Most of the existing leak detection systems are based on the analytical methods. The telemetric data from the pipeline system (flow rates, pressures, temperatures) is continuously compared with the mathematical model of the system. The analysis of the differences between the model and the real pipeline (so called residuum) enables the leak detection and localization.

The residuum is usually expressed as the difference between measured pressure \( p \) and calculated pressure \( p_{0} \).

The first question is: how to distinguish between a normal situation and the situation where the leak occurs?

The criterion can be:
- Uncertainty fields \( U(p_{0}) \) and \( U(p) \) do overlap - there is no reason to suspect the leak.
- Uncertainty fields \( U(p_{0}) \) and \( U(p) \) do not overlap - there is probability of the leak, and need to start localization procedures.

The uncertainties of the individual input quantities propagate as follows:

\[
U=(\sum_{i=1}^{n} A_{i} U_{i})^{2}
\]

Where

\[
A_{i} = \frac{\partial {p}_{i}}{\partial {p}_{0}}
\]

\[
U_{i} = \sqrt{U_{i1}^{2} + U_{i2}^{2} + ... + U_{in}^{2}}
\]

The sensitivity coefficients – sensitivity of the system to the leak. They tell us how much will change pressure in the nodes when the leak occurs.

We can assess and analyze this through calculation of another kind of sensitivity coefficients – sensitivity of the system to the leak coefficients. They can be calculated as partial derivative, i.e. for input quantity \( q_{n} \):

\[
A_{n} = \frac{\partial {p}_{n}}{\partial {q}_{n}}
\]

The uncertainties must be still related to the residuum (pressure change effect due to the leak). This effect depends on:
- the grid configuration,
- flow rate (rise with the rise of gas flow rate)
- and the localization of the leak (rise with the distance of the leak from the source).

We can assess and analyze this through calculation of another kind of sensitivity coefficients – sensitivity of the system to the leak. They tell us how much will change pressure in the nodes when the leak occurs.

For this purpose any commercial grid simulator can be used. The small leak is introduced to the simulator in subsequent points of the network and changes of the pressure in the various places of the grid are analyzed.

The examples of these “sensitivity to the leak coefficients” for a given gas network (in Pa/m^2/h) are presented nearby.

The uncertainty assessment of the measured pressure is rather simple, form the supplier data or calibration certificates. It must be however taken into account, that filtering or averaging of the data can improve this component.

The main uncertainty sources are: pressure measured at the inlet of pipe, flow rate and friction coefficient:

\[
U_{p} = \sqrt{U_{p1}^{2} + U_{p2}^{2} + ... + U_{pn}^{2}}
\]

\[
U_{q} = \sqrt{U_{q1}^{2} + U_{q2}^{2} + ... + U_{qn}^{2}}
\]

\[
U_{\lambda} = \sqrt{U_{\lambda1}^{2} + U_{\lambda2}^{2} + ... + U_{\lambda n}^{2}}
\]

The presence of the leak 
\[
\Delta p = p_{0} - p
\]

The uncertainty of the calculated pressure depends on the uncertainties of all the input quantities as follows:

\[
\Delta p = \sum_{i=1}^{n} A_{i} U_{i}
\]

The sensitivity coefficients \( c \) have to be taken into account, they can be calculated as partial derivative, i.e. for input quantity \( q_{n} \):

\[
\frac{\partial {p}_{n}}{\partial {q}_{n}} = c_{n}
\]

The main uncertainty sources:

1. The sensitivity of the system is better for higher flow rates.
2. Pressure is proportional to the square of flow rate, so the same leak \( \Delta q \) at higher flow rates induces much higher pressure changes.
3. The effects of the leaks are higher when the leak is located at greater distance from the source.

The residuum must be less than the sum of uncertainties.

\[
\Delta p < U_{p} + U_{q} + U_{\lambda}
\]

This alarm criterion can be in mathematical form written as

\[
\frac{\Delta p}{p_{0}} < \frac{U_{p}}{p_{0}} + \frac{U_{q}}{q_{n}} + \frac{U_{\lambda}}{\lambda_{n}}
\]

The uncertainty assessment is the main part of the localization systems. The telemetric data from the various points of the grid are analyzed. The leak detection and localization are performed as a result of this analysis.

Some examples of these "sensitivity to the leak coefficients" for a given gas network are presented nearby.

The leak was located in station 17.

The method consist on comparison of the uncertainties of calculations and measuring instruments with the value of the residuum.

This methodology make it possible to assess the accuracy of the leak detection and localization system, depending on the leak localization and intensity and measuring instruments uncertainty.

It also enables to correctly match the accuracy of the measuring instruments to the desired accuracy of the system.

More general conclusions and procedures of system accuracy assessment will be the subject of the doctor thesis.