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PROCEDURES FOR GAUGING OF VOLUMINA AT FUEL STATIONS

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ABSTRACT.

In this Paper the principles of measuring volumina of fuel delivered at fuel stations are shown. Used is a comparison measurement between the gauging device and the indication of the gasoline pump. The volumetric principle of measurement is the common principle for the attribute testing. It is tested if the error of measurement is within the Maximum Permissible Error (MPE) of 0,5% of the delivered amount [8].

This attribute testing is the most important part for legal verification of gasoline pumps.

Another principle is the gravimetric measurement. Within this Paper, a measuring device is shown, that allows the economically verification of gasoline pumps even with high viscous fuels.

1. INTRODUCTION

The verification of the correct delivered amount of fuel is secured by the verification authorities based on the Verification Act [1] and the Verification Ordinance [2]. To determine the correct amount, adherent to the Maximum Permission Error, the utilization of appropriate measuring devices is obligatory. Calculating this amount is of great economically importance, not only due to rising fuel costs. In order to use these devices, the personnel of the verification authority are in need of fulfilling legal and technical requirements.

In [3] and [4] technical and legal requirements are shown and important technical requirements are explained in chapter 1.1.

These requirements explain what needs to be done to verify gasoline pumps. Numerous variants of measuring systems for solving these requirements historically evolved.

1.1. Technical requirements for verification of volumina

The source for this is the administrive regulation “Legal Metrology GM-P5” [4]. Requirements for measurement period and the calculation of the measurement error can be found, which will lead to the determination of the volumina and its corresponding uncertainty.

According to [4], the verification has to be done at the minimal and maximal flow (q_{min} and q_{max}) of the gasoline pump. In order to gain a better distribution of the error of measurement across the flow range, a third measuring point q_{middle}, besides q_{min} and q_{max}, can be necessary, if {1} is true.

$$\left| f_{\max} - f_{\min} \right| > \left| F_V \right| \qquad \{1\}$$

Within {1}, f_{max} is the maximal and f_{min} the minimal error of measurement that occurred within the verification of one gasoline pump.

The allowed range of the error of measurement in order to determine, if the third measuring point is needed, is given by F_V. It is based on know-how and technical specifications. Here F_V is determined by the half of the legal error of measurement for the whole measuring system of 0,5% from the delivered amount. This results in F_V with 0,25%.

Typical gasoline pumps for passenger cars have a maximum flow q_{max} lower than 50 liter per minute and a minimum (verified) flow q_{min} with 5 liter per minute.

The flow delivered from high-performance gasoline pumps for trucks can reach up to 120 liter per minute, but this type of pumps will not be considered. The third measuring point q_{middle} can be chosen within the range of {2} and a reasonable realisation of {2} is practically given by available gauging tanks.

$$1{,}5 * q_{\min} < q_{middle} < 0{,}8 * q_{\max} \qquad \{2\}$$

The measuring time T also is given by [4].In common, 60 seconds are necessary. This time can be reduced, if some conditions are fulfilled. One condition is, that 20 seconds measuring time can be used, if the flow q is below 50 liter per minute.

1.2. State of the Art

The common devices to verify delivered amounts of fuel are based on volumetric measurement.

In order to gain a result, a comparison measurement between gasoline pump and verification device is done.

Fig. 1: typical gauging tanks [5]

Common used verification devices are gauging tanks as shown in Fig. 1. They are used as working measurement standards with a common uncertainty of 0,1% [2], §5 (2)] of the delivered amount, the metrological traceability to national standards is given. Typical nominal volumes of these tanks are 5, 10, 20 and 50 dm³. In conclusion, the delivered amount is gained from the scale mounted at the tanks.

2. EXAMPLES OF VOLUMETRIC MEASURING SYSTEMS

The following images shall show the possible variants, which have evolved to fulfill the technical and legal requirements. Some of the advantages and disadvantages shall be shown.

In general, some steps of verification cannot be simplified or shortened by better equipment.

For example, those are the whole quality inspection, the required measuring time and dripping time.

What can be shortened or simplified are processes that require the utilization of verification equipment, which do not influence the value of the measurement, such as emptying the tanks, moving the vehicle or steps to bring the verification vehicle into operating condition.

