FIA Guidance

GUIDE TO FIXED FIRE EXTINGUISHING SYSTEM CONTAINER CONTENT TEST, MEASUREMENT & VALIDATION

FIA Guidance for the Fire Protection Industry

This Guidance Note is intended as a general guidance and is not a substitute for detailed advice in specific circumstances. Although great care has been taken in the compilation and preparation of this publication to ensure accuracy, FIA cannot in any circumstances accept responsibility for errors, omissions or advice given or for any losses arising from reliance upon information contained in this publication.

Fire Industry Association
Tudor House
Kingsway Business Park
Oldfield Rd
Hampton
Middlesex TW12 2HD
Tel: +44 (0)20 3166 5002
Fax: +44 (0) 20 8941 0972
e-mail: info@fia.uk.com
<table>
<thead>
<tr>
<th>FIA Guidance – GUIDE TO FIXED FIRE EXTINGUISHING SYSTEM CONTAINER CONTENT TEST, MEASUREMENT &amp; VALIDATION</th>
<th>September, 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issue 1</td>
<td></td>
</tr>
</tbody>
</table>

Guidelines for Fixed Fire Extinguishing System Container Content Test, Measurement & Validation
1. Scope / synopsis ..........................................................6
2. Products covered in this document ........................................6
  2.1. Extinguishant types ......................................................6
  2.2. Exclusions .........................................................................6
3. Executive Summary / Abstract ...............................................6
4. Introduction / Background ....................................................7
  4.1. Reasons for this publication ..............................................7
  4.2. Reasons for container content TMV ......................................7
5. Terms and Definitions ........................................................7
  5.1. Active device .................................................................7
  5.2. Agent weight .................................................................7
  5.3. Competent person ..........................................................7
  5.4. Fill weight .........................................................................7
  5.5. Gross weight ......................................................................7
  5.6. Liquefied extinguishant .....................................................7
  5.7. Liquid level .........................................................................7
  5.8. OEM ................................................................................7
  5.9. Passive device ...............................................................7
  5.10. Non-liquefied ...............................................................7
  5.11. Re-filler ...........................................................................7
  5.12. Super pressurization .......................................................8
  5.13. Tare weight ......................................................................8
  5.14. TMV ................................................................................8
  5.15. Training ...........................................................................8
6. Summary of TMV requirements per extinguishing system type ....8
7. Available test equipment and technologies ................................8
  7.1. Radio-active devices ........................................................8
  7.2. Ultrasonic devices ..........................................................9
  7.3. Thermal indicators ..........................................................9
** May also be achieved through thermal imaging cameras or other infra-red contactless thermometry 9
  7.4. Weighing (manual) ..........................................................9
  7.5. Weighing (automatic) .......................................................9
  7.6. Capacitance siphon tube ..................................................10
  7.7. Float device (automatic) ....................................................10
  7.8. Float device (manual) ......................................................10
  7.9. Pressure measurement .....................................................10
8. The test requirements ........................................................11
  Those employed for the purpose of verification of container contents shall be Competent Persons ........11
  8.1. Manual confirmation of contents by liquid level ..................11
  8.2. Manual confirmation of contents by weight .......................11
  8.3. Manual confirmation of contents by pressure measurement ..................................................12
  8.4. Automatic passive continuous contents monitoring systems ....................................................12
9. Actions resulting depending TMV results .................................12
10. Summary of perceived existing test equipment problems ...........13
10.1. External liquid level sensors (active manual level measurement) ..................................................13
10.2. External liquid level sensors (passive manual level measurement)- thermally operated devices temporarily or permanently attached to the container ..................................................13
10.3. Internal liquid level sensors (passive automatic level measurement) - capacitance siphon tubes and float devices........................................................................................................................................ 14
10.4. Continuous weight monitoring (passive automatic weight measurement) - mechanical or electronic devices which indicate an alarm on specified loss of contents.................................................................................................................. 14
10.5. Continuous pressure monitoring (passive automatic pressure measurement) - mechanical, electronic or electromechanical devices, which indicate an alarm on specified loss of contents such as pressure gauges and switches........................................................................................................................................ 15
11. Container / Extinguishant properties / hindering factors .............................................................................................................................. 15
11.1. Relationship of liquid volume with temperature ........................................................................................................................................ 15
11.2. Extinguishant density data ........................................................................................................................................................................ 15
11.3. The liquid / vapour interface ........................................................................................................................................................................ 15
11.4. Container construction / condition .............................................................................................................................................................. 15
11.5. Container installation configuration ............................................................................................................................................................... 16
12. Discussion of current situation ........................................................................................................................................................................... 17
12.1. Common TMV misconceptions ...................................................................................................................................................................... 17
12.2. Commentary on standards .............................................................................................................................................................................. 17
12.2.1. British Standards .................................................................................................................................................................................... 17
12.2.2. Regulations ......................................................................................................................................................................................... 18
12.2.3. Marine ............................................................................................................................................................................................. 18
13. Conclusions ............................................................................................................................................................................................... 18
14. Recommendations ......................................................................................................................................................................................... 18
15. References and Bibliography ..................................................................................................................................................................... 19
15.1. Requirements and Criteria for testing .................................................................................................................................................... 19
GUIDE TO FIXED FIRE EXTINGUISHING SYSTEM CONTAINER CONTENT TEST MEASUREMENT AND VALIDATION

