# Modernizing the leak-detection system for MOL's oil-products pipelines - Part 2

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IN PART 1 OF this paper, published in the September issue, the author introduced MOL's pipeline network, and went on to describe in detail the company's licensing, operational, and safety requirements. Part 2 begins with a description of the company's new approach to a leak-detecton system (LDS) which has now been installed on a section of the network.

## MOL's new LDS for oil-product pipelines

The new LDS is the final stage of the 'Operational system for oil product pipelines' modernization project. It includes the pipeline system SCADA function, batch tracking and recording of transported oil products, monitoring the system infrastructure, and leak-detection modules.

Key features of the LDS project:

- introducing new leak-detection algorithms, and improving the accuracy of currently used ones;
- installing new, faster and more accurate *Foundation Fieldbus* pressure sensors at all stations.
- using new measuring instruments to determine the temperature profile along the entire length of the pipeline;
- nstalling new Coriolis flow meters in DN200 pipelines at Szajol receiving station and DN300 at Tiszaújváros (Fig.1) (Coriolis flow meters are used to determine the mass flow rate);
- integrating into the system additional isolation stations at Mezőszentgyörgy and Iregszemcse (Fig.2) in order to obtain a greater quantity of data about the pipelines;
- replacing out-of-date time servers with more precise and modern models;
- replacing time markers of the 16-bit analogue-to-digital converter with PLC modules supporting the 32-bit *OMNI Flow* communication;
- improving the system's level of reliability in various ways, and upgrading batch tracking and calculation of oil-product transportation in accordance with the necessary requirements.

## Defining the requirements for leak detection

Taking into account the assessment of LDS technologies (Table 1) and the existing conditions, an expert team has prepared a SCADA system project with a high level of availability, developed to account for the pipelines' operational regime. These system works in parallel with independent algorithms, which provides a high level of availability and reliability in the new LDS. The pressure-wave method (PWM) acts as the main way of detecting third-party interference, since:

in combination with other methods (PDM, VBM, DMRT) it provides an optimal solution from the point of view of cost-quality ratio, as well as corresponding

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| | RTTM | Statistical analysis (SA) | Negative pressure (NP) | Fibre optic (FO) |
|---|---|---|---|---|
| **LDS principle** | Hydraulic simulation and analysis of difference between measured and calculated values | Statistical analysis of volume balance and pressure | Analysis of rarefaction wave generated by a leak | Distributed sensing of temperature, noise / vibration or hydrocarbons |
| **Application requirements** | Measurements of ambient temperature, density or gas composition in addition to flow, pressure, temperature; SCADA and communication | Measurement of flow and pressure; SCADA and communication | Measurement of pressure, dedicated data acquisition equipment and communication | Installation of proprietary fibre optic sensing cable |
| **Fluid application** | For gas and liquid pipelines, onshore and offshore | For gas, liquid and multiphase pipelines onshore and offshore | For gas, liquid and multiphase pipelines onshore and offshore | For gas, liquid and multiphase pipelines, mostly onshore |
| **Reliability** | Medium, depending on model performance | High, designed to minimise false alarms | Low to medium, depending on tuning and system | Low to medium, depending on environmental factor and leak effect |
| **Sensitivity** | Low to medium due to difficulty in maintaining high accuracy models | Medium | High, detecting small leaks and thefts quickly | Very high, detecting small leaks quickly |
| **Robustness** | Medium, loss of function due to missing data, slack flow or transient operations | High, can still detect leaks even if some instruments fail. Works under steady state, transient and shut in conditions | Medium, loss of function if pressure sensors are not available. Works under steady state, transient and shut in conditions | Low; may not detect leaks if cable is cut or if the hole is not located near the cable. Works under steady state, transient and shut in conditions |
| **Leak location accuracy** | Low | Medium | High, down to 100s of metres | Very high, down to 10s of metres |
| **Calculation of leak size** | Yes | Yes | Yes, accurate only after leak calibration tests | No |
| **Installation cost*** | High | Medium | Low | Very high if cable is to be installed |
| **Maintenance cost** | High, expert tuning required | Medium | Medium | Medium |
| **Remarks** | Suitable for existing and new pipelines if flow, pressure, gas composition / density and ambient temperature measurements are available | Good track record on both gas and liquid pipelines.<br><br>Suitable for existing and new pipelines. | Requires pressure sensors only.<br><br>Suitable for existing and new pipelines. | DAS / DVS can be used for intruder detection.<br><br>Difficult test the performance.<br><br>Difficult to retrofit. |

*Installation cost has assumed that no field instruments exist on the pipeline. The cost for RTTM and Statistical systems would be reduced if field instruments are already in place.

