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OPASC PIPELINE OPTIMIZATION USING DRA

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Abstract

The objective of this paper is evaluate the use of DRA for increase flow and optimize energy consumption under certain conditions, using as model the OPASC pipeline.

The OPASC is batch pipeline located in the southern region of Brazil, used mainly for the transport of diesel, gasoline, ethanol and LPG. The pipeline is dependent on the seasonality of both the production and the demands of the sector. It usually presents an increase in demand in the summer and a decrease in the winter.

This situation accounts for two of the pipeline major problems. During the peak season, the pipeline is operating on its maximum capacity, but still cannot supply with the market needs, causing an income loss. During the low season, the average flow causes the pipeline to operate using PCVs to control its flow and the pumps to operate at low efficiency points, causing unnecessary energy consumptions.

The OPASC 10" is 197 km pipeline, from the REPAR refinery to the Tejaí terminal, with a delivery at the Guaramirim base, with receive most products at a smaller flow rate. The pipeline works with small batches, from 2 to 6 thousand cubic meters. The DRA was only applied on the gasoline and diesel batches, which are the most transported products.

The DRA field test occurred on July 2010, and was sponsored by several sector of both Petrobras e Transpetro, such as: the Presidente Getúlio Vargas Refinery (REPAR), the Guaramirim Terminal (TEMIRIM), The Itajaí Terminal (TEJAÍ) e o National Operational Control Center (CNCO), located at Transpetro headquarters in Rio de Janeiro. Several batch plans and DRA concentrations were tested during the course of the test.

This paper proposes the use of DRA to increase pipeline flow and to change operating conditions to optimize energy consumption. This works was based on a worldwide action supported by TRANSPETRO and involved several sectors of the company. The result gathered from both the field test and the hydraulic simulations support and verified the assumption made.

1. Introduction

The OPASC Pipeline (Paraná - Santa Catarina) is an oil products and two types of alcohol pipeline that deliver from the REPAR Refinery (President Getúlio Vargas) to the TEMIRIM Terminal (Guaramirim) and the TEJAI Terminal (Itajaí). The TEMIRIM Terminal works only as a strip, occasionally receiving part of the pipes products. The pipeline is controlled at TRANSPETRO Main Control Center in Rio de Janeiro, where most of its variables are monitored constantly. A simple view of the pipeline is show on Figure 1.

The OPASC pipeline has a peculiar situation. Due it's seasonal regime, it's demand varies from exceeding the pipeline capacity to working in a much lower demand, where the pipeline works at a low efficiency point because of the market restrictions.

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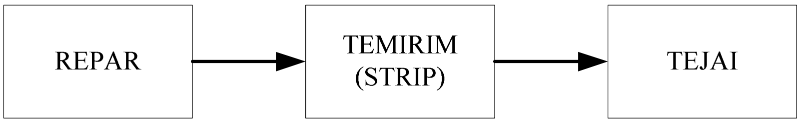

Figure 1 – Simplified Flowchart of OPASC Pipeline

In the REPAR, as shown on Figure 2, the pipeline system works with two parallel booster pumps for LPG and two serial pumps for other products. The pipeline also has three serial main pumps. For operational security, one booster pump and one main pump must be consider back-up, in other words, it can only operate with one booster and one or two main pumps.

