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Adaptive information management system of dynamic monitoring of actual water content in jet fuel in technological processes of aviation fuel supply

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Abstract: Modern domestic and international standards, regulators of the aviation fuel industry, considering the negative impact of the presence of mechanical impurities and water in aviation fuel on the performance and life cycle of aircraft engines, fuel metering equipment, fuel systems of aircraft (A/C), as a threat factor for flight safety, impose high requirements for the purity of aviation fuel while operating aeronautical equipment. At the same time, the causes and sources of water content in jet fuel are a source of economic losses, the most important criterion for the success of the Aerodrome Fueling Complex business. The article considers the task of developing reliable and automated methods as well as technologies for controlling these contaminants, for example for determining water content in aviation fuel when refueling aircraft, and the necessity to minimize an effect of a human factor. The automation of aviation fuel quality monitoring processes, the transition from discrete control methods to continuous ones, from static control methods to dynamic ones (in-line), from indirect methods to direct ones are becoming relevant. The possibilities of end-to-end accounting and analysis of aviation fuel purity parameters at all stages of the aviation fuel life cycle are shown. The article considers the methods and conducts the analysis of known techniques and devices used to determine, measure and indicate actual water content, presence of dissolved, free and total water in jet fuel. The technical solution of continuous automated control of the actual water content level of the jet fuel flow in the processes of aviation fuel supply and aircraft refueling in an information system that provides on-line monitoring and dynamic measurement of the quantitative content of dissolved and free water in the jet fuel flow, is presented. The technical solution for the continuous determination of the quantitative water content in the jet fuel stream is proposed. At the same time, the solution of the problem of monitoring water content in jet fuel is combined with the technological process to control the purification of jet fuel from water. The paper represents an adaptive information management system for continuous monitoring of the water content level of the jet fuel flow, which will allow specialist to substantially increase a level of automatization of aircraft aviation fuel supply technological processes, decrease a negative impact of a human factor, increase economic effectiveness of the aviation fuel supply complex. The system is designed to carry out continuous, automated control (monitoring) of water content in the jet fuel flow at all the stages of the jet fuel movement: receiving, storing and delivering jet fuel and refueling aircraft, in particular fuel and lubricants warehouses (fuel and lubricants), refueling complexes and pre-apron filling points. It can also be used in the fuel system of the aircraft, as a system to prevent water content in the jet fuel. The integration of automation tools will enable us to improve the quality of management of aviation fuel supply and aircraft refueling to ensure timely operational decision based on real data in real time mode, provided the proposed system integration into the airport system for operational data exchange.

Key words: refueling complex, the actual water content in jet fuel, porous polyvinyl formal (PVFM), selective separation, coagulation, programmable logic controller (PLC), adaptive information management system, dynamic monitoring.

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Адаптивная информационно-управляющая система динамического мониторинга фактической обводненности авиатоплива в технологических процессах авиатопливообеспечения