1. Scope / synopsis
   The document defines the physical procedure and calculation methodology of the container content within fixed fire extinguishing system containers to enable comparison and interpretation of the results obtained against the requirements.

2. Products covered in this document
   2.1. Extinguishant types
      The extinguishing systems using the extinguishant types as listed below are covered by this document:
      - CO₂
      - Liquefied super pressurised extinguishants, examples including:
        - HFC 227ea (e.g.: FM 200, FE227, <Solvay>, etc),
        - FK5-1-12 (e.g.: Novec 1230),
        - Halon 1301, 1211
        - Other HFC based extinguishants
      - Liquefied non-super pressurised
        - HFC 23 (e.g.: FE-13),
      - Inert gases
        - IG-01 (Argon)
        - IG-100 (Nitrogen)
        - IG-55 (e.g.: Argonite)
        - IG-541 (e.g.: Inergen)
   2.2. Exclusions
      The following extinguishing system types and containers are specifically excluded from this document:
      a) Containers containing extinguishants stored in a non-pressurised state (e.g. dry powder, water mist, foam etc).
      b) Portable fire extinguishers (compliant to EN3-7).
      c) Water mist/fog systems using pumped systems or water storage tanks

3. Executive Summary / Abstract
   The correct verification of the contents within containers of fixed gaseous extinguishing systems is essential to ensure such systems remain fully serviceable and thus able to effectively fight fires.

   Limitations of available test equipment, potentially exaggerated by dependence on the skill of the operator, combined with the required validation of results, can lead to errors in the determination and correct verification of the container contents.

   This guidance document provides details of gaseous extinguishant types and the characteristics by which the determination of correct container contents can be verified, with currently available test equipment. Also included is information on which type of extinguishants are suited to each measurement technology along with its pro’s and con’s.

   All current methods of container contents measurement are discussed in the document, all have limitations, but this guide helps interested parties make informed decisions and maintenance companies provide an effective service.
4. Introduction / Background
4.1. Reasons for this publication
   a) Common inadequacies in conducting liquid level testing
   b) Limitations in the available test equipment
   c) Lack of necessary published data
   d) Limiting factors on site (access etc.)
   e) Lack of operator training
   f) Guidance and clarity on best practice for system maintenance

4.2. Reasons for container content TMV
   a) To ensure the on-going capability of the fixed fire extinguishing system to extinguish the perceived fire risk (by verifying the quantity of extinguishant and pressure)
   b) Containers and valves contain leak paths; although not common, leakage can occur, which has a detrimental effect on the above capability
   c) To identify any possible leakage as soon as possible, such that depending on the source of the leak, rectification can be initiated with the minimum of downtime or cost, or loss of protection for the asset
   d) To comply with the requirements of the F-Gas Regulations for systems that contains an F-Gas