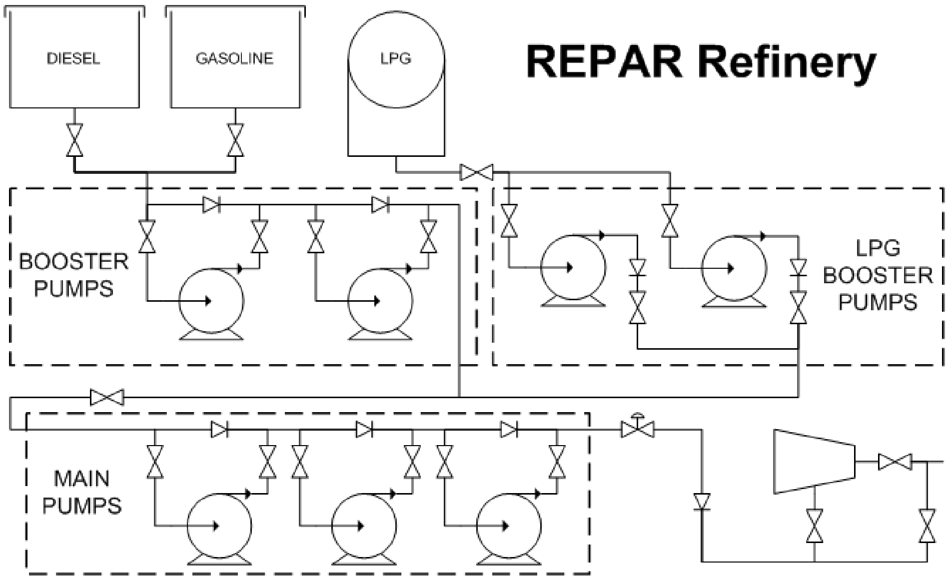

Figure 2 – Simplified Pump Flowchart at REPAR Refinery

Aiming to solve these problems, the Operational Management of the South in set with the CNCO and support of the PUC, the use of the DRA was proposal as a fast alternative to solve this problem. The main is to use the DRA in the period in which the pipeline is in the pass to increase the flow and in the periods where it will be operating outside of the BEP, to use the DRA to improve this efficiency. This can be made using one main pump with DRA or operating the pipeline out of the BEP with two pumps.

The paper was divided in four parts, the first one is the description of what it occurred in field, second is the comparison of the theoretical results and of field for the evaluation of the model, third it is the evaluation of the profits of capacity in the biggest demand and fourth it is the evaluation of energy efficiency. The main objective of this article is to solve in the way most economic the problem happened of the high demand and low the demand.

2. Preliminary Study

Before starting with the field test, to insure a more accurate test with fewer variables, the Thermal Hydraulic Pipeline Simulation Group (SIMDUT), a laboratory belonging to the PUC-Rio University, at the request of TRANSPETRO, made several simulation using pre-validated models using the GL-Noble Denton software Stoner Pipeline Simulator®.

One of the purposes of the simulation was also to determine the maximum concentration of DRA to obey the pipeline's limitations. The model used 1 booster and 2 main pumps and different concentrations of DRA. The simulation considered the pipe with only one product at a time, with DRA acting only on Diesel and Gasoline. On Figure 3, the DRA curves used and validated in the preliminary study. This curve was obtained from the DRA producer and tweaked to fit the pipeline's normal flow. From Table 1 to Table 4 the results are show, and were again validated by the field testing team, as show on topics 3 and 4.