***Table 1. Comparative characteristics of pipeline leak-detection technologies (DMRT, SA, NP, and FC) [3]. (Note: (DAS – distributed acoustic sensing; DVS – distributed vibration sensing.)***

to the work scheme to which the operators are accustomed the LDS is part of a general system and interacts with a module for calculating Excise data, a module for batch tracking, and SCADA functions of process management it is important to establish a reliable LDS (Figs 4 and 5).

Thus the main elements and the basic specification for the new system are as follows:

- the principal method is PWM in conjunction with PDM (pressure-drop method), VBM (volume-balance method), and DMRT (dynamic modelling in real time)
- leak sensitivity:
- in closed conditions (without transportation): 3-15 l/min
- with transportation: 10-40 l/min
- leak localization accuracy: ±120 m in 0.1 sec with accurate time markers.

| No. | Location | Permissible number of errors and outages | Availability |
|---|---|---|---|
| 1 | Tiszaújváros | 3 errors - 24 hours / year | 99.73% |
| 2 | Szajol | 3 errors - 24 hours / year | 99.73% |
| 3 | Szőny | 3 errors - 24 hours / year | 99.73% |
| 4 | Pécs | 1 error - 8 hours / months | 99.00% |
| 5 | Székesfehérvár | 1 error - 8 hours / months | 99.00% |
| 6 | Csepel | 1 error - 8 hours / months | 99.00% |
| 7 | Ferihegy | 1 error - 8 hours / months | 99.00% |
| 8 | Kecskemét | 1 error - 8 hours / months | 99.00% |
| 9 | Nyírbodány | 1 error - 8 hours / months | 99.00% |
| 10 | Supply station, Százhalombatta | 1 error - 8 hours / months | 99.90% |
| 11 | Isolation stations | 6 errors - 48 hours / year | 99.45% |

***Table 2. Expected availability of the pipelines.***

The accuracy depends on the pipe diameter, the length of the section, the position of valves, and distance between pressure sensors. Exact values were determined separately for each section.

Some technical characteristics of the PWM used [8] are presented below:

- resolution of pressure measurement: ≈ 1mbar at 63 bars
- total sampling time: 100 ms
- process 'noise' during operation:
- during work (pumping): ≈ 15 mbar

***Table 3. Specification of minimal leak detection for a section of the Százhalombatta-Szőny pipeline.***

| Part of section (between two adjacent stations) | Diameter, mm | Length, km | Volume, $m^3$ | Minimal sensible leakage, l/min | | |
|---|---|---|---|---|---|---|
| | | | | Shut-in/static condition | | Under operation (entire section is open) |
| | | | | Shut-in condition (between two adjacent isolated stations) | Entire section is open | |
| Százhalombatta-Szőny DN150 | | | | | | |
| 1201-1501 | 200 | 17.9 | 562 | 1.2 | 5 | 15 |
| 1501-1701 | 150 | 24.8 | 438 | 1 | | |
| 1701-1702 | 150 | 16.8 | 296 | 0.7 | | |
| 1702-7000 | 150 | 26.4 | 466 | 1 | | |
| Százhalombatta-Szőny DN300 | | | | | | |
| 1201-1501 | 300 | 18.4 | 1 300 | 3 | 10 | 30 |
| 1501-1701 | 300 | 24.8 | 1 753 | 4 | | |
| 1701-1702 | 300 | 16.9 | 1 194 | 2.7 | | |
| 1702-7000 | 300 | 26.3 | 1 859 | 4.3 | | |

