Bulk Liquid Fuel Road Tanker Measuring Systems

Background

In July 1998, LACORS published a document entitled Bulk Liquid Fuel Measuring Systems Guidance. It revised and consolidated previous guidance relating to the testing and sealing of bulk liquid fuel road tanker meter measuring systems.
It was subsequently updated in January 2002 with regard to the testing of gravity drop metering systems.

Whilst some of the specific systems that were originally described have now been superseded, the principles of operation, testing and Health and Safety are still valid.

It is also appreciated that dipsticks are now not commonly used, but in order to provide assistance for occasions when they are encountered, references to them have been retained.

In order to try to 'future proof' this guidance, it concentrates on technical aspects rather than specific legislative requirements.

Legal Metrological and associated Health and Safety Requirements.

The Legal Metrology Expert Group has reviewed the previous guidance and endorses the following:-

Bulk Liquid Fuel Road Tanker Measuring Systems Guidance

GLOSSARY AND EXPLANATION OF TERMS

Anti-milking valve
A valve incorporated into the nozzle at the end of a full-hose meter system to prevent draining out of the hose.

Bottom-loaded Tanker
These tankers are filled at a fuel terminal by loading fuel through the tanker outlet valves at ground level on the near side of the tanker.

Empty hose measuring system
Measuring system in which the transfer point is located upstream of the delivery hose in a measuring system designed to deliver product (and downstream of the receiving hose in a measuring system designed to receive product)
(OIML R117-1:2019 Dynamic measuring systems for liquids other than water)
Note: Also known as a dry hose measuring system

Foot valve
A closure valve in the base of each compartment of a tank which controls release of fuel from that compartment.

Full hose measuring system
Measuring system in which the transfer point consists of a closing device located at or near the end of the delivery hose in measuring systems designed to deliver product (or near the beginning of the receiving hose in a measuring system designed to receive product)
(OIML R117-1:2019 Dynamic measuring systems for liquids other than water)
Note: Also known as a wet hose measuring system

Gas Elimination Device
Device used to remove any air, gas, or vapour contained in the liquid
Note: There are several different types of gas elimination devices, including gas separators, gas extractors, and special gas extractors.
(OIML R117-1:2019 Dynamic measuring systems for liquids other than water)

Gas Extractor
Gas elimination device used to extract air or gases accumulated in the supply line of the meter in the form of pockets that are no more than slightly mixed with the liquid
(OIML R117-1:2019 Dynamic measuring systems for liquids other than water)

Gas Separator
Gas elimination device used to continuously separate and remove any mixed air or gases contained in the liquid
(OIML R117-1:2019 Dynamic measuring systems for liquids other than water)

Special gas extractor
Gas elimination device which, like the gas separator but under less stringent operating conditions, continuously separates any air or gases contained in the liquid, and which automatically stops the flow of liquid if there is a risk of air or gases, accumulated in the form of pockets no more than slightly mixed with the liquid, entering the meter

(OIML R117-1:2019 Dynamic measuring systems for liquids other than water)

Hose dilation
A measure of the amount of fuel trapped in a wet hose meter measuring system when the closure device is shut under pumping conditions.

Hose retention
A measure of the amount of fuel left behind in a dry hose meter measuring system after ‘blow down’ of the system has taken place at the end of a delivery.

Manifold
A mechanism to allow several compartments to be joined together avoiding the need to disconnect and reconnect a hose to switch between compartments thereby minimising the risk of spillage and environmental contamination.

Measuring System
A measuring system (other than one used in connection with the refuelling of aircraft, ships or hovercraft) which is used for the continuous and dynamic measurement in a quantity exceeding 100 litres or 100 kilograms of liquid fuel delivered from a road tanker other than—
(a) Liquefied gases;
(b) Lubricating oils;
(c) Liquid fuels of a temperature below -153°C; or
(d) Liquid fuels of a dynamic viscosity exceeding 100 millipascal seconds at 15°C.

(The Measuring Instruments Regulations 2016)

Measuring system
System comprising a meter for quantities (volume or mass) of liquids and its ancillary devices and additional devices

(OIML R117-1:2019 Dynamic measuring systems for liquids other than water)

Meter (for quantities {volume or mass} of liquids)
Instrument intended to measure continuously and display the quantity of liquid passing through the measuring device at metering conditions, including at least a measuring device, a calculator (including adjustment or correction devices if present) and an indicating device

(OIML R117-1:2019 Dynamic measuring systems for liquids other than water)

Meter Tests:-

- Empty hose system - this test can be carried out by disabling the blowdown mechanism, fully priming the test equipment, and carrying out meter-to-meter tests by continuously stopping deliveries at the pre-set valve, so that the system is constantly full while the tests are carried out, but the hose is never under pressure.

- Full hose system - the test that is applied where before the test starts the hose is not under pressure, both trade and reference meters start at zero, and the test is ended at the appropriate volume by the automatic closing of the tanker meter's pre-set valve such that the hose is not under pressure.

Minimum specified quantity deviation
Absolute value of the maximum permissible error for the minimum measured quantity, MMQ

(OIML R117-1:2019 Dynamic measuring systems for liquids other than water)

MMQ
Minimum Measured Quantity.

Negative Error
In this guidance means that *less* liquid passes through the meter than is indicated by the meter (i.e. the meter reading is a higher figure than the actual amount passed). Also said to be 'In Deficiency'.

Positive Error
In this guidance means that *more* liquid passes through the meter than is indicated by the meter (i.e. the meter reading is a lower figure than the actual amount passed). Also said to be 'In Excess'.

Pulser/Analogue to digital converter
In electronics, an analogue-to-digital converter (ADC, A/D, or A-to-D) is a system that converts an analogue signal, such as a sound picked up by a microphone or light entering a digital camera, into a digital signal.
An ADC converts a continuous-time and continuous-amplitude analogue signal to a discrete-time and discrete-amplitude digital signal. The conversion involves quantization of the input, so it necessarily introduces a small amount of error or noise. Furthermore, instead of continuously performing the conversion, an ADC does the conversion periodically, sampling the input, limiting the allowable bandwidth of the input signal.
(Wikipedia: https://en.wikipedia.org/wiki/Analog-to-digital_converter)
For the purposes of this guidance the ADC converts the rotational motion of the meter to a digital signal.

Q_{Max}
Maximum approved flowrate of the meter system.

Q_{Min}
Minimum approved flowrate of the meter system.

Reference Meter/Master Meter
A meter rig normally made to the Secretary of State's Specification produced under Section 5(5) of the Weights and Measures Act 1985. The current specification is 7330 of 1986. Approved Verifiers may use other suitable equipment subject to the permissions granted to them by their Licence.

Simulated Delivery Test
See Headed Section and description later in these notes

System Test

- Empty hose system - there is no specific test. The system test errors are determined by carrying out meter tests, and then adding or subtracting from these errors a further correction factor called the "hose variation". This represents the variability that might be introduced by different amounts of liquid being retained in the dry hose after blow down. This enables a range of errors that may be experienced in normal operation to be determined.

- Full hose system - the test that is applied where before the test starts the hose is not under pressure, both trade and reference meters start at zero, and the test is ended at the appropriate volume by closing the tanker hose end trigger such that the hose is under pressure.

Top-loaded Tanker
Where a tanker is loaded by overhead gantries at a terminal through manholes in the top of the tank, it is called a top-loader.

Ullage
The space in a tanker compartment above the level of liquid.
Note: There should *always* be an ullage space, that is to say no compartment of a tank should ever be so filled as to be full to the brim.

Vapour Recovery
This is a concept which originated for environmental reasons.

- With a conventional top-loaded tanker, petrol vapour in the tanker compartments was pushed out into the atmosphere when loading took place at the terminal. Similarly when a tanker was unloaded at a fuel station, the act of dropping the petrol into the underground tanks pushed the petrol vapour from the storage tank vent pipes out into the atmosphere.

- With a bottom-loaded tanker, the filling at the terminal is through the outlet valves at the base of the road tanker, and the tops of the tanker compartments are sealed so that vapour is not released from the tanker compartments to atmosphere. A coupling close to the outlet point on the tanker enables connection of a hose so that the vapour can be pushed back into the refinery process.

- In general, fuel stations are also fitted with vapour recovery equipment. When a bottom-loaded tanker is discharging, a coupling similar to that at the refinery enables the vapour from the underground tank which is receiving fuel to be pushed back into the tanker rather than to the atmosphere. In order to effect this, the fuel station will have a pressure balancing valve system to direct almost all of the displaced vapour into the tanker, rather than to atmosphere via the fuel station vent pipes.

- The physical act of taking dipstick readings exposes the compartment that is being dipped to the atmosphere and this will inevitably cause vapour loss from the tanker compartment. In most circumstances therefore, the taking of dipstick readings in the conventional sense has ceased.

GENERAL 'ON SITE' HEALTH AND SAFETY

The overall responsibility for health and safety lies with all nominated "Managers" and "Supervisors".

- In general when undertaking operational duties, the most senior officer present should have authority for, and take responsibility for, safety matters. This will however be a matter for decision by each Local Weights & Measures Authority.

- Before commencing operations at any depot, report your presence to the person in charge of that depot. Be aware of any local health and safety procedures.

- You should have regard to the respective responsibilities of the person(s) in charge of the premises, road tanker and tank container.

- You should be aware of your Authority's Health and Safety policy and any relevant procedures.

The following points aim to ensure, as far as reasonably practicable, the safety of personnel using bulk fuel testing equipment, and highlight some particular safety issues in carrying out such activities.

Personal Safety

- Smoking should not be permitted at any time. Smoking requisites should not be carried by any person engaged in meter or dipstick testing. This includes vaping requisites as these devices are operated by non-ATEX approved electrical circuits.

- People who suffer from vertigo should not carry out any duties requiring climbing on to the vehicle top or other activities requiring working at height.

- Always take care when opening dip-tubes / man-lids, as pressurised vapour may be present.

- Keep to safety walkways on the vehicle under test.

- Appropriate protective clothing should *always* be worn. The minimum requirements include use of suitable overalls, footwear and gloves or gauntlets.

- Also recommended for use at all times are protective headgear, plastic goggles, and ear defenders when actually testing meters.

- Completely synthetic material garments must not be worn, in order to avoid the possibility of static discharge. Wherever possible, the material should also be non-absorbent. Steel equipment must not be used and steel caps on boots must not be exposed.

- Oil products are hazardous and skin contact should be avoided. Barrier creams and latex type gloves must be used.

Use of Equipment

- Take care when manoeuvring bulk fuel equipment. Heavy items should not be handled by one person.

- Check that all hoses and fittings are securely tightened and undamaged.

- If a hose is used to return liquid from the reference meter to storage, it should be secured so that it is below the level of liquid in the storage container.

- Avoid splash loading. When loading empty compartments the hose should be secured so that it is as near to the bottom of the compartment as possible so that the end is covered by liquid as quickly as possible.

- Before liquid is passed through the system, a bonding wire should be connected between the reference meter assembly and the trade vehicle chassis. The vehicles should also be bonded to earth.

Petrol Vapour and Spirit Contamination

- While testing replacement dipsticks, or inspecting dipstick systems, extreme care should be taken when examining compartments containing petrol vapour

- When testing meter systems, ensure that the liquid to be used in the test is not contaminated with petroleum spirit, as it will be subject to pumping.

- Ensure that empty compartments on the vehicle do not contain petrol vapour, by using an explosimeter at the faucet valve location. If in doubt, information should be obtained from the operator.

Spillages and Hose Bursts

- Try to prevent spillages. If they occur close down all equipment immediately.

- Contain or disperse spillage with appropriate materials and report the incident to the depot operator.

- During the hose dilation test on full-hose systems the readings should be taken as quickly as possible to minimise the strain on the hose, etc. and then the pressure should immediately be relieved

- Also when testing for the hose dilation on full-hose systems, if there is any significant increase in the trade meter indication, it must be dealt with by relieving the hose pressure immediately and closing down the system. This can be done by, for example, stopping the engine or disengaging the power take-off. The reason for this is that there have been incidences of pump by-passes being isolated or defective, and this could cause the bursting of the hose.

High Flow-rate Dry-Line Systems

- When testing dry-line systems, extreme caution should be taken to avoid the blow-down mechanism being activated when the line is open through the reference meter itself otherwise damage to the reference meter will almost certainly occur. Additionally, care must be exercised on systems with hydraulic drive cargo pumps as closing the pre-set at maximum flow could cause serious damage.

Ancillary Equipment

- Equipment that should be available for safe operation and testing of systems includes: an explosimeter, safety torch, at least one dry powder fire extinguisher, warning signs and / or cones and a First Aid box containing oil proof plasters.

Vehicle under test

- Initial inspection of the vehicle under test should only take place when the engine is not running.

- Before starting the vehicle under test, ensure there is adequate ventilation or other means to dispose of exhaust fumes, such as a suitable extraction system or working outside.

- Trading Standards personnel should familiarise themselves with the controls of the vehicle under test in case of emergency. In case of doubt, seek advice. Do not operate the controls yourself. It is preferable to get a representative of the owner to operate the vehicle and measuring system controls.

- In particular, when testing meters, you must first identify and become familiar with the pre-set controls (including the correct sequence of inputs for software activated systems), emergency stop and engine stop facilities and manifold and faucet controls. Use these facilities should any incident occur.