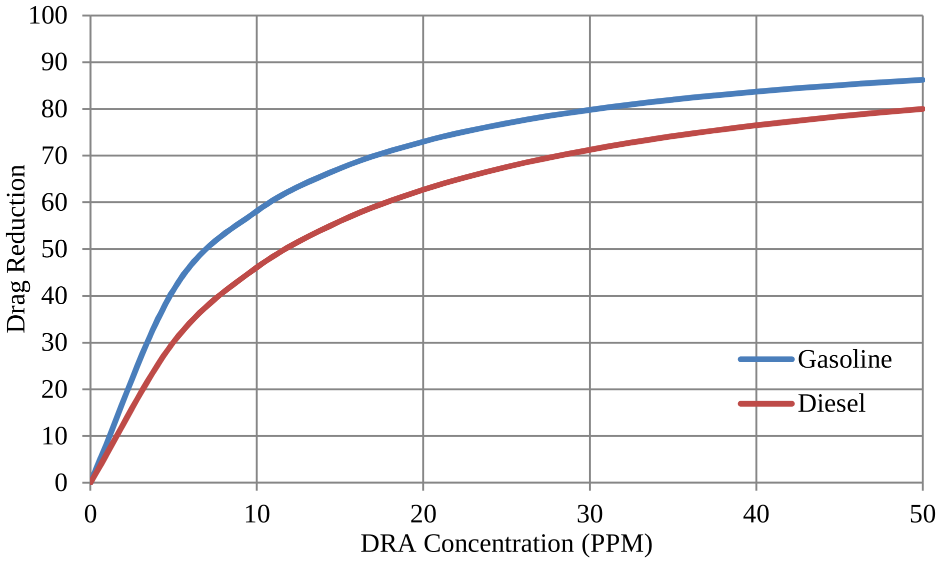

Figure 3 – DRA Efficiency Curves for Gasoline and Diesel

Table 1 – Diesel without Strip

DRA Concentration (PPM)	Flow (m^3/h)	REPAR (kgf/cm^2)	TEMIRIM (kgf/cm^2)	TEJAI (kgf/cm^2)	Specific Power (HP/(m^3/h))
0	238	50.9	47.8	9	2.65
3.3	270	50.8	47.7	9	2.5
8.07	310	48.3	46.9	9	2.33
15.4	362	43	45.1	9	2.15
13.6*	350	44.3	45.1	9	2.19

* Target Flow of 350 m^3/h

Table 2 – Diesel with a 100 m^3/h Strip

DRA Concentration (PPM)	Flow (m^3/h)	REPAR (kgf/cm^2)	TEMIRIM (kgf/cm^2)	TEJAI (kgf/cm^2)	Specific Power (HP/(m^3/h))
0	264	50.4	30.7	11	2.52
3.3	295	49.3	32.2	11	2.39
8.07	333	45.9	33.5	11	2.25
15.4	383	40	34	11	2.08
10.4*	350	44.1	33.8	11	2.19

* Target Flow of 350 m^3/h

Table 3 – Gasoline without Strip

DRA Concentration (PPM)	Flow (m^3/h)	REPAR (kgf/cm^2)	TEMIRIM (kgf/cm^2)	TEJAI (kgf/cm^2)	Specific Power (HP/(m^3/h))
0	298	40.4	38.9	8	1.89
2.1	343	37	37.8	8	1.76
5.07	395	31.8	36.1	8	1.63
9.95	463	24.5	33.7	8	1.48
3.8*	375	34	36.8	8	1.68

* Target Flow of 375 m^3/h

Table 4 – Gasoline with a 100 m³/h Strip

DRA Concentration (PPM)	Flow (m³/h)	REPAR (kgf/cm²)	TEMIRIM (kgf/cm²)	TEJAI (kgf/cm²)	Specific Power (HP/(m³/h))
0	322	38.4	26.3	9	1.82
2.4	372	34	27.1	9	1.69
5.81	428	28.1	27.1	9	1.56
10.98	494	20.7	26.4	9	1.4
2.6*	375	33.7	27.2	9	1.68

* Target Flow of 375 m³/h

3. DRA Field Equipment and Testing

The planning of this activity started in the middle of 2009 when the pipeline was continuously approaching the limit level of utilization, near 100%. Before deciding to use DRA, a lot of alternatives were studied in order to increase the pipeline's transportation capacity, but the one that demonstrated the best result in a short time, was the Flow Improver Solution, or the Drag Reduction Agent Injection. After the decision was made, a Work Group was created to plan and execute a test in order to evaluate the performance of a DRA in the OPASC 10" pipeline.

3.1. Equipment and Assembly

The DRA Skid assembly is composed with the following basic features.

- Injection Pump – Positive Displacement;
- Booster Pump;
- Pressure Relief System;
- Instrumentation panel with remote communication;
- Flow Meter;
- Metallic protection, for leak contention;

An example of the Skid can be found on Figure 4. Due to the area where the installation occurred, all the electrical equipment was of the explosion-proof type. Two Skids were hired in order to avoid any test interruption due to non-programmed stops in the injection equipment. The Skid is connected to the pipeline just after the scraper by a ¾ inches, 10 meters long pipe, just before where the pipe is buried.

