature of bulk oil at 37°C Temperature of cold finger at 32°C			
	0 ppm	600 ppm	900 ppm	1,200 ppm
20	4.23	3.39	3.12	2.02
25	8.23	6.25	5.07	3.01
421B	10.15	8.85	7.13	3.57
422	5.25	4.98	2.21	2.10
423	8.02	3.46	3.22	3.15
424	8.05	7.79	3.54	3.08
425	6.69	2.53	2.41	2.32
426	7.32	6.51	5.23	2.84

Table 5. *Deposition of paraffin of crude oil RC-5 treated by cold finger method*

Wells	Deposition of paraffin (kg/m²) Temperature of bulk oil at 37°C Temperature of cold finger at 32°C			
	0 ppm	500 ppm	700 ppm	1,000 ppm
15	2.19	1.41	1.38	0.77
17	1.79	1.32	1.23	1.17
503	1.89	1.46	1.12	0.31
506	7.02	2.51	2.44	2.18
507	6.89	5.44	4.90	4.76
508	6.57	3.42	3.30	3.22
509	8.47	5.38	4.86	4.74
510	2.78	2.76	2.71	2.70

Table 6. Optimized PPD dosage

Well	Used dosage before Optimization (ppm)	Optimized dosage (ppm)
20/RC-4	900	1,200
25/RC-4	900	1,200
412B/RC-4	900	1,200
422/RC-4	900	900
423/RC-4	900	900
424/RC-4	900	1,200
425/RC-4	900	600
426/RC-4	900	1200
15/RC-5	700	1,000
17/RC-5	700	500
503/RC-5	700	1,000
506/RC-5	700	700
507/RC-5	700	500
508/RC-5	700	500
509/RC-5	700	500
510/RC-5	700	0
2X/RC-DM	1,300	1,300
405/RC-DM	1,300	0
406/RC-DM	1,300	1,300
407/RC-DM	1,300	1,300
410/RC-DM	1,300	1,300

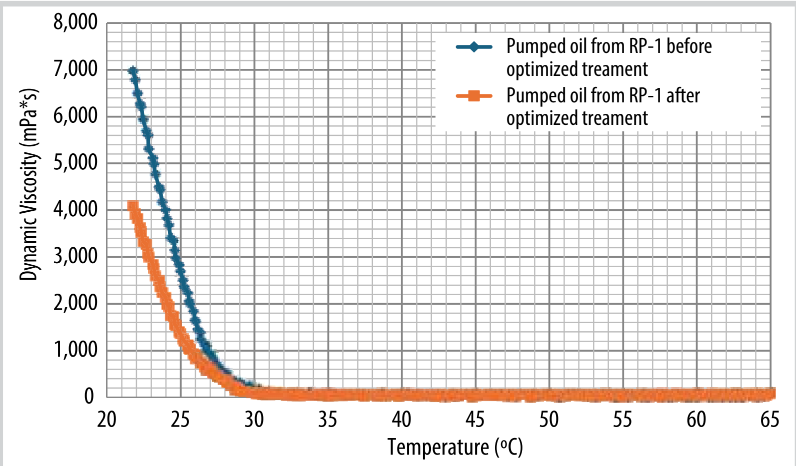

Figure 6. *Rheological properties of crude oil pumped from RP-1.*

(a)

(b)

Figure 7. *Wax tendency of crude oil pumped from RP-1, before (a) and after (b) optimized treatment.*

Based on the study results of the rheological properties of treated crude oil from oil wells in the Central of Rong and Nam Rong - Doi Moi fields, optimal chemical dosages were determined and implemented in field trials (Table 6).

The optimization of chemical treatment using PPDs was implemented on platforms RC-DM, RC-4, and RC-5 with the optimal dosages mentioned above. After field trials, the pour point of crude oil pumped from RP-1 to FSO-03 decreased from 31 - 32°C to 29 - 30.5°C.

In addition to optimizing PPD treatment, demulsifiers are also used on the RC platforms to treat the produced liquid mixture, improving water separation and reducing mixture viscosity.

Lowering the pour point helps reduce the pressure drop in pipelines. The transportation operations from RP-1 to FSO-3 remain stable, with all system operating parameters consistently maintained within allowable technical limits.