- When conducting tests on the efficiency of the gas elimination system, do not run the pump dry for excessive periods since the pump may rely upon the product being pumped for lubrication. The vehicle is likely to be powered by a turbo charged diesel engine and so the engine must be allowed to tick over at idle for a period after starting before increased engine speeds are used. Similarly the engine should not be revved and then turned off - it should be allowed to idle for a period before shutting down. If in doubt, confirm these details with the operator.

The Avoidance of Static Electricity Dangers during Bulk Fuel Tanker Tests

- This is an example extracted from a Local Authority Policy, but individual Local Authorities *must* have their own specific procedures:-

  The testing of bulk fuel tankers is a source of generation of static electricity. This occurs when gas oil and kerosene are:

  - pumped through hoses and filters - the faster the rate of flow, the greater the static generation
  - allowed a free fall discharge from outlets (splash loading).

  Such occurrences arise when tanker meter to reference meter tests are conducted, and also when product is circulated via the tanker's own pump back into an on-board compartment. The latter might occur, for example, when testing following ticket printer or air separator repairs.

  These risks *must* be minimised by the use of suitable equipment and a safe method of work.

  There are sources of reference in order to be able to quantify and overcome potential hazards and risks including those of;

  - Control of undesirable static electricity.

- Road and rail tanker hoses and hose assemblies for petroleum products, including aviation fuels.
- Thermoplastic hose assemblies for dock, road and tanker use.

Steps taken to address hazards must include ensuring that effective earth bonding exists within the system such that electrical continuity is maintained between the tanker under test, the reference meter, reference meter discharge hose and a suitable earthing point within the tanker depot. The impedance of these continuities must be suitable.

Methodologies can include:

- The use of insulated copper core cables of a suitable gauge and resistance linking the reference meter to the tanker earth pin and the reference meter to a suitable earth point within the terminal. This will usually be at the loading gantry. Metal perimeter fences or metal spikes driven into the ground are, in most cases able to meet the criteria where a proprietary earth point is not available. Extreme care must be exercised in the case of the latter to avoid penetration of underground services. The advice of the person in charge of the premises should always be sought.
- Suitable crocodile clip connections may be acceptable for links to the tanker and earthing points, providing they are specifically made for low impedance earthing and the connections are uninterrupted by rust corrosion or heavy paint protection.
- Bonded connections should be permanently made to the reference meter.
- Proprietary recoil earthing reels, to the requisite standard, are available.
- The reference meter discharge hose should have electrical continuity within suitable impedance levels. The wire reinforcing braiding must be in contact with both end couplings or by the use of conductive hose.

System of Working

The following procedure should be adhered to prior to commencing any meter to meter tests;

- All earthing connections should be securely made before any attempt to open tanker compartment lids or connection of the tanker hose to the reference meter inlet.
- When the earthing connections are made, consideration must be given to the risk of people tripping over them.
- The reference meter outlet hose must be lowered into the tanker compartment and allowed to come to rest on the compartment floor before any flow commences
- If fitted a wet-hose 'gun' must remain completely below the surface of the product, to prevent splashing, during discharge. The compartment must always contain sufficient product to cover the 'gun'.
- Before commencing draining of the outlet hose at the conclusion of flow, several minutes should be allowed to elapse between the cessation of the discharge and its removal from the tanker compartment. This will allow any static to dissipate to earth.
- Pumped returns to tanker compartments from the reference meter drip tray must be completed before disconnection of earth leads.

In addition to the above procedures;

- Air separator and ticket printer, and other similar partial system tests involving re-circulation of product on the tanker, must only be carried out with the tanker earthed to the depot point. The same connection principles apply, as explained above

- Again, steps should be taken to ensure that the delivery hose nozzle does not spray product into the compartment and time must be allowed for static to dissipate after pumping ceases.

In every circumstance, only when all pumping has ceased and dissipation time has expired may the earth bonding be disconnected.

Testing of Earthing Equipment

- As with all items of equipment, regular inspection and testing is required;
- If for any reason a repair to the discharge hose is carried out then continuity testing will be required before its subsequent use.
- Removal and re-installation of the meter from its mountings will necessitate continuity testing after re-installation and before its subsequent use.
- Portable earthing kits should be regularly tested for continuity and resistance.
- Before use, all equipment should be checked and any apparent deterioration of the earthing capability will render the equipment unserviceable until tested.

The need for the integrity and effective capability of all earthing equipment cannot be overstated.

TYPES OF TANKER

There are several types of tanker design, having different types of metering systems and possibly also with dipsticks:

- A petrol-only tanker will generally not have dipsticks and will be either a top-loaded or a bottom-loaded vehicle. It may have a gravity fed meter system.
- Tankers for products other than petrol may have dipstick and metering systems.
- A tanker could possibly have a gravity drop metering system, either on its own or as an additional system, but these are rare.

Deliveries by dipstick can be achieved by gravity drop directly through faucet (outlet) valves to underground tanks, or by using the vehicle pump to discharge product. Where tankers have both dipsticks and meters, a 2-way valve downstream of the pump, often in conjunction with a manifold, enables dipstick deliveries to be discharged without the product reaching the meter.

TYPES OF MEASURING SYSTEMS

1. Dipstick Measuring Systems

Dipstick measuring systems may still occasionally be used to measure bulk or split deliveries.
The calibration of dipstick measuring systems is a specialist process and can only be carried out by Calibration Centres with facilities to test the necessary relationship between the dipstick and the compartment it is used within.

Where a tanker is loaded by overhead gantries at a terminal, it is called top-loaded and the dipstick within the tanker compartment will have been calibrated only to measure fuel within the confines of that compartment

Bottom-loaded tankers are filled by loading fuel through the outlet pipes. Although pre-dating it, this is linked with the concept of vapour recovery, but has metrological implications in that when the fuel is delivered, the pipework between the bottom of the compartment and the outlet will already contain fuel. This means that the dipstick calibration chart must take account of this fuel. There are also requirements to ensure that dip readings can only be taken with the pipework open to the compartment, so that the true contents are actually measured.
It is worth noting that bottom-loaded tankers were originally required to have a Certificate of Approval, but this has not been the case for a long time.

The full initial calibration and verification process is *not* covered in these notes, but it is important that Trading Standards Officers and Approved Verifiers are aware of the following points about the calibration chart which is associated with each and every dipstick measuring system.

When Calibration Centres calibrate such a system, they produce a calibration chart for each tanker compartment to be used when making up and subsequently verifying any associated dipstick. These calibration charts enable replacement dipsticks to be made by using linear measurement to mark replacement or spare dipsticks, provided the compartment itself remains unaltered.

Calibration Centres occasionally receive requests from tanker operators for copy calibration charts where the original has been lost or destroyed. This enables replacement dipsticks to be made, marked up and subsequently submitted with this copy chart to a Trading Standards Officer or an Approved Verifier.

When such requests are received, if the Calibration Centre still has the required information, a copy certificate may be issued. This will be clearly dated and also refer to the fact that the actual calibration has been carried out some time previously. It would be important to check that the tank has not been damaged or altered since the date of original calibration. The Calibration Centre will also inform the Local Weights & Measures Authority in whose area the operator is resident of the request.

Original charts and certified copies are identified by calibration centres in a variety of ways to prevent the substitution of photocopies, which may be inaccurate or obsolete, including:

- Use of coloured ink.
- Use of coloured seal.
- Use of U-V sensitive marking.
- Encapsulation.
- The word 'COPY' in coloured print.

- Watermarking of the paper
- Embossing of the Authorities crest in the paper

Weights and Measures Inspectors and Approved Verifiers should be aware of the possibility of duplicate calibration charts being held by operators, which may be rendered invalid following a recalibration of the tank or a compartment within it.

The policy adopted by calibration centres when carrying out a recalibration (e.g. following accident damage) is to:

- Attempt to recover any certified copies of charts as well as the original. (Centres should keep records of the number of certified copies issued).
- Endorse the chart when re-issued following a recalibration.
- Inform the original centre of the recalibration.
- Add a second date to the prescribed stamp when recalibrating.

It is consequently vital that when stamping a replacement dipstick, the original (or certified copy) of the chart is produced and a physical inspection is made of the prescribed stamp on the compartment to ensure that the chart is still valid.

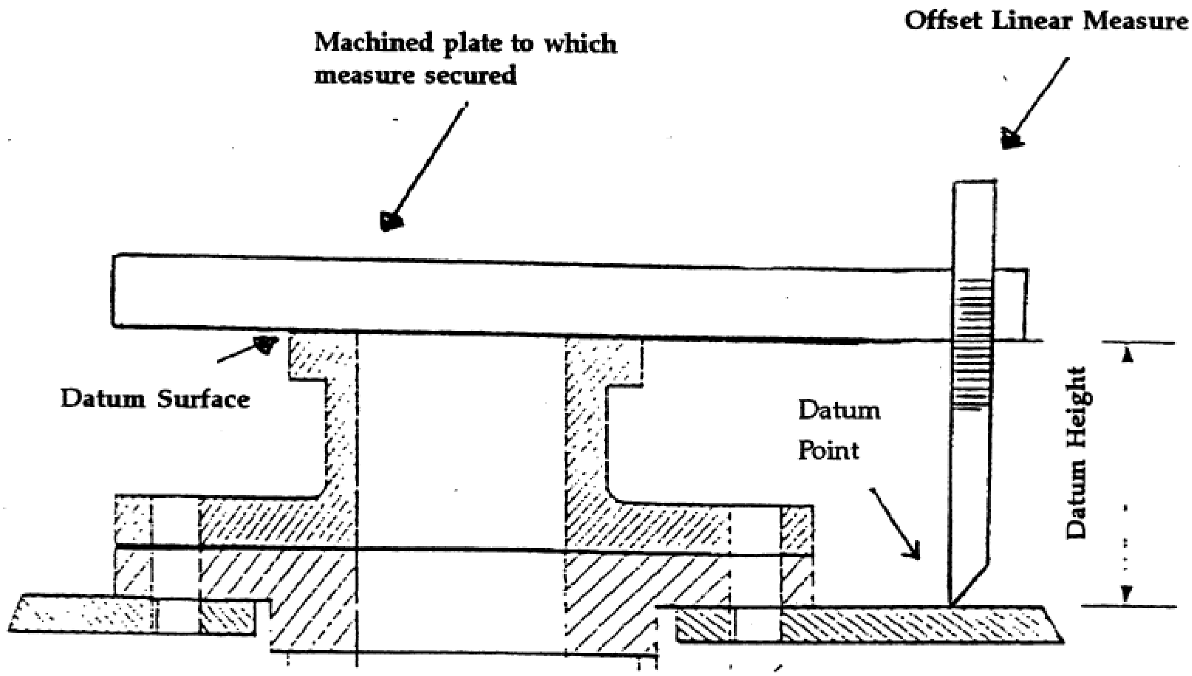
These notes describe the process of verifying or inspecting replacement or spare dipsticks, and also include some guidance on inspection procedures, but the full initial verification process is *not* covered.

Testing of Replacement Dipsticks (and spare dipsticks submitted at the same time as replacement dipsticks).

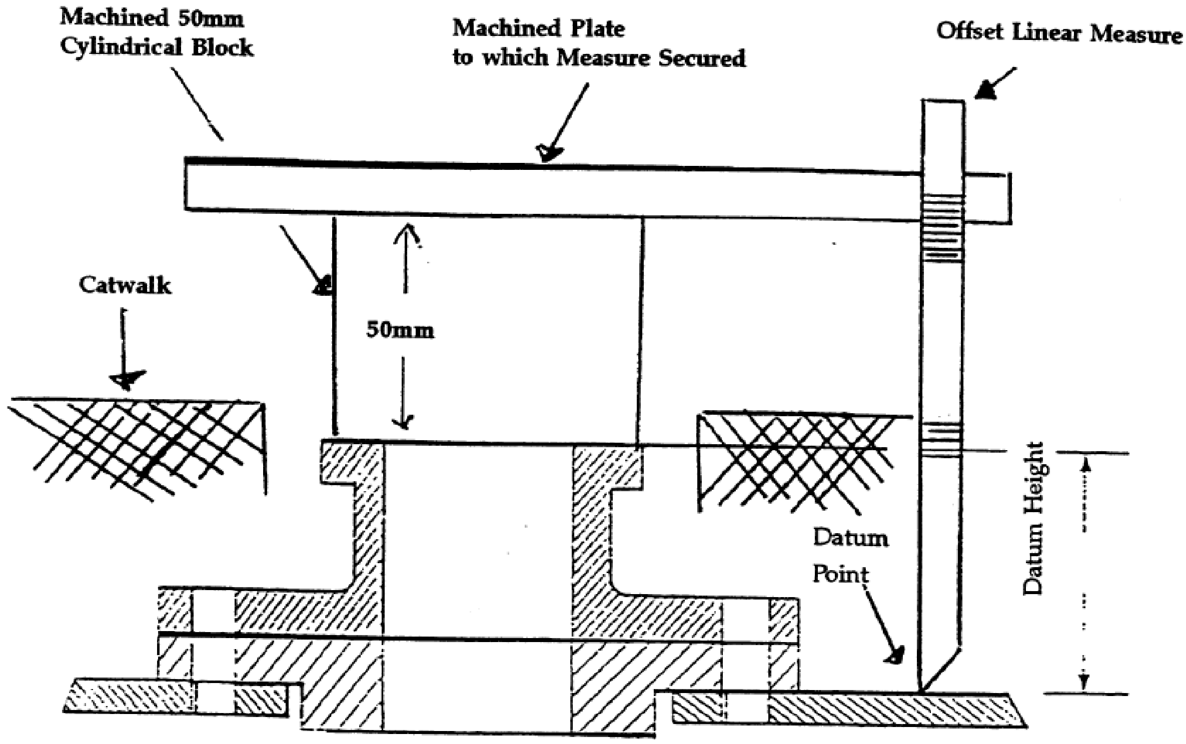
The following equipment will be necessary to verify *replacement* dipsticks:

- An appropriate rigid measure of length, subdivided into millimetres and mounted on a rigid bed with provision for securely fixing the dipstick alongside the graduated face. (A 2 metre rigid measure is often used, although dipsticks of greater overall length are not unusual).