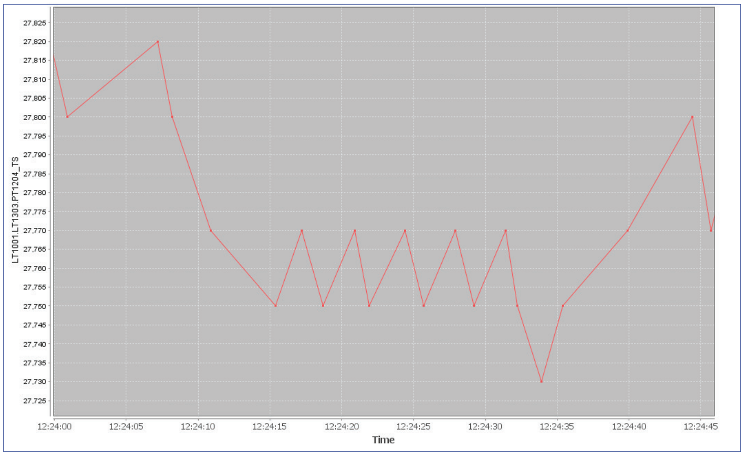


***Fig.9. Resolution of pressure measurement (vertical axis indicates pressure in the pipeline), bar.***

- in a closed state: ≈ 1mbar
- the use of highly productive standard components:
- full digital transmitters,
- without ADC (analog-digital converter), 32-bit resolution FF (*Foundation Fieldbus*) PLC circuit board (≈ 1 mbar),
- time of PLC FF cycle – 100 ms

Some important aspects of the technical content of the EPC contract:

After carrying out the tender, the MOL company signed an EPC contract with a contractor (engineering, procurement and construction).

The *PipeMan* (Slovakia) LDS monitors all sections of the MOL's oil product pipelines. However, its sensitivity level has proved to be lower than expected in the majority of sections with the exception of the Tiszaújváros-Százhalombatta pipeline for benzene and toluene transportation. The reduction in sensitivity is due to the low frequency and quality of the data received, which is limited by the installed instruments and the remote terminals (RT).

One of the aims of the project was to improve the effectiveness of PWM, providing the very best productivity of LDS with a reasonable investment cost. Among other aims one could mention the improvement of leak-detection methods as a whole.

Besides this, the project includes the replacement of the main equipment, as well as functions directly impacting the availability of pressure measuring sections. The facilities are equipped with no-break power sources (NBP), as well as with RT containers and boxes.

Table 2 displays the expected levels of availability for various pipelines.

In the previous system, pressure together with other analogue signals is converted into digital format before processing by PLC, SCADA, and LDS. The resolution of pressure data is presented as the minimum detectable change in pressure. Currently, data from all LDS pressure sensors (with the exception of the butane-transport pipeline) are provided with minimum resolution of 20-30 mbars (Fig.9).

Because the resolution of pressure data is one of the most important factors, directly influencing the sensitivity of the PWM, every pressure transducer in the LDS has been replaced together with RTs, which collect data from the transmitters. Figure 10 presents the new expected pressure resolution: after replacement, it is 4 mbar.

The actual sensitivity depends on the diameter and extent (volume) of the pipeline section under investigation. For each section, minimum detectable leaks were calculated with 4-mbar resolution, based on the following assumptions:

- the leak causes a drop in pressure up to values two times lower than the minimum resolution of pressure measurement at all installed sensors
- hydraulic 'noise' in the pipeline (caused by pumps, valves, etc.) and electronic 'noise' are lower than the expected minimum change in pressure
- the section is isolated (a closed state) and is under pressure (the pressure in any part of the section is higher than 10 bar).

Table 3 presents an example of these characteristics.

Replacing RT for collection of pressure data makes it possible to achieve sweep frequency of 100 ms. Since the average speed of sound propagation in oil products is approximately 1,200 m/s, the given accuracy of ± 120 m (see above) will also be met.

The expected collection of high-resolution pressure data has not been possible due to the existing technical limitations of RTs. Therefore it has been necessary to replace RTs, while observing the following conditions:

- installing new transmitters at existing sections: 42 items
- installing new transmitters at new sections: 6 items
- replacing transmitters at existing sections: 162 items
- installing new telemetric RTs: 4 items
- replacing telemetric RTs: 68 items.

Further modernization measures include:

- improving the availability level of RTs at all isolation stations
- installing intelligent pigs
- upgrading the *PipeMan* batch-tracking system
- upgrading the module for calculating the transportation of oil products in accordance with new rules
- expanding the supervision system for all isolating valves and terminal/receiving stations by installing IP (inter-network protocol) video cameras at all sections
- increasing the quantity of clients of the *Fast/Tools LOGIR* SCADA platform for the oil product pipeline operation system (OOS)
- unifying the system for monitoring the state of isolation stations
- distance monitoring of the temperature of IT-infrastructure at terminal/receiving stations.

