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# Experimental Stand Used to Simulate Oil Transport through Pipelines

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## Abstract

*A stand was built in the laboratories of the Petroleum and Gas University of Ploiesti in order to simulate the transport of crude oil by pipeline, after various problems occurred in the real systems carrying crude oil from Romania. On this stand various scenarios that occur in the real system can be simulated. This paper presents the simulator built for the transport of crude oil through pipelines and some results obtained with it when the pipes are connected in series.*

**Key words:** *oil, transport, simulation, pipeline, series*

## Introduction

The major problem in the process of designing a pipe for the non-isothermal transport of crude oil is represented by the ability of the used mathematical model to reflect, as faithfully as possible, the real phenomenon. Starting with the design stage, an efficient mathematical model allows the reduction of construction and operating costs.

The phenomena that occur in crude oil transportation systems are complex and, apart from adequate numerical models, experiments have to be made. Since real transport systems are built with a special financial effort and their exploitation is made in the restrictive legal conditions, conducting experiments on them is excluded. Therefore we thought it would be necessary to build in our laboratory an experimental stand for the transport of oil through pipelines, because we can simulate and study adverse situations that may arise during the operation of the pipeline.

## Presentation of the crude oil transport simulator through pipelines

### Stand description

The system is designed to simulate the oil transport process through pipelines. The system can be configured so that the pumping of oil from station 1 to station 2 is effected by various types of pipe configurations.

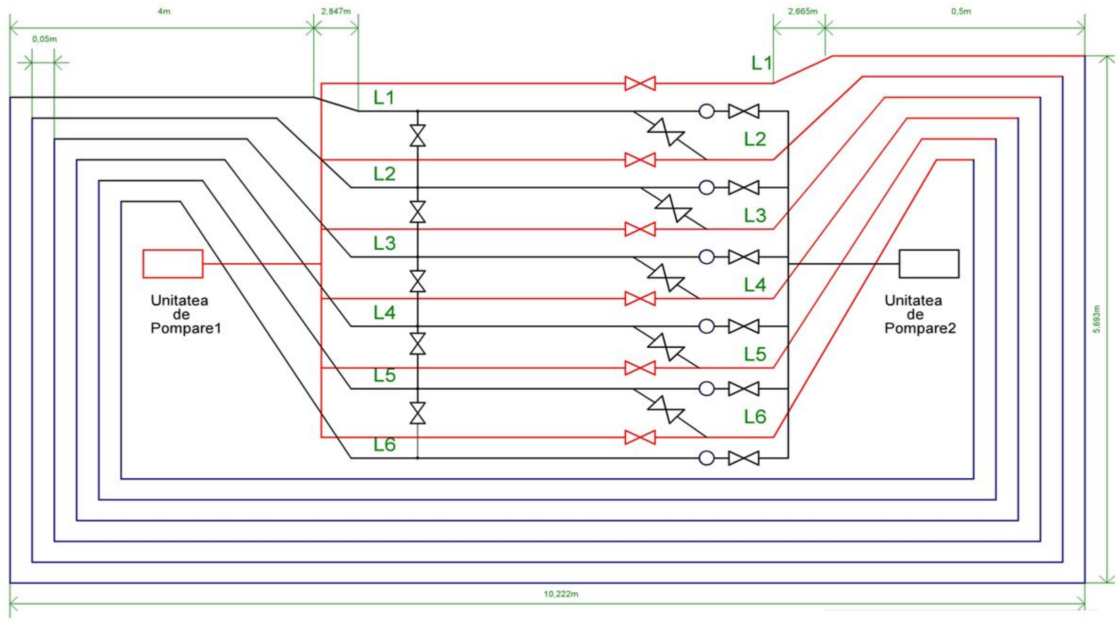


**Fig. 1.** Crude oil transportation system layout

The pipeline system makes the connection between two warehouses equipped with pumping units called 1 and 2. These deposits have three tanks each, one of 60 l and two of 20 l (Figure 2).

