DIUS-LAB LLC

TRGA UNIT VISCOSITY REDUCTION

Progress report

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1. Introduction

This report was made under the contract between **TnT High Pressure Waterworks Ltd** and DIUS-LAB LLC. According to contractual obligations, **DIUS-LAB LLC** had to test the efficiency of crude oil viscosity reduction due to TRGA (made by Ruban AndrII) module influence.
TnT High Pressure Waterworks Ltd bring the samples of tatar viscous crude oil (4x50 liters tanks each, 200 liters total) and a TRGA unit.

DIUS-LAB LLC work scheme:

1) Crude oil samples preparation.
2) Technological scheme of TRGA module test installation approval.
3) TRGA module test installation assembling and and start-up procedures.
4) Providing tests with a TRGA module and viscosity measurements of different samples of crude oil.

2. Crude oil samples preparation.

Crude oil samples preparation in this case was necessary to make sure that all the samples are:

1) Identical;
2) Has no mechanical inclusions.

Standard DIUS-LAB LLC Samples preparation procedure consists of:

1) Mixing all volume of received crude oil.
2) Circulation on high rate of all crude oil in FlowLoop close circle (see ANNEX 1 for the details) for 3 hours through mechanical filter and heat exchanger. During this procedure the whole sample of crude oil was warmed up (up to 60 °C) and stayed on this temperature for 2,5 hours, after that the whole sample of oil was poured in 4 50 liters tanks.

3. Technological scheme of approved TRGA module test installation.

The principal scheme of TRGA module test installation is shown bellow possibilities:

1) System pressure of hydraulic lines (excluding pump) up to 60 bar;
2) Anti-corrosion design – installation made with AISI 316&304 steels, 1 inch diameter;
3) Pump, TRGA unit line and tanks are changeable – to raise the future possibilities of a test installation;
4) Tanks connected to instalation by high pressure hoses;
5) Possibility of pumping the sample of liquid from Tank 1 to Tank 2 using TRGA unit line or bypass line;
6) Possibility of pumping the sample of liquid from Tank 2 to Tank 1 using bypass line;
7) Possibility of pumping the sample of liquid from Tank 1 to Tank 1 using TRGA unit line or bypass line;
8) Possibility of cleaning by solvent and (after solvent) by neutral gas (if needed);
9) Installation equipped with 2 pressure sensors and a flowmeter, data acquisition board and a Windows-compatible software to track, collect and record test data for future use.
10) Has folding design for easy storage and transportation;