5. Terms and Definitions
5.1. Active device
   A device which provides visual and/or audible indication requiring skilled operator interaction

5.2. Agent weight
   Weight of the extinguishant agent only contained in the container

5.3. Competent person
   Designated person, suitably trained, qualified by knowledge and practical experience and with the necessary instructions to enable the required tests and examinations to be carried out

5.4. Fill weight
   Combined weight of agent and super pressurisation gas contained in the container

5.5. Gross weight
   The maximum weight of the container (i.e. the tare weight plus fill weight)

5.6. Liquefied extinguishant
   A gas or gas mixture (normally a halocarbon), or fluid, which is liquid at the container pressurisation level at room temperature (20°C)

5.7. Liquid level
   The physical level of the liquid in the container

5.8. OEM
   OEM refers to the company that originally manufactured the product or the company that placed the product on the market under their brand

5.9. Passive device
   A device which provides visual indication only with minimal operator interaction

5.10. Non-liquefied
   A gas or gas mixture (normally an inert gas) which, under service pressure and allowable service temperature conditions, is always present in the gaseous form

5.11. Re-filler
   Organisation that fills, replaces, re-fills or tops up an extinguishing agent in a container
5.12. **Super pressurization**
Addition of a gas to the extinguishant container, where necessary, to achieve the required pressure for proper system operation

5.13. **Tare weight**
Weight of the empty container, valve and permanently fixed ancillaries (e.g. siphon tube)

5.14. **TMV**
Test, measurement and validation (of the container contents)

5.15. **Training**
The acquisition of knowledge, skills, and competencies as a result of the teaching and learning of vocational or practical skills and knowledge that relate to specific useful competencies. Training has specific goals of improving one's capability, capacity, and performance

6. **Summary of TMV requirements per extinguishing system type**

<table>
<thead>
<tr>
<th>Product type</th>
<th>Measurement methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>Liquid level only</td>
</tr>
<tr>
<td></td>
<td>Weight only</td>
</tr>
<tr>
<td>Liquefied super pressurised</td>
<td>Weight and pressure</td>
</tr>
<tr>
<td></td>
<td>Liquid level and pressure</td>
</tr>
<tr>
<td></td>
<td>Float device reading and pressure</td>
</tr>
<tr>
<td>Liquefied non-super pressurised</td>
<td>Liquid level only</td>
</tr>
<tr>
<td></td>
<td>Weight only</td>
</tr>
<tr>
<td>Inert gas</td>
<td>Pressure only</td>
</tr>
<tr>
<td></td>
<td>Weight only</td>
</tr>
</tbody>
</table>

*Note – in all cases, any liquid level and pressure measurements must be corrected for container temperature.*

7. **Available test equipment and technologies**

7.1. **Radio-active devices**

a) Summary of principles – an active device containing an isotope and sensor placed on opposite sides of container, the sensor detecting changes in radioactivity due to absorption by liquid

b) Pros - Effective device in trained hands

c) Cons - Requires operator training, can be susceptible to spurious results. Health & safety risk. Not temperature compensated

d) Safety – Radioactive devices, may now be restricted in use or be prohibited

e) Training – specialist training required

f) Calibration - Calibrated by the user for each individual container
7.2. Ultrasonic devices

a) Summary of principles - Active device emitting ultrasonic energy placed on container surface, presence of liquid changes the reflected signal
b) Pros - Effective device in trained hands, ease of use
c) Cons - Requires operator training. Susceptible to spurious results. Requires sensor to have good ultrasonic contact with container (while gel type products may assist, measurements close to welds or on rusty areas will adversely affect results). Potentially large tolerance on detected level depending container size and geometry (potentially wider tolerance with smaller containers). Needs temperature compensation.
d) Safety - No known risks
e) Training – equipment specific specialist training and competence required
f) Calibration – requires periodic calibration as specified by manufacturer

tip: Some technicians, working with gases such as CO₂, will determine the weight of one container with scales and its fill level with an ultrasonic indicator before, in the knowledge that all containers in a bank are at constant temperature, calculating the weight of gas in the other containers based on their fill height as measured with the ultrasonic indicator.