***Table 7.** Deposition of paraffin of treated crude oil pumped from RP-1*

Chemical	Deposition of paraffin (kg/m^2)	Deposition reduction (%)
	Crude oil pumped from RP-1	
Before optimized treatment	7.20	70.8
After optimized treatment	2.45	

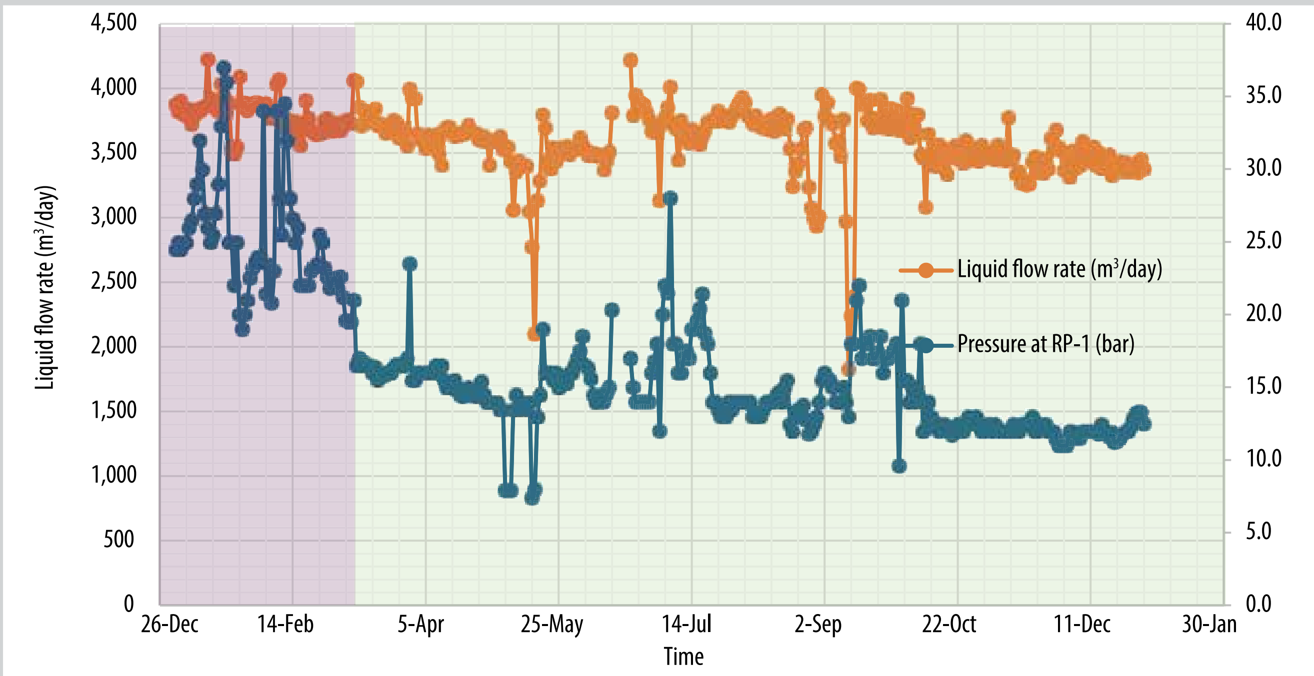

***Figure 8.** Operating parameters of RP-1 → FSO-3 pipeline before (green zone) and after (yellow zone) optimization.*

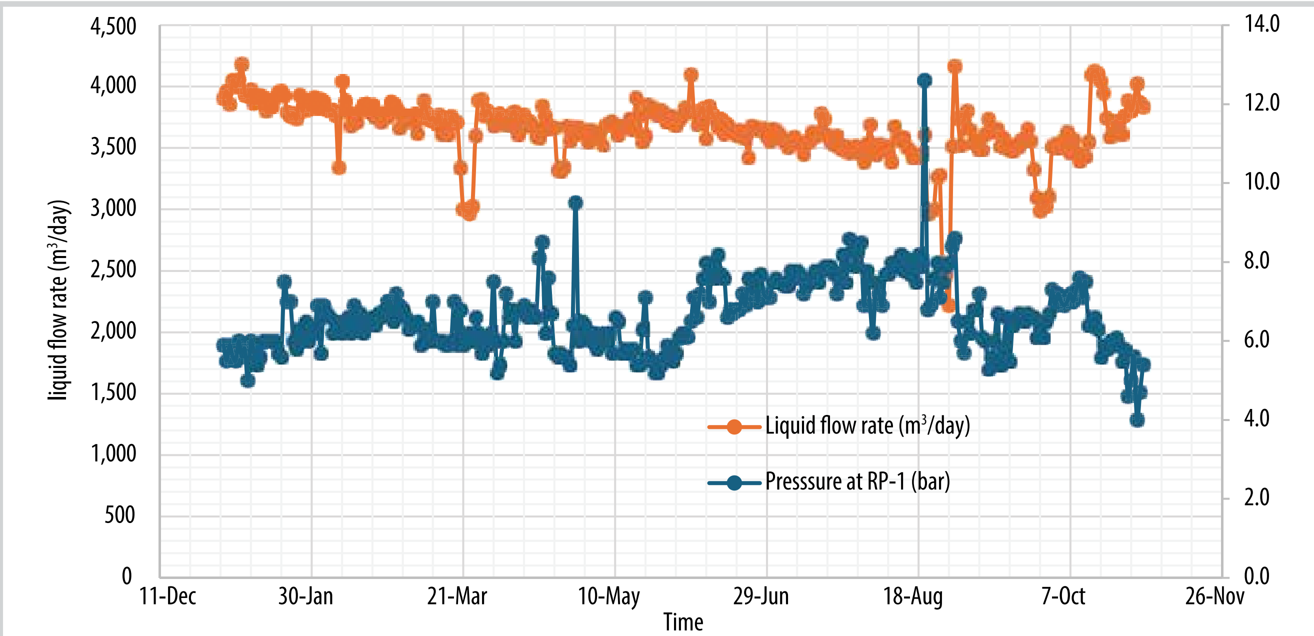

***Figure 9.** Operating parameters of RP-1 → FSO-3 pipeline in the latest period.*

5. Conclusion

The transportation of high-paraffin crude oil through uninsulated pipelines is inherently risky and complex. The main problem is intensive heat loss, which promotes paraffin deposition on the inner surface of pipelines and increases fluid viscosity, resulting in substantial pressure loss during transportation.

The study results indicate that crude oil properties vary significantly among wells within the same satellite platform. Notably, the effectiveness of pour point depressant treatment fluctuates considerably from well to well.

For optimal PPD usage, applying uniform dosage to all oil wells can result in either ineffective treatment or chemical waste. Through rheological and deposition studies of crude oil from individual wells, optimal treatment regimes can be determined. The optimal PPD dosage should be established based on well-specific treatment requirements.

In particular, the uninsulated RP-1 → FSO-3 pipeline operates with oil temperature approaching the pour point, leading to increased average pump pressure and creating high risks for the transportation system.

Therefore, PPD treatments enhance pour point reduction effectiveness, lower viscosity, and minimize wax deposition. However, the conventional approach of applying uniform dosage across all wells has not adequately reduced back pressure. The well-specific optimization approach has proven to be more effective in maximizing PPD treatment efficiency.

The study results of the Central of Rong and Nam Rong - Doi Moi fields demonstrate that implementing these concepts has significantly improved crude oil treatment efficiency. As a result, the field's crude can now be safely transported through the uninsulated RP-1 → FSO-3 pipeline.