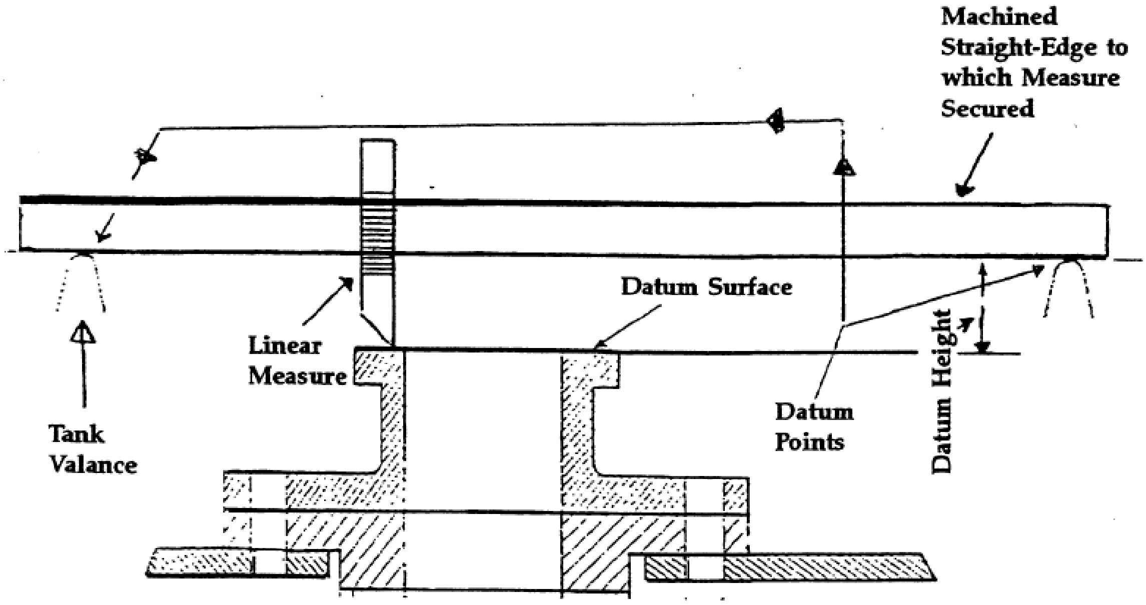
- An offset linear measure capable of measuring the offset vertical height of the datum height. This distance is never capable of direct measurement.



- Machined blocks to facilitate the measurement of the datum height on the compartment are often necessary, and are used in conjunction with the offset linear measure. This is because of physical obstructions, such as catwalks, interfering with the measuring. Blocks are typically of 50mm height and of sufficient diameter to rest on the dip tube datum surface.



- When datum points are located on the tank valances a rigid, non-flexing, machined straight-edge capable of spanning the width is required, with a vertical linear measure incorporated.



- A method to test the depth of scale marks on the dipstick itself, if in doubt about their compliance (e.g. depth gauges).

- For wooden dipsticks, a branding-iron for applying the prescribed stamp. Traditional cutting punches are unsatisfactory when used on wooden dipsticks as the material rapidly recovers and a stamp becomes indecipherable. Details of a suitable device can be provided by calibration centres.

- An intrinsically safe torch, which can be used in explosive atmospheres, to facilitate internal inspection of tanker compartments – to check for new dents or possible 'displacement' fraud, by reducing the size of the compartment.

It must be noted that, when a replacement dipstick is submitted it is the dipstick measuring system which is being assessed and not just the dipstick itself.
The dipstick measuring system comprises the compartment and its associated dipstick.
Data concerning the calibration of the system is contained in the calibration chart, the original or a certified copy, which must be presented at the time of submission.

Inspection of the Road Tanker
The vehicle compartment is as much a part of the dipstick measuring system as the dipstick itself and every effort, short of volumetric recalibration, should be made to ensure that it is in the same state as when it was originally calibrated.

The 1983 Measuring Equipment (Liquid Fuel Delivered From Road Tankers) Regulations, SI 1983 1390, made it clear that the Weights and Measures Inspector or Approved Verifier must examine the compartment when testing a dipstick (for verification and for inspection) if the calibration of the system took place more than 42 days previously, which emphasises the importance of considering each component in the system as part of the whole.

The following should be checked:

- Tank serial numbers on the mandrels (and, if present, on the tank itself) should correspond to the tank number quoted on the calibration chart.
- Signs of tank damage or repair both external and internal. Any significant dents present at time of calibration will be detailed on the chart. It should be noted that some tankers have man lids bolted to the compartment such that internal examination is not possible without time consuming removal and replacement of the man lid. This is relevant to Bottom Loaded Vehicle Systems.
- The prescribed stamp, located on the dipstick mandrel, which should be intact
- The height of the datum surface (annulus at top of dipstick) from identified datum point (specified on mandrel and chart in millimetres).
- Tank labelling.

Examination for Testing and Stamping of Dipsticks

Weights and Measures Inspectors and Approved Verifiers should satisfy themselves that:

- The dipsticks are correctly identified with the vehicle and compartment numbers.
- The dipsticks should be manufactured from an appropriate material (often hard rock maple, impregnated to reduce absorption)
- The dipsticks should comply with all the relevant requirements of the Regulations.
- Every dipstick associated with a bottom loaded vehicle shall be marked with the letters 'BLV' before the related tank number and on the graduated face of the dipstick at the other end of the blade.
- The blade of the dipstick is suitably straight and free of flaws to allow it to allow it to slide in and out of the dip tube freely and fully.

Determination of Errors

The dipstick should be tested to ascertain the accuracy of the positioning of each scale mark, and the ‘50mm line’.

Particular attention should be paid to the overall length of the dipstick to ensure that it does not "bottom" in its guide tube preventing the ‘cross piece’ from properly sitting down on to the datum surface.

If the Weights and Measures Inspector or Approved Verifier is satisfied that the measuring system complies with the requirements of the Regulations, the replacement dipstick should be stamped as laid down by the Regulations.

Tolerances

- Tolerances for dipstick systems are given in terms of linear measurement and not volumetric measurement.
- The tolerances are the same for verification and inspection:
- From the dipstick datum face to the lower edge of the dipstick 50mm line, the tolerance is 1mm.

- From the dipstick datum face to the lower edge of each scale mark on the dipstick, the tolerance is 2mm.
- From the datum surface of the guide tube to the datum point (the datum "height"), the tolerance is 1mm

Inspection of Dipstick Measuring Systems

The inspection of a dipstick system is no different from the process for the verification of replacement dipsticks. Inspection of the *whole* system is important in ensuring the continuing integrity of the system.

As with meter systems, some inspection tests can be carried out without the use of large amounts of specialist equipment The opportunity could also be taken to carry out such tests if a ’roadside’ audit is being conducted using the documentation required by the Weights and Measures (Liquid Fuel Carried by Road Tanker) Order 1995; SI 1995/778.

Examples of inspection tests include:

- Ensuring that the dipsticks belong to the tanker in question by comparing tank numbers.
- Ensuring that dipsticks are not of excessive overall length by inserting them in the appropriate compartments.
- Having ensured that the dipsticks relate to the compartments, checking the critical errors of the 50 mm lines on the dipsticks and the datum heights (height from datum surface to datum point) of each compartment.
- 50 mm lines can be checked by a simple measure of length.
- The datum heights (marked on the mandrels) are more difficult to check without the necessary offset linear measures but it may be possible, by using an available straight edge, to approximately establish the height.
- The blade of the dipstick remains suitable straight and free of flaws that might prevent it from sliding in and out of the dip tube easily and fully.

If there are doubts about the genuine compliance of the dipsticks or the mandrels of the tanker in question, as much detail as possible should be taken from the tanker in order to check it against the tank calibration chart held by the operator.

2. Meter Measuring Systems

All meter measuring systems require Type Approval. Existing older systems could have UK Pattern Approval or EC Approval whereas later systems will have MID Type Examination.

New systems will require Approval in accordance with prevailing legislation that is current at the time.

For legal integrity it is vital that Weights and Measures Inspectors and Approved Verifiers consider the relevant Approval Certificate for the submitted system and apply the appropriate seals.

Currently there are 3 broad types of system:

- Wet line (Full Hose)
- Dry Line (Empty Hose)
- Dual Hose - combined Full Hose / Empty Hose System

There is also a Gravity Drop Metering System, but these are not commonly found in use.

Technology has advanced rapidly and modern tankers have progressed a long way from the simple top-loaded wet line systems with mechanical headworks that were in use in the early 1980s when Local Weights and Measures Authorities first became heavily involved with them.

New systems may have different principles of operation from those that had been previously established. The testing of such systems involves different techniques and sealing practices, and the study of, and adherence to, individual Approval Certificates is essential.

Great care is needed when testing modern systems due to high operating pressures and the high flowrates involved.
When empty-hose systems are purged, the air pressures involved are considerable, will seriously damage the connected reference meter and could also cause injury as the hoses move vigorously when the blow down takes place.

The Combined Full hose / Empty Hose systems have an interlocking device to ensure that each delivery is either a complete full-hose or empty-hose delivery. The full-hose deliveries are in the region of a maximum of 450 litres/minute (l/min.) flowrate although typical values are nearer to 350 l/min. The empty-hose deliveries use a larger hose and work at considerably higher flowrates, typically up to 700 l/min. They also "blow-down" the remaining (measured) contents of the hose into the customer's tank at extremely high pressure.

The operation of such systems should be clearly understood before any testing is commenced. If there is any doubt as to operational principles or testing procedures, advice should always be sought.

Testing Meter Measuring Systems

The following equipment will be necessary to verify meter measuring systems:

- For all practical purposes the accuracy of a meter measuring system will be determined by using a reference meter.

  There are three variables in particular which affect the accuracy of meters, including reference meters. These are:
  - The viscosity of liquid being measured
  - The flowrate of liquid during testing
  - The pressure of liquid during testing

  Consequently the Weights and Measures Inspector or Approved Verifier must make allowances for these three factors to enable an adjustment to be made to the reference meter indications during testing in order to arrive at a figure of the true quantity passed

through the meter. This figure can then be compared with the indication of the meter which is being tested.
The method of making these allowances is discussed later in this Guidance.

- Other Metrological Equipment. For testing empty-hose systems it will be necessary to carry suitable calibrated volumetric measures, for example 1000 ml or 2000 ml subdivided glass measures. The total, likely hose retention will be in the order of six to eight litres and so suitable containers will be required.

- Miscellaneous Equipment. Appropriate safety equipment (including a fire extinguisher) should be associated with the reference meter test rig. The rig should also be equipped with cleaning equipment, tools, buckets, hose fittings, sealing equipment and a first-aid kit. In addition a trailer should be equipped with appropriate road safety equipment such as a spare-wheel, foot pump, etc.

The first task is to determine which of the three types of meter measuring systems is to be tested:

- Wet Line (Full Hose),
- Dry Line (Empty Hose) or
- Combined Full-Hose / Empty-Hose Systems

All systems must have a data plate, which contains information required by the Approval document. Use of this Approval document will make it possible to check the general conformity of the system.

Practical guidance has previously been given on a number of questions of interpretation and practicality relating to these systems and these are reproduced below:-

a) Anti-Swirl Device
An anti-swirl device is designed to prevent the entrainment of air in the fuel by 'swirling', or spinning, as it exits the compartment of the tank.
In most cases the foot valve will fulfil the functions of an anti-swirl device. The effectiveness of the anti-swirl device can be tested by visual observation of the product in the compartment during discharge.

b) Gas Extractors
For the distinction between gas extractors, special gas extractors, and gas Separators, see the Glossary.

- Where a pipe runs from a gas extractor to a vent or a catch tank, the vent pipe from the gas extractor should not permit the interruption of the escaping gas. This may be achieved by rigid pipework or armoured flexible hose. This requirement is essential to ensure air and gases brought into the system by the removal of jumper hoses, or by compartments running dry, are extracted from the system by the gas extractor and are allowed to be vented from the extractor. If the venting pipe is obstructed the extracted gas will not be vented and instead will eventually be pushed along the line of least resistance (through the meter) which will measure both liquid and gas. This mix will then be dispensed.