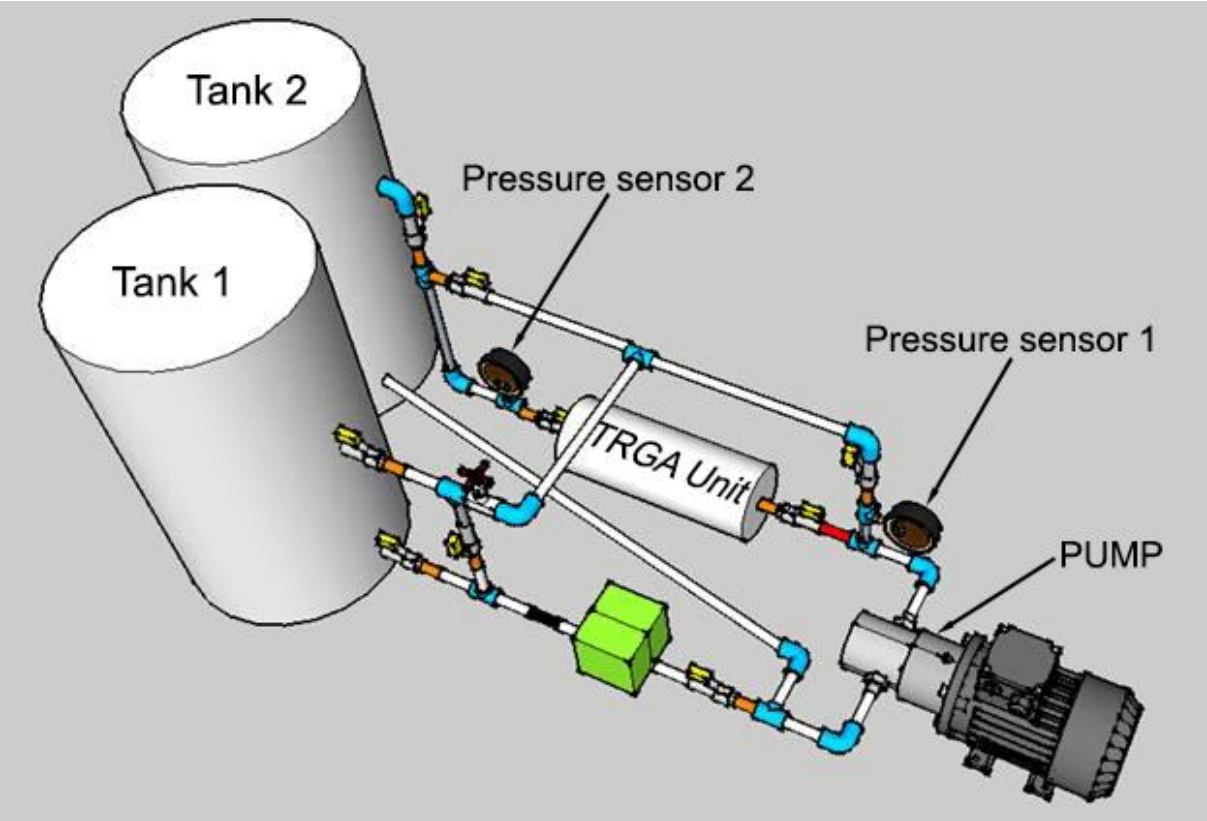

Figure 1 - Principal scheme of TRGA module test installation

4. TRGA module test installation assembling and start-up procedures.

Assembled instalation is shown on a picture on next page.
According to TRGA datasheet, pressure up to 10 bar and fluid flow 6 m3/hour should be provided to ensure that TRGA module works properly.
Main part list, which was used in instalation assembling is shown bellow .

Figure 2 - Image of a assembled instalation, ver 1

Table 1 - List of main parts of the installation

Equipment	Model/make
Pump	Livhydromash НМШ8-25-6.3/10-5 gear pump (up to 25 bar diff. pressure, **6,3 m^3/hour fluid flow**) aggregated Siemens Micromaster 420 VFD
Pressure sensors	PTAA A-Flow pressure sensors
Flowmeter	Darkont OGM Series gear flowmeter
Hydraulic line, valves, filter, fittings, etc.	AISI 304 or AISI 316 steel
Data acquisition system (DAS)	DIUS-LAB LLC make data acquisition system based on certified Rudnev-Shilyaev LLC's ADC board.

To ensure that all sensors works correctly, calibration procedures were made. The procedure was to compare the data, received from pre-calibrated industrial design Yokogawa pressure sensors and Coriolis mass flowmeter from DIUS-LAB Wax Flow&Friction loop (see ANNEX 1) and a sensors, used in TRGA test installation.

During the start-up process, to raise the pump's capabilities, we change the pump's feed line from 1 inch diameter to 2 inch, using high pressure hoses. These changes doesn't show on a picture, right know the instalation is under upgrade. Finally, the tests were made using this installation, but with 2 inch diameter high pressure hoses, no other changes were made.

5. TRGA module viscosity reduction test and viscosity research program.

There were TRGA efficiency 3 tests done (pump crude oil through TRGA unit):

1) Test 1. Transfer from Tank 1 to Tank 2 through TRGA unit of whole sample 1 of crude oil. Sample collecting;
2) Test 2. Repeated transfer of the Sample 1 of crude oil from Tank 1 back to Tank 1 through TRGA for 20 seconds. Sample collecting;
3) Test 3. Adding chemical additive – viscosity modifier (340 ppm concentration, known effective concentration is 200…500 ppm) to Sample 1, mixing it in whole Sample 1 of crude oil by pumping it for a 5 minutes by bypass line back to Tank 1 and repeated transfer of the Sample 1 of crude oil with chemical additive from Tank 1 back to Tank 1 by TRGA line for 20 seconds. Sample collecting