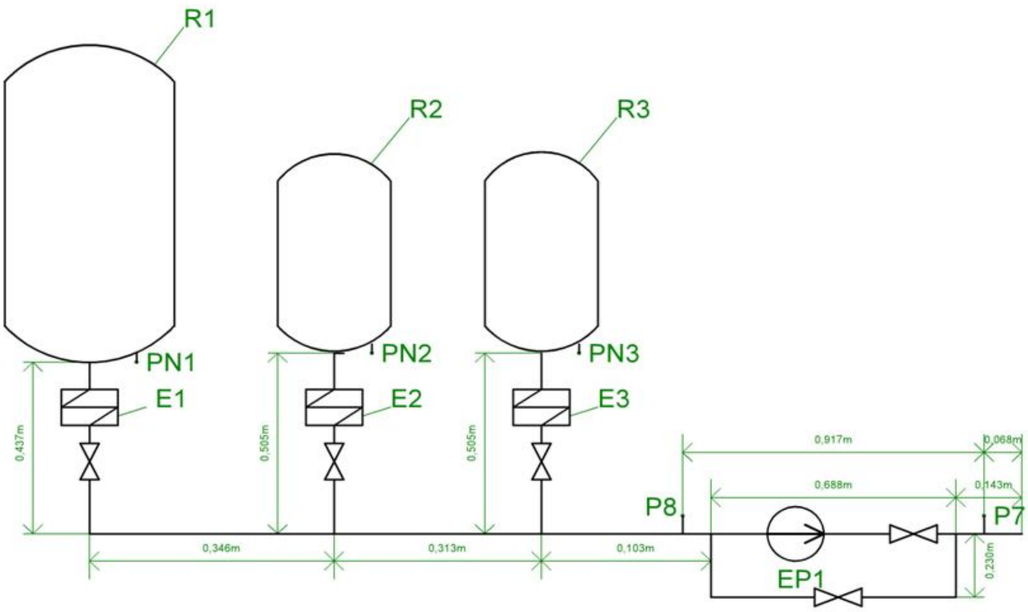


**Fig. 2.** Pumping unit 1

All tanks are fitted with level transducers, pressure sensors mounted at the base of tanks PN1, PN2, PN6 ..., sensors that allow calculating the fluid level in the tank. The tanks are connected to a platform through electrical valves E1, E2, ... E6, valves that allow them to open and close automatically. Each deposit is equipped with a pump (EP1 and EP2).

The piping manifold is the main modeling part of the pipeline system. It was designed to allow pumping between deposits, through the pipes L1, L2, L6 ..., all mounted in series, all in parallel or to choose different combinations, for example: two in series, three in parallel and the following in series, etc.

Figure 3 shows the transport system built in the laboratory.

**Fig. 3.** System Overview

## Instrumentation, command and control used on stand

A scheme that includes all devices and related sensors for monitoring and controlling the transport operations from station 1 to station 2 of the transport system in real-time was achieved.

Pressure sensors P1, P2, P3, ..., P6 are mounted on the transport pipelines L1, L2, L3, ..., L6. They provide us information about the pressure in each pipe. They are piezoceramic sensors that work in 0 ... 5 [bar] and measure the relative pressure. They can detect the pipeline pressure shocks (water hammer) and transmit the information to the microcontroller. Also, with this type of sensor is fitted the entrances and exits of electrical pumps to measure the pressure so that if one electropump blocks they will immediately sense the pressure difference. On the scheme they are noted P7, P8 for Pumping Unit 1 and P9, P10 for Pumping Unit 2.

Level transducers are used to measure the liquid level in the tanks and they work in the range 0 ... 70 [mbar].

When pumping from pump station 1, the pump from station 2 is bypassed with the help of the valves that exists in the pumping unit, and vice versa. The electro pumps are directly activated by the microcontroller with the help of the power relays because they absorb a high current at startup and hence they damage the microcontroller relays.

Electrical valves are driven by the microcontroller according to the information received from the level transducers.

Flow meters measure the liquid flow that circulate through the pipes

The microcontroller is performing all transport operations and supervises them to be held in good conditions, the human operator is just viewing the various parameters of the system.

Because the connection with the microcontroller is made on RS - 485, the pressure, level and flow transducers are connected to an adapting device.

In order to see how this system works, we need an electrical scheme that is represented below.