All following variants need two persons, trained for verification and utilization of their variant.

Some Images are simplified to their abstract functionality, so that only the important metrological components are shown, that are relevant.

2.1. Gauging tanks with additional storing tank(s) mounted on a truck

Fig. 2 shows a variant with additional storing tanks, so that more gasoline pumps of the same fuel can be verified without emptying the tanks. This reduces the overall measuring time.

The gauging tanks and additional tanks are combined together, so that only pumps with the same fuel type can be verified.

Fig. 2 set of gauging tanks and additional tanks at the bottom, property of the Thuringian State Authority of Metrology and Verification

This leads to a rising time effort, because the verification vehicle must be moved to the next gasoline pumps with the same fuel type. If there are high numbers of customers at the same time, the personnel of the fuel station will prefer those customers and the verification vehicle has to wait until the customers are gone.

In order to verify the delivered amount of fuel, the verification personnel has to work at the loading space, where the gauging set of tanks is mounted. The risk of falling down from the loading space should not be underestimated and be generally avoided by using a variant, which can be handled from outside the truck.

2.2. Gauging tanks mounted on a trailer

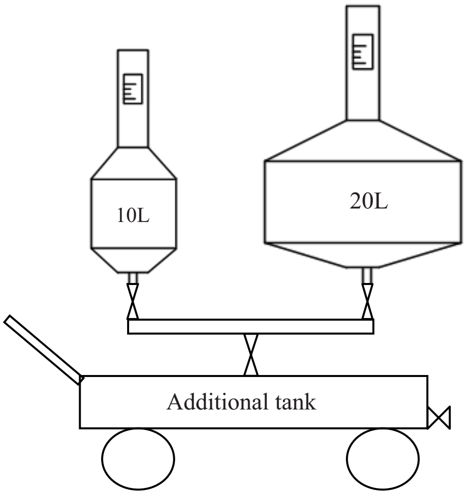

Fig. 3 abstract principle of a gauging tank mounted on a trailer and an additional tank underneath

Fig. 3 shows the abstract variant. On top of the additional tank at the bottom of the trailer, the gauging set is mounted.

If the set of gauging tanks can not be driven by itself, it can either be moved manually (only at the fuel station) or by a car or small truck.

Moving this variant manually can be difficult, if its tanks are filled, so that to its own weight the mass of the fuel is added. If the fuel station is built on gradient ground, the physical load for the verification personnel is increased, too.

With its relatively small width and length, this trailer can be used for small fuel stations, where a bigger verification vehicle would freeze the stations business nearly completely.

With its additional tank, 3 gasoline pumps can be verified with one emptying.

Due to legal restrictions, the top speed of vehicles with a trailer while driving on a highway is limited to 80 km/h. Some verification vehicles can be driven with the German driver license type B.

This limitation at 80km/h will lower the amount of verified gasoline pumps per day proportional to the distance between the responsible verification authority and the fuel station.

In order to prepare the trailer for the verification, the tarpaulin must be removed by recoiling it. Afterwards the covering with the tarpaulin has to be dismantled to gain access to the gauging tanks. At the end of the verification of the fuel station, this covering has to be moved to its origin position, which cannot be done with one person.

If the trailer is moved manually between the gasoline pumps, a higher physical load for the verification personnel is additionally given.

2.3. Gauging tanks with additional storing tanks for more than one fuel type

This variant, shown in Fig. 4, uses two additional fuel pumps mounted at the truck, that transport the fuel from the gauging tanks after the utilization into additional storing tanks. Each of the 4 storing tanks has a capacity of 240 liter.

Due to the size of the additional tanks and the gauging set, it is not necessary to verify one type of fuel after another. Each side of one gasoline pump array can be verified without moving the vehicle. This can save a lot of time in the verification of the whole fuel station.

This variant was designed in a way, which allows the personnel to work with the verification set and the other components from the ground without climbing at the loading space of the vehicle.