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Аннотация: Современные отечественные и международные требования регуляторов отрасли авиатопливообеспечения, принимая во внимание негативное влияние присутствия механических примесей и воды в авиатопливе на работоспособность и ресурс авиадвигателей, топливорегулирующей аппаратуры, топливных систем воздушных судов (ВС) как фактора угрозы безопасности полетов ВС, предъявляют к чистоте применяемого при эксплуатации авиационной техники авиатоплива высокие требования. Вместе с тем причины и источники обводнения авиатоплива являются источником экономических потерь, важнейшим критерием успешности бизнеса топливозаправочного комплекса. В статье рассматривается задача создания надежных и автоматизированных методов и технологий контроля этих загрязнений, в частности определения воды в авиатопливе при заправке ВС и необходимости ухода от человеческого фактора. Актуальным становится автоматизация процессов мониторинга качества авиатоплива, переход от дискретных методов контроля к непрерывным, от статических методов контроля к динамическим (поточным), от косвенных способов к прямым. Показаны возможности сквозного учета и анализа параметров чистоты авиатоплива на всех этапах жизненного цикла авиатоплива. Рассмотрены способы, и проведен анализ известных методов и устройств, используемых для определения, измерения и индикации: фактической обводненности; присутствия растворенной, свободной и суммарной воды в авиатопливе. Представлено техническое решение непрерывного автоматизированного контроля уровня фактической обводненности потока авиатоплива в процессах авиатопливообеспечения и заправки ВС в информационной системе, обеспечивающей on-line контроль и динамическое измерение количественного содержания растворенной и свободной воды в потоке авиатоплива. Предложено техническое решение по непрерывному определению количественного содержания воды в потоке авиатоплива. При этом решение задачи мониторинга воды в авиатопливе совмещено с технологическим процессом контроля очистки авиатоплива от воды. Представлена адаптивная информационно-управляющая система непрерывного мониторинга уровня обводненности авиатоплива в потоке, которая позволит существенно повысить уровень автоматизации технологических процессов авиатопливообеспечения воздушных судов, снизить негативное влияние человеческого фактора, повысить экономическую эффективность комплекса авиатопливообеспечения. Система предназначена для осуществления непрерывного автоматизированного контроля (мониторинга) обводненности авиатоплива в потоке на всех этапах движения авиатоплива: приема, хранения и выдачи авиатоплива, и заправки ВС, в частности складов горюче-смазочных материалов, топливозаправочных комплексов, и пунктов предперонного налива, а также может быть использована в топливной системе ВС как система предотвращения обводнения авиатоплива. Внедрение средств автоматизации позволит повысить качество управления процессами авиатопливообеспечения и заправки ВС для обеспечения принятия своевременных оперативных решений на основе реальных данных в реальном режиме времени при условии интеграции предложенной системы в систему аэропорта для оперативного обмена данными.

Ключевые слова: топливозаправочный комплекс ТЗК, фактическая обводненность авиатоплива, пористый поливинилформаль, селективная сепарация, коагуляция, программируемый логический контроллер ПЛК, адаптивная информационно-управляющая система, динамический мониторинг.

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Introduction

Preservation of jet fuel quality is the main purpose of fueling complex operation while performing the aviation fuel supply technology, along with quality specification level provision when refueling aircraft [1]. This requires the provision of maximum possible pressurization of the jet fuel drainage, filling, storage and transportation processes, as well as aircraft refueling, application of the efficient water elimination technologies and equipment, preventive measures of aviation fuel-water adulteration [2–5], along with continuous monitoring of the jet fuel cleanliness level and water content in aviation fuel at all the aviation fuel supply stages [6, 7].

The possibility of water contamination of aviation fuel during transportation, storage and aircraft refueling is very high, and elimination of water from jet fuel is associated with significant difficulties as the process is cost-based and expensive (excessive filter elements consumption, increase of settlement duration), which eventually leads to the significant losses and not effective expenses for aviation fuel supply business, and represents a flight safety hazard.

The conventional jet fuel control to determine the mechanical impurity and water content is conducted both visually and by means of the express method using POZ-T facility. According to the regulatory requirements, such contamination should be not available while determining the content of mechanical impurities and free water using these techniques. The authors of the research [8, 9] analyzed the application of the mechanical impurities and the water content determination express method and its low sensitivity was identified, the obtained data proved sufficiently subjective.

A range of facilities means and techniques of water detection and elimination in jet fuels was considered in order to search of technical solutions. Nowadays the separator filters [10–12] are used for water elimination from the jet fuel. The principle of their operation is the coagulation of the water micro drops in the jet fuel on the surface of the filtering element glass fiber with formation of the water film. However, such a construction allows us to eliminate water from jet fuel, but not to determine its quantity, as the regulations require.

The authors set a task of solving the problem of not only purification of the jet fuel from water contamination, but also to determine probable quantity of water. The analysis of methods of jet fuel purification from free water [13, 14], based on optical devices usage [15–18], is conducted in this article. Thus, the paper suggests [16] the use of the polymeric optical fiber, the material of which, absorbs water, depending on its quantity, and varies its properties such as the geometrical dimensions, throughput capacity, light refraction, which allows us to quantify water in jet fuel.