The results of study have been applied for another oil fields produced by Vietsovpetro, especially for the small and marginal oil fields.

References

[1] А.Г. Ахмадеев, Фам Тхань Винь, Буй Чонг Хан, Ле Хыу Тоан, Нгуен Хоай Ву, и А.И.Михайлов, "Оптимизация безнасосного транспорта продукции скважин в условиях морской нефтедобычи", *Нефтяное Хозяйство*, № 11, с. 140 - 142, 2017.

[2] А.Г. Ахмадеев, Тонг Кань Шон, и С.А. Иванов, "Комплексный подход к обеспечению транспортировки высокопарафинистых нефтей шельфовых месторождений", *Нефтяное Хозяйство*, № 6, с. 100 - 103, 2015.

[3] Từ Thành Nghĩa, Phạm Bá Hiển, Phạm Xuân Sơn, Tống Cảnh Sơn, Nguyễn Hoài Vũ, Ngô Thường San, Nguyễn Văn Minh, và Nguyễn Thúc Kháng, "Những khó khăn, thách thức của Vietsovpetro trong vận chuyển dầu nhiều paraffin bằng đường ống ngầm ngoài khơi", *Tạp chí Dầu khí*, Số 5, trang 20 - 25, 2015.

[4] Phung Dinh Thuc, Ha Van Bich, Tong Canh Son, V.P.Vygovskoy, and Le Dinh Hoe, "A new approach to study on thixotropic properties of waxy crude oil from Dragon and White Tiger fields offshore Vietnam", *SPE Asia Pacific Oil and Gas Conference and Exhibition, Jakarta, Indonesia, 20 - 22 April, 1999*.

[5] Phung Dinh Thuc, Ha Van Bich, Tong Canh Son, Le Dinh Hoe, and V.P.Vygovskoy, "The problem in transportation of high waxy crude oils through submarine pipelines at JV Vietsovpetro oil fields, offshore Vietnam", *Journal of Canadian Petroleum Technology*, Volume 42, Issue 6, pp. 15 - 18, 2003.

[6] Nguyen Thuc Khang, Ha Van Bich, Tong Canh Son, and Le Dinh Hoe, "Transporting oil and gas mixture in gathering system at White Tiger oil field", *SPE Asia Pacific Oil and Gas Conference and Exhibition, Jakarta, Indonesia, 9 - 11 September, 2003*.

[7] Nguyen Thuc Khang, Ha Van Bich, Tong Canh Son, Le Dinh Hoe, and Phung Dinh Thuc, "A new approach for regime optimization of oil and gas mixture pipeline transportation", *SPE Asia Pacific Oil and Gas Conference and Exhibition, Perth, Australia*, *18 - 20 October, 2004*.

[8] Tong Canh Son, Le Dinh Hoe, and Nguyen Quang Vinh, "Schematic of oil and gas transportation from Nam Rong - Doi Moi to RP-1 of Rong oil field subsea pipelines from a marginal offshore oil field", *Petrovietnam Journal*, Volume 10, pp. 38 - 43, 2015.