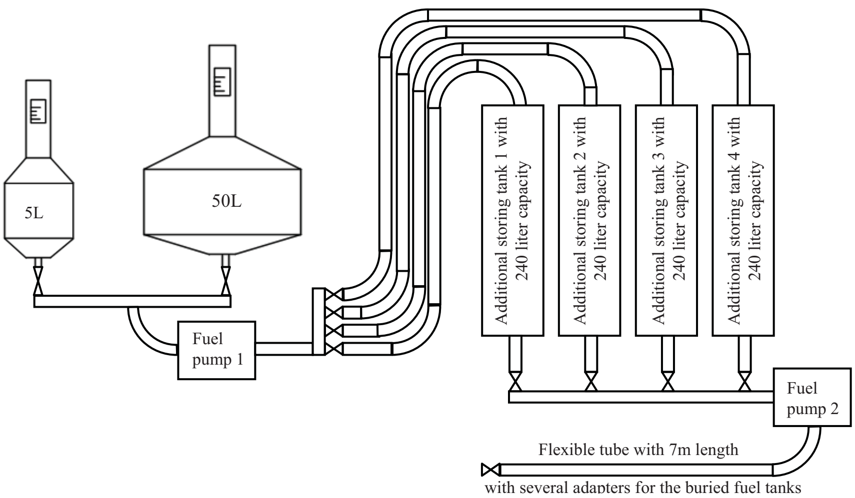

Fig. 4 abstract principle of gauging tanks with additional storing tanks for more than one fuel type

A newer version of this variant has a rear view camera, so that moving the vehicle at fuel stations from one gasoline pump to the next can be done in a safer way. Another optimization is that the seat of the co-driver can be turned towards the rear side of the passenger cell. A folding table is mounted at the cell's backside, so that the measured values and the results of the measurements can be entered into the laptop in a place, which is safe from weather conditions.

Emptying the storing tanks can be done with or without the pump in the backside of the vehicle. Several adapters allow the emptying of the fuel in a closed system, so that no fuel can leak.

This variant is the most expansive out of all investigated variants, but it will raise the time efficiency significantly.

2.4. Measurement of high viscous fuels

Emptying the utilized devices can be difficult, if the fuel is based on vegetable oils. This problem affects all gauging tanks that have been used with these fuels.

The wetting inside the device after emptying them is rising in relation to the viscosity of the fuel.

Common tanks are visibly closed, so that the degree of wetting or even if wetting is given cannot (or only in a difficult way) be checked.

If high viscous fuel was used the device must be cleaned, before a new measuring cycle can be started.

Otherwise the result of measurement is falsified by a wrong volumina and maybe even a mixture of fuels. The cleaning of these devices has to be done manually, in common by purging the device with benzine or diesel.

Commonly, due to the problems explained above, those types of fuels are verified by gravimetric measurement. Additional measuring equipment is needed and has to be transported separately inside the volumetric measuring vehicle or with an extra vehicle, to avoid dirtying these devices.

Another aspect of importance is the economical utilization itself. With the rising number of fuel stations, fuel types and limited personnel it is aimed to realize the verification with minimal effort.

With that, the rising amount of time used for one gasoline pump and many steps done manually, the advantage of Experience and well-known measurement procedures can be reduced.

Lacking time efficiency, caused by decreasing personnel capacity and rising numbers of fuel stations, induce a search for an optimal variant, so that a better comparability between different verification measuring systems can be achieved.

2.5. Selection of the best variant in terms of time-efficiency and minimal effort

Out of all investigated variants, variant 2.3 shows the best potential. Its Design is optimized for verification and was planned from verification personnel with dozens of years experience and know-how.

In Comparison to the other variants, it allows the usage of personnel and material with the highest benefit-costs ratio. In conclusion, this variant allows the verification of up to 80[1] gasoline pumps each week (with an average value of 10-30 pumps at one fuel station). Other variants, such as in 2.1, allow the verification of only 60[2] gasoline pumps each week.

At the time of working at this paper, more variants have to be investigated, but the general properties, arrangement and the design of the missing variants in Thuringia are known to the author and will not change the gained results in a significant way.

