Justification for the introduction of in-line diagnostics technology for field pipelines

Yu N Savicheva, E I Nafikova, K S Davletchina and K Yu Sandyrev
Ufa State Petroleum Technological University, 1, Kosmonavtov street, Ufa, 450062, Russia

E-mail: elyanannet@yandex.ru

Abstract. The article discusses the problems of introducing the technology of in-line diagnostics in field pipelines of small diameters. The necessity of introducing optimized in-line diagnostics for oil and gas companies is substantiated. A description is given of the concept of creating in-tube defect indicators (IDI), based on the use of electromagnetic and galvanomagnetic converters with magnetization by a constant magnetic field.

1. Introduction
The market for in-line diagnostics services of field pipelines is formed by foreign firms or their Russian intermediaries. Russian producers of in-line diagnostics are oriented to work in the segment of trunk pipeline transport and are not yet interested in creation of devices for diagnostics of pipelines of small diameters. At the same time, it is the objects 114-219 mm in diameter that give 64% of the pipeline failure flow.

Nowadays, magnetic in-line inspection devices (IID) are traditionally used for diagnostic inspection of main and field pipelines. Along with good informativeness, their application is characterized by high inspection cost. The approximate price is about 3-4 thousand am. Dollars for inspection of 1 km of the pipeline route. Such prices are acceptable for periodic diagnostics of main pipelines transporting slightly aggressive products [1].

However, the situation is different when operating and diagnosing field pipelines. Maintaining their operability and safety requires reducing the time between repeated inspections by 2-3 times. But thus realization of more frequent diagnostics, for example, combined with operations of passing of clearing devices (once or more times a year), is prevented by high price of diagnostic inspection, and the basic expenses are connected with invariable cost of mobilization in the presence of hundreds objects of control. At a low oil price, "traditional" in-line diagnostics of field pipelines becomes unprofitable in many cases, and its absence leads to increased risk of accidents and losses. Availability of in-line diagnostics technology is determined by its price balance with probable damage of pipeline depressurization, associated with their specific accident rate and length [2].

2. Magnetometric diagnostics
Over the past few years, production pipelines at Gazprom Neft’s assets have been actively equipped with small and relatively inexpensive start-up chambers designed to run treatment facilities. This circumstance made us take a fresh look at the possibility of developing diagnostics of small diameter
The presence of cameras is already half the battle. However, the length of the in-line inspection devices existing on the market today does not allow the use of small-sized cameras for their launch.

The disadvantage of in-line inspection devices for use on field pipelines was their complexity - some of the technical achievements incorporated in them remain unclaimed and redundant. Modern devices are able to detect thousands of anomalies in the pipes (alleged defects), of which only a few critical ones. Such efficiency in field pipelines is an excess that only makes the process more expensive.

As an alternative to in-line diagnostics, Gazprom Neft launched R&D to develop a device for external inspection of pipelines using the magnetometric method. During the control, the distribution of the intrinsic magnetic fields of the pipe, caused by the natural magnetization in the Earth’s magnetic field, is measured and analyzed. During operation of the pipeline, the magnetization changes in areas of maximum metal stress, including those caused by corrosion. It is these zones that can be detected by the magnetometric method [3-4].

The KBD-2 device developed for remote diagnostics was able to detect defects longer than 100 mm, i.e. brook corrosion. It can be successfully applied on pipelines not equipped with start-up chambers for in-tube shells [5-6].

![Figure 1. Tests of in-line defect indicators on the bypass stand of an existing oil pipeline.](image)

![Figure 2. Dependence of the intensity of the replacement of pipelines on the level of scanning with accurate diagnosis.](image)
Accurate diagnostics allow not only timely warning of a possible accident, but also significantly reduce the length of the replaced pipelines (Figure 2). Experience shows that up to 80% of the emergency pipeline can have sections with a residual life of 5–10 years. By identifying such areas, it is possible to exclude their premature replacement.

3. Technical implementation

In accordance with the terms of reference for the development, a choice was made of the concept of creating in-tube defect indicators based on the use of electromagnetic and galvanomagnetic transducers with magnetizing the object with a constant magnetic field, private specifications for the in-tube defect indicator units and software were developed and implemented, including, on-board electronics, battery measuring and magnetic system, section, navigation, control and telemetry subsystems, and that the software collection and interpretation of diagnostic data [7-8].

Figure 3. Distribution of the magnetic induction module in the model volume.

Considering the dimensional requirements specified in the technical specifications and the conditions for the passage of the nodes of the in-tube defect indicators, the type of magnetization was selected and the magnetic system was calculated: the most optimal configuration of the brushless magnetizing system under the given conditions was adopted. Computer simulation of the nodes of the in-tube defect indicators confirmed the possibility of creating the specified dimensions with the in-tube defect indicators. Figure 3 shows the distribution of the magnetic induction module in the volume of the magnetic circuit model.

Figure 4. Analysis of the distribution of the axial component of the magnetic field induction in the area of the sensors.
An analysis was also made of the distribution of the axial component of the magnetic field induction in the zone of the sensors (Figure 4), confirming the given level of magnetization of the pipeline.

**Figure 5.** Calculations and analysis of the effect of defects on the distribution of the magnetic field using a standard model.

**Figure 6.** Signal view when fixing the axial component of the scattering field.

Calculations and analysis of the effect of defects on the distribution of the magnetic field were carried out using the standard model shown in Figure 5. The characteristic form of the signal obtained in this case when the axial component of the scattering field is fixed, shown in Figure 5, confirms the level sufficient for its registration.

**Figure 7.** Drawing of the device IDI219.

According to the terms of reference, a set of design and operational documentation for a line of in-line defect indicators designed for diagnostic inspection of pipelines with a nominal diameter of 114, 159, 168 and 219 mm was developed. Figure 7 shows a drawing of the device IDI219. The on-board electronics are housed in a single design module in a compact design together with a power supply and are made at the modern technological level. In accordance with the design documentation the IDI prototypes were developed and conducted their bench and field tests.

4. **Scientific and practical value**

While performing research and development, the following original technologies were developed and scientifically proved to be unparalleled in Russia:

- devices that allow to carry out in-line diagnosis of small diameter pipelines, including 114 mm and 159 mm, using galvanomagnetic and eddy current sensors to register defects;
- magnetization systems without "brushes" and with the use of special «magnetic concentrators»;
• software allowing automatic search, identification and evaluation of pipeline defects.

Reliability of the received results is provided by correctly carried out calculations with use of methods of the theory of electric circuits and an electromagnetic field, application of methods of finite element modelling, experimental methods of acknowledgement of results of theoretical researches, experience of practical use developed IDI on objects.

Within the framework of the IDI project for the first time the intra-tube devices for diagnostic inspection of pipelines of small diameter from 114 to 2119 mm allowing to carry out inspection of pipelines with taps to 1,5D have been created and passed pilot tests, metrological certification of the IDI line has been carried out and certificates of conformity to Technological Regulations of the Customs Union on safety have been received.

5. Conclusion
The introduction of a set of defect indicators for pipelines with a diameter of 114–219 mm will complement traditional methods and will allow timely identification and elimination of defective areas in field pipelines. Thus, it will be possible to extend the life cycle of pipelines, reduce the cost of their operation, minimize the number of failures and reduce the burden on the environment.

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