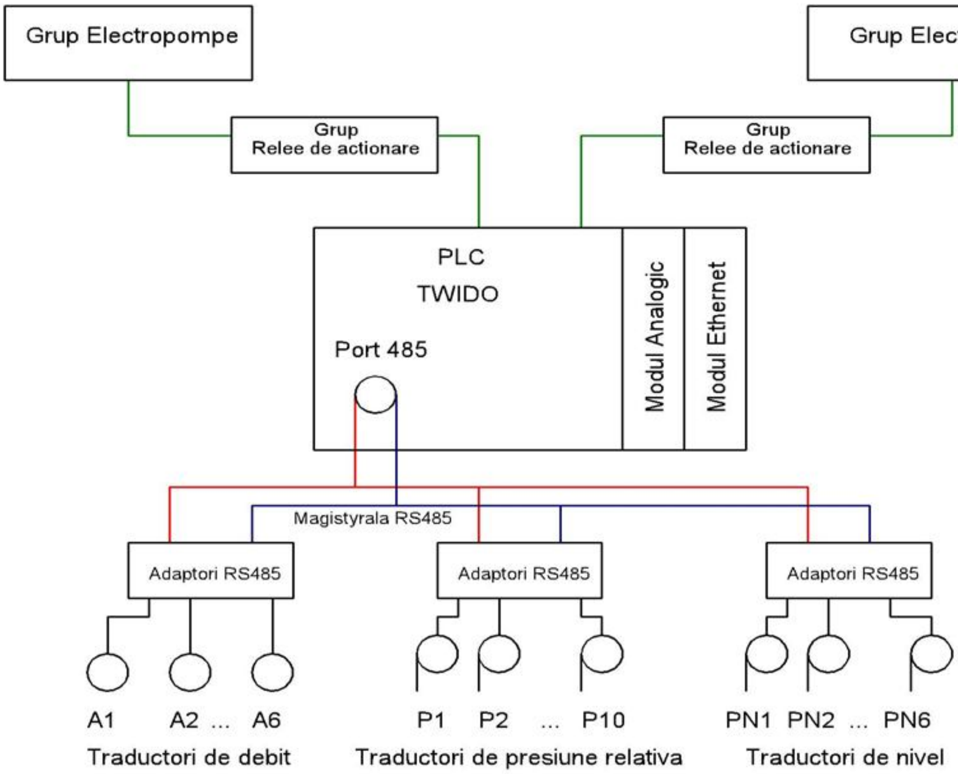


**Fig. 4.** Electrical diagram of the stand

In order to real-time monitor the designed transport system, a programmable logic controller (PLC) Twido type produced by Schneider Electric was used. It is possible to attach on this controller various modules depending on the way in which they will be used. In the present configuration there are attached three separate modules as follows:

- Communication module on the standard RS - 485;
- Analog signal acquisition module;
- Ethernet module which can be connected in a network and various parameters could be visualized with a computer

## Pipeline design software

In order to calculate the pipes of the fluid transport simulator, a program that includes all the equations was used. The software makes the calculation based on data input and data for each part of the pipe (length and elevation) placed in a text file.

The input data are:

- *Q* – flow [m3/h]
- *v* – speed [m/s]
- *H* – final height [m]

According to the data obtained, the estimated diameter is calculated by pressing *Estimate diameter*. After that, by pressing *STAS OL*, the real diameter of the pipe is chosen according to STAS, which should be the closest to the estimated diameter pipe. The pipeline profile is shown by clicking *Pipeline Profile* after the *DATA* field contains the file name with the input data *.txt*. Then click on *Calculate* and the calculations for $\Delta p$, cumulative $\Delta p$, cumulative $\Delta H$, *w* - the real flow speed, Reynolds *Re* and hydraulic resistance coefficient $\lambda$ and the chart relating to the hydraulic gradient and profile of the pipeline are shown. When pressing the *Report* button, the program shows a report of the calculations made.