The method of quantifying water in fuels and oils is used considering water electrical conductivity. The principle of the following method is based on determining breakdown voltage at the electrodes, in case of water presence in fuel or oil, and comparing with the identified dependence of this voltage on the quantity of free water.

The facility, based on the fixation of released hydrogen by the photodiode in the process of the water-reagent chemical reaction, is used while controlling the available water in diesel fuel. Water is quantified by the quantity of released hydrogen [17].

The analysis of applicable techniques to detect water in oil products shows, that the facilities are complicated enough. They allow us to detect the presence of water, but not to eliminate, and require definite qualification to deal with.

Among the drawbacks of conventional techniques and methods of jet fuel water content monitoring and the express analysis, we can refer to the following:

- the given methods of water content control are not continuous, as they are based on the spot and discrete sampling from the assigned zones or the pipeline areas, as a result, not the whole amount of jet fuel is controlled for water,
- the existing methods are manual and visual, significantly labor-consuming, do not possess the required sensitivity and are especially subjective, their accuracy and reliability depends on the negative impact of a human factor involving a high probability of mistakes, malfunctions and contributing risks,
- failure to determine quantitative water content in jet fuel, not only its availability,
- it is difficult to automatize the conventional techniques and methods of water content monitoring and express-analysis. In the circumstances of intensive transportation

volume growth and modern tendencies of civil aviation development, they do not solve a task of ensuring the automatized jet fuel control at the point, approved for refueling the aircraft,

- the given methods of water content control, based on the normative standard (order No DB-126 from October 17th, 1992) of time of settling – 4 hours/m of innage level – without considering the level of water content and impurity, which leads to ineffective costs.

The listed shortcomings are complicated with the refueling complex loading rate, that is a large volume and the number of aircraft refueling cycles typical for high-capacity airports.

A possibility of making a timely decision is excluded while using the given control methods, due to the long delay in obtaining the laboratory analysis results, therefore, the duration of a cycle activity of technological aviation fuel supply processes increases, causing economical costs to increase respectively.

The use of the conventional control methods hinders implementing automatization of the technological process of aircraft refueling and aviation fuel preparation, which leads to increase in prices for jet fuel and aircraft refueling services, and to the risks of decrease in airlines flights punctuality, in some cases.

Description of the dinamic monitoring system

Foreign and domestic experience [3, 7] shows us, that it is feasible to solve the problems of jet fuel purity control from free water and mechanical impurities by implementing the automatized measuring instruments (AMI), information measuring systems (IMS) and data management systems (DMS), which can subsequently become a basis (or components) of a single automatized system of airport refueling complex technological processes management.

The authors proposed the adaptive data management system of maintaining the assigned level of water content, based on the constant monitoring of jet fuel water content control [18, 19]. The system allows us to make a timely decision about jet fuel delivery for aircraft refueling, based on the constant quantifying of water content in jet fuel, approved for the aircraft refueling. Using of the proposed system in the whole aviation fuel supply process enables us to assess the efficiency of aviation fuel purification from water devices, means for aircraft refueling and filtration. In addition, the given system provides us with a possibility of possessing the objective data on jet fuel quality in real-time mode and throughout the entire technological chain from jet fuel reception to its filling into the aircraft wing tanks.

Functional capabilities of the developed system:

- quantifying of free water in jet fuel,
- control of water separating filter state,
- jet fuel purification from water.

The essence of the proposed system is that jet fuel flow (fig. 1) is passed through a water separating filter, which has several sequentially installed water-separating cells. Structurally each of the cells is made of porous polyvinyl-formal material (fig. 2), as an autonomous water separating filter. Differential pressure is measured on every partition, being processed by PLC (fig. 3), and calculations of the partition flow resistance are carried out. Flow resistance of every cell will depend on the quantity of detained water. After separation in a cell, the collected water is drained into the sump.

