METROLOGICAL SUPPORT OF MEASURING TECHNOLOGY Of AIRCRAFT REFUELING SERVICES

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https://doi.org/

Abstract. The article investigates the possibility of carrying out verification of volumetric liquid meters at the place of operation and presents the procedure for carrying out such verification. The issues of metrological support of measuring instruments (MI) of the aircraft refueling service are considered. The data on the verification of measuring instruments of the aircraft refueling service in the EU member states are presented.

Key words: Metrological support, measuring equipment, volumetric liquid meter, calibration equipment, Coriolis flow meter.

1. Introduction

The measurement equipment used in aircraft refueling services would help ensure the accuracy and reliability of measurements of various parameters of the fuel in aircraft. These parameters may include volume, weight, pressure, temperature, fuel quality, composition, etc. One of the problems that has not been resolved yet is the issue of calibration of fuel meters at the point of installation of fuel dispensers at the airport. Measuring equipment applied in the aircraft refueling service must be calibrated and verified following the requirements of metrology and relevant standards to ensure the accuracy and reliability of the measurement results.

Following the "Instruction on the Procedure for Acceptance, Transportation, Storage, Release and Accounting of Oil and Oil Products at Enterprises and Organizations of Ukraine" [1], oil and its products are accounted for at oil refineries, product supply companies, pipeline companies, filling stations in units of mass, and at fuel refueling complexes in units of volume. Metrological support of MIs of the aircraft refueling service is a system of measures aimed at verifying the accuracy and reliability of measurements [2]. This is important for flight safety and the efficiency of the aircraft refueling service.

The procedure for calibration of volumetric liquid meters applied in aircraft refueling is inherent in its peculiarities, for example, in comparison with the procedures for refueling cars and fuel control. One of the primary distinctions is the following. During aircraft refueling, the fuel volume is assessed by volumetric meters known for their high measurement precision and are subject to verification. Conversely, when refueling cars, fuel quantity can be determined by electronic fuel level sensors located in the tank, which offer comparatively lower measurement accuracy and do not necessitate verification.

When refueling aircraft, it is important to follow strict safety rules and avoid any damage to the equipment. For example, the load on an aircraft volumetric meter can be significantly higher than on vehicle meters, which can affect their accuracy. Aircraft MIs would be checked and verified on-site, as their placement and connection can be quite complex and vary between aircraft types. In vehicle fuel control, electronic systems can be used to monitor fuel levels and consumption. However, there the measuring devices are not as important as aircraft fluid meters.

2. Disadvantages

One of the main concerns is that the majority of aviation fuel metering stations and fuel resellers do not offer the option to disassemble the measuring equipment for periodic verification. This can result in the accumulation of measurement errors, which in turn may lead to significant issues in ensuring air transport safety [3]. For numerous volumetric fuel meters, the option to calibrate the MIs using the water spill method is not available. This can potentially hinder the calibration process in situations where it is impractical or undesirable to dismantle the equipment.

Insufficiencies in the metrological support of aircraft refueling equipment can result in unreliable fuel volume measurements and an elevated risk of accidents. The inability to perform calibration of MIs using the water-based method and the absence of dismantling capabilities for calibration equipment are notable drawbacks that may lead to disruptions in the operation of fueling stations and inaccurate measurements.

Technical limitations, such as exposure to noise, vibrations, and temperature fluctuations, can also impact measurement accuracy and contribute to unreliable outcomes. The absence of automated monitoring for fuel levels and consumption is the next drawback as it can lead to inaccurate measurements and subpar performance. In general, the shortcomings of the metrological support of aircraft refueling service measuring equipment are serious and require attention to improve the accuracy and efficiency of fuel stations and the ability to verify volumetric liquid meters on site.

3. Goal

Investigation of the possibility of on-site verification of volumetric liquid meters for metrological support of measuring equipment of the aircraft refueling service.

4. Verification of aircraft refueling service measuring equipment

Investigation of the possibility of on-site verification of volumetric liquid meters is an important stage of metrological support of measuring equipment for aircraft refueling services. On-site verification reduces the time and cost of verification of MIs, as well as provides more accurate and reliable measurement results, which is especially important for flight safety.

