VOLUME

Mobile calibration rig for volumetric testing

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Introduction

In January 1999 the Norwegian Metrology and Accreditation Service (Justervesenet) took delivery of a mobile calibration rig for volumetric testing, consisting of a truck with several standard capacity measures (volume standards), a reference meter, instrumentation (temperature, pressure) and supplementary equipment such as valves, a pump, etc. The rig is also equipped with a computer and instrumentation which automatically record and calculate the measurement results, and which generate the calibration certificate and the historical data for each meter. This rig is a great improvement in efficiency, accuracy and working conditions for the volumetric control of flowmeters.

Background

The acquisition of the rig was initially envisaged in the light of a report drawn up in April 1996 which concluded that an improvement in efficiency potentially as high as 30 % could be achieved compared to the traditional method based on separate volume standards. Positive changes were also anticipated concerning safety, accuracy, the environment, and operator working conditions.

The contract was signed in June 1998 and the rig was completed in December of that year, built by the Norwegian company *MoPro*. The instrumentation and software were installed in May 1999, delivered by *Intelligent Control*.

Fig. 1 Mobile calibration rig for volumetric testing

Application

The maximum capacity of the rig is 3 000 – 3 500 l/min and it is mainly used for verifying flowmeters with dimensions from 75 mm to 150 mm. The rig is manufactured in aluminium and can be used for any liquid that is not aggressive to aluminium, though it is basically used by Justervesenet for petroleum products. However, it is not used on high viscosity products, since these necessitate an extensive cleaning procedure. Most of the meters tested are positive displacement meters, but all kinds of flowmeters can be tested using this rig.

In Norway the verification interval for flowmeters is one year. Some customers subcontract calibration work and internal controls out to Justervesenet to complement their internal quality program; primarily concerned are filling racks for tanker trucks, loading racks for boats, tanker trucks and airports.

The truck serves about 1 000 flowmeters in the southern part of Norway.

Design and construction

The main challenges for the rig are to handle large capacities (typically 3 000 l/min), minimize the time taken per meter and still achieve an acceptable level of accuracy. This means that attention had to be focused on the pipe design, couplings and the global arrangement for returning the liquid with the objective of minimizing pressure loss. If it is possible to circulate the liquid within the rig, then one standard can be emptied whilst another is being filled. If not, the slop tank is used and it is of note that the standards can also be used as slop tanks. Another critical parameter is the total height of the rig, and a compromise had to be reached to ensure that filling racks with a low maximum height could be accessed.

Figure 2 shows the control room at the rear of the truck. From this room the operator can control the rig and access the following functions:

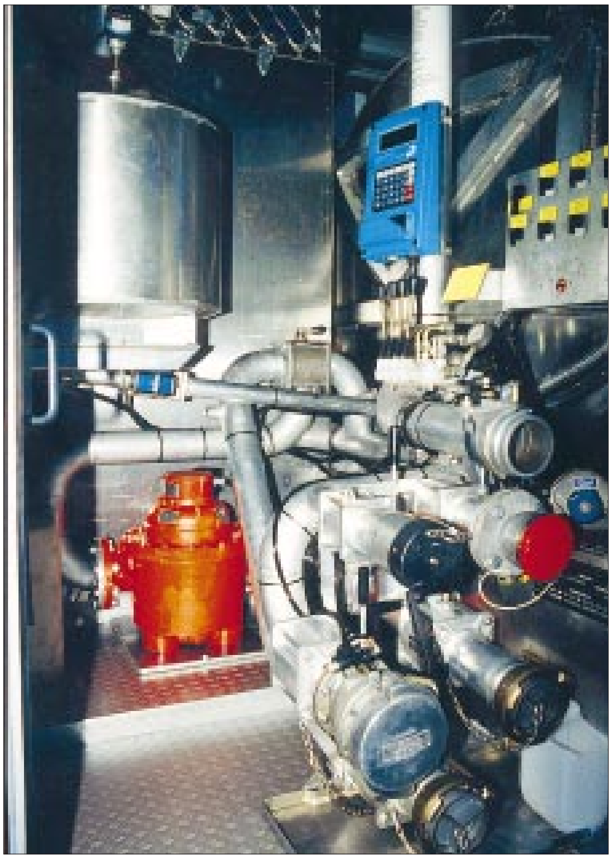

Fig. 2 Control room and pipe fittings

- leveling of the truck by means of hydraulically supported legs;
- pump (700 l/min) for return of the liquid back to the rack or from the standards to the slop tank;
- hydraulic hose reel (return of the liquid);
- control panel for the pneumatic assisted valves;
- inlet manifold with most of the common couplings;
- couplings for the gas recovery system;
- terminal to operate the computer and the instrumentation. The terminal indicates the temperature and volume; the historical data can be read from the data base for the meter and the values entered from the measuring object. This terminal is also used to operate the flow computer;
- tools; and
- equipment in case of oil spills.