As a result of the system operation, water is eliminated from the jet fuel; the level of water content is quantified, based on measurement of porous partitions flow resistance value; the porous partition state is assessed.

The principle of the proposed water separator operation is concerned with the properties of the porous polyvinyl formal material, particularly with its water absorbing properties. It is of rough glasslike porous structure before the contact with water, and after water saturation the material plumps and obtains the elastic state and water coagulating features. Afterwards, the porous polyvinyl formal material is dried with dehydrated fuel flow (of a very low water content level) in order to restore the system in its original condition (to regenerate). Subsequently, the collect-

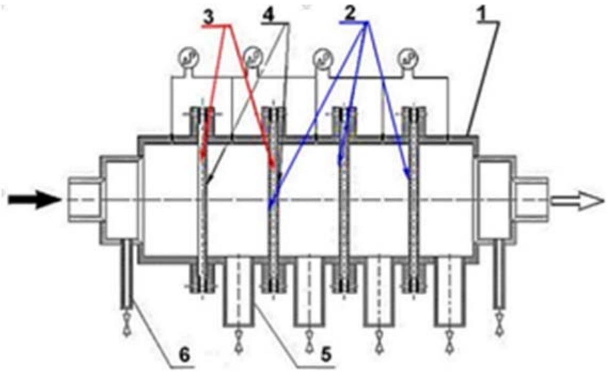

Fig. 1. Water separator diagram of the jet fuel water content monitoring system: 1 – housing; 2 – separator; 3 – coagulator; 4 – support grid; 5 – drain outlets; 6 – sampler outlet

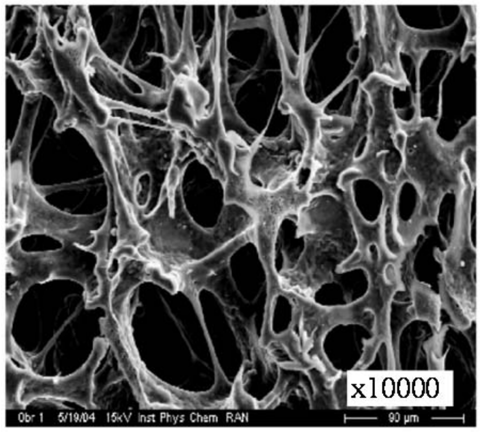

Fig. 2. Porous polyvinyl formal

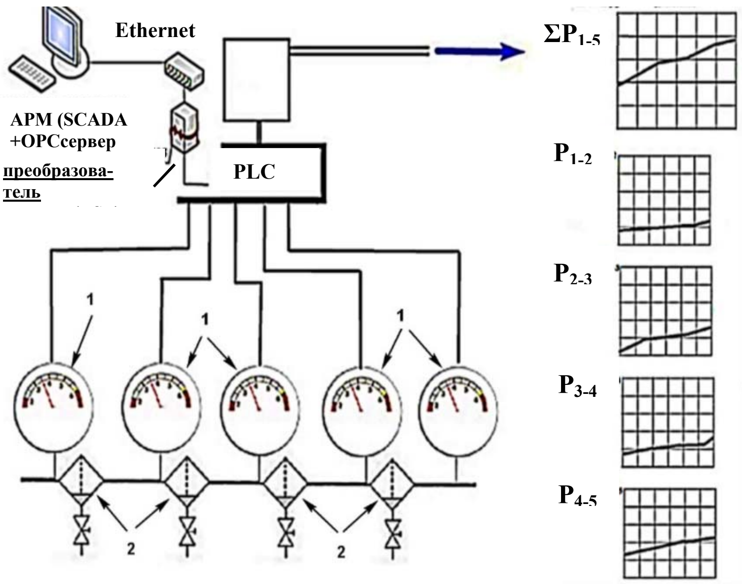

Fig. 3. Schematic diagram of the jet fuel water content monitoring system: PLC-programmable logic controller implementing algorithm; 1 – pressure sensors; 2 – water separator

ed water in the partition is eliminated and transfers into jet fuel in the molecular, diluted state, (water content in fuel is less than 0,001% (by mass).

