



IMPROVING THE SYSTEM FOR MONITORING THE TECHNICAL OPERATION OF NATURAL GAS- CYLINDER BUSES

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ABSTRACT: *This article examines the monitoring of the technical operation of compressed natural gas (CNG) fuelled buses. The main factors affecting the reliability of gas-cylinder equipment and failure statistics are analysed. A structural scheme of a telematic monitoring system providing continuous observation of the technical condition of buses is proposed. The system includes pressure, temperature and gas-leak sensors, a data transmission module and a predictive maintenance algorithm. The results show that the implementation of the monitoring system allows optimising maintenance intervals, reducing the risk of emergency situations, and cutting operating costs by 12–18%.*

Keywords: *CNG bus, compressed natural gas, technical operation, monitoring system, gas-cylinder equipment, predictive maintenance, transport safety.*

INTRODUCTION

In recent years, converting the public transport system of the Republic of Uzbekistan to environmentally safer and more economically

efficient fuel types has become one of the priority directions of state policy. Because natural gas is cheaper than diesel and petrol, and because it produces far fewer harmful emissions into the atmosphere, the retrofitting of city buses to run on compressed natural gas (CNG), as well as the purchase of new gas-cylinder buses, is proceeding at a rapid pace.

However, the operation of gas-cylinder buses gives rise to specific technical-safety requirements. Gas cylinders kept under high pressure, pressure reducers, solenoid valves and other elements of the gas supply system require regular technical monitoring. Practice shows that faults in gas-cylinder equipment often go undetected in time, which can lead to increased fuel consumption, reduced engine power, and, in some cases, serious consequences such as gas leakage and fire hazard.

For this reason, creating a system for continuous, real-time monitoring of the technical condition of natural gas-cylinder buses is a pressing scientific and practical problem. The purpose of this article is to analyse existing methods of monitoring the technical operation of gas-cylinder buses and to develop a system that automatically monitors their technical condition.

LITERATURE REVIEW

Issues of the technical operation of gas-cylinder vehicles have been studied from various angles by foreign and local researchers. Much of this work focuses on the structural reliability of gas-cylinder equipment, methods for calculating cylinder strength, and maintenance regulations. At the same time, the number of studies devoted to monitoring systems based on telematics and Internet of Things (IoT) technologies, which allow remote observation of the technical condition of vehicles, is steadily increasing.

Analysis of existing work shows that the traditional inspection system - that is, maintenance performed according to a fixed time interval or mileage - does not fully reflect the actual technical condition of gas-cylinder equipment. On the one hand, this leads to the premature replacement of parts that still have remaining service life (resulting in unnecessary costs); on the other hand, it can lead to the later detection of emergency faults. This is why contemporary research recommends moving toward condition-based and predictive maintenance models, which form the scientific basis of this article.

RESEARCH METHODOLOGY

The following methods were used in the course of the research: a systematic analysis of maintenance and repair statistics for gas-cylinder buses operated by urban passenger transport enterprises during 2023–2025; classification of gas-cylinder equipment faults by type and a study of their causes; and a systems approach together with expert-assessment methods in developing the structural-functional model of the monitoring system.

The analysis was based on operational data for more than 120 gas-cylinder buses belonging to local motor transport enterprises, as well as the technical documentation of gas-cylinder equipment manufacturers. Faults were classified using a cause-and-effect (Ishikawa) diagram, which made it possible to identify the key parameters that the monitoring system needs to control.

ANALYSIS AND RESULTS

Classification of gas-cylinder equipment faults

According to the results of the analysis performed, the technical faults of gas-cylinder buses fall into the following main groups: pressure

drop and loss of tightness in the gas cylinders; freezing or malfunction of the pressure reducer and evaporator; faults of the solenoid valves and the control unit; and contamination of the elements that form the gas–air mixture. According to the statistical data, approximately 40 percent of these faults are related to disturbances in the pressure and temperature regime, and these can be detected in advance through sensor-based monitoring.

No.	Type of fault	Share, %	Monitored parameter
1	Pressure drop and loss of tightness (gas leakage)	27	Pressure, gas concentration
2	Freezing or malfunction of the pressure reducer/evaporator	22	Temperature, pressure
3	Faults of the solenoid valves and control unit	19	Voltage, current signal
4	Contamination of the gas–air mixture formation system	16	Lambda-sensor signal
5	Mechanical damage, loosening of fastening elements	10	Vibration, torque
6	Other causes	6	-

Table 1. Distribution of the main faults occurring in natural gas-cylinder buses

Structural-functional model of the monitoring system

Based on the results of the analysis, a three-layer system is proposed for continuous monitoring of the technical operation of gas-cylinder buses:

1) Sensor layer - pressure sensors installed on the gas-cylinder equipment of each bus (at the cylinder and at the reducer outlet), temperature sensors, gas-concentration sensors (in the passenger cabin and in the engine compartment), and a CAN-bus interface that reads the diagnostic signals of the control unit.

2) Data transmission and processing layer - a telematic controller integrated with a GPS/GLONASS module that transmits sensor data to the central server in real time via a mobile communication network (GSM/LTE).

3) Analysis and decision-making layer - software located at the central dispatch centre that automatically detects deviations of pressure, temperature and gas concentration from threshold values, predicts the probable cause of a fault, and dynamically generates the maintenance schedule.

An important advantage of the proposed system is that it does not merely perform an emergency-alarm function; on the basis of accumulated historical data it also makes it possible to estimate the remaining service life of the gas-cylinder equipment and to implement a predictive maintenance algorithm.

Economic and safety effectiveness

A preliminary analysis of the pilot-test results shows that implementing the monitoring system makes it possible to achieve the following outcomes: a 25–30 percent reduction in the number of unscheduled stoppages; a 12–18 percent reduction in operating costs owing to the optimisation of the time and resources spent on maintenance; and a significant reduction in the risk of emergency situations related to gas leakage, which is of major importance for ensuring the safety of passengers and drivers.

In addition, the data obtained from the monitoring system can also be used to improve the maintenance policy of vehicle fleets, to optimise the stock of spare parts held in reserve, and to assess drivers' style of vehicle use.

CONCLUSION

The results of the research conducted show that, in order to effectively manage the technical operation of natural gas-cylinder buses, it is expedient to move from the traditional scheduled-maintenance system to a condition-based monitoring system. The proposed three-layer (sensors - data transmission - analysis) monitoring model makes it possible to observe the technical condition of gas-cylinder equipment in real time, to detect faults at an early stage, and to organise the maintenance process on a predictive basis. This, in turn, serves to increase transport safety, reduce operating costs, and improve the technical-readiness coefficient of buses. It is expedient to direct future research toward applying machine-learning algorithms to the monitoring system and toward increasing the accuracy of predicting faults in gas-cylinder equipment.

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