Standard capacity measures

The standard capacity measures (volume standards) are constructed in accordance with the requirements in OIML R 120 *Standard capacity measures for testing measuring systems for liquids other than water*. Justervesenet possesses four volume standards: 2 × 3000 l (which can be used as 1 × 6000 l), one 1000 l and one 200 l. There is also a 3500 l slop tank. The measures are built from 6 mm thick aluminium and to avoid deformation a number of strengthening rings are incorporated around the measures. The scales of the capacity measures have a range of ± 0.6 % of the nominal volume and the sensitivity is 0.02 % for a 5 mm rise.

The measures are gravimetrically calibrated and are therefore traceable to the national standard for mass. The overall uncertainty of the rig itself is ± 0.5 l (k = 2) for the 3000 l standard. The uncertainty of the total measurement is also dependent on the repeatability and scale division of the measuring object and the surrounding system such as pumps, valves, hoses, etc.

Instrumentation - general

For communication between the computer and the sensors a field bus is used, which is a digital communication system. This system is an open system which means that any supplier may be used - in the present case, components from 6 suppliers are used. To handle the calculation Microsoft Excel® is used, and Microsoft Access® is used to manage the history data base. Microsoft Visual Basic® is used for the interface and control of the process.

The instrumentation system can automatically read the temperature, the level or volume in the volume standard and also the results from the reference meter. The operator has to manually read the indication of the measuring object and enter the value into the terminal. Based on this information the instrumentation will automatically perform the corrections in line with the thermal expansion of the standard, calculate the result, generate the calibration certificate and record the historical trend. These documents are printed out and handed over to the customer on site.

Fig. 3 Volume standards

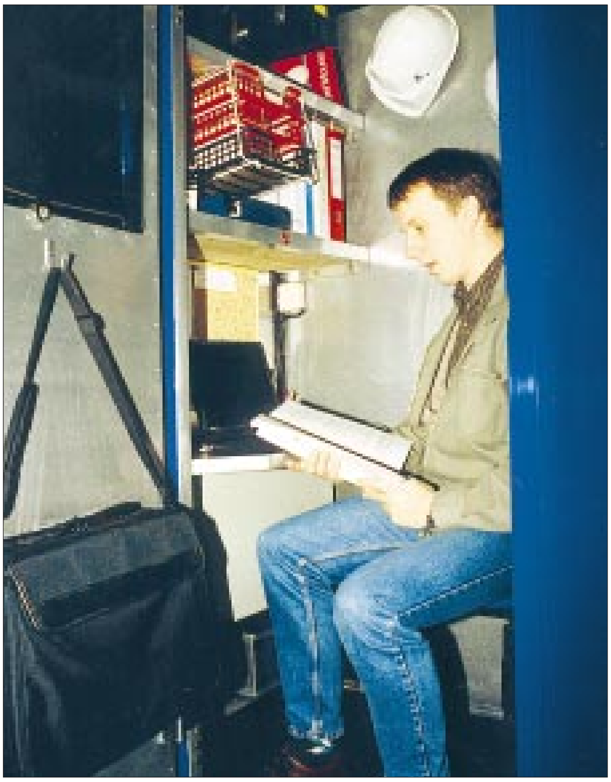

Fig. 4 Office for computer, printer, etc.

Figure 4 shows a small office towards the back of the truck where the computer, printer and other electrical equipment that is not Ex-proof are stored. The room is not defined as an Ex-zone as long as the door is locked. Manuals, data sheets, documentation, historical data on CD-ROM, etc. are also stored in this room.

Instrumentation - reference meter

As a supplement to the volume standards, a reference standard flowmeter is installed in the rig (100 mm Smith meter, stainless steel, Q_{max} = 4000 l/min). The flow can be directed in two ways, either in a loop from the filling rack, through the meter and back to the filling rack, or from the meter to a volume standard. In this way the reference meter can be calibrated on site with the actual liquid. The flow computer has a 5-point flow characteristic for each liquid and the operator can decide the actual placing (in the capacity range) for each point. This means that a special curve can be plotted for each case, illustrating not only the k-factor but also the gap between the points. The reference meter allows for much larger measured quantities and is a good alternative for checking meters used for loading ships, for example, where there are no possibilities of presetting the measured quantity.

Instrumentation - level metering

The level is measured by means of differential pressure transducers. Differential pressure transducers were chosen since they are very robust, compact, accurate and inexpensive; the drawback, however, is that the density influences the result, since the density varies according to the type of liquid, temperature and from batch to batch. When the operator begins the measuring operation he chooses a liquid from a menu, the computer checks the actual density from a database and calculates the temperature-induced density variations.

The transducer is placed just below the scale of the capacity measure, in order to reduce the effect of these density variations. The transducer is a ceramic differential pressure transducer with a range of 0–50 mbar and repeatability < 0.01 %.

The density for each liquid (15 °C) is stored in a database. Density changes due to the temperature are calculated in accordance with "Petroleum Measurement Tables - 54C". Corrections for density variations are made using a procedure to compare the calculated volume with the visual reading of the volume standard.

