Modernizing the leak-detection system for MOL’s oil-products pipelines - Part 1

by F. Péterfalvi
MOL Group, Budapest, Hungary

Leak-detection systems (LDS) have become a standard component of pipeline-management systems. There are various reasons which may prompt the pipeline operator to introduce or modernize the LDS. It became necessary to introduce a new system for the MOL company’s pipelines because the previous system was out-of-date, and its operation was accompanied by a multitude of shortcomings.

This article examines the real experience and long practical search carried out by MOL’s logistics department, thanks to which effective LDS functioning could be provided for pipelines which had been in long-term operation. Having considered the advantages and disadvantages of current technologies, pipeline characteristics, and operating conditions, the decision was taken to apply PWM (the pressure-wave method) as the basic method for detecting leaks. New LDS efficiency design factors were identified. Test results show that the new system has justified the calculated expectations for efficiency.

Key words: operation control system, leak-detection system, pressure-wave method, efficiency factors, pressure measurement, resolution

The MOL oil-products pipeline system

The first oil-product pipeline (DN150) was constructed in 1965 between Dunaiiski petroleum refinery in Százhalombatta and the petroleum depot at Szajol. The most-recent pipeline (DN200) was built in 2007, connecting the chemical plant in Tiszaujváros (today the petrochemical enterprise MOL Petrochemicals) and Százhalombatta, and providing transportation for benzine and toluene fractions. Most of the country’s currently existing pipeline system, with length of 1278km, was built over a single decade, starting from 1965. The average age of the pipelines is about 40 years. There are high-pressure sections, with design pressure of 64 bar. The main function of the pipeline system is to consistently pump batches of various semi-finished products and completed oil products, which is accomplished on the basis of direct contracts.

In order to guarantee a high level (around 99%) of availability in the pipeline system, MOL employs the best industry practices. The company is introducing modern inspection methods: in-line inspections (ILI) of every section of pipeline are carried out using intelligent pigs. Based on the results of these inspections, plans are developed for renewing future manufacturing parameters.

Complex operation of the pipeline...
system is ensured thanks to the use of an OCS (operational-control system), which includes the SCADA (supervisory control and data acquisition) function. Pipelines are equipped with active and passive cathode protection. There is a reliable fibre-optic connection between terminals, based on WAN (wide-area network) technology. This connection has isolation stations which are supported by two independent GSM providers. In total, there are 57 isolation stations and seven underwater crossings.

Figure 1 presents a map of the oil-product pipelines, while Fig. 2 shows the same system, but with isolation stations (by section).

Licence to operate, safety and operating requirements

The rules for granting authorization for operation, as well as several operational requirements and safety requirements are set down in Hungarian and international law:

Hungarian legislation

All aspects are explained in Act XLVIII on Mining, 1993.

Industry standards and regulations, establishing safety requirements for high-pressure pipelines used in hydrocarbon transportation, are based on Decree No. 79/2005 of the Hungarian Ministry of Economics and Transport.

Specified detailed instructions were formulated within the framework of the system of technical safety management. A company which receives authorization for the given type of activity is also required to develop its own instructions. The Mining
Office will be responsible for assenting to these, and checking that they are observed.

International law

Computational pipeline monitoring for liquid pipelines, in accordance with American Petroleum Institute (API) Recommended Practice 1130, was confirmed in April 2012.

Pipe leak detection: programme management, in accordance with API Recommended Practice 1175, first edition, December 2015.

Background

In view of the increased quantity of illegal intrusions into pipelines in the mid-1990s (including tappings), the position and condition of the Hungarian pipeline system became critical. An international tender for constructing a leak-detection system did not provide results, because leading Western companies did not have available experience of working with illegal tappings.

In the end, Cason Engineering plc, a small Hungarian technological firm, together with MOL experts, developed a fundamentally new leak-detection system (LDS) for pipelines. The system functions on the principle of duplicate measurement of pipeline pressure. Data are transferred to the supervisory centre, where they are used to calculate the location of the leak with the help of a special algorithm, as well as to calculate the volume of leaking liquid.

The introduction in 1998 of the new LDS led to a sharp reduction in the number of illegal tappings in MOL’s oil-product pipelines (Fig.3).