Figure 4 – Example of the Injection Skid Installed in the Field

3.2. Testing the DRA

Before following up with the test, it was decided to perform a pre test in order to verify the effects the DRA injection on the products quality. It was decided to inject some DRA in a small batch of diesel in a dosage higher than the maximum operational value (12 ppm) defined in the operational procedure, and lower than the maximum value recommended by the supplier (80 ppm). The chosen value was 20 ppm. The batch was monitored and stored in a specific tank in order to assure the quality of the product. The results showed that the DRA didn't affect neither the Diesel's nor the Gasoline's quality.

The operational procedure used for the test was defined and registered by the local operational team and the Control Center's Engineers and Technicians. The DRA was applied in all batches of diesel and gasoline in different levels of dosage in order to elaborate a performance curve for the product. The injection was performed by the local team and all the pipeline parameters, including the functioning skid, were remotely monitored by the Control Center.

Besides operating the pipeline and the Skid, the Transpetro's field staff was responsible for the product homogenization. Despite having a small recirculation system, the process had to be complemented by a mechanical and manual process, using a thin rod to mix the product. This activity was necessary once a day, when the DRA Skid start up after a period longer than 24h. During weekends there wasn't any DRA injection due to the products in the pipeline at the time didn't correspond to the testing products. Because of this, it was necessary to clean the injection line with water in order to avoid DRA stiffness inside the line and, consequently, creating an obstruction.

4. Comparing the Simulation with the Field Test

For the simulation part of the DRA comparison, one week of onsite tests was analyzed using simulations. Different concentrations of DRA, different batch sizes for both diesel and gasoline and different strip flow values. Due to the complexity of the real life test in opposition to the simplifications needed to simulate the same pipeline, the main comparison method use was the final batch time. On Table 5 is exposed the batch planning used for this test. The DRA concentration was decided based on the simulations and in junction with the DRA supplier.

Table 5 – Test Batch Plan

Batch	Product	DRA (PPM)
01	Diesel	4.0
02	Gasoline	4.0
03	Diesel	8.0
04	Gasoline	8.0

In this evaluation it is necessary to consider the following points:

- The beginning of the analysis started when the DRA injection with some products in the line. The ideal would be to start with an only product to reduce the uncertainties of the flow.
- Unlike what was simulated, the DRA concentration, based on the pipeline's flow (in PPM) didn't remain constant trough out the procedure. This happened because unlike the computer model, the pump can only be set to a specific flow value, which was changed hourly by the TRANSPETRO field team. Moreover, the pipeline flow changed accordingly to operational circumstances, such as a strip occurring during the operation.

The comparison scenes are described below:

4.1. Field Test

After the test, the pipeline's instrument data were acquired at the Control Center for analysis and comparison. The pipeline's operators controlled the flow accordingly to the batch plan, including the strip at Temirim, and to ensure a flow without slack line. The pipeline's pressure and flow limitation were followed at all times.

The test was divided in two phases, considering the previous amount of DRA from the simulations results. In Figure 5 the results for 4 PPM of DRA concentration are showed, and in Figure 6 the results for 8 PPM, both for Diesel fuel.