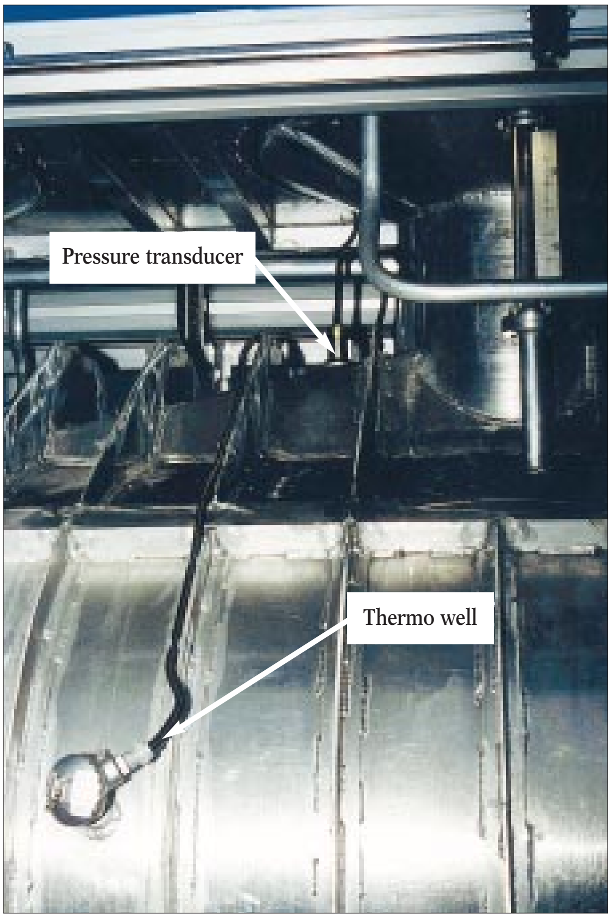

Fig. 5 Placing of sensors

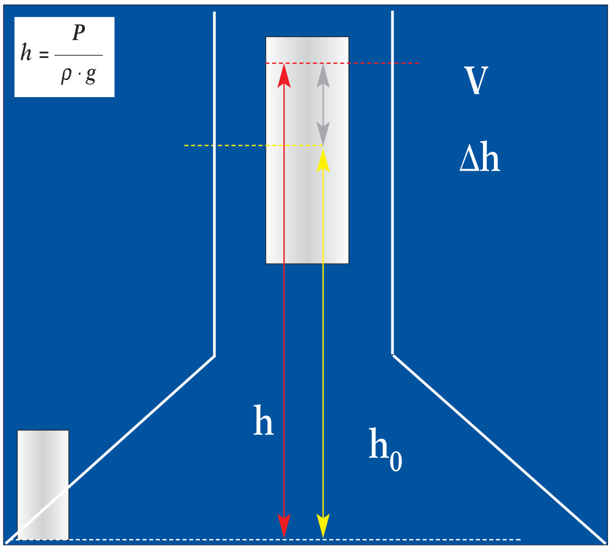

Fig. 6 Principle for automatic reading

If there is a difference the operator enters the read volume into the terminal. The computer then automatically corrects the value of the density so that the calculated volume agrees with the read volume. The system does have some limitations and is still not good enough, but staff are working on a number of modifications that will hopefully serve to improve it.

Environment and safety

Many requirements must be met for a rig such as this one to operate in an Ex-area.

All the electrical components in the Ex-zone (zone 0: liquid, zone 1: gas) are Ex-proof and the total installation is approved by NEMKO.

It must not be possible to start the engine when the couplings are mounted, to prevent the truck from driving away.

The chassis has to be grounded to avoid potential differences between the filling rack and the truck.

All the electrical parts on the chassis that are not Ex-proof have to be disconnected from the battery during gasoline filling.

To avoid flashover inside the standard from the static-charged liquid, the temperature sensor and the optical overfill sensor are connected to grounding wires.

There are two kinds of overfill protection: firstly an optical sensor that detects if the level becomes too high. This sensor can activate a shut-off valve in the filling rack. There is also an overflow pipe that feeds the liquid to the slop tank. If any liquid is spilt, equipment is on hand to handle such a situation in the truck and the operator is also required to be aware of the emergency routines on the actual site.

The rig has also a Gas Recovery System (stage 1) to lead the vapor back to the filling rack.

Test period

During the test period the rig was serviced several times. Typical problems encountered - and fixed - were leakage in the liquid and pneumatic valve systems, and some software bugs. The test period was also used to make some small modifications and to add some other functions. Testing was carried out during ordinary verification. The rig has worked very well and depending on the filling rack, the average time required to check each flowmeter is one to one and a half hours.

Conclusion

As a conclusion, the rig presents a number of advantages compared to the former method using separate standards. It is very functional and the practical solutions seem to be successful. The accuracy of the measurement is increased due to better sensitivity and leveling possibilities and efficiency appears to have increased by approximately 30 %, which is consistent with pre-launch expectations. Operator working conditions are very good, the rig meets the requirements concerning environmental and safety regulations and the total cost of the rig was in line with the budget. Running expenses are even lower than expected and due to the gain in efficiency, customers get a better service for a lower cost.

All in all the rig has given Justervesenet very positive publicity and plans are already being made for the next truck. ■

CONTACT INFORMATION

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