The viscosity determination tests was made on Rheotest 4.1 rotational viscometer, shown on a picture bellow:

Figure 3 - Rheotest 4.1 Rotational viscosimeter, used for viscosity determination tests

The algorithm of viscosity determination was:

1) Placing the sample of crude oil to the viscosimeter test chamber;
2) Heating up the sample up to 60 °C, after that the sample remains at this temperature for 30 minutes.
3) Starting viscosity determination of the sample in from 60 °C to 10 °C. The cooling speed was 0,5 °C per minute. The shear rate is 100 1/s.
4) To ensure the correct determination this procedure repeated 1 time.

All viscosity measurements tests, which was made, had equal parameters.
The viscosity research program is shown in a table bellow:

Table 2 – viscosity research program

Sample list	Viscosity measurements list		
	Before TRGA processing	After TRGA processing	2 weeks after TRGA processing
TRGA Untreated crude oil sample	X		
TRGA Untreated crude oil sample with chemical additive ___ ppm concentration	X		
TRGA processed Test 1 crude oil (first processing)		X	X
TRGA processed Test 2 crude oil (repeated processing)		X	X
TRGA processed Test 3 crude oil (2nd repeated processing with chemical additive 340 ppm concentration adding)		X	X

6. TRGA module viscosity reduction test program execution.

6.1. Test 1 execution.

As mentioned before, the Test 1 is to pump oil through TRGA unit from Tank 1 to Tank 2. To proceed with such task, the test was made in 3 phases:

1) Transfer the oil from Tank 1 back Tank 1 through pump and bypass pipeline. During this process, frequency was smoothly rose by adjusting it by VFD.
2) After VFD frequency became 50 Hz and the pump runs on it's maximum power, the flow and pressure parameters was controlled, to ensure that these parameters are fit TRGA unit working conditions.
3) After that, valves switches and the whole sample of oil runs from Tank 1 through TRGA unit line to Tank 2.
4) When Tank 1 runs out of oil, the Test 1 was considered complete and the processed oil samples was taken.

Important note.

*During the construction of the test bench, the viscosity of the crude oil and the temperature of its processing were significantly changed by the customer. In this way, the hydraulic resistance of the entire system without a TRGA homogenizer, was approximately **12 bar**. This means the following.*

1. In the case of increasing pipe diameters, the resistance of the system will decrease to 1-2 bar.
2. It will improve the efficiency of the homogenizer and the results.
3. In industrial use, this will allow the use of a pump with a working pressure of 10-15 bar, but not 25 bar, as in the conditions of this experiment.

Below the DAC Test 1 registered parameters is shown:

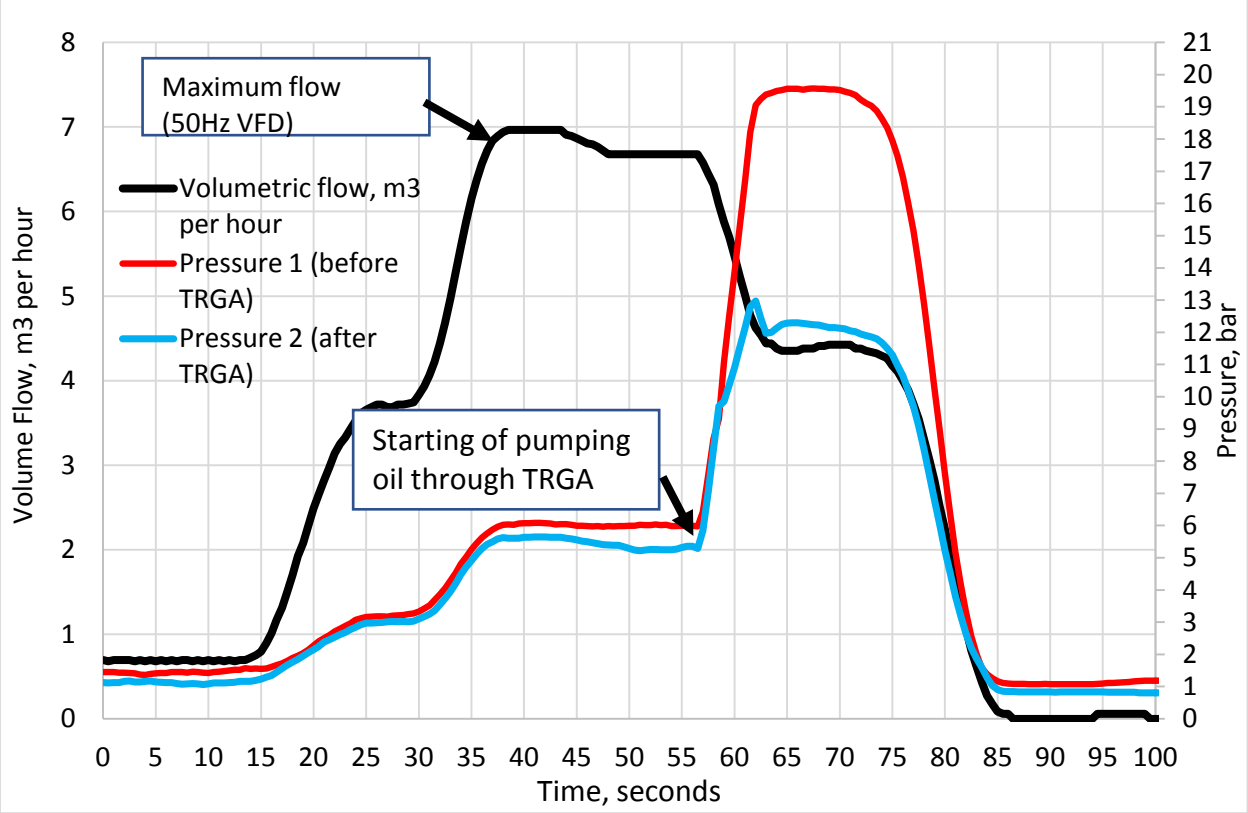

Figure 4 – Test 1 DAS info.

As You can see in a chart above, the before switching the valves, the volumetric flow was higher, than 6 m3 per hour, the pressure loss is about 2 bar (hydraulic system pressure), after switching, the pressure extremely rises and the volumetric flow drops down and was about 4,5 m3 per hour during pumping through TRGA unit. Average value of TRGA unit pressure drop was 8 bar.
After Test 1 was done, samples of processed oil was taken.

6.2. Test 2 execution.

Test 2 is to pump the oil from Tank 1 through pump and TRGA unit back to Tank 1. Time of processing was registering, to ensure that the whole Sample of crude oil run through TRGA unit. The test was devided in these phases:

1) Start pumping the oil from Tank 1 back Tank 1 through pump and bypass line. During this process, frequency was smoothly rose by adjusting it by VFD. Ball valve on bypass line was slightly closed for TRGA unit pressure drop imitation.
2) After VFD frequency became 50 Hz and the pump runs on it's maximum power, the flow and pressure parameters was controlled, to ensure that these parameters are fit TRGA unit working conditions.
3) After that, valves switches and the oil runs from Tank 1 through TRGA unit line back to Tank 1., 20 seconds (enough time to pump all the oil through TRGA) the oil proceeds through TRGA unit, after that the installation turns off.
4) After that the Test 2 was considered complete and the processed oil samples was taken.

Below the DAS info of the Test 2:

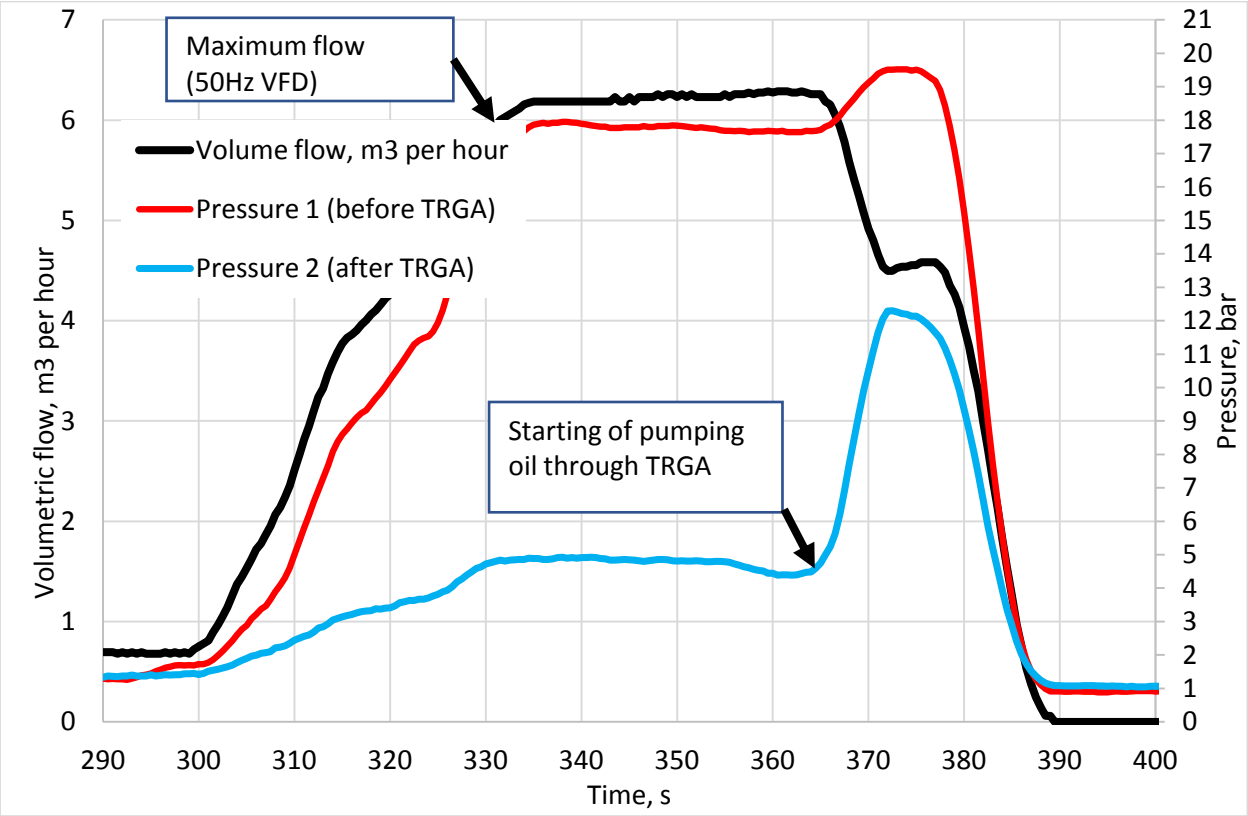

Figure 5 – Test 2 DAS info.

As You can see on chart above, Volume flow before pumping through TRGA unit was more than 6 m3 per hour, the pressure was even more than in Test 1 due to semi-closed bypass line valve. During pumping through TRGA, the parameters is almost equal: the volume flow is 4,5 m3 per hour, pressure before TRGA unit is close to 20 bar, after TRGA unit – 12 bar. TRGA pressure drop is 8 bar, similar to Test 1 parameters.

6.3. Test 3 execution.

Test 3 is similar to Test 2, but the chemical additive was added.
Concentration was 340 ppm. Here's the DAS Test 3 info:

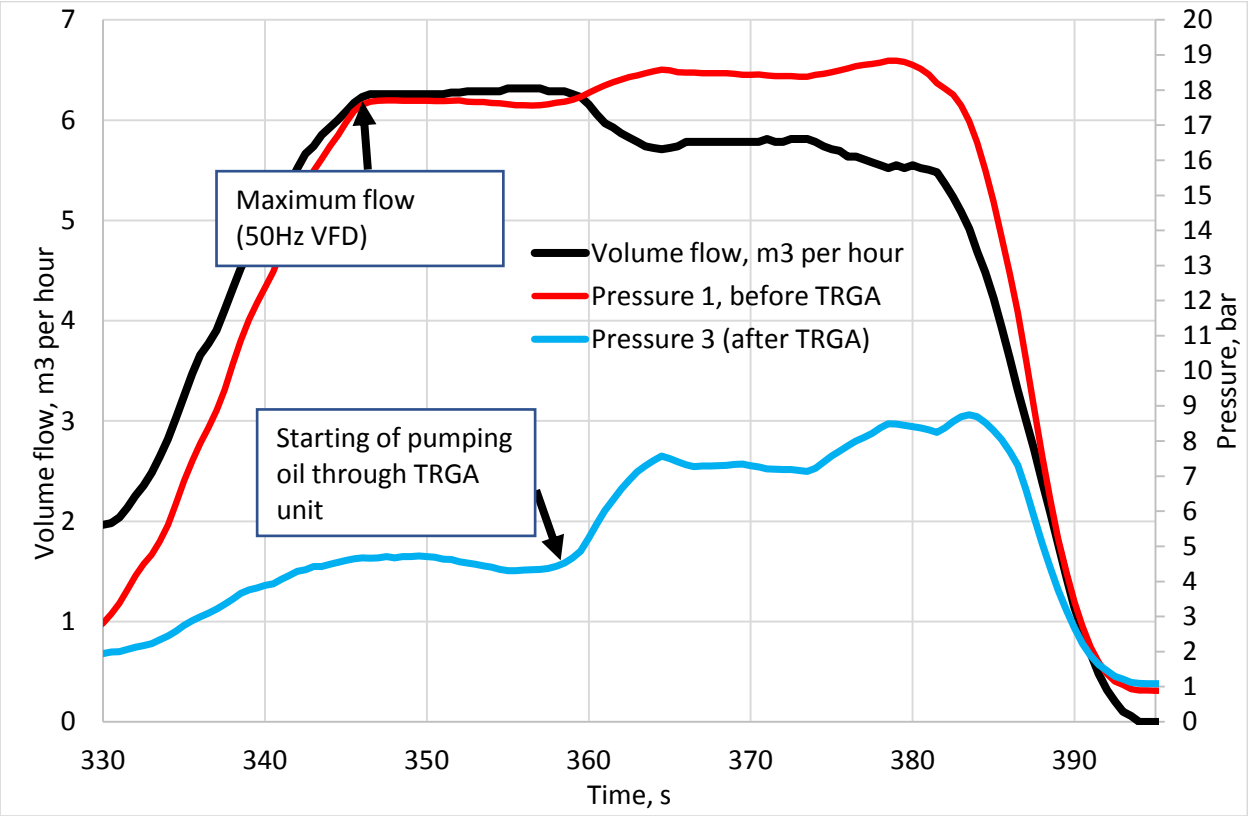

Figure 6 – Test 3 DAS info.

Adding the viscosity modifier changes the Q-H characteristic of the test. The TRGA unit pressure drop grows from 8 to **11** bar, the volume flow increased from 4,5 m3 per hour to **5,5 m3** per hour. The process was the same as Test 2.

7. Viscosity measurements results.

Below the Viscosity charts are shown. As You can See, the TRGA Unit reduced viscosity of oil in Tests 1&2 by 20-21%. Viscosity graphs of Test 1&2 seems to be equal. Adding the viscosity modifier reduce the TRGA Unit efficiency. Additional tests are needed to prove such fact. As a possible explanation, it can be additive overdose. Highly recommended to reduce the concentration of additive to 100…200 ppm and run test again. Absolute and relative values, which was measured:

Table 3 – Untreated oil and Tests 1-3 viscosity data

Sample	Viscosity, Cp		Percentage difference, %	
	at 20 °C	at 40 °C	at 20 °C	at 40 °C
Untreated oil	197,8	62	----	---
Test 1 oil	156,2	49,83	20,8	19,35
Test 2 oil	159,4	51,06	19,2	17,7
Test 3 oil	172	55,15	14,5	11,2