Many banks of containers are now kept in climate controlled areas under constant temperature. Levels of gas, especially CO₂, are therefore expected not to deviate on successive inspections.

7.3. Thermal indicators

a) Summary of principles – Heat sensitive linear device attached permanently or temporarily to container exterior. Device changes colour when heated indicating level by different rates of cooling. **
b) Pros - Low cost, ease of use
c) Cons - Requires a means of heating the container, may require considerable heat which, in itself, will change liquid level which may / may not be material. Using hot water or steam to activate not suitable for moisture intolerant areas. If using hot air guns a permit may be required. Not temperature compensated. Indicative device only
d) Safety – no known risks (boiling water excepted)
e) Training – no specialist training required
f) Calibration – not appropriate – no stated tolerance

** May also be achieved through thermal imaging cameras or other infra-red contactless thermometry

7.4. Weighing (manual)

a) Summary of principles – active process physically removing and weighing the container
b) Pros - reliable method of determining container contents. Unaffected by temperature
c) Cons - Practicalities of physically removing and weighing containers, inconvenient
d) Safety - Risk due to manual handling
e) Training – specialist training required
f) Calibration - requires use of calibrated weighing equipment

7.5. Weighing (automatic)

a) Summary of principles – passive device continuously monitoring the weight of the container, causing an alarm on a specified loss. Container either suspended from device, or placed on top of it
b) Pros - reliable method of determining container contents. Unaffected by temperature. Can provide remote alarm

c) Cons – dependent on some equipment being set up correctly on installation. Mechanical devices (if used) can be tampered with or losses be adjusted out resulting in inaccurate readings. Requires manual weighing of containers if original settings lost (if container state unknown). High initial set up cost

d) Safety – possible risk due to manual handling on installation

e) Training – specialist training required

f) Calibration – according to manufacturer’s recommendations

7.6. Capacitance siphon tube
a) Summary of principles – internal passive device detecting varying capacitance of double wall siphon tube with changing liquid levels.

b) Pros - Fully automatic system. Can provide remote alarm.

c) Cons - Requires integration with dedicated control panel. High initial set up cost. May not include temperature compensation.

d) Safety - no known risks

e) Training – commissioning training required

f) Calibration - according to manufacturer’s recommendations

7.7. Float device (automatic)
a) Summary of principles - Internal passive device which changes orientation when floating on liquid, providing an electrical signal on change of position

b) Pros - Fully automatic system. Can provide remote alarm.

c) Cons - Requires integration with control panel. High initial set up cost. May not include temperature compensation.

Safety - No known risks

e) Training – commissioning training required

f) Calibration – according to manufacturer’s recommendations

7.8. Float device (manual)
a) Summary of principles – passive device using a magnetic float in conjunction with a manual indicator scale inserted from the top of the container

b) Pros - Ease of use. Calibrated for contents of bottom dished end and fixed datum for level measurement.

c) Cons - Requires equipment to be built into the container from the outset. Only available on larger containers. May not include temperature compensation.

Safety - No known risks

e) Training - specialist training required Calibration - according to manufacturer’s recommendations.

7.9. Pressure measurement
a) Summary of principles – passive device providing continuous monitoring of container pressure, using pressure gauge (with or without alarm contacts) indicating container pressure or pressure switch indicating loss only. Not for use on CO₂ or FE13

b) Pros – Fully automatic system. Can provide remote alarm.
c) Cons - Requires equipment to be built into the container from the outset. No temperature compensation. Pressure indicators may be difficult to read. No known method of in service gauge calibration check for certain gauges

d) Safety - No known risks

e) Training - specialist training required

f) Calibration – Where gauges can be removed on site periodic calibration may be required according to manufacturers’ recommendations

8. The test requirements
Those employed for the purpose of verification of container contents shall be Competent Persons.