The application of PLC allows us to record the obtained values of differential pressure and compare them with the current ones of every partition, comprising an array of mathematics. Such an approach enables us to quantify the current water content in the transmitted flux of jet fuel, at the output of the intermediate partitions and the final porous one.

If the polyvinyl formal cells reach the ultimate water level (most commonly, the first one), it transfers into a coagulation mode. Drying the polyvinyl formal cell allows us to return it to its original state, as its flow resistance decreases.

Based on the conducted investigations, the system (fig. 4), which can be integrated into the airport systems and services, such as, for instance: GroundStar (GS) – a complex of software applications, automatizing the airport operations; RMS – Resource Management System – resource management system; AFMS – Aircraft Fueling Management System – information system for aircraft refueling operations management; CoTAS – Computer Terminal Automation System – for a refueling complex production processes management.

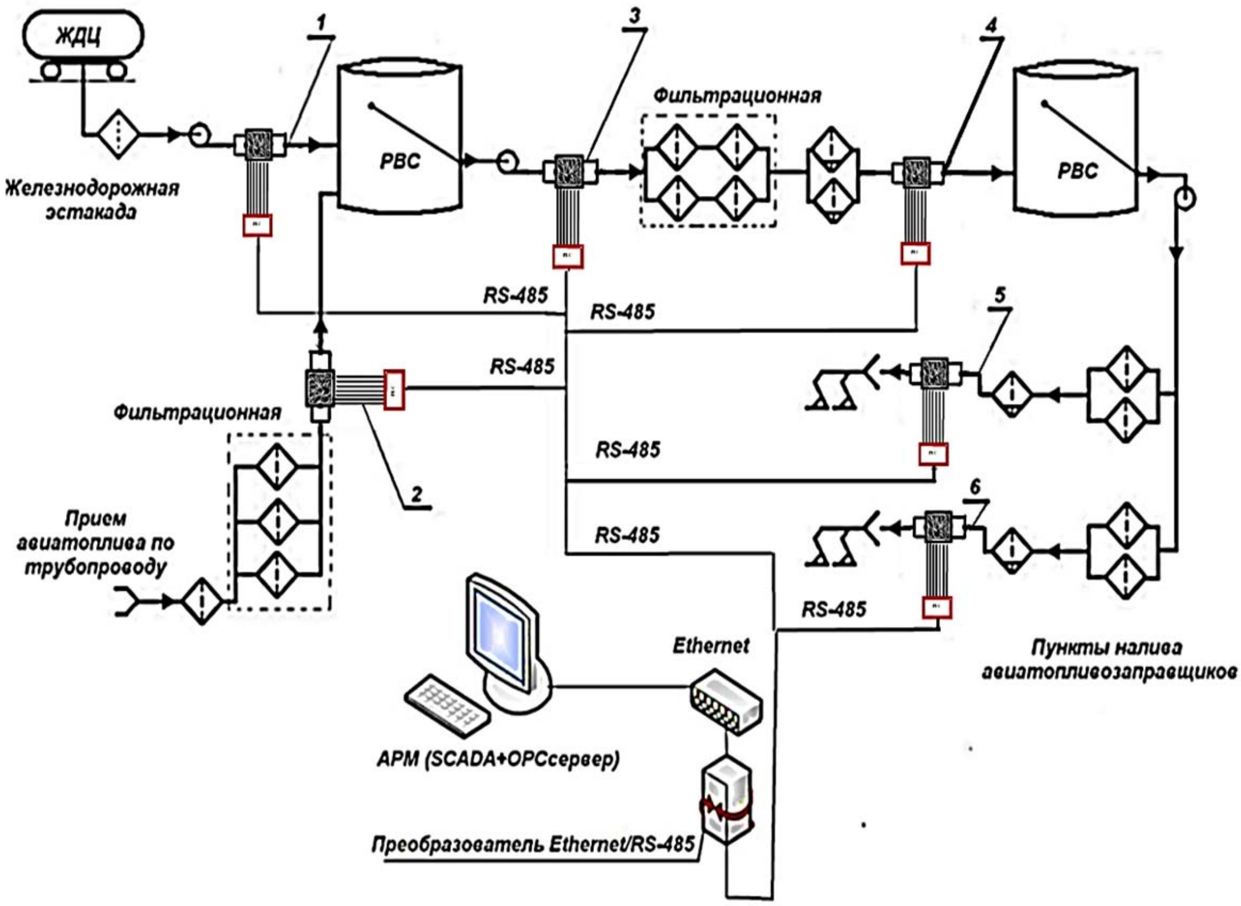

Fig. 4. The structural diagram of the information management system for monitoring the water content of jet fuel, data acquisition about the water content level:
1. When receiving jet fuel from the railway. 2. When transferring jet fuel through the pipeline. 3. When transferring jet fuel from recipient reservoirs to service tanks (after sedimentation). 4. When transferring jet fuel from recipient reservoirs to service tanks (after filtration and water separation). 5. When delivering jet fuel to refueling facilities (refuellers). 6. When delivering jet fuel to refueling facilities (refuellers).

Advantages of the system

The implementation and integration of the adaptive data management system of dynamic monitoring of actual jet fuel water content will allow us to significantly increase the aviation fuel supply process automatization level, to minimize the negative impact of a human factor, to optimize the refueling complex economical losses in a significant way, to increase flight safety and regularity.

The system of continuous jet fuel water content monitoring allows us to:

- conduct the on-line control of the whole jet fuel flow volume at all the aviation fuel supply technological process stages, from reception to supply for the refueling,
- provide the quantity water content control, by weight and percentage,
- build the balance of jet fuel contamination, instrument for making the timely technological decisions and business analysis,