- Joints should be kept to a minimum. Any joints should be capable of being sealed except where soldered metal pipes are used.
- An outside vent should be difficult to block, preferably surrounded by a secure cage.
- The catch tank should be positioned or protected such that the vent cannot be readily blocked, e.g. at the top of the tank.
- The pipe and vent must be of adequate bore so that air extraction is effective at all flowrates.
- A number of types of flexible, armoured piping have been submitted for use on gas extractor vent lines. Some of these have been judged to be acceptable, whereas others were felt to have been insufficiently strong to prevent kinking or crimping. It is suggested that, if in doubt, the Weights and Measures Inspector or Approved Verifier should apply practical tests to a specimen of the pipe submitted to ensure that it is effectively armoured. It should not be possible to "uncrimp" it, without leaving signs that the manipulation has occurred.
- There is not usually a definitive requirement for a particular form of pipework in Approval documents. Manufacturers and repairers have generally co-operated to provide armoured / hydraulic pipes which cannot be easily crimped, or if they are, will leave indications which allow Weights and Measures Inspectors and Approved Verifiers to identify these vehicles for further investigation and action.

c) Manifolds
Where several compartments are connected through a manifold there should be a device to prevent more than one compartment from communicating with the measuring system simultaneously.

d) Marking
The minimum delivery of the meter must be marked on the indicating mechanism. This marking must not contradict the marking on the descriptive plate of the system.
The Approval Certificate will require the meter to be Test Certificated and the descriptive plate on the meter must show the Approval Certificate number.
All the markings for the system can be on a single plate.

e) Pre-set Valve
Some Approval Certificates may require the pre-set to have a two stage cut off.

f) Pumps
The is no objection to a 3” pump being fitted on a 2” nominal meter system provided it functions within the declared limits, and does not cause the gas extractor to fail.
Early Type Approvals had listed suitable pumps for each system, but this has now been discontinued as it is no longer considered necessary.

g) Ticket Printer
The ticket printer must print, in addition to the figures, the unit of measurement or the S.I. symbol for it.

h) Valves

A full-hose system must have an anti-milking valve incorporated in the nozzle to ensure that the hose contents cannot be drained. This is tested by opening the nozzle-trigger and attempting to drain the hose whilst the meter pre-set valve is closed.
Some meter systems may incorporate a check valve fitted after the gas extractor, to aid the operation of the gas extractor. This is not necessarily mentioned in the Approval Certificate, but it is considered that it is unlikely that this would constitute sufficient grounds on its own for rejecting a system. Pressure differential valves could be introduced to close the pre-set valve when air is present, but would need to be noted in the Approval Certificate

Some Approvals show R2 (an optional 2 way valve, for direct unmetered delivery) schematically in a diagram as a 2-way valve and it is recommended that two-way valves should be fitted for the following reasons:

- Only one outlet at a time may be accessed and 2 way valves prevent simultaneous communication between three orifices
- Fraud could be committed by a product being delivered elsewhere through the meter system while making an unmetered delivery or vice versa - although this is considered to be unlikely as there would be easier ways to deliver short measure.
- If there is a long length of pipe between the T in the pipework and a gate valve, air could be trapped or contamination could occur while the meter system is in use.
- The meter system could be subjected to pressures from the pump during the whole time the unmetered delivery point is in use.

It was recommended that tankers without 2-way valves, which were already stamped, may continue to be stamped but new tankers must be fitted with 2-way valves before being accepted for stamping.

A Dry Line System must not have any kind of valve or other end closure on the delivery hose which could possibly retain a significant quantity of dispensed liquid in the hose.

Reference Meter Corrections and Allowances

The indication of the quantity of liquid passing through the reference meter is subject to certain influences and it is therefore necessary to consider them in order to determine the actual true quantity of liquid which passes through the reference meter.

A reference meter will be calibrated using two fuels of significantly differing viscosity. These are usually kerosene and gas oil (diesel containing a red dye)

This Section describes the method used to make allowances for variations in:

- viscosity of liquid being measured
- flowrate of liquid during testing
- pressure of liquid during testing

in order to determine the true quantity of liquid passed through the reference meter during a test.

Pressure
When testing trade meters it is the usual practice to make allowances for the differences in pressure between the test being carried out and the pressure which existed during the testing of the reference meter itself - even though this correction is relatively minor compared with viscosity and flowrate corrections. Indeed, relative

to other variables, the pressure differential is so insignificant that it is not considered as a correction factor in calculations by some Weights and Measures Inspectors.

Viscosity and flowrate
These are significant factors which must be taken into account.
A calibration graph must be produced for each type of fuel, thereby taking the effect of viscosity into account. This *must* be used for flowrate corrections.
The usual way of composing the calibration graph is to plot the % error against the flowrate.
The calibration graph will usually have been drawn at a standard pressure of 20 lbs/sq.in. though this will not necessarily be the case where differing practices are adopted in relation to the significance of the error due to pressure variations.

Alternatively, some Local Weights and Measures Authorities draw a graph of error against flowrate without correcting for pressure, but indicating pressure measurements at specific flowrate points. This enables the Weights and Measures Inspector or Approved Verifier, when testing a bulk fuel meter, to make judgements about reasonable parity between pressures. It will have separate curves for different viscosities of liquid.

During testing of a trade meter, the curve for the liquid under test is read at the flowrate determined by either a flowrate indicator on the reference meter, where one is fitted*, or by determination against a stopwatch. The percentage quantities are added to, or subtracted from, the reference meter reading as appropriate in order to determine the true quantity of liquid passed.

The pressure during testing is determined by gauges on the reference meter.
As an example, using a correction factor of 0.001**%** of quantity for every1 lb / sq.in. differential from a graph figure of 20 Ibs/sq.in, the reference meter reading is adjusted. The reference meter reading will be reduced where operating pressures are under 20 lbs/sq.in. and increased where operating pressures are greater than 20 lbs/sq.in.

The following is a mathematical example for gas oil, using the Reference Meter Calibration Graph printed below, and pressure differential figures:-

During the test on the bulk fuel meter it was noted that the flowrate of the test was 150 litres / minute and the operating pressure was 12 Ibs / sq.in.
The nominal quantity used for the particular test was a delivery of 1000 litres.

The Officer stopped the test with:
Reference Meter indication: *998.5 litres*
Trade Meter Indication: *1000.1 litres*

Error from calibration graph at 150 litres/ min: -0.057%

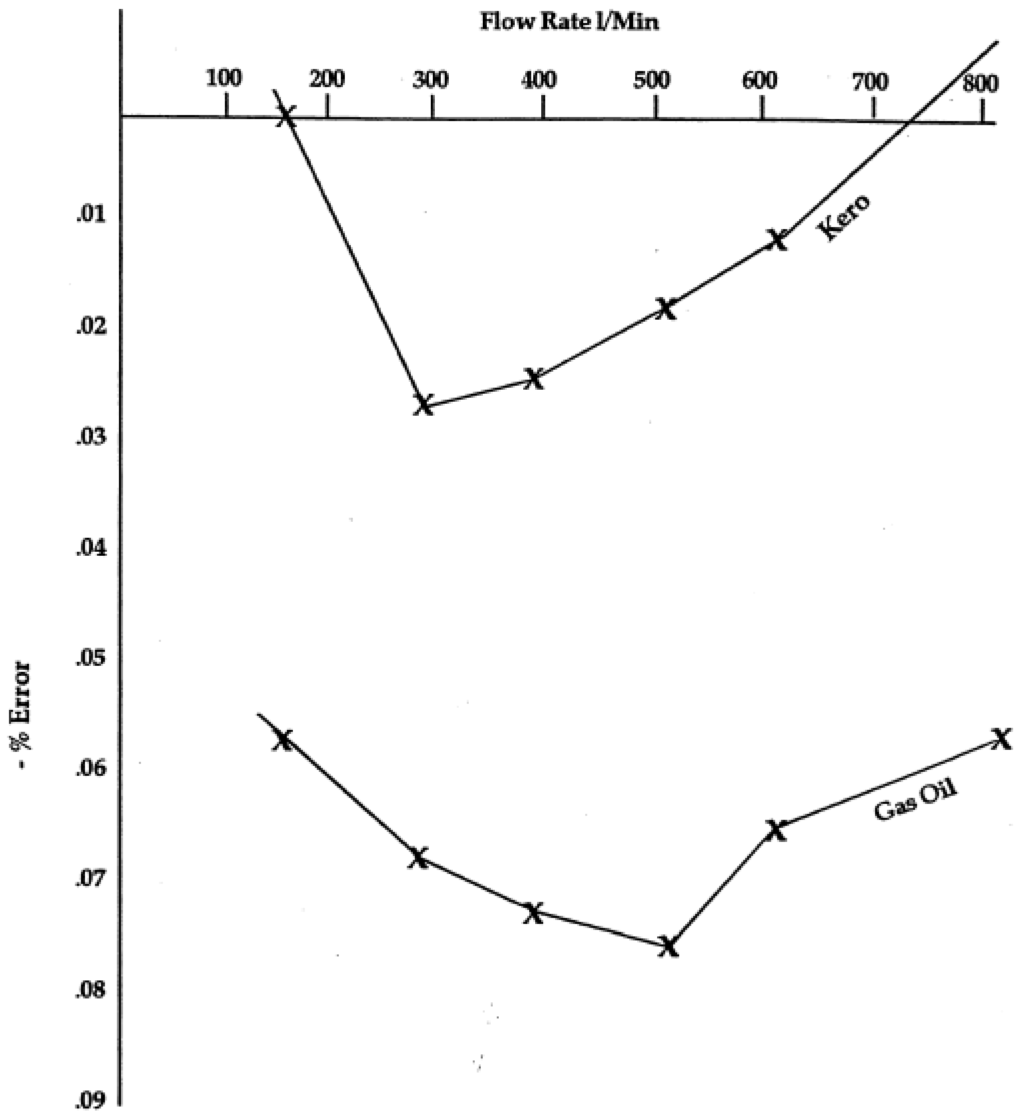
Pressure:	*12 Ibs/ sq.in.*
Calibration pressure:	*20 Ibs/ sq.in.*
Differential	*-8*
Error:	*- 8 x 0.001% = - 0.008%*
Combined Errors:	*- 0.065%*
Actual Error	*-0.065% x 998.5 litres = - 0.65 litres*

True quantity passed through reference meter = 997.85 litres

Trade Meter Error = 997.85 - 1000.1 = -2.25 litres

This is -0.225% and in this case is in deficiency or short measure.
This compares with a figure of -1.6 litres were the reference meter corrections not made at all and -2.16 litres if the effect of pressure is ignored.

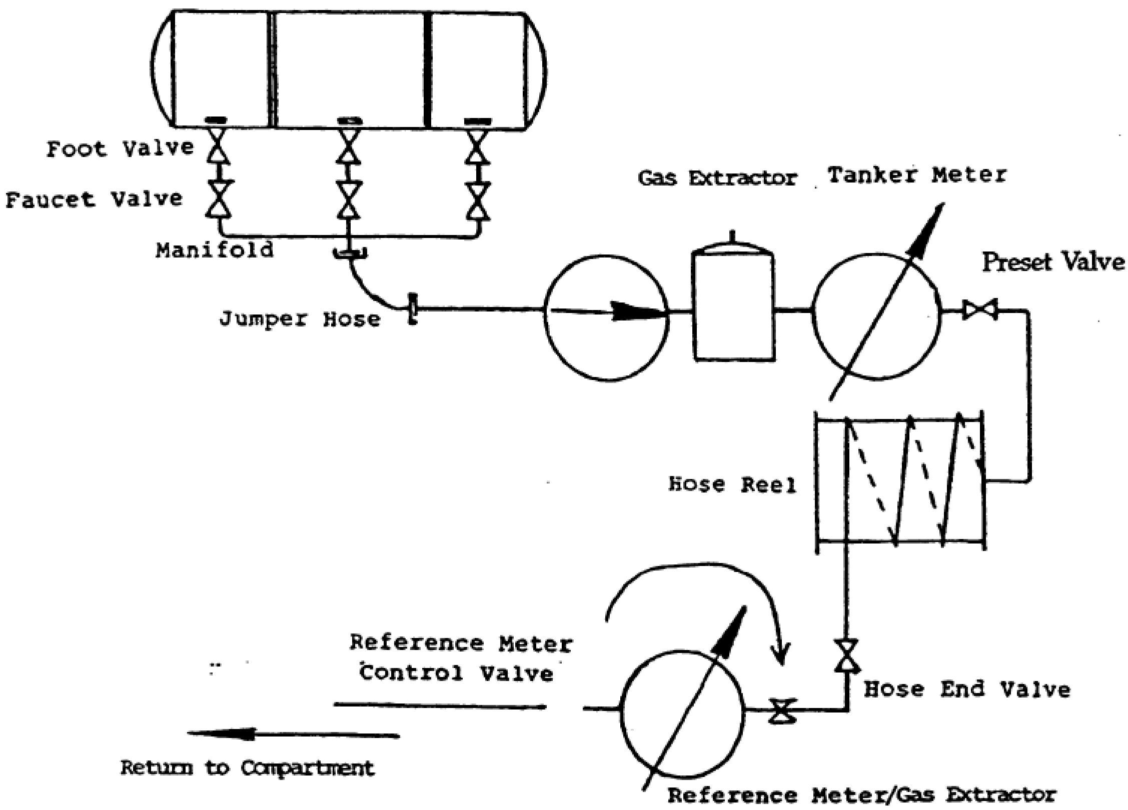
Example of a Reference Meter Calibration Graph



Graph corrected to 20.P.S.I.