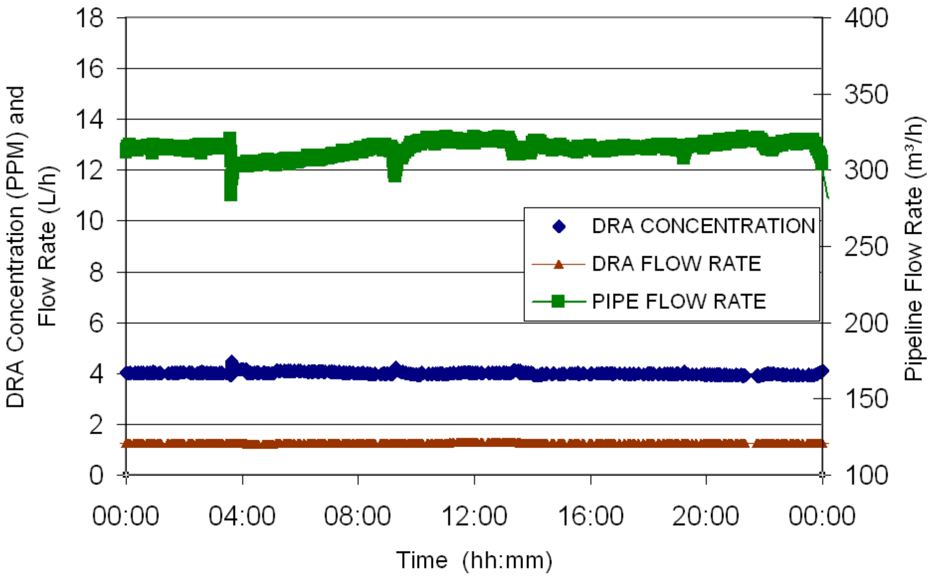

Figure 5 – Short Field Test – 4 PPM of DRA

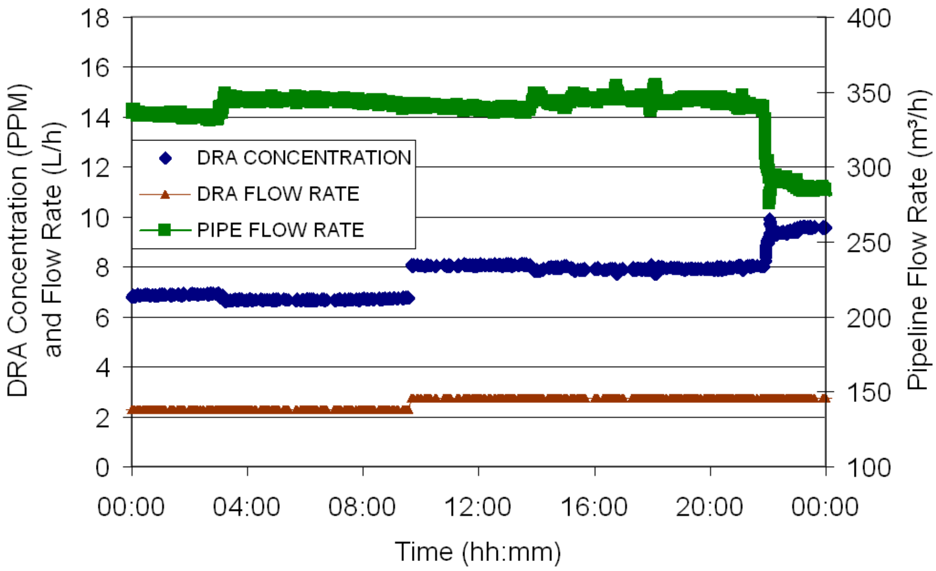

Figure 6 – Short Field Test – 8 PPM of DRA

4.2. Simulation

The simulation used the same batch plan as de field test, using the same strips and set points for its control valves. During the field test, a problem with a pump occurred, which was emulated in the simulation. On Table 6 the result of both tests can be seen.

Table 6 – Comparison between Field Test and Simulation

Case	Duration (h)
Field Test	107.8
Simulation	113.0
Time Difference	4.9%

Taking in consideration the complexity of the analysis and the uncertainties, we can infer from Table 6 that the results from the field test demanded less time than the simulations, but within an acceptable margin of error. Thus, the model used was consider validated as were the DRA curves.

5. Evaluation of Capacity Gain

As mentioned before, some field tests were realized with the objective to evaluate the capacity gain using DRA. The tests were divided in regarding their time length. The first was used to validate the simulation model, as demonstrated before. The second, during the period of one month, was used to study a broader use (and gain) of using DRA.