- adopt as a system of preliminary prevention, signalizing about the exceedance of water content limits and allowing us to make timely decisions, along with adjusting the commercial relations (ceasing, blocking of improper fuel reception), also to optimize the equipment operation, determining the early signs of failure in advance and setting the maximally efficient modes,

- choose, in an automatic mode, the optimal algorithm and aviation fuel supply strategy, depending on jet fuel water content level, basing on the measurements, to use the rational technology and the correct conjunction of settling time, specifics and graduation of filtration, providing the flexibility and economic efficiency due to the optimal equipment use,
- exclude the negative impact of a human factor,
- implement the function of the flight data recorder (self-recording device) – the "black box" analogue on the aircraft, due to the function of logging and dispatching, and provide data for the incident investigation and business disputes solutions,
- provide the integration of airport ground support services into the refueling complex automatization platform and represent good possibilities for implementing the innovational digital technologies such as artificial intelligence, IIoT – Industrial Internet of Things, visualization and predictive analytics, as well as AFSC – Aviation Fuel Smart Contracts, blockchains and other cutting-edge airport digitalization technologies.

Conclusion

It is feasible to implement the automatized systems, to integrate them into the collaborative systems of airport ground service and the aircraft flight preparation (Groundstar Inform GmbH)[1] and to develop the hardware-software "Warehouse – Refueling" module, functionally intended for jet fuel quality planning and control and its delivery for refueling, in order to increase the capabilities of the system due to the addition of new components, for solving the problem of automatized jet fuel quality control, along with the optimization of jet fuel preparation processes for aircraft refueling.

Implementation of the dynamical monitoring system of actual water content will allow us to decrease the economic costs for fuel dehydrating, thus, to contribute to extra profit, to avert the risks of human factor negative impact on flight safety.

Implementing the automatized water content control system is particularly relevant for a major refueling complex, with a high level of jet fuel consumption.

Thus, implementing the means of jet fuel water content monitoring automatization, will enable us to increase the quality of aviation fuel supply and aircraft refueling processes management. Integration and data sharing with all the systems of APCS in real-time mode, will ensure to make timely decisions, based on the real data.

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