2.6. Conclusions of the variants and their possible outcome

With many variants that fulfill the legal requirements and are used today for verification, lacking comparability will probably lead to:

- High costs teaching the new and old personnel, if one of the two needed persons of the verification personnel can not do their job for whatever reason. Each verification authority has more than one variant and only the normal persons, that use this variant commonly, can handle their variant without further needed training. Interchangeability between different authorities' verification personnel is not given.
- Different physical loads and activities are needed for each variant. Even health risk changes, for example working inside a loading space or not. These differences can lead to avoidable damages for human and material.
- The effort designing these many variants could have been saved, if only the best variant had been chosen out of the proposals of the all verification personnel involved in verifying fuel stations, if such proposals were collected.
- If some component of one variant is broken or damaged due to abrasion or other causes, it can not be easily changed or fixed with spare components, that may be available at other authorities using the same variant

With this ongoing development of designing and using own variants for each verification authority, even more variants will show up and cause costs, that could be much lower, if the most promising variant is optimized with the best partial solutions used in other variants.

If only one variant is used in the future, the effort for verification can be lowered, interchangeability for personnel and equipment is given and even easy comparison measurements between the different vehicles of the same variant can be done in order to proof their functionality, if the metrological trueness is doubtful.

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[1] This value is gained from the verification personnel out of their statistics in one year, calculated down to one week.

[2] This value is calculated out of the average verified gasoline pumps verified in one day, with 4 days a week verification and the fifth day finishing

Of cause, if some problems appear with this variant, all vehicles will have it, but this can be solved easier and faster, as it could be done with only 2 or 3 people knowing to fix the problem or even know what causes the problem. Volumetric gauging tanks used for verifying volumina at fuel stations are a well-known and developed technique, so that significant problems that afflict the metrological functionality are doubtful.

3. GRAVIMETRIC DETERMINATION OF VOLUMINA

One possible alternative solution to determine the volumina of the delivered fuel is the gravimetric measurement. Following equation {3} a simultaneous density and mass measurement is necessary to gain the volume.

$$V(\vartheta) = \frac{m}{\rho(\vartheta)} \qquad \{3\}$$

Weighing devices are available in various types and accuracy classes. Measuring the density is, of course, also possible, but in order to determine the density, the actual temperature of the fuel is obligatory, too.

Some general influence quantities for the determination of the volumina are sensitivity, nonlinearity, repeatability of the corresponding measuring devices for mass, density and temperature.

Eccentric loading, tilt and trueness at a minimum/maximum and intermediate loads are examples for the mass related quantities. Trapped air, aborted temperature equalization between fuel and sensor, and most important temperature are significant for the determination of the density.

Those and other influence quantities have to be determined in order to gain verification information for the actual delivered volumina in comparison to the indication of the gasoline pump

3.1. Examples of important quantities of influence for the density

In general, most density measuring devices are only operable, if the fluid is constantly filling the volume of the device at any time. They are also working in closed fluid loop without any trapped air or significant variations in temperature.

These operational conditions cannot be complied with the conditions given for the measurement at fuel stations.

Solving this and other circumstances is partially still in development.

3.1.1. Trapped air

This is the most important disturbance. One example of its Importance can be seen in Fig. 5. The measurement of the operational density is disturbed by trapped air inside the flowing diesel stream from pump to sensor. As shown, the density dropped to nearly 450kg/m³. If air is the only medium left in the sensor, it can even drop to 1kg/m³.

This is already solved by mathematical algorithms in the Software.

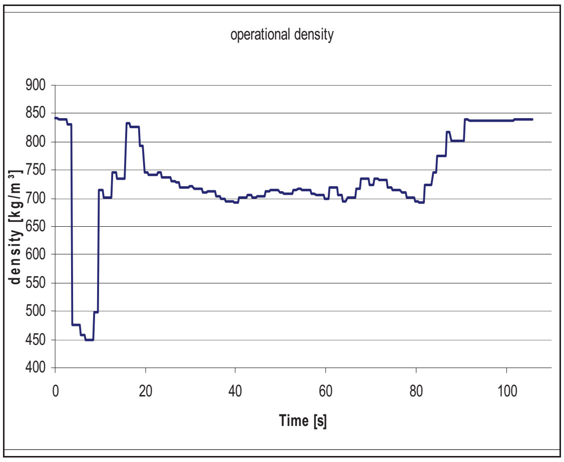

Fig. 5: density with trapped air disturbance inside diesel

3.1.2. Aborted temperature equalization between fuel and sensor

In order to verify fuel stations, some rules for the verification procedures exist (see State of the Art), such as measuring with minimum and maximum possible flow from the gasoline pump.