Testing a Wet Line Meter Measuring System - Full Hose

Schematic Diagram of Wet Line System and Reference Meter connections



Safety
Particular care should be taken to ensure the safety of all persons and property when carrying out the test.

Tests
The order in which elements of the test are carried out may be varied taking into account the nature of the system, location, or history of any problems encountered.

Tolerances:

i. System

MMQ to and including MMQ x 2 ± 1% x MMQ

Greater than MMQ x 2	± 0.5% x quantity delivered

- If an MID compliant measuring system is adjusted, it must not be used for trade unless the calibration of the system is set as close to zero error as is practicable.
- For systems complying with the Measuring Equipment (Liquid Fuel Delivered from Road Tankers) Regulations 1983 (Crown stamping) if all errors are either positive or negative, at least one error in 5 must not exceed 0.3%
- The Measuring Instruments (EEC Requirements) Regulations 1988 did not set any additional requirement.

ii. Hose Dilation

a. As part of the systems test, any hose or hose reel fitted to the system is part of the Measuring System and therefore any errors due to the effect of hose dilation when tested will contribute to the overall system error

but

b. For full hoses in a measuring system provided with a hose reel, the increase in internal volume due to the change from the coiled hose position when not under pressure to the uncoiled hose position when under pressure without any flow of liquid, shall not exceed twice the minimum specified quantity deviation.
(OIML R117-1:2019 Dynamic measuring systems for liquids other than water)

That is to say, if MMQ is 200 litres at the tolerance of ±1% of MMQ then minimum specified quantity deviation is 1% or 2 litres and hose dilation shall not exceed 4 litres. The consequence of this is that, were hose dilation to be 4 litres, the meter would have to be set to +2 litres, it is argued, for the system to be within tolerance of ±1%: +2 litres – 4litres = -2 litres.

iii. Sales Indicator

- Must be set to zero before measurement of the liquid fuel commences;
- Must remain at zero until fuel starts to emerge from the instrument;
- Must not be reset to zero during measurement of fuel and
- Must not be able to be advanced by any means other than by the discharge of fuel from the instrument and the proper operation of instrument.

iv. Ticket Printer

A measuring system must not be used for trade unless it is fitted with a ticket printing mechanism which provides an individual printed ticket.

Markings

Where a measuring system is marked with—

- A temperature range, it must not be used for trade at temperatures outside that range;
- A flowrate range, it must not be used for trade at a flowrate outside that range;
- A mark which signifies the manner and purpose of use, it must not be used for trade in a manner or for a purpose which does not accord with that marking.

Condition of the System to be tested

The system to be tested should be presented in a satisfactory condition, with one empty compartment and two liquids for testing.

The liquids should represent the extremes of viscosity with which the system is designed to be used (for practical purposes this will usually be gas oil and kerosene). The compartments containing the liquid should be at least half full and contain at least 1000 litres. The intention is to create a closed circuit with minimal aeration and risk of 'splashing'.

The reference meter should be sited so that adequate access can be gained to its controls and those of the meter system under test and the two readings can be compared.

To avoid cross-contamination it should be confirmed that the type of fuel throughout the system is the same. In unusual circumstances it is possible that they may differ if, for example, the driver's last delivery was "frustrated" whilst fuels were also being changed.

Preparation for further testing

With the hose reel withdrawn fully, connect the nozzle (control valve) to the inlet of the reference meter - the spout of the nozzle can be removed leaving a 'female' coupling which, with the use of adapters, facilitates connection.

Connect a hose of suitable length to the outlet of the reference meter. It is useful if a short section of this hose, close to the reference meter, is transparent. Alternatively the end part of this could be a length of rigid pipe of sufficient length to reach the base of the tank – it has been found that having a length of rigid pipe makes for easier handling.

Place the other end of this hose in the compartment of the tanker which contains the liquid to be used for testing and which is the one from which fuel is being drawn. Ensure that this hose is:-

- Secured so that it cannot be forced out of the compartment by the force of liquid being discharged from it,
- Below the level of the liquid in the compartment to avoid aeration and splash loading,
- Clear of the foot valve.

It is suggested that a non-return valve is incorporated in this return hose to prevent any product drain-back across the reference meter.

Ensure all connections are securely tightened and that all ancillary valves on the reference meter are in their correct positions to permit flow only through the meter. It is particularly important to ensure proper operation of any air separators.

Place a suitable receptacle under the outlet of the reference meter gas extractor to catch any spillage.

Valves Used to Control the Tests

It has become apparent that use of the reference meter outlet control valve (which is downstream of the reference meter) to terminate deliveries when carrying out the system test, can result in a false indication of the amount delivered due to compression of residual air in the reference meter gas extractor. Consequently, it is advisable that when carrying out the system test, delivery should be terminated using the hose-end valve as this simulates operational practice or, if felt preferable, the inlet valve on the reference meter could be closed to terminate the system test.

When carrying out meter tests the delivery should be allowed to terminate itself at the pre-set value programmed into the system, which should be the appropriate test quantity.

Hose Dilation Test

Depending on the system under test one of three options should now be followed to determine the hose dilation volume: -

a) With the hose end nozzle open start the delivery and when the system is up to full speed close the nozzle. Promptly stop the system pumping. Zeroise the reference meter and open the hose end valve. The fuel released and measured by the reference meter is the hose dilation. This is the normal, recommended, method to use as it places the least stress on the hose for the shortest time!
b) With the hose end nozzle open start the delivery and when the system is up to full speed close the nozzle. Promptly stop the system pumping. Record both the meter under test and reference meter readings. The difference between the two is the hose dilation. As soon as the readings have been taken open the hose end valve to release the pressure in the hose. This is the recommended method for systems such as the Emco Wheaton DataPlus II which using method a) appear to give a zero hose dilation error.
c) With the hose end nozzle closed start the delivery, monitor the meter under test display. Once it stops increasing stop the system pumping. The hose dilation is the meter under test reading. This is the recommended method for systems such as the Alpeco TE550 with a clutchless PTO which dissipates the pressure in the system as soon as the pump is stopped so no hose dilation can be recorded using method a).

Determine the Maximum and Minimum Flowrates/Pressures

- Start the system and run liquid round the system.
- Allow the test liquid to circulate until stable conditions, including temperature stability, have been achieved, accepting that 100% temperature stability is not fully achievable as over time the fuel will get warmer.
- Speed up the pump using the engine hand throttle control (if fitted) until the pressure shown on the pressure gauge of the reference meter ceases rising or until the indication of the rate of flow has reached a maximum value. This indicates that the system is operating at the maximum rate of flow.
- Note the flowrate and pressure.

Determine the reference meter correction for that flowrate and pressure.

- Adjust the engine hand throttle to the minimum possible, so that the engine does not stall
- Note the flowrate and pressure and determine the reference meter correction
- If this flowrate is below the minimum that the system is designed to operate at, the throttle will have to be adjusted up, until that minimum is reached
- If this flowrate is above the minimum that the system is designed to operate at, it is possible, if appropriate, to "strangle" the flowrate by means of the hose end valve, until the minimum design flowrate is obtained.
- Close pre-set valve.

For verification and inspection purposes the meter and system are tested within the range of the marked maximum and minimum flowrates.
It is argued that if the system is capable of operating outside its marked and plated flowrates it cannot be stamped as it is not compliant with the plate.
Should the system be used outside these limits an offence may be committed and consequently the trader should constrain the flowrate capability of the equipment to be within the design parameters.

A number of factors can affect the flowrate within which any given meter system operates. These include the type (and condition) of the cargo pump, the power take off gearing, condition of the filters, the hose reel diameter, the bypass pressure setting and product used.

Testing the System in Operation
When considering which combinations of test conditions will produce the greatest errors, the following points are worth considering;

- The effects of hose dilation give a negative error generally, but in some circumstances a positive error may occur in practice when starting a run from a pressurised state.
- Generally, errors will follow this pattern:
  - Thick liquid - slow delivery, gives the maximum negative error
  - Thin liquid - fast delivery, gives the maximum positive error

- Insert a ticket in the metering system under test and zeroise both meters.
- Ensure the security pin, if there is one, is engaged in the ticket.
- Start the system and run product through at a constant flowrate.
- Terminate the delivery at the hose end control valve or by the pre-set valve as required, for system or meter tests respectively.
- Record both meter readings and determine the meter under test error, by the method described above.
- Repeat the test using each of the two liquids and the maximum and minimum flowrates, together with the use of the pre-set valve and hose end valve to terminate the delivery. The latter will induce any system error due to hose dilation.
- Tests should be applied a sufficient number of times to ensure that the system has acceptable repeatability, but not less than three repeat runs at each rate of flow.

Optimum Test Quantities to Use for the Tests
The most stringent condition is at double the minimum delivery and it would be appropriate to conduct the majority of tests at this quantity.
* Note that the minimum dry hose delivery is normally greater than for a wet hose system. This means that when testing a dry hose system, particularly on a dual hose meter system fitted tanker, the test quantity differs between the dry hose and the wet hose system.

Ancillary Equipment Tests
The tests above will also allow the correct operation of the following to be assessed:-.

- Ticket Printer
  - Note the difference between the bulk fuel meter reading and that printed. Vary the quantity to check the various numerals and also to check that the ticket cannot be removed until the final quantity is printed.
  - There should also be printed a code or number which advances numerically for each delivery to allow the continuity of delivery tickets to be checked.
  - Only "single handle" action printers or zeroising arrangements are permitted on mechanical headworks

.

- Zeroising Mechanism

- Gas Elimination Device Test

  A test should be carried out to determine the efficiency of the gas elimination device:-

  - The test is carried out at the maximum possible flow rate by allowing the compartment to run dry with the pump still running, in which case there will have had to be sufficient ullage elsewhere on the vehicle in which to place the removed liquid.
  - The vehicle meter should not advance after liquid has been cleared from the upstream side of the gas elimination device. If it does advance, then the gas elimination device is not functioning properly.
  - It has been found that some systems may pass air, and therefore could be used fraudulently with an increase in engine speed. This means that the gas elimination device is likely to pass air if the hand throttle stops are adjusted. Weights and Measures Inspectors and Approved Verifiers are advised that the use of the foot throttle may be justified in some instances if it is suspected that the gas elimination device is inefficient, or the hand throttle stops are such that the hand throttle does not significantly increase engine speed. Extreme caution is needed if the foot throttle is used.

  It is essential that when this test is done, it is conducted with extreme care in order to avoid damage to the cargo pump.
  Because the liquid will have cleared the pump, the pump itself ~~it~~ will be running in a less lubricated state. Some pumps must never be run dry.

  It is important, however, to be aware that there are some dry line systems that are required to run in this state, in order to pump air to clear the line, for several minutes. This can be clarified with the vehicle operator.

Pressure Build-Up

Where the vent pipework terminates inside a tanker compartment it has been found that some systems can allow air to be metered due to pressure build up. The pressure may be sufficient to prevent the operation of the gas elimination device but not high enough to enable the breather on the man lid to open to atmosphere. Under these circumstances, opening the man lid allows the gas extractor to function normally.
This problem may be more apparent when the compartment is full of liquid with only a small volume of air to be pressurised. Therefore the product must be taken from and returned to a different compartment than that in which the vent terminates to allow the lid to be left closed whilst testing.

Simulated Delivery Test

This is a particularly useful test to determine whether the gas elimination device will cope satisfactorily with the air / liquid mixtures experienced when empty pipework is first flooded with product, and when a compartment is actually in the process of running dry.

Whilst it is not a complex test, it is time-consuming to set up and to conduct. Because of this it is likely that this test will only be carried out if the performance of the gas elimination device during earlier tests has given cause for concern and been inconclusive.

- The test involves delivering a quantity of liquid measured by the bulk fuel meter directly to an empty, but wetted compartment
- This liquid is then removed, allowing the compartment to run dry
- The two readings are compared
- The reference meter is not required for this test.
- Care must be taken in setting up such a test to ensure that pipework beneath the initially empty compartment is empty both before and after the simulated delivery, and that the pipework up to the gas extractor is likewise empty both before and after the simulated delivery.
- Any errors due to metering gas and air will be shown.

Inspection Tests

Inspection tests on full hose systems are basically the same as verification tests. Such tests are important as they ensure the continuing integrity of the system.

Some inspection tests can be carried out without the use of a reference meter, and examples are given below. The opportunity could be taken to carry out such tests when 'roadside audits' are being conducted on documentation which is required to be carried. This documentation would need to be amended if fuel is transferred during any tests.

Inspection tests on a gas elimination device can be carried out using all the gas elimination device tests previously mentioned without a reference meter being necessary. However they can only be used as a guide in the case of the simulated delivery test.

Limited metrological tests could be applied by:

- Comparing the dipstick, if carried, and loading note details
- Overseeing a delivery being made by meter and comparing dipstick readings both before and after the delivery
- Making a "delivery" from one compartment to another via the meter and hose reel, and checking the relative decrease and increase in fuel levels in the compartments concerned, by use of the two dipsticks – contamination between fuels should be avoided.