8.1. Manual confirmation of contents by liquid level

a) Test
   I. Use a method suitable for determination of liquid level
   II. Determine the temperature of the container

   Notes:
   some thermometers can exhibit wide tolerances (e.g.: + / - 3°C) and a tolerance of + / - 0.5 °C is more desirable
   care should be taken since there may be significant differences between ambient temperatures and liquid temperature.
   Contactless infra-red devices are preferred since they measure the target rather than the ambient

b) Measure
   I. Determine the physical liquid level of the container
   II. Determine and record the physical distance of the liquid level from the point of datum defined for the test equipment (different test devices may measure from different datum points (be that the floor, the dished end or the test point boss.

c) Validate
   I. Calculate, or compare with published values at the determined temperature, the theoretical liquid level position and then compare the two values to establish any difference and evaluate if the difference renders the container below its minimum fill tolerance
   II. Compare the measured values against those stated in the data provided by the system manufacturer in order to determine the container contents
   III. Check the tolerance allowances against the relevant standards (e.g. BS EN 15004, BS 5306-4, etc)

8.2. Manual confirmation of contents by weight

a) Test
   I. Establish the original ‘tare weight’ and ‘fill weight\(^{(1)}\) of the container assembly (to determine the ‘gross weight’).

b) Measure
   I. Measure the ‘gross weight\(^{(1)}\) of the container.

c) Validate
   I. Use the formula:
      \[ \text{gross weight} - \text{tare weight} = \text{actual fill weight}. \]
   II. Compare the actual fill weight to the original fill weight.
III. Check the tolerance allowances against the relevant standards (e.g. BS EN 15004, BS 5306-4, etc).

(1) The weight of the super pressurising gas (e.g.: nitrogen) may not be included within the fill weight and may need to be added by calculation using manufacturer’s data

Notes
- The tare weight is marked on the container.
- The fill weight is marked on the container for liquefied extinguishants
- The fill weight for carbon dioxide (CO₂) containers is 45 kg (or exceptionally, 50 kg).
- The fill weight for inert gas containers will rarely be stated on the container – but is available in the data from the container manufacturer.

8.3. Manual confirmation of contents by pressure measurement

a) Test
   I. Determine the temperature of the container
   II. Use a device suitable for determination of pressure

b) Measure
   I. Determine the pressure in the container

c) Validate
   I. Compare with published values of the theoretical pressure at the determined temperature, and then compare the two values to establish any difference and evaluate if the difference renders the container below its minimum fill tolerance.
   II. Check the tolerance allowances against the relevant standards (e.g. BS EN 15004, BS 5306-4).

8.4. Automatic passive continuous contents monitoring systems

Devices exist that continually monitor liquid level or weight. Provided these systems are configured correctly at initial installation and subsequently maintained in accordance with the manufacturer’s instructions, the use of such equipment can eliminate the need for separate, manual, checking of container contents.

Automatic devices exist that continually monitor pressure, however these devices only provide any indication once the low pressure limit has been reached. Such devices are normally used in conjunction with manual pressure indicators.

If the container is fitted with continuous contents monitoring, any further establishment of correct fill is not necessary, however it must be ensured that the device/system is still operational and reading true.

Any container equipped with such a system shall be refilled or replaced if the continuous content monitoring system indicates a low contents alarm condition and the continuous contents monitoring system is verified as being fully operational.

9. Actions resulting depending TMV results

- Where the verification of the container contents has been established by a manual means as described in 8.1, 8.2, or 8.3:
• If the determined agent weight and/or container pressure is the same as the original agent weight and/or container pressure, the container remains correctly filled and is exhibiting no loss.
• If the determined agent weight and/or pressure is less than the original fill agent weight and/or pressure, but above the specified limits required by the relevant standard, the container does not need to be refilled or replaced, but the container may be exhibiting a leak. The percentage loss should be recorded in the system log book.
• If a loss had been previously reported and the contents are showing a trend of decreasing, this indicates a slow leak. The container may require leak checking and mandatory rectification, as required by the F-Gas Regulations.
• If the determined agent weight and/or pressure are less than the specified limits, the container must be refilled or replaced.