The absence of automated control over fuel levels and consumption can lead to incorrect measurements and an increased risk of accidents. Measurements are made usually by volumetric liquid meters installed at aviation fuel metering stations and fuel refueling stations. As a rule, these MIs are inherent in a permissible relative error range of ± 0.25% to ± 1.0%. Some types of volumetric liquid meters are shown in Figure.

Volumetric liquid meters

Portable calibration units designed for on-site use can be employed to calibrate volumetric liquid meters. These units possess a compact size and can be easily transported to the location where the MIs are being utilized. Equipped with pressure, temperature, and liquid level sensors, these units ensure precise calibration. A distinctive characteristic of aircraft refueling is the utilization of specialized instruments for measuring and monitoring fuel properties that offer high levels of accuracy and reliability. Specifically, volumetric liquid meters are employed, which exhibit exceptional precision in volume measurement. To guarantee measurement accuracy and fuel quality control, filling stations employ measuring equipment that requires regular checks and verification. The verification process adheres to metrological standards and the manufacturer's documentation, utilizing verification facilities and equipment [4]. The specifics of aircraft refueling also include the high responsibility for measurement accuracy and fuel quality control. Consequently, fuel quality assessment and control procedures are vital in upholding the safety and reliability of air transport.

Before performing the verification, it is necessary to check the meter's compliance with the requirements of metrological standards and the manufacturer's documentation. It is necessary to check that the meter is properly connected and functions correctly. After that, the meter can be verified using the verification unit. After the verification, the appropriate verification documentation can be drawn up and the meter can be marked to confirm that it has been verified and is accurate. It is also important to verify that measuring instruments are regularly verified to be sure of their accuracy throughout their lifetime. Regular verification is important to ensure that MIs meet the requirements of regulatory documents and ensure their accuracy in operation [5].

On-site verification has obvious advantages, as it allows monitoring the errors not only of particular devices as well as the entire measuring complex. In addition, on-site verification provides confidence that the installation conditions of the MI do not increase the measurement uncertainty.

Calibration of MI of the aircraft refueling service is a mandatory procedure to meet the requirements of international and national standards for the accuracy of fuel measurements in air transport. The calibration of fuel measuring instruments is carried out under the requirements of the European Union Directive 2014/32/EU (IMID – International Measuring Instruments Directive). This Directive provides for requirements to ensure the measurement accuracy and verification of CMMs used for transactional purposes. In non-EU countries [6], verification of MIs is carried out following national standards and regulations, which often differ from the European ones. To guarantee mutual recognition of verification results, some countries are negotiating mutual recognition of the results of FTA verification. For example, in 2018, Ukraine and Spain signed an agreement on mutual recognition of the verification results of MI.

Verification of volumetric liquid meters at the place of operation depends on the method of refueling aircraft (open – through a "refueling gun", closed – through a "lower refueling tip") and safety requirements,

control of the relative error of volumetric liquid meters when measuring the volume of oil products is carried out by one of the following methods using:

– a measuring tape;

– scales, a container, and a necessitate verification;

– a Coriolis flow meter.

A Coriolis flow meter is a device that facilitates the measurement of mass flow rates of liquids and gases, as well as their density, by harnessing the Coriolis force. This allows for direct determination of the mass flow rate, without relying on speed or volume measurements [7].

The instruments for ensuring accuracy are transported to the designated site. To guarantee explosion safety during this process, the instruments and auxiliary devices, classified as electrical equipment, must be designed with explosion-proof features, and the connecting lines must meet the requirements for intrinsic safety [8].

The procedure involves measuring the volume of dispensed petroleum products by both the meter under scrutiny and reference MI. The volumetric liquid meter readings are considered to ascertain the volume of the oil product. The reference volume value is established based on the chosen calibration method:

– when calibrating with a gauge, the reference volume of the oil product V_3 in cubic meters, is determined by the gauge scale readings by the formula:

$$V_x = V_m\left[1+(t-20)\beta\right], \quad (1)$$

where V_x is the meter reading, m^3; t is the temperature of the gauge during the measurement, ^{o}C; β is the coefficient of volume expansion of the gauge material, for stainless steel gauges; $\beta = 36\cdot10^{-6}\frac{1}{^oC}$ in accordance with MI 1864-88 "Fuel dispensers. Method of inspection". The temperature of the gauge is determined by measuring the temperature of the oil product in it using a thermometer.