It is also important to consider the earthing of the system during such tests due to the possibility of static discharge caused by the movement of fuel.

Testing a Dry Line Meter Measuring System - Empty Hose

The provisions outlined in the above relating to wet-line systems apply equally to dry line systems except, as there is no hose-end valve or closure, the test for hose dilation does not apply, nor will there be any errors due to hose dilation in use.

The following additional test should be carried out at the outset, as failure at this stage would make further testing pointless.

On systems that automatically blow down on closure of the pre-set valve, it will be necessary to disconnect the mechanism whilst carrying out this, and all other tests on the dry line system:

Hose-Variation, or Blow-Down, Test
The efficiency of the system's capability to effectively clear the hose of liquid must be checked. Any variation in this will affect the quantity of liquid delivered by the system and has to be taken into account when ascertaining the total system error.

In order to perform a blow down test, the only safe methodology is to have a by-pass fitted to the reference meter rig and, with the meter isolated, blowdown via the by-pass:-

- Isolate the reference meter by closing off the inlet and outlet valves protecting it and open up the by-pass.
- Prime the system fully and then blow the system down for the recommended "blow down time", which should be marked on a plate fixed to the meter housing, or until it is clear no fuel is passing along the reference meter return line – another good reason to have a clear section of pipe or an observation window fitted on the reference meter rig.
- Switch off the engine and pull out the hose to its maximum extent, laying it out on the ground.
- Disconnect the hose from the reference meter rig.
- Drain the hose. It is suggested that the hose is drained by "shouldering" the hose a couple of times. Measure the fuel drained and record the result.
- Repeat the above test at least once more.
- When the system has "blown down" and the line is clear, there is less resistance in the system and it is suggested that the gas extractor test be applied in this condition as well. A delivery would commence with the equipment in this condition hence the metering of air/gas at this stage is unacceptable and would put the system outside the permitted tolerances.

It is the difference between the results of the two different tests that is important and constitutes the hose retention error, although the difference may in fact be found to be minimal and therefore taken to be insignificant as modern blowdown mechanisms are very effective.

For each metrological test subsequently carried out on the dry-line system, this difference must be:

- added to,
  and
- removed from

the meter error to determine the system error.

There is no other system test on a dry-line system.

As an example:
If a particular meter test gave a negative error of - 2 litres before conversion to a percentage, and the hose variation was 2 litres, the two errors possible in the system for the quantity delivered under test would be:

- Zero litres, and
- minus 4 litres

before conversion to a percentage

The former would represent a situation where an 'uphill' delivery (when the tank connector was above ground), causing fuel to be retained was followed by a 'downhill' delivery (when the tank connector was below ground) expelling the retained fuel.

The latter would represent the reverse scenario where a 'downhill' delivery was followed by an 'uphill' delivery.

Gravity Drop Meter Measuring Systems

Summary
The legislative requirements covering approval and testing remain the same for gravity drop metering systems as for conventional vehicle mounted systems, however, the systems and their associated operating characteristics present practical difficulties for Local Weights and Measures Authorities and Approved Verifiers, in particular those who do not have access to suitable facilities for dropping fuel into a tank below ground.

It is considered that initial verification must be carried out when there is access to such suitable 'below vehicle' facilities, whereas it is acceptable for reverification to be carried out by more conventional use of a reference meter.

History

With the advent of environmental protection legislation, dipsticks are no longer permitted as a means of determining quantities of petrol delivered to garages from tankers, either rigid or articulated, that entered service after 31st December 1999.

This requirement generated a need for alternative means of security for the garage, including sealed parcel delivery systems, with various interlocks, and metering systems.

As it had not been permitted to pump petroleum spirit from a road tanker in the UK there was an emergence of gravity drop metering systems whereby fuel is unloaded from a tanker in the conventional manner, flowing un-pumped into the underground storage tank, but now flowing through an on-board metering system. This presents a method for measuring the actual quantity dropped rather than loaded, and also facilitates split deliveries. There were, therefore, great attractions for the small garage customer.

It was difficult to estimate the size of the market for gravity drop tankers, and they are not common, but there is merit in considering them in these notes, in case they are encountered.

System Characteristics

Gravity drop metering systems are very simple in concept, being a metering system located down-stream of the tank compartment on a vehicle so that fuel flows through the meter into the underground receiving tank. Some such systems exist that are also approved for pumped deliveries, and systems can be fitted as an addition to a vehicle that already carries a stamped approved 'conventional' system.

Meters may be of the positive displacement type or of the inferential type (i.e. turbine meters). These two design principles may give rise to different operating characteristics and they present different problems.

The operating characteristics of these systems differ from conventional systems. They start with no flow rate, rapidly ramp up to full speed, which is unlikely to exceed 400 l/min, and then ramp down to no flow as the head in the discharging tank compartment falls, or a pre-set point is approached.

Legislative Requirements

All meter measuring systems for liquid fuels require Approval and these systems also need to comply with the same regulations and tolerances as do conventional vehicle mounted systems, despite their different operating characteristics.

Testing

Testing gravity drop metering systems presents challenges for Local Weights and Measures Authorities and Approved Verifiers since, in order to check proper operation, it is necessary to replicate the obvious fact that fuel is discharged into a tank below vehicle level, under gravity.

There needs to be a method of accurately knowing the quantity of fuel passing through the meter, either by passing a known quantity through it, and relying on a constant retention factor, or by measuring the actual quantity dispensed to a level below it.

This would mean that testing of systems can only be carried out where there is a facility for dropping fuel into a tank below ground, accompanied by a pumped return system. It is recognised that this

presents a burden for business as there are only a small number of such facilities available and these may not be readily accessible.
It was therefore agreed that, whilst initial verification must be conducted by a verifier with such suitable facilities, effective reverification may also be carried out by verifiers with access to a reference meter and in accordance with this guidance.

Initial Verification
Initial verification of new systems must be carried out at a full testing facility.
The ability to conduct some of the tests will depend on the storage capabilities of the particular test centre.
It would appear that the most likely used test method is to discharge a known quantity of fuel through the gravity drop meter.

In order to conduct tests effectively, a number of safeguards have to be considered:-

- Compartments must be top or bottom loaded by means of a traceable reference meter.
- Where appropriate, the hose used for filling the compartments must be fixed so that it cannot move. It must either be above the level of liquid in the compartment to avoid possible siphoning, removed from the compartment after loading or fitted with a non-return valve at its end.
- It is considered good practice for such a non-return valve to be fitted to avoid possible generation of static caused by splash loading.
- Time must elapse after filling and before discharging to avoid excessive cavitation due to any splash loading of compartments if a non-return valve is not fitted.
- There must be a wetting run for all compartments.

An important part of the initial verification would be to ensure that the pipework of the vehicle, *as actually fabricated*, did not have differing retention characteristics in the discharge routes from each individual compartment – different discharge routes may have different retention characteristics.

In order to check this, tests should be conducted, having first wetted all pipework, with a quantity of MMQ *delivered from each compartment* and then, if there is no significant difference between compartments, one compartment only need be used for further tests.
This test can additionally be used to simultaneously test performance at MMQ and the operation of the air eliminator as the compartment is run dry.

- Each meter should be tested at maximum and minimum head, but operational constraints may limit this to volumes between MMQ and 2.5 x MMQ, and, in the case of maximum head, the ability to confidently summate deliveries so that they add up to the volume loaded into the compartment under test.
- Tests should be conducted on 2 x MMQ and there should be at least 3 runs for each fuel. The maximum and minimum flow rates should be checked, Q_{Max} being tested with high head using pre-set and Q_{Min} with MMQ.
- Volumes tested should include 2 x MMQ at both maximum and minimum head. In order to achieve this, for the minimum head tests, the compartment should be empty at the end of each 2 x MMQ run.
- A maximum head run may be incorporated when other parameters are being tested.
- Tests should be carried out to check pre-set deliveries

- There should be safeguards to ensure that wet lines remain wet and that dry lines have a constant retention.

Additionally, whilst the ability of a system to deal with split loads will have been addressed at the Approval stage, it is important to ensure that individual systems function correctly in practice:-

- A test on a split drop at 2 x MMQ could incorporate the maximum head test and the pre-set test.
- Constant retention will have been initially tested in repeat runs.

It is important to drain compartments to empty, to replicate in service use. With turbine meters it is essential that tests ensure that air is not sucked from empty compartments.

As with many systems, there is an ability to input calibration factors for different fuels. There will undoubtedly be pressure to input factors for all fuels, and whilst ideally no factors should be introduced for fuels that have not been used for testing purposes, there is a need to address this issue in a practical way for petrol. Some test centres may be able to offer tests using certain petroleum substitutes. Where this is not possible, a two stage initial verification could be considered under certain circumstances where the vehicle has been satisfactorily tested on other fuels. An observation of a loading of petrol from a traceable gantry meter could be compared with the readings as discharged on site. The readings should not exceed the maximum permissible error. This assumes that temperature effects will not be
critical, or are compensated for.
Alternatively, it may be possible in the future to input a calibration factor for petrol by establishing a reference relationship of this factor with other fuels.

Reverification
Reverification may be conducted at the test facilities detailed above but may also be carried out by Weights and Measures Inspectors and Approved Verifiers who have access to a reference meter by means of a two stage testing process as detailed below.

This two stage test process can only be carried out if a vehicle appeared to be
unchanged or undamaged since initial verification, and so an inspection of pipework (which of necessity is close to ground level) should be made.

The two stage testing process should be carried out as follows:

- A test should be conducted on the meter / air separator system by using a reference meter, connected such as is usual for verification of vehicle mounted systems, using diesel, kerosene or gas oil. Following this, the meter calibrator should be secured by means of a seal, such as that identifying the Authority.
- An empirical test would then follow whereby a delivery was checked in practice, to ensure that the gas extraction system worked properly. This would entail the observation, or certification, of the loading of any fuel from a traceable gantry meter and the comparison of these quantities with the readings of the gravity drop meter when the load was discharged on site taking into account any significant temperature effects. Such readings should not exceed maximum permissible error, and should be conducted on as many compartments as possible.

General Sealing Arrangements

Sealing points
The sealing arrangements for systems are generally laid down in the Approval Document but are often in a simple form.

As a general concept the principle is that unauthorised access to components of the system that could affect the measured quantity or the system safeguards, should be prevented, obvious or traceable.

Such components include:-

- Meter calibration points
- Meter to 'pulser'
- Meter to the rest of the system
- Meter and register
- Gas extractors, etc.
- Air venting systems, including joints in pipework and any catch tanks or return points
- Pneumatic and electronic control systems
- Outlet pipes for blowdown control pneumatics and the associated air pipes
- The data plate for the system, which is required to be displayed, must be sealed to a support of the system. This is often sealed to the side of the meter housing cabinet by a wire passing through both plate and cabinet.

Air venting pipes should either be uncrushable, or should retain any imposed distortion that might impede the passage of air, so that interference is obvious

Sealing Techniques
The most effective method of sealing points in the system is to use stainless steel

braided wire and cross-over seals. Copper wire was found to work-harden and fracture and nylon thread has too great a stretch factor for effective sealing.

Hollow seals should be avoided as they can be easily opened without serious damage to any verification mark

An individual bolt must not be used as a sealing point when the wire approaches that bolt from directly above its head as it can easily be rotated and removed without breaking the wire. The use of two bolts in close proximity alleviates this problem.

If the sealing wire between two bolts is to be plaited it should be such as to oppose the direction of removal of the bolts.

The seal on the wire should be as near as practicable to the head of a bolt and not with free ends twisted together after passage through the bolt as this can be easily unwound allowing manipulation. It is suggested that if one tail of the wire is passed through the bolt head and the other over the top greater security is provided.

If "jubilee" type clips are used to secure any pipes, their operating heads should be drilled and sealed to prevent removal.

If an air pipe is to be sealed, it may be secured by a hexagonal special headed fitting located adjacent to it, which is itself sealed

Verification marks, especially stickers, need to be situated and protected from the elements and cleaning, as much as is practicable.