If the fuel has a significant lower or higher temperature than the density sensor, noticeable temperature equalization starts. If this process is aborted, the measured temperature of the fuel is not "true" and leads to a falsified density determination.

In order to test the trueness of the temperature measurement, several tests are planned. A temperature gain or loss will be induced and the reaction of the sensor to this induced change will be analyzed.

3.2. Gravimetric measuring system

At this time only the Prototype exits. It is a tank mounted at a weighing device. A bypass leads some of the fuel pumped inside the tank towards the density measuring system. A PC collects all measured values and calculates the volume of the delivered amount.

In comparison with volumetric measuring systems, this gravimetric system can avoid problems of falsified volume caused of wetting deposits by taring the weight of the tanks. The tank may still have deposits, but they can not falsify the volume. An installed plausibility check with 40kg weight pieces allows testing the trueness of the weighing system at any time.

It is possible to measure the delivered volumina successively without emptying the tank until it is filled. This avoids additional emptying.

The weighing also leads to the possibility of verifying any wanted nominal value, if the standard volume of gauging tanks like 10, 20 or 50 liters is insufficient.

3.3. Future development and goals

The gravimetric measuring system for volumina is a system developed and designed for high-viscous fluids that can not be easily measured with the common volumetric tanks.

The development is still ongoing, but in a late state and most problems have been solved already. Some are still subject of ongoing investigations and measurements, but solutions for all problems have been found or are in sight. Due to its late state, the prototype needs to be tested practically to confirm if the legal requirements for verification of volumina and the goals of development are fulfilled.

The most important goal is the metrological functionality with its uncertainty of 0,1% from the delivered volumina.

This goal is already reached [6] for fluids and fuels like water and others with a density above 800 kg/m³, so that the practical tests shall show, if this measuring system can fulfill the expectation of long-term stability and reliability.

4. CONCLUSION

Comparability is an important factor in metrology. It ensures that different measuring methods and principles deliver the same measurement result with an uncertainty of measurement as small as possible or wanted.

For verification of delivered amounts of volumina at fuel stations this comparability of measurement methods and standards is only given with an additional uncertainty of up to 0,15% [7].

If one variant would be used, this additional influence quantity could be avoided.

5. REFERENCES

[1] Verification Act {German: Eichgesetz in der Fassung der Bekanntmachung vom 23. März 1992 (BGBl. 1 S.711), das zuletzt durch Artikel 2 des Gesetztes vom 3. Juli 2008 (BGBl. 1 S.1185) geändert worden ist}, 2008

[2] Verification Ordinance {German: Eichordnung vom 12. August 1988 (BGBl. I S. 1657), die zuletzt durch Artikel 3 § 14 des Gesetzes vom 13. Dezember 2007 (BGBl. I S. 2930) geändert worden ist}, 2007

[3] Appendix 5 of the Verification Ordinance {German: Anlage 5 (zu § 7k) der Eichordnung: Messanlagen für die kontinuierliche und dynamische Messung von Mengen von Flüssigkeiten außer Wasser}, 2007

[4] Legal Metrology GM-P5 {German: GM-P5: Prüfanweisungen für strömende Flüssigkeiten außer Wasser (GM_P_5_Nov_2004)}, 2004

[5] http://edelstahlbau.de/index.php?option=com_content&view=article&id=72&Itemid=66&lang=de

[6] Tino Almeroth: diploma thesis „Metrologic investigations of a gravimetric measuring device for volumina, especially considering high-viscous biofuels" {German: Diplomarbeit "Messtechnische Untersuchungen einer Vorrichtung zur gravimetrischen Volumenmessung, insbesondere hochviskoser Biokraftstoffe", TU Ilmenau; Chapter 4.4 and Appendix 25}, 2009

[7] Dr. Balhorn: Investigation for periods of verification validity of gasoline pumps {German: „Erhebung zur Eichgültigkeitsdauer von Zapfsäulen";, Hessische Eichdirektion}, 1999

[8] Directive 2004/22/EC of the European Parliament and the Council on measuring instruments, especially appendix MI-005 {German: Richtlinie 2004/22/EG (MID), insbesondere Anhang MI-005}, 2004