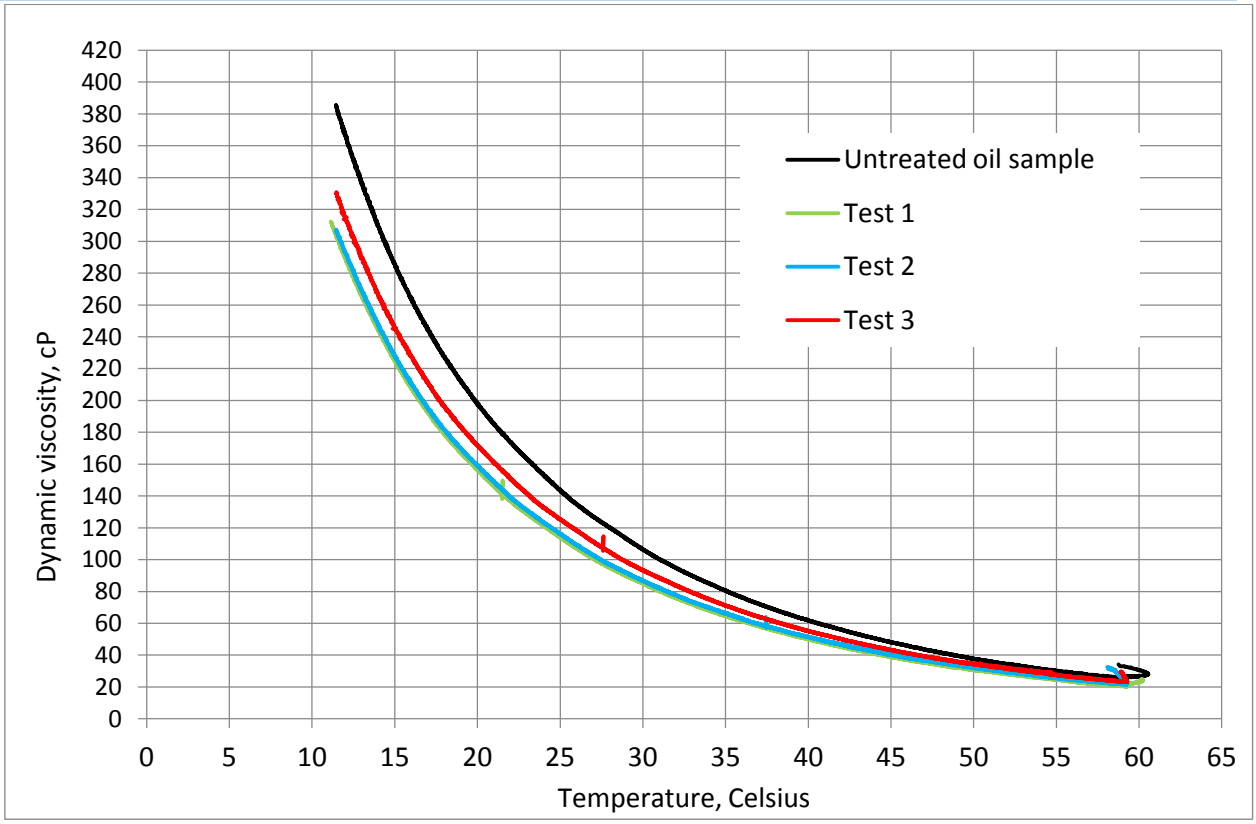

Figure 7 – Viscosity of untreated oil and test 1-3.

After 2 weeks, additional viscosity measurements were made to determine the viscosity changes in this period.