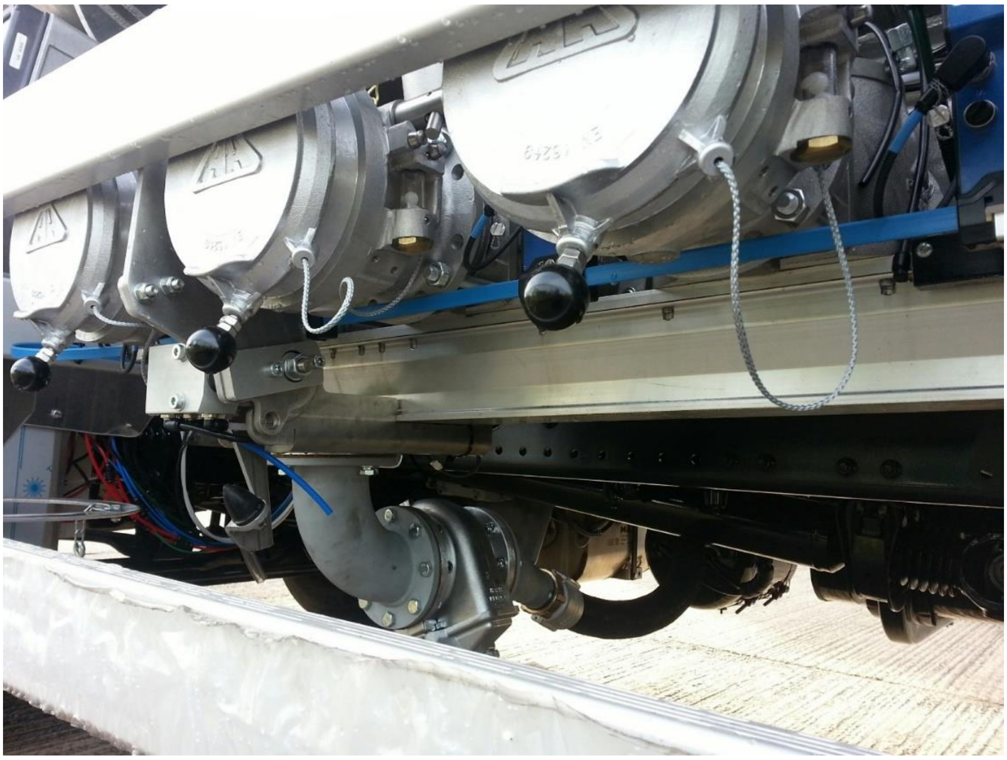
Data plates may have the MID Notified Body number / UKCA Approved Body number punched into them in the appropriate place where removal from the system is not possible without damaging the plate.

Photographs of Various Systems and Components

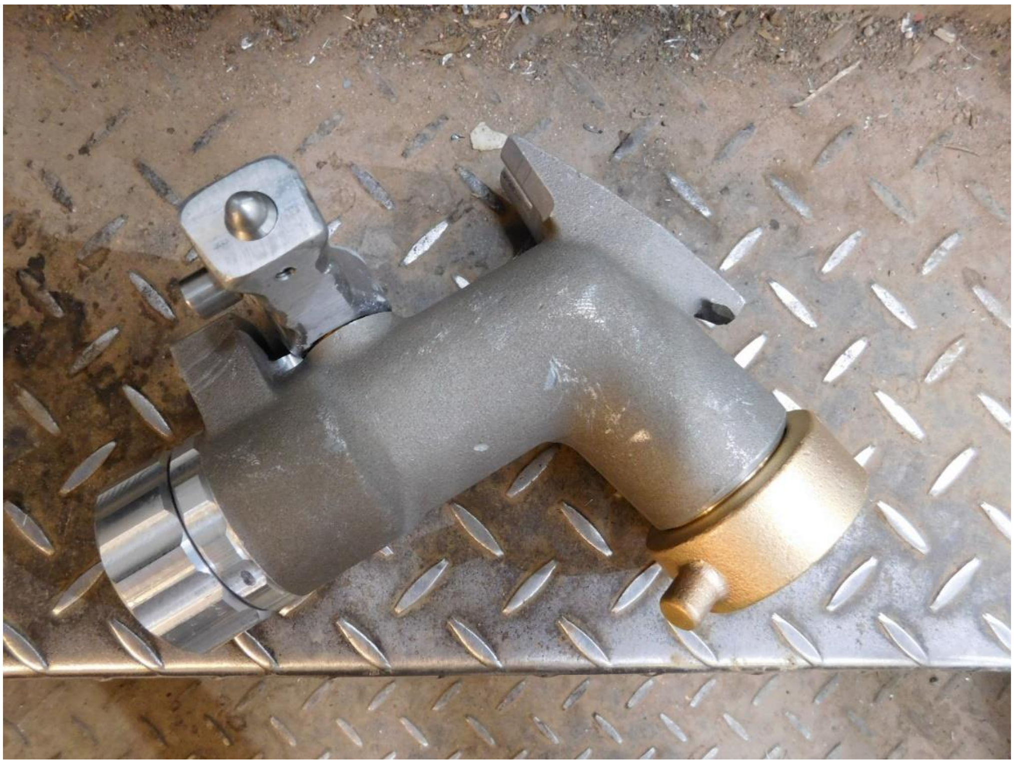
Reference Meter Rig connected to Tanker under Test

Bottom Loading Valves

Underside of Manifold



Wet Line Hose end Nozzle



Footvalve within Tank Compartment

Alpeco Systems - Data plate

Meter

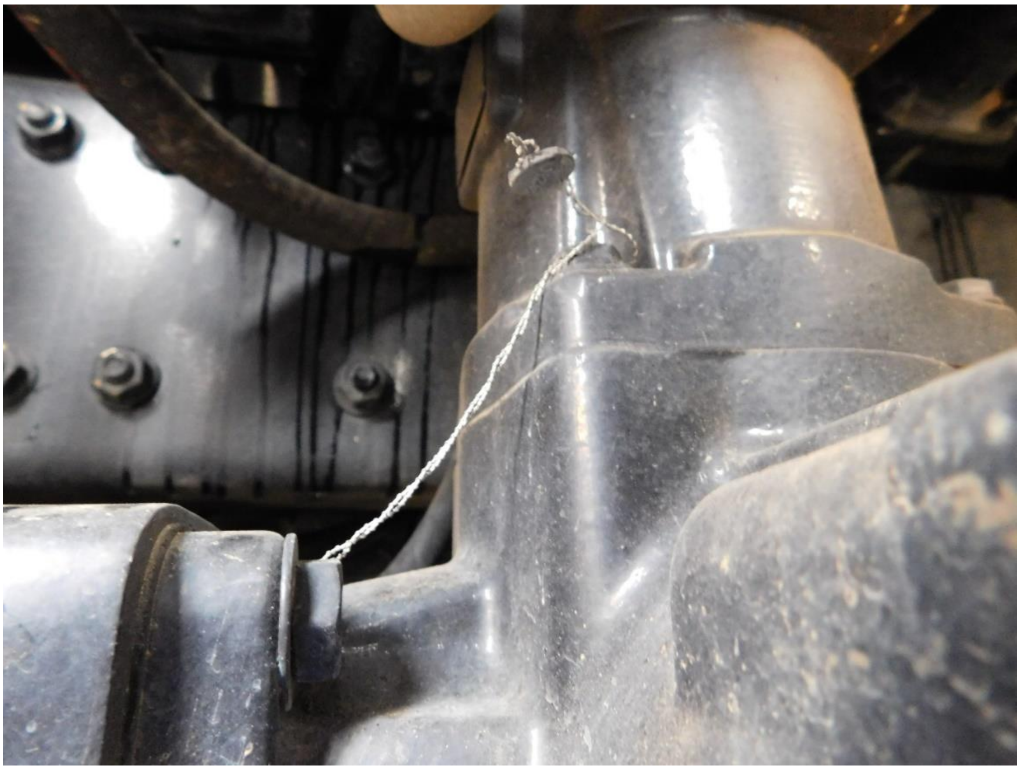
Pulser

TE 550 Headwork

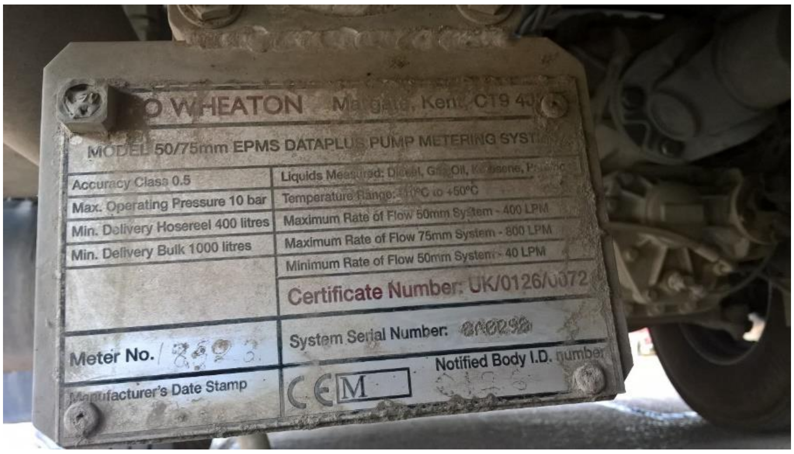
Temperature Probe Access Point

Bottom Loading Valve

Air Separator



Emco Wheaton Systems - Data plates

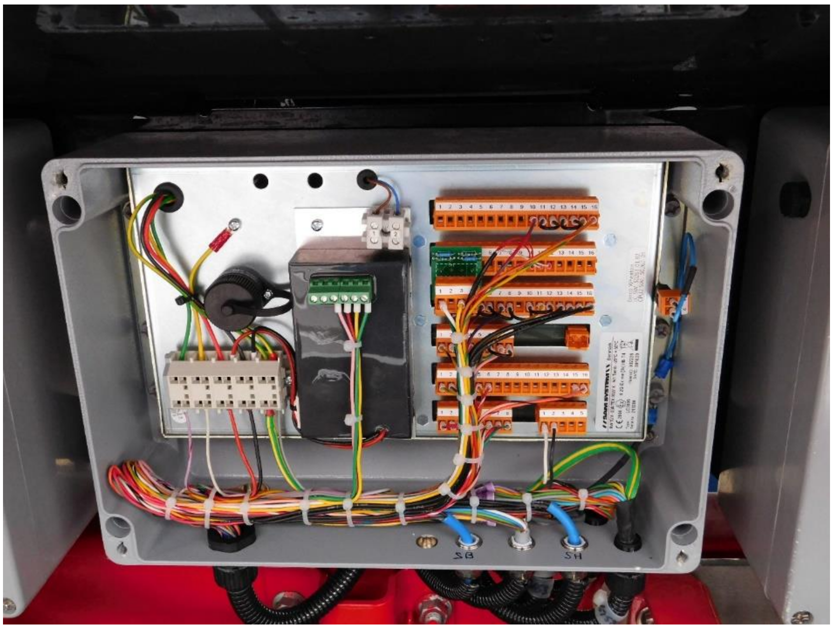

WHEATON
MODEL 50/75mm EPMS DATAPLUS PUMP METERING SYST
Accuracy Class 0.5
Max. Operating Pressure 10 bar
Min. Delivery Hosereel 400 litres
Min. Delivery Bulk 1000 litres
Maximum Rate of Flow 50mm System - 400 LPM
Maximum Rate of Flow 75mm System - 800 LPM
Minimum Rate of Flow 50mm System - 40 LPM
Certificate Number: UK/0126/0072
Meter No.
System Serial Number:
Notified Body I.D. number
Manufacturer's Date Stamp
CE M