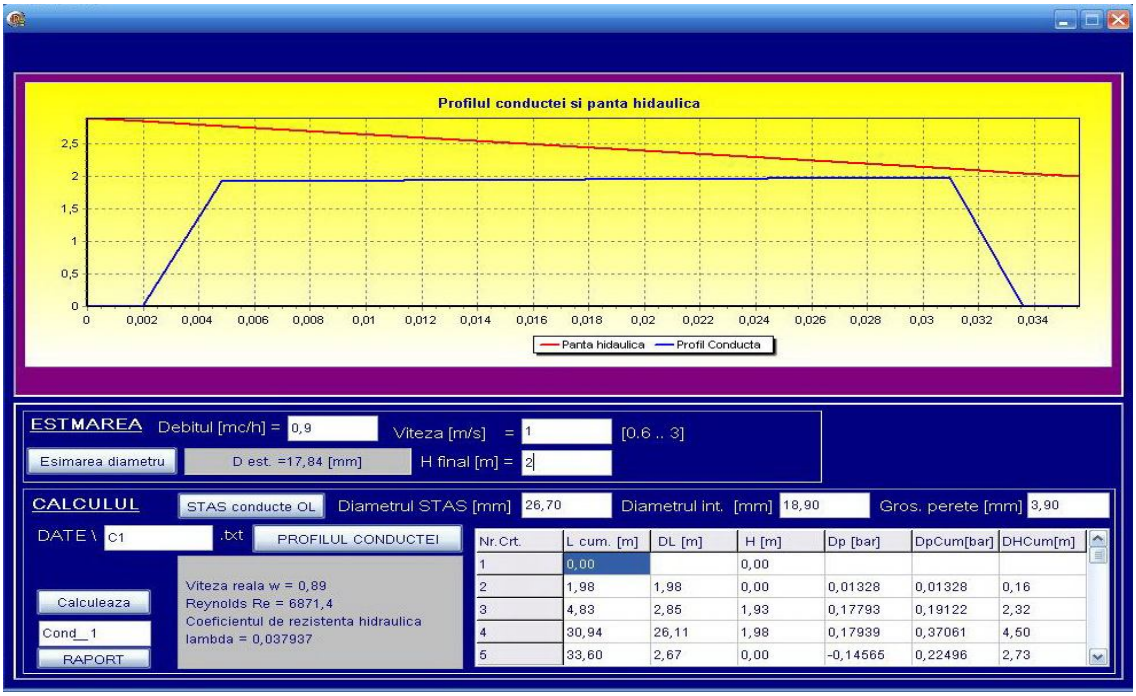


**Fig. 5.** Displaying the hydraulic slope and profile of the pipe

## The results obtained with the simulator

### Calculation for a pipeline

Based on the input data for a ½ inch nominal diameter pipe L1, the calculations were performed and the resulting graphs are presented below (Figures 6 and 7). A report is generated after calculation (Figure 8).

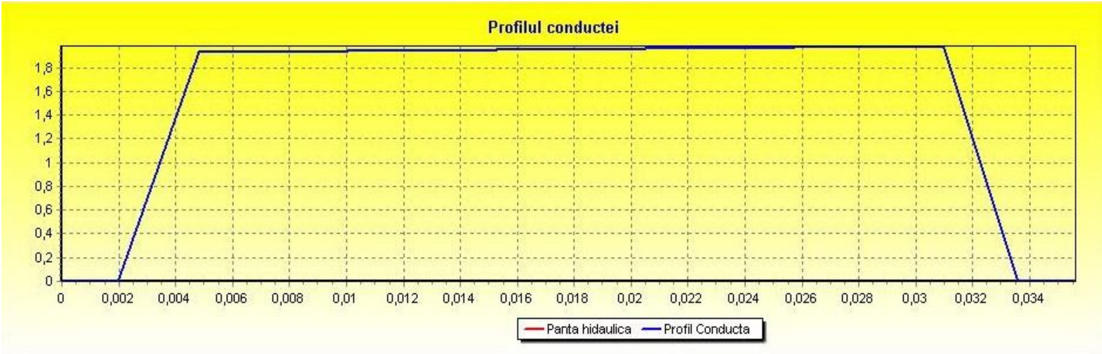


**Fig. 6.** L1 Pipeline profile


**Fig. 7.** L1 Hydraulic slope and Pipeline profile

Debitul Q = 0,300 [mc/h]

D ext. = 17,100 [mm] D int. = 12,500 [mm] Gros. perete = 2,300 [mm]

Viteza reala = 0,68 [mm] Re = 3463,2 Coef. de rezistenta hiraulica lambda = 0,045923

| | L cum. [m] | DL [m] | H [m] | Dp [bar] | DpCum[bar] | DHCum[m] |
|---|---|---|---|---|---|---|
| 1 | 0,00 | | 0,00 | | | |
| 2 | 1,98 | 1,98 | 0,00 | 0,01412 | 0,01412 | 0,17 |
| 3 | 4,83 | 2,85 | 1,93 | 0,17913 | 0,19325 | 2,35 |
| 4 | 30,94 | 26,11 | 1,98 | 0,19038 | 0,38363 | 4,66 |
| 5 | 33,60 | 2,67 | 0,00 | -0,14453 | 0,23910 | 2,90 |
| 6 | 35,61 | 2,00 | 0,00 | 0,01424 | 0,25335 | 3,07 |

**Fig. 8.** L1 pipeline report

## Calculation of pipe in configuration series

The pipes from the transport simulator are able to be connected in series. From all six pipelines, there results one pipe with the length of all added up. For the calculations of this pipe the same software is used. Figure 9 presents the simulation results for pipes in configuration series.


**Fig. 9.** Hydraulic slope and Pipeline profile for configuration series

The report is generated based on the data entered in a single text file by adding the lengths of the six pipes. At the serial configuration one will observe the same pumping flow rate, not different for each pipeline as resulted from the calculations for each pipeline in part.