During the initial period of the long test with 31 days, part without DRA and part with DRA the increase of the average flow in pipeline can be observed clearly. These results are shown on Table 7 and on Figure 7.

Table 7 – Comparison between Field Test and Simulation

Data / Time	Whole Month (31 Days)	Until the 17th (without DRA)	After the 17th (with DRA)	Gain
Working Hours	739.6	382.6	357.0	-
Available Hours	744.0	384.0	360.0	-
Pipeline Usage	99.4%	99.6%	99.2%	-
Transported Volume (m^3)	226488	112247	114241	1.8%
Average Operational Flow (m^3/h)	310.2	297.2	324.2	9.1%
Average Global Flow (m^3/h)	308.4	296.2	321.4	8.5%

Global average flow mentions to it the period of monthly movement taking in consideration the hours stops, while average work flow is only related with the pipeline operating.

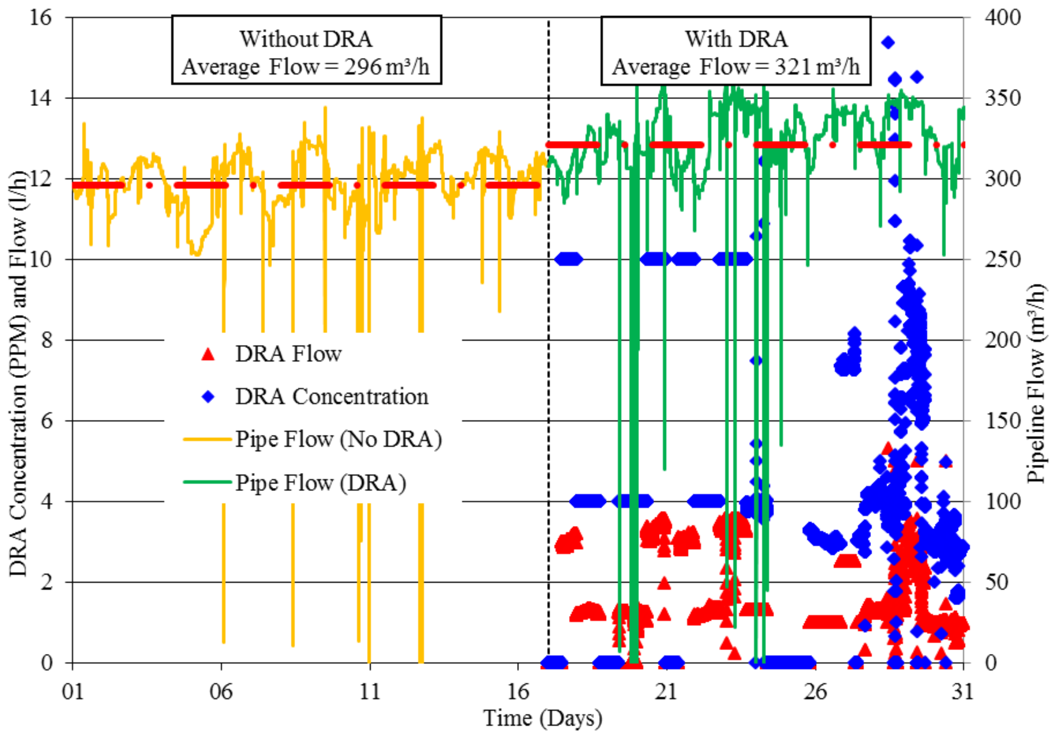

Figure 7 – Long Field Test – Monthly Cycle

Table 8 – Monthly Transport

Monthly Transport	Volume (m³)	Average Operational Flow (m³/h)	Pipeline Usage
Work Capacity	173196	280	85 %
Maximum Capacity Installed	208500	280	100 %
Current Month	226488	310.2	99.4 %

The Table 8 show a gain of 8,6% in relation to the maximum capacity installed and this value can be even higher, considering the DRA was only used during 17 days of the month in question.