– when verified by applying scales and an areometer, the reference value of the volume of oil product V_x in m^3, is determined according to the formula:

$$V_x = \frac{m_{ef}}{\rho_{ef}}, \quad (2)$$

The reference value of the mass of the oil product m, in kilograms, is determined by the readings of the scales by the formula:

$$m_{ef} = C_v\left(m_k - m_n\right), \quad (3)$$

where m_n are values of the scales with an empty weighing tank, kg; m_k are values of the scales when the weighing tank is full, kg; c_V is the correction factor. Since the measurements are made in the field, this factor must be calculated from the measured values of atmospheric pressure, temperature, and humidity. When calibrating with a Coriolis meter, the reference value of the volume of the oil product, in cubic meters, is determined by the readings of the Coriolis meter. The gauge and the container, into which the oil product is collected to determine the reference volume, have a significant windage, so protective screens must be used to prevent the influence of air flows on the measurement result.

Since the scales are transported by road, after installation at the calibration site, it is necessary to control the error of the scales to ensure that their error does not exceed the permissible value limit.

The sample for measuring the density of the oil product must be taken after the aviation fuel has fully settled in the tank and after the scales have been read.

During verification, operations are carried out to check the completeness, marking, external inspection, check the electrical strength of the insulation of the power supply circuits, the electrical resistance of the insulation, the electrical resistance between the grounding contacts and the housing, check the tightness and functioning [9]. The stability of the readings in the absence of flow is subject to control, the relative error in measuring mass (volume) flow and mass (volume) of water and the absolute errors in measuring density and temperature are determined. Based on the positive results of the verification, a verification certificate is issued, a record is made in the operational documentation and the flow meters are sealed.

Statistical data on the verification of CMMs of aircraft refueling services in European countries can be found in reports and documents that support metrological activities. For example, the reports of the European Association of National Metrology Institutes (EURAMET) [10] contain information on the verification of CMMs in EU member states and documents of national metrology services, information on the verification of CMMs of aircraft refueling services in the country.

According to EURAMET statistics for 2020, the number of FTA verifications of aircraft refueling services in EU member states totaled around 3,000. The most active countries in this regard were those with major airports and international airlines. In particular, France, Germany, the United Kingdom, Spain, and Italy carried out more than 500 verifications each. In turn, national metrology services also carry out the verification of aircraft refueling services in the country. For example, in Ukraine, this procedure is carried out by the State Agency for Metrology. According to the agency, in 2020, about 50 CMM verifications were carried out in different regions of the country.

For some airlines, the availability of the necessary equipment and qualified specialists to carry out on-site verification of the measuring equipment may be a challenge. It is also necessary to ensure that the fuel temperature is stable during the calibration of the meters.

In addition, there are issues regarding the application of the latest measurement technology and the standardization of measurements following international norms and standards. Another problem is the lack of automated control over fuel levels and consumption, which can lead to incorrect measurements and increase the risk of accidents. Solving these problems requires further research and development of new measurement technologies, improvement of verification methods, and introduction of standards that meet international norms. In addition, it is necessary to improve the processes of metrological support for measuring equipment and ensure automated control over fuel levels and consumption in ships and aircraft. It is also important to ensure that the specialists working with measuring equipment have the appropriate level of qualification and have access to modern methods and technologies.

5. Conclusions

The ability of on-site verification of aircraft refueling service measuring equipment is crucial in maintaining measurement. The calibration process for volumetric liquid meters requires adherence to strict safety regulations and specialized measurement methods. However, limitations in metrological support for this equipment include the restricted possibilities of dismantling for verification and the absence of automated control over fuel levels and consumption. It poses challenges when verification is required but equipment dismantling is not feasible. Continual improvement in metrological support for aircraft refueling equipment is an ongoing process that necessitates the adoption of new technologies, staff training, and the utilization of modern verification methods.

To emphasize that conducting on-site verification of measuring equipment in aircraft refueling services, a mandatory procedure under international aviation safety standards is necessary. This procedure guarantees the precision and reliability of measurements during aircraft refueling, which is crucial for the safe operation of aviation equipment. Therefore, conducting on-site verification of measuring equipment in aircraft refueling services serves as a significant element of metrological activities and ensures flight safety.

6. Gratitude

The authors express their gratitude to the Staff members of the Department of Information-Measuring Technologies of Lviv Polytechnic National University.

7. Conflict of interest

The authors declare the absence of any financial or other potential conflict related to this work.

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