The current situation: why should the system be modernized?

Internal reasons

Internal and external inspection of the LDS has revealed a range of shortcomings in its software and hardware components, such as:

- problems synchronizing data between the system and the computer calculating flow of transported liquid;
- frequent faults and hang-ups in the working terminals of the operators;
- the use of inappropriate programmable-logic controllers (PLCs), as a result of which incorrect values are given for the duration of production cycles and data formatting. Remote
monitoring of production processes also fails;
- database servers and versions of MS Windows operating system belong to different generations, as a consequence of which the quality and stability of work is reduced;
- unreliable accuracy of operation of the LDS, which is attached to out-of-date, inaccurate, slow, analogue, measuring instruments and transmitters for pressure parameters, as well as the absence of flow meters;
- the operating system is vulnerable to outside interference and hacker attacks;
- the use of databases with different generations of structured query language (SQL).

These shortcomings were linked to the absence of timely and appropriate support for the LDS. Although expenditure on system maintenance constantly grew, the system was nevertheless unable to meet the necessary technical parameters.

Therefore in recent years the LDS has turned into a fragmented and varied structure.

External reasons

Concawe identifies five underlying reasons for liquid leaks (with the exception of theft) from high-pressure pipelines: mechanical failure in the pipe; operational errors; corrosion of metal; natural causes; and third-party activity [1].

As is shown in Fig.5, the LDS plays a defining role in detecting and identifying leaks or spillages of the transported liquid [2].

Leaks can lead to serious consequences, in that they present a threat for people, cause damage to the environment and property, undermine the reputation of the

Fig.4. Distribution of primary and secondary spillage causes – all pipelines [1].
operating company, and entail additional expense associated with the responsibility of carrying-out cleaning and repair works, as well as fines imposed by ecological supervisory agencies.

Developing and introducing a reliable, highly-sensitive, and accurate LDS that is also convenient in use and detection is therefore of great significance for pipeline transport companies.

An overview of leak-detection technologies

When choosing from the wide range of LDSs, operators can be guided by various physical principles; pipeline parameters and operational requirements can help to narrow-down the choice.

There are various classifications for the methods and technologies of pipeline leak detection. Figure 6 shows an overview presented by Zhang and a group of co-authors to the PSIG (Pipeline Simulation Interest Group) at its annual meeting in 2013 [3]; Fig.7 presents the classification drawn up by Scott and Barrufet from the Texas A&M University [4]. According to the latest classification given by the API (American Petroleum Institute), leak-detection methods can be divided into two basic groups: continual and periodical [5].

In practice, each LDS has its own strong
and weak points, which depend on the characteristics of the system, actual usage, leak-detection method, degree of development of technology and pipeline complexity.

A brief description of pipeline leak-detection technologies

**Fibre-optic cable** (FC): leaks can be detected through identifying temperature changes or mechanical vibrations in the FC zone, since they impact changes in the cable’s optical properties.

**Gas-sensing pipe**: if the product inside the pipeline is highly volatile, samples of gas for hydrocarbon content are taken from a perforated pipe of small diameter, laid along the entire length of the pipeline. Sensors for detecting hydrocarbon fumes may also be used as portable instruments.

**Cable for detecting liquid leaks**: this is a special cable which reflects changes to electrical properties on contact with the liquid hydrocarbon [6].

**Acoustic devices**: any leak makes a noise signal, which is picked up by acoustic sensors installed on the outside of the pipeline.

**Infrared camera**: this is used for detecting hydrocarbon fumes over the pipeline, as well as abnormal drops in temperature of the soil or the pipe on account of evaporation of the pumped liquid.

**Soil monitoring**: leaks are identified by analysing the concentration of fumes in the soil surrounding the pipeline.

**Ultrasonic flow meter**: this works according to the principle of directional signal, expressed in the form of an axial sound wave which is directed at the pipe wall.

**Volume-balance method (VBM)**: this assumes a measurement of imbalance between two sections of pipeline.

**Analysis of the distribution of pressure points – pressure-drop method (PDM)**: this allows leaks to be detected through comparing the current signal from the pressure sensor with the data taken over a set period. The values of pressure or flow changes are compared with values under normal operating conditions.