10. Summary of perceived existing test equipment problems
10.1. External liquid level sensors (active manual level measurement)
This includes radioactive and ultrasound equipment

a) Equipment suitability
I. The equipment can generate inaccurate readings when used on small diameter containers and / or greater wall thicknesses (rule of thumb being that if a container can be lifted that it would be better weighed).
II. Surface condition (both internal and external) is also critical to reliable readings (beware internal container rust as well as external paint delamination for example)
III. A good contact is required between the probe and container. This may require the use of a suitable gel or grease (the latter having a rust prevention benefit).
IV. The equipment’s relatively large tolerance can adversely affect the ability to detect subtle changes in liquid contents and may not indicate a positive ‘low level alarm’ until the container is well outside its prescribed contents tolerance.
V. The use of radioactive devices can be harmful to health and the continued use of such devices may be prohibited.

b) Operator training
I. Early generation devices can be very operator dependent to obtain accurate and consistent readings.
II. Training of operators is essential - operators using devices without proper levels of Training and Competence may be unlikely to obtain accurate or reliable readings.

c) Cost
I. The equipment requires an initial capital outlay commensurate with the technology.

10.2. External liquid level sensors (passive manual level measurement)- thermally operated devices temporarily or permanently attached to the container.

Equipment suitability
I. Applying sufficient external heat to the container to obtain a reading from the device can be problematic.
II. Heat generating equipment must be easily portable by the operator and if powered electrically, requires a power supply nearby (which may not always be the case). See 7.3 (c)

III. The use of a ‘kettle of boiling water’ would not be acceptable in moisture intolerant protected areas (e.g. computer rooms, data centres).

IV. There is no stated tolerance for some devices

10.3. Internal liquid level sensors (passive automatic level measurement) - capacitance siphon tubes and float devices

a) Equipment suitability
   I. The devices have to be connected to a control panel; manual verification using the device may not be possible.
   II. The devices require individually calibrating to each container
   III. The devices may not have any temperature compensation.

b) Cost
   I. The devices may be relatively high cost.
   II. One device is required per container
   III. The potentially significant cost added to the fixed extinguishing system by the incorporation of these devices may inhibit the widespread acceptance and use of such systems.

10.4. Continuous weight monitoring (passive automatic weight measurement) - mechanical or electronic devices which indicate an alarm on specified loss of contents.

a) Equipment suitability
   I. The correct use of the device is entirely dependent on the accuracy of setting up on the initial installation.
   II. If the correct setting of the device is not tamperproof or tamper evident, it would be possible to readjust the unit, consequently losing its correct setting without this being noticed.
   III. The equipment may be sensitive to external influences such as draughts, vibration, shock etc.
   IV. Equipment not fitted with a remote alarm feature requires a weekly visual inspection of the system.

b) Operator training
   I. Installation engineers must be trained and competent to perform the initial installation and calibration.
   II. Service engineers need to be aware of the functionality and care of the devices.
   III. Service engineers shall be both trained and competent to perform installation and calibration of the devices, should they be involved in the reinstatement of containers.
   IV. Training may be available only from the OEM.

c) Cost
   I. The devices may be relatively high cost.
   II. One device is required per container
   III. The potentially significant cost added to the fixed extinguishing system by the incorporation of these devices may inhibit the widespread acceptance and use of such systems.
10.5. Continuous pressure monitoring (passive automatic pressure measurement) - mechanical, electronic or electromechanical devices, which indicate an alarm on specified loss of contents such as pressure gauges and switches.

a) Equipment suitability
   I. These devices add a potential leak path from the container.
   II. These devices are not temperature compensated
   III. Equipment not fitted with a remote alarm feature requires a weekly visual inspection of the system.

b) Operator training
   I. Where devices are fitted to pressurised containers on site, installation engineers must be trained and competent to perform the initial installation.
   II. Service engineers need to be aware of and adjust for the impact of temperature on pressure.