WHEATON, MARGATE, UK
DATAPLUS 800
ACCURACY CLASS:0.5
DIESEL, GAS OIL, KEROSENE

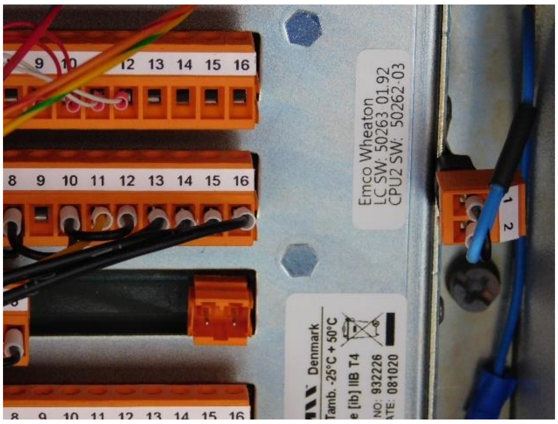
Headwork


EMCO WHEATON
DataPlus II
F1
F2
F3
DataPlus
BLOW DOWN
TRANSFER
START
STOP

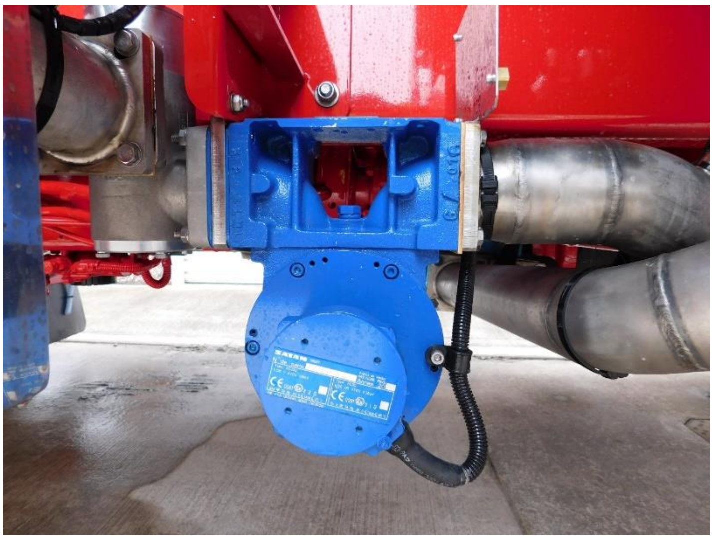
Control Box



Calibration Point



Meter and Pulser

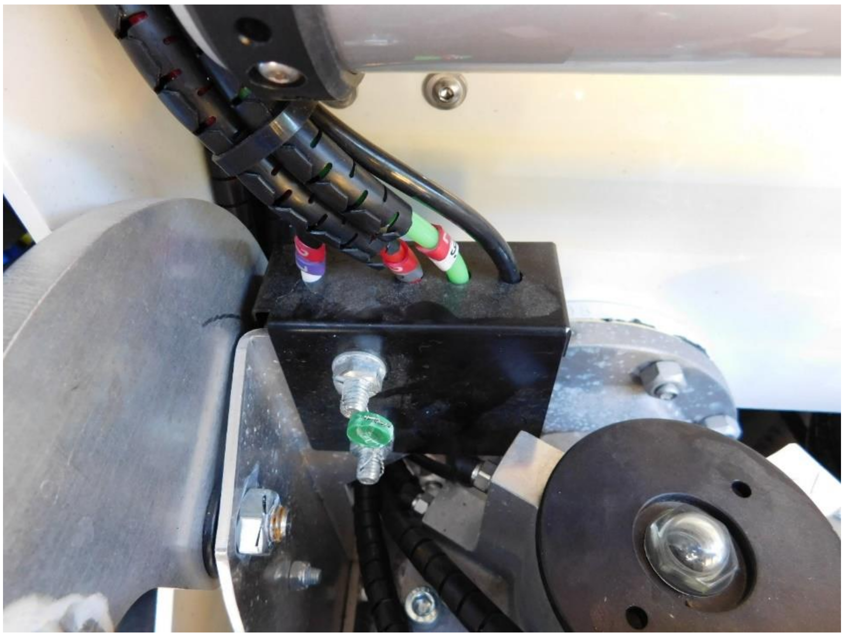


Satam Meter

Meter Pulser Seal

Underside of Footvalve

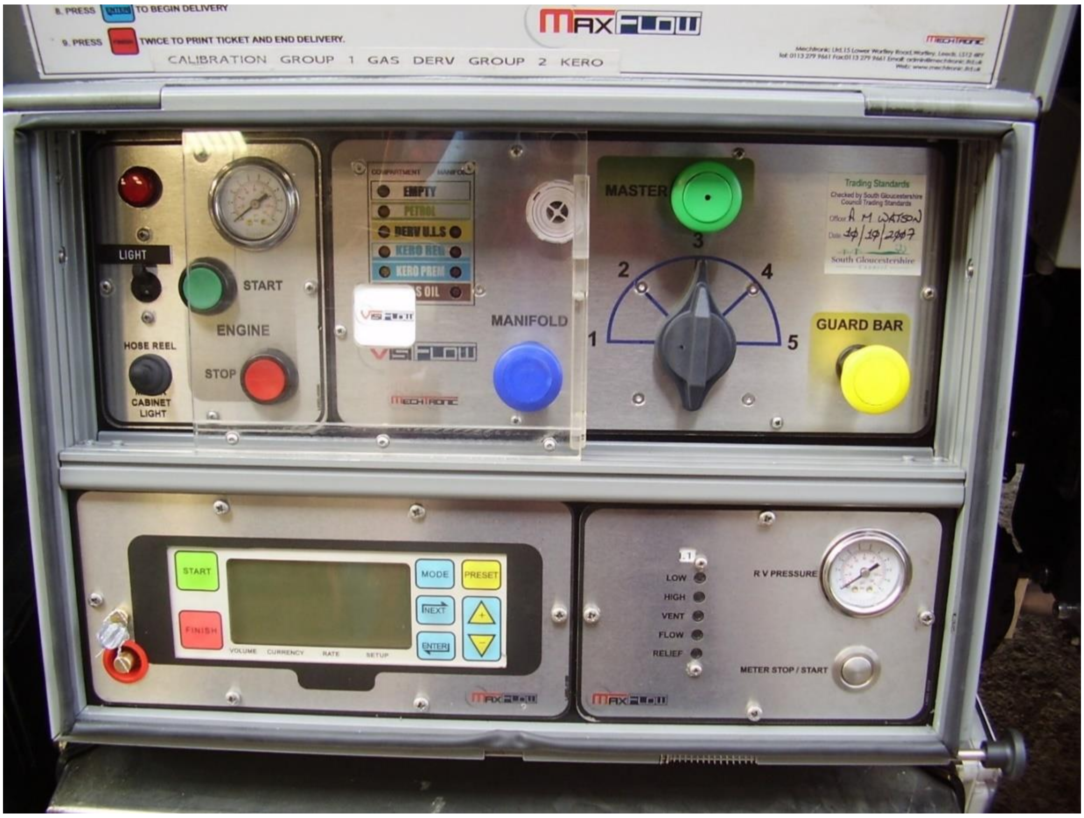
Emco Wheaton DataPlus Product Return Sealing



Mechtronic Systems

Mechtronic Crown Dataplate

Mechtronic Headwork

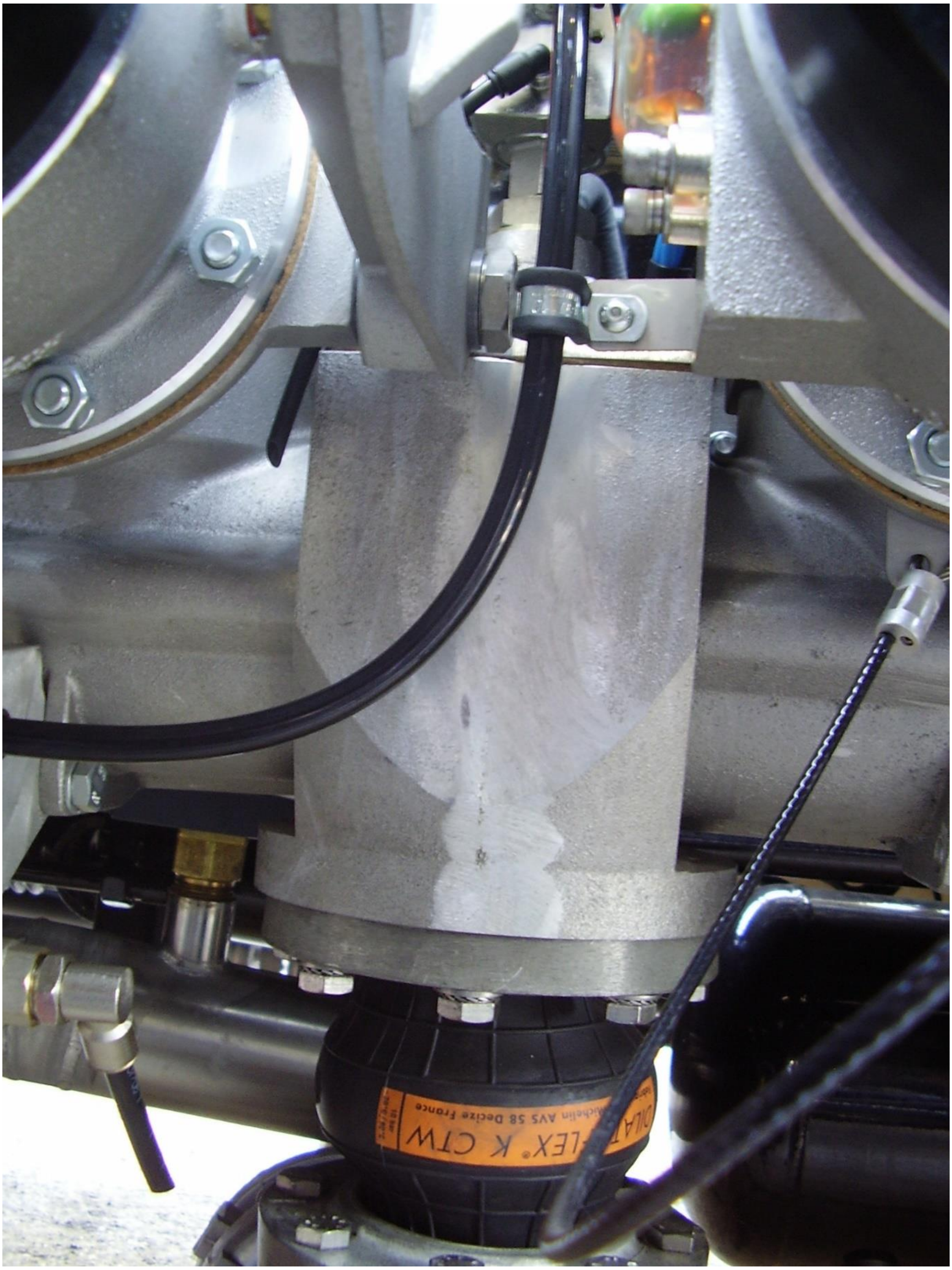


Front Plate Sealing

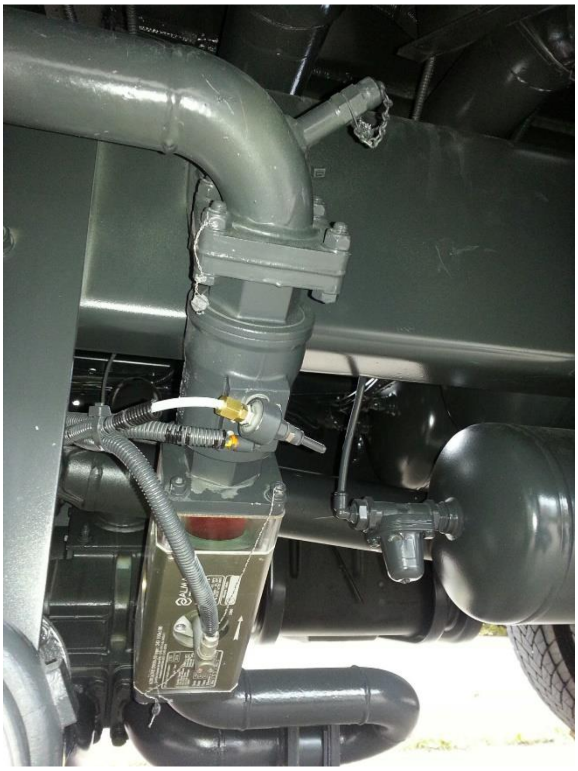
Mechtronic Tuthill Meter

Temperature Probe

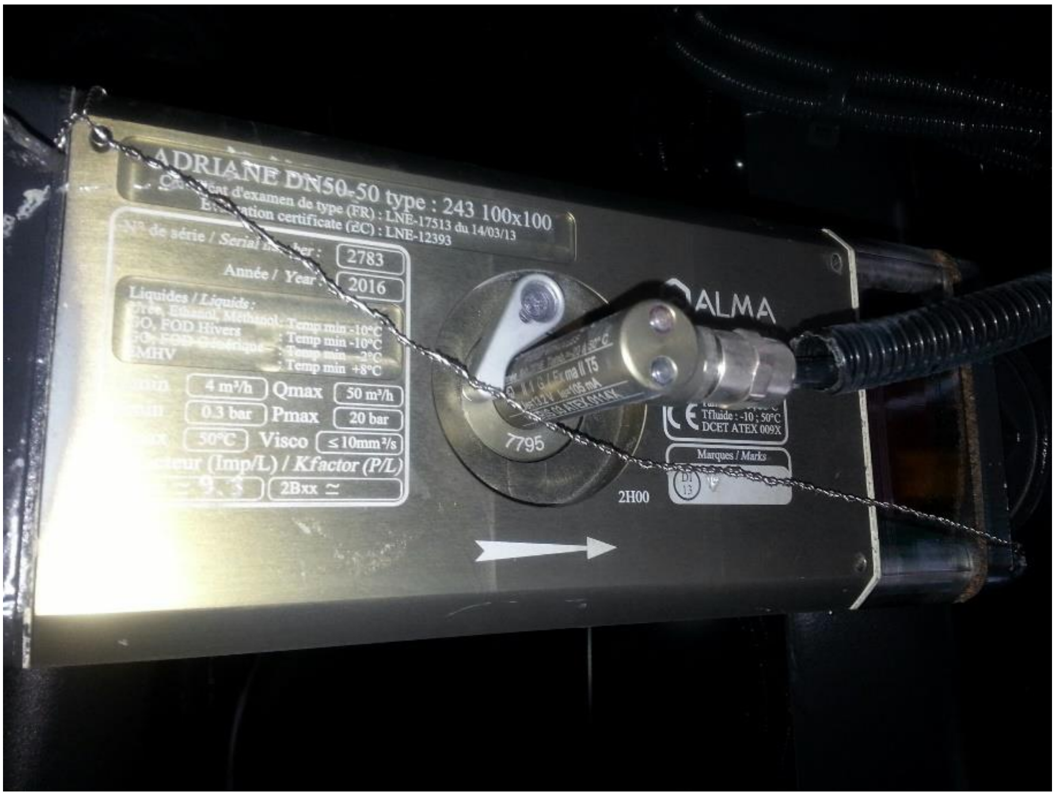
Air Elimination Device



Alma Mechtronic Turbine Meter



Turbine Meter Sealing



Calibration Sealing

Compartment Selection Switch

Alfons Haar Systems - New Type Metering Unit

Older Type Hydraulics

Older Type Headwork

Maine Tankers

Data Plate

Headwork


System Pressure
Guard Bar
1
2
3
4
5
Product Return
Master
Footvalve Controls
START
MODE
PRESET
TRUFLOW
High Flow
Low Flow
Stop/Start Meter
Pump Pressure
Engine Start
Engine Stop
Hose
Bulk

Meter


TOTAL CONTROL SYSTEMS
MODEL NUMBER
MANUFACTURE DATE
SERIAL NUMBER
"Made in the U.S.A."

Air Separator