Debitul Q = 0,900 [mc/h]

D ext. = 26,700 [mm] D int. = 18,900 [mm] Gros. perete = 3,900 [mm]

Viteza reala = 0,89 [mm] Re = 6871,4 Coef. de rezistenta hiraulica lambda = 0,037937

| | L cum. [m] | DL [m] | H [m] | Dp [bar] | DpCum[bar] | DHCum[m] |
|---|---|---|---|---|---|---|
| 1 | 0,00 | | 0,00 | | | |
| 2 | 1,98 | 1,98 | 0,00 | 0,01328 | 0,01328 | 0,16 |
| 3 | 4,83 | 2,85 | 1,93 | 0,17793 | 0,19122 | 2,32 |
| 4 | 30,94 | 26,11 | 1,98 | 0,17939 | 0,37061 | 4,50 |
| 5 | 33,60 | 2,67 | 0,00 | -0,14565 | 0,22496 | 2,73 |
| 6 | 35,61 | 2,00 | 0,00 | 0,01340 | 0,23836 | 2,89 |
| 7 | 37,59 | 1,98 | 0,00 | 0,01328 | 0,25164 | 3,05 |
| 8 | 42,42 | 4,83 | 1,93 | 0,19122 | 0,44285 | 5,37 |
| 9 | 73,08 | 30,66 | 1,98 | 0,20986 | 0,65271 | 7,92 |
| 10 | 106,40 | 33,32 | 0,00 | 0,05959 | 0,71230 | 8,64 |
| 11 | 141,73 | 35,33 | 0,00 | 0,23648 | 0,94879 | 11,51 |
| 12 | 143,71 | 1,98 | 0,00 | 0,01328 | 0,96207 | 11,68 |
| 13 | 148,54 | 4,83 | 1,93 | 0,19122 | 1,15328 | 14,00 |
| 14 | 178,92 | 30,38 | 1,98 | 0,20798 | 1,36126 | 16,52 |
| 28 | 461,88 | 4,83 | 1,93 | 0,19122 | 3,25083 | 39,45 |
| 29 | 491,42 | 29,54 | 1,98 | 0,20236 | 3,45318 | 41,91 |
| 30 | 523,62 | 32,20 | 0,00 | 0,05209 | 3,50528 | 42,54 |
| 31 | 557,83 | 34,21 | 0,00 | 0,22899 | 3,73426 | 45,32 |

**Fig. 10.** Report for series connected pipes

The software can perform calculations for the parallel configuration of pipelines, or any system configuration.

## Conclusions

The stand for the transport of crude oil through pipelines is a useful tool because it allows the analysis of the phenomena that occur in real transport networks in Romania.

The complex data acquisition and control system allows the simulation and study of no stationary phenomena in crude oil transport systems through pipelines.

The stand is also a powerful tool that allows defining the operating regimes and training of specialists in the field.

## References


1. Albulescu, M., Eparu, C. - *Cercetări teoretice şi experimentale privind transportul produselor petroliere în regim neizoterm*, Buletinul Universităţii Petrol-Gaze din Ploieşti, vol. VII, Seria tehnică, nr. 2/2005, p. 161
2. Eparu, C.: *Cercetări privind fenomenele termo-hidrodinamice specifice curgerii ţiţeiurilor vâscoase prin conducte,* Teză de doctorat, Ploieşti, 2009
3. Neacşu, S. - *Termotehnică şi maşini termice*, Editura Printeh, Bucureşti, 2009
4. Pătărlăgenu, M., Neacşu, S. - *Posibilităţi de reducere a consumului energetic de transport în cazul curgerii neizoterme a produselor petroliere prin conducte*, Industria de Petrol şi Gaze. Prezent si Perspectivă, Ploieşti, 1992, Vol. Energetică, p. 111
5. Oroveanu, T., David, V., Stan, Al., Trifan, C. - *Colectarea, transportul, depozitarea şi distribuţia produselor petroliere şi gazelor*, Editura Didactică şi Pedagogică, Bucureşti, 1985
6. Trifan, C., Albulescu, M., Neacşu, S. - *Elemente de mecanica fluidelor şi termodinamică tehnică*, Editura U.P.G., 2005, Ploieşti.


# Stand experimental pentru simularea transportului ţiţeiului prin conducte

## Rezumat


*În urma diverselor problemele apărute pe sistemele reale de transport ţiţei din România în cadrul laboratoarelor din Universitatea Petrol-Gaze din Ploieşti s-a construit un stand pentru simularea transportului ţiţeiului prin conducte. Pe acest stand se pot face simulări pentru diverse scenarii apărute în sistemul real. Lucrarea prezintă simulatorul pentru transportul ţiţeiului prin conducte şi unele rezultate obţinute cu acesta pentru cazul în care conductele sunt legate în serie.*