**Dynamic model in real-time (DMRT) / dynamic-modelling method (DMM)**: These methods create a mathematical model of liquid flow in the pipeline. The following equations are used to model the flow: the law of conservation of mass and momentum, and the equation of state for the liquids. Leaks can then be detected by comparing measurements values with values calculated using the model.

**Statistical analysis (SA)**: a conclusion about spillage of raw material is made on the basis of statistical analysis of various signals from the pipeline. Parameters such as flow rate, pressure, and temperature are used.

**Negative pressure wave (NP) / pressure-wave method (PWM)**: a pressure wave formed as a result of the
leak spreads up and down relative to the leak location. Spillage can then be determined by analysing the data for pressure, transmitted at high speed.

**Basic productivity indices**

**Reliability**

Reliability is defined as an index of the capability of the LDS to produce accurate information about the possible presence of a leak in the pipeline. It follows from this that reliability is directly connected to the probability of detecting leaks, taking into account the fact that a leak really exists; and the probability of a false leak identification, where a leak has not occurred. The system is considered more reliable if it is able consistently to identify leaks without creating false notifications. And vice versa: a system which has a tendency to report false leaks is often considered less reliable [7].

**Sensitivity**

Sensitivity is defined as a complex index of the volume of the leak which the system is able to detect, and the time the system needs to raise the alarm if such a leak should arise [7].

**Accuracy**

The idea of this index is closely linked to the concept of leak detection and reporting, but does not take into account certain additional data which may accompany a leak warning. Despite the fact that the volume and character of such data may vary depending on the company, the index usually includes an evaluation of the following leak parameters: leak intensity, total volume of loss, type of liquid lost, and location of leak in the pipeline network, given certain pipeline parameters. The correctness of evaluations of parameter data is the third index of productivity, known as 'accuracy' [7].

**Stability**

Stability is defined as an index of the LDS’s ability to continue functioning and providing useful information even under changing conditions of pipeline operation, in conditions of data loss or in the case of unreliable information. A system is considered stable if it continues to function in conditions far from ideal. On the other hand, if the system disconnects certain functions, in the future great reliability may be achieved, but all the same the system will be considered ‘unstable’ [7].

Other parameters, such as calculating the volume of the leak, the cost of installation and maintenance of the LDS, etc., may also be taken into consideration.

**A comparison of various LDSs [3]**

Table 1 depicts the comparison according to various principles of four of the above-mentioned technologies: DMRT, SA, NP, and FC. As can be seen from the data, none of these technologies could be described as perfect. Their profitability and productivity depend on operational characteristics, type of transported liquid, the route of the pipeline, operational conditions, external conditions, and the legal and regulatory environment.

**Significant elements of the LDS [8]**

The architecture of an efficiently functioning LDS is shown in Fig.8. All systems are based on control and measuring instruments, while the system’s main elements can be listed in the following order:

- functioning of control and measuring instruments
- possibilities of PLC (programmable
logic controller) / RT (remote terminal)
• communication lines
• time synchronization
• SCADA system
• the algorithm for leaks detection
• the interface.

The important elements of PWM are described in detail below [8].

• Properties:
  • wave propagation at the speed of sound in the medium (oil or oil-products): 1200-1300 m/sec.
  • all stations must be synchronized by time: PLC / RT, SCADA, and LDS servers (as a general rule, 1ms Dt leads to error of approximately 1m when determining the location of the leak)

• Influential components:
  • GPS (global-positioning system) time server (> 1ms)
  • setting of time markers PLC / RT (> 10ms)

• Data collection:
  • frequent (short scanning time) high-resolution measurement of pressure
  • integration and interaction of PLC-SCADA-LDS systems

• Leak-detection technology:
  • LDS algorithm with emphasis on helper methods, sensitivity, enlarged filtering and methods of compatibility with events
  • manual analysis of the dynamics of pressure change.

In Part 2 of this paper, to be published in the December issue of Pipeline Science & Technology, the author describes in detail MOL’s new LDS for its oil-product pipelines and the conclusions drawn from this important project.