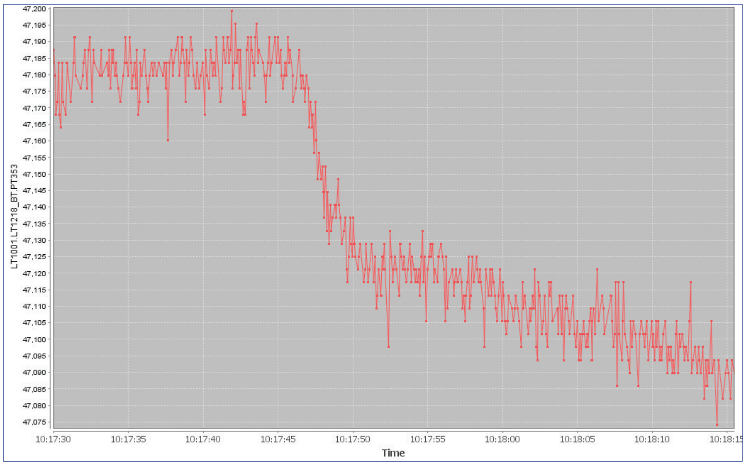


***Fig.10. The resolution of new pressure measurement (vertical axis indicates pressure in the pipeline), bar.***

## The test procedure

The principal aim of carrying out tests is to confirm that the LDS transmits a signal in the case of a liquid leak. One more aim is to check the signalization in the case of faults and in conditions of incorrect operation.

The choice of methods and parameters for testing depends on the operating conditions in the pipelines. Testing was 'announced' and conducted by extracting a controlled quantity of liquid from the pipeline ('announcing' the testing implies notifying the pipeline controller and exclusively testing the LDS).

The PWM tests were mainly carried out at isolation stations, but also directly at pipeline sections. Each subsequent test was performed with a lower leak-flow rate until the detection limit was reached. The PDM tests were conducted in closed conditions. The PWM tests were conducted in closed conditions and in a pumping regime. (Tests of the DMRT and VBM also counted on the volume of liquid leaking being around 1 $m^3$ in real operating conditions. The minimum detectable leak flow rate was approximately 1.5 % of the nominal flow rate.)

Before the test results began to correspond to set expectations, multi-stage accurate adjustment and tuning of the system was necessary. During testing it became clear that the GPS coordinates of some pipelines were not accurate. As a result, the location of the leak was also calculated incorrectly, and the values were indicated beyond the limits of the previously established parameters. However, in those pipelines where mapping was carried out at the same time as diagnostic studies, the accuracy of calculating leak location was found to be within the limits of the expected parameters. In future after carrying out inspections (using intelligent pigs), accurate measurements and mapping will be performed in every case, and the relevant information will be updated in the system's database. When the tests were being planned and carried out, API Recommended Practice 1175 and 1130 were observed.

## Conclusions

The introduction of a new LDS became a real test for the pipeline operators. It was necessary to find a balance between the high technical factors, the investment expenses, and other particular conditions. There is no such thing as an ideal technical solution.

It was necessary to introduce a new system for the MOL because the previous system was out-of-date, and its operation was accompanied by a multitude of shortcomings.

Taking into account the advantages and disadvantages of currently existing technologies, pipeline characteristics, and operating conditions, the expert team took the decision to use PWM as the basic principle, and determined new design factors for the system's effectiveness. According to test results, the new system has justified calculated expectations of effectiveness, which indicates the given method has achieved its technical limit.

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## References

1. Performance of European cross-country oil pipelines. Statistical summary of reported spillages in 2014 and since 1971. Report no 7/16 Concawe reports. Available from: www.concawe.eu [accessed 16 Jan., 2017].
2. Product theft from oil pipelines. Concawe review [online] (25)1. Available from: www.concawe.eu [accessed 16 Jan., 2017].
3. J.Zhang, A.Hoffman, K.Murphy, J.Lewis, and M.Twomey, Review of pipeline leak detection technologies. PSIG-1303 In: PSIG Annual Meeting, Prague, Czech Republic (2013).
4. S. Scott and M.Barrufet, Worldwide assessment of industry leak detection capabilities for single & multiphase pipelines, Tech. rep. Dept. of Petroleum Engineering, Texas A&M University (2003).
5. API Recommended Practice 1175. Pipeline leak detection – program management. API, Washington DC (2015).
6. J. Zhang, A.Hoffman A.Kane and J.Lewis, Development of pipeline leak detection technologies. 10th International Pipeline Conference, Volume 1: Design and Construction; Environment; Pipeline Automation and Measurement, ASME, Calgary, Canada, (2014).
7. API Recommended Practice 1130. Computational pipeline monitoring for liquid pipelines. API, Washington DC, (2012).
8. F.Péterfalvi and Sz.Szelmann, New software based leak detection system in a brownfield environment. 11th Pipeline Technology Conference, Berlin (2016).