6. Cost Evaluation

Because of a lighter demand in the winter months, the operation considered the substitution of a main pump for the injection of DRA. The main idea is to reduce the cost of using two pumps at the low demand period and for a alone pump not to supply flow enough to fulfill the demand.

They had been chosen solely batches of diesel and gasoline because they are the products where the DRA can be used and besides simplify the problems by the complexity of the real batch one. Different concentrations with and without strip, depending on the product had been chosen, and had been used values of cost of energy and esteem DRA of the market, as described in the Table 9:

Table 9 – Energy and DRA Costs at REPAR

Demand ($/kW)		Energy ($/MWh)		DRA
On-Peak	Off-Peak	On-Peak	Off-Peak	$/L
51.76	12.86	0.3394	0.2188	32

Using the data above as reference and a support software, the following results were found for 30 days of simulation with diesel or gasoline, described at Table 10, Table 11, Table 12 and Table 13.

Table 10 – DRA Main Results – Diesel without Strip

Pump Configuration	Transported Volume (m³)	Average Pipeline Flow (m³/h)	Specific Electrical Cost ($/m3)	Specific DRA Cost ($/m3)	Specific Total Cost ($/m3)
2 Main Pumps, 0 PPM	177733.60	247	0.63	0.00	0.63
1 Main Pump, 4 PPM	188098.40	261	0.37	0.13	0.50
1 Main Pump, 10 PPM	213000.00	296	0.34	0.32	0.66

Table 11 – DRA Main Results – Diesel with a 120 m³/h Strip

Pump Configuration	Transported Volume (m³)	Average Pipeline Flow (m³/h)	Specific Electrical Cost ($/m3)	Specific DRA Cost ($/m3)	Specific Total Cost ($/m3)
2 Main Pumps, 0 PPM	193983.20	269	0.60	0.00	0.60
1 Main Pump, 4 PPM	205963.00	286	0.35	0.13	0.48
1 Main Pump, 10 PPM	153269.80	213	0.44	0.32	0.76

Table 12 – DRA Main Results – Gasoline without Strip

Pump Configuration	Transported Volume (m³)	Average Pipeline Flow (m³/h)	Specific Electrical Cost ($/m3)	Specific DRA Cost ($/m3)	Specific Total Cost ($/m3)
2 Main Pumps, 0 PPM	216955.60	301	0.47	0.00	0.47
1 Main Pump, 4 PPM	251676.50	350	0.26	0.13	0.39

1 Main Pump, 10 PPM	237000.00	329	0.25	0.32	0.57

Table 13 – DRA Main Results – Gasoline with an 80 m³/h Strip

Pump Configuration	Transported Volume (m³)	Average Pipeline Flow (m³/h)	Specific Electrical Cost ($/m3)	Specific DRA Cost ($/m3)	Specific Total Cost ($/m3)
2 Main Pumps, 0 PPM	229987.00	319	0.45	0.00	0.45
1 Main Pump, 4 PPM	265547.50	369	0.25	0.13	0.38
1 Main Pump, 10 PPM	291607.40	405	0.24	0.32	0.56

From these results, we can infer that depending on the concentration of used DRA, in this in case that 4ppm is a good value, we can substitute a pump for the injection of DRA without losses of demand. It is important to remember that the normal monthly batch plan has different products, such as LPG, with different flow rate.

7. Conclusion

From the results, this paper shows that the use of DRA for the OPASC pipeline was a success. Initially there were some doubts due to the field equipment (SKID), careful manipulation of the reduction agent, quality of the transported products and all the equipment involved. All these questions were solved or answered to satisfaction.

In relation to the comparative test, the results gather in both the simulation and the field test were satisfactory, and allowed for the continuation of the long period of DRA testing on the pipeline.

In related to the specific problems of the pipeline, during the peak demand period the DRA can reach the needed flow rate without reaching the pipeline’s operational limits, insuring a safe operation. During the low demand period, the use of a single pump in junction with the DRA allows for a lower energy and overall cost and a higher efficiency point for the same needed flow rate.

8. References

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