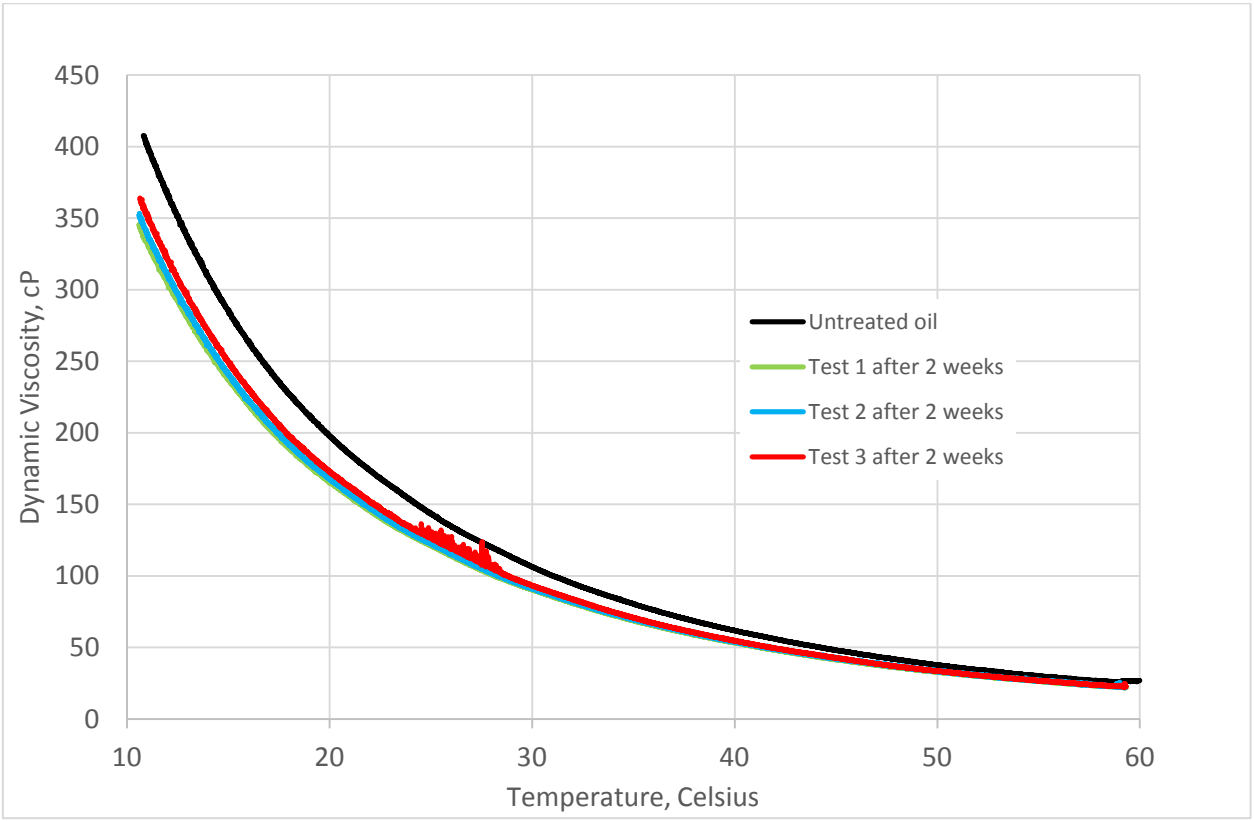

*Figure 8 – Viscosity of untreated oil and test 1-**3 after 2 weeks.***

Absolute an relative viscosity data is shown in the table bellow:

Table 4 – Untreated oil and Tests 1-3 viscosity data

Sample	Viscosity, Cp				Percentage difference, %			
	at 20 °C		at 40 °C		at 20 °C		at 40 °C	
	1 day	15 day	1 day	15 day	1 day	15 day	1 day	15 day
Untreated oil	**197,8**	**197,6**	**62**	**63**	----	---	---	1,5
Test 1 oil	156,2	165,6	49,83	53,15	**21,03%**	**16,19%**	**19,63%**	**15,63%**
Test 2 oil	159,4	167,6	51,06	54,2	**19,41%**	**15,18%**	**17,65%**	**13,97%**
Test 3 oil (+ additive)	172	172,8	55,15	54,56	13,04%	12,55%	11,05%	13,40%

Test 1&2 oil viscosities increased, the efficiency of TRGA unit decreased from value 19-21% to value of 15% average. As for test 3, we see stable results. We might think that chemical viscosity modifier worked as «result fixer». Also it need to say, that viscosity reducing by 15% only by physical impact is very interesting result.

8. Summary.

1. TRGA module is suitable for viscosity reducing of crude oil.
2. Possible applications of TRGA unit seems to be:
   - Different crude oils or oil/solvent mixing for lowering mixture viscosity;
   - Crude oil TRGA processing for oil properties/price increasing;
   - Refinery processes upgrading.

DIUS-LAB proposal to continue research process of possible TRGA unit applying.

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