11. Container / Extinguishant properties / hindering factors
11.1. Relationship of liquid volume with temperature
   All substances expand and contract with increasing and decreasing temperature; for the extinguishant contained in the container, this means that the volume occupied by the liquid changes. The change in volume of the liquid is reflected in a change in liquid level. A container where the liquid level shows an apparent reduction may therefore be as the result of reduced temperature, not due to any loss.
   Consequently to be able to correctly verify liquid level, the temperature of the container must be known.
   If the container is at the same temperature, any change in level from a previously recorded value indicates a loss.
   At temperatures above 31°C, CO₂ will be in the gaseous state and there will be no liquid level to measure.

11.2. Extinguishant density data
   The expansion and contraction of the liquid extinguishant causes changes in density and it has to be quantified in order to enable the expected liquid level to be calculated.

11.3. The liquid / vapour interface
   Determination of a liquid level requires a clear demarcation between the liquid and vapour above it. This gives a clear change which is easier to identify.
   Some extinguishants do not form a clear boundary between the liquid and vapour, but a band of changing density liquid between liquid and vapour.
   The depth of the boundary zone can also change with temperature.

11.4. Container construction / condition
   a) Container diameter
      For the same quantity of extinguishant, the larger the container diameter, the smaller the physical change in liquid level for the same loss of quantity or fluctuation in temperature.
      Conversely, a small diameter container containing the same quantity of extinguishant will have
a larger variation of liquid level. The smaller the liquid fill, the less the variation in liquid level tolerance.

Liquid level devices have a tolerance on the determined liquid level. On large diameter containers at low fill rates, the variation level between normal fill and the minimum tolerance may be approaching the tolerance band of the device. E.g. if the allowable change in level were 20mm and if the tolerance of the measuring device were ±10mm, it may be impossible to accurately determine if the container is at normal fill or minimum tolerance.

b) Container manufacture process
Containers are made either of seamless construction formed from a single piece of material (either billet or tube) or fabricated from a number of sections welded together.

The change in thickness of a weld on fabricated construction containers may give a spurious reading for an active liquid level device.

The presence of welds on the container may be obvious to the experienced, but overlooked by the inexperienced.

Seamless construction containers are generally used for the storage of higher pressures and consequently may utilise a thicker wall. The increased wall thickness may have a detrimental effect on the use of any external liquid level devices.

c) Container base geometry
Container bases vary in shape, depending on the construction of the container. The liquid volume contained in the base needs to be known in order to be able to calculate where the liquid level should be.

The distance from the physical surface the container is mounted on (usually the floor) to the lowest point of the liquid needs to be known. In calculating the liquid level, this is taken from the lowest point inside the container, but when measured on the outside of the container, the baseline is usually taken from the mounting surface or floor.

The distance from the floor (used as the datum in all measurements) to the lowest point of the liquid is undeterminable and unspecified.

d) Container condition
The presence of any internal or external surface rust or other surface irregularity in the region where the device is being used may affect the readings obtained by an active type liquid level device.

11.5. Container installation configuration.
Systems using large diameter containers generally will be installed as separate containers located in a group or singly. Grouping of containers may present any problems with gaining access to conduct the liquid level test.
In systems using small diameter containers, the number of containers used may increase. It may therefore be easier to install such containers in a container bank. It can be common with banks containing a large number of containers (e.g. CO₂ systems) for the containers to be installed in two or more rows. Gaining access to the second and subsequent rows of containers to undertake liquid level testing may entail the complete removal of the front row of containers. This adds to the complexity of the activity, increasing the time required and cost, with associated health and safety implications. Use of an extension arm may also overcome the challenge.

12. Discussion of current situation

12.1. Common TMV misconceptions

A common inadequacy has been to use an external liquid level device (active or passive) to determine the liquid level and then put a mark (and sometimes a date) on the outside of the container corresponding with the liquid level. The operator then does not determine (or does not have the required information to be able to determine) where the liquid level should be. This test therefore does not verify that the liquid level is correct.

On subsequent services, other liquid level marks are added to the container, the liquid level often varying (due to changes in temperature or leakages), but no validation of the correct level, or why the level has changed, is made.

Without the correct validation of results, the test is meaningless.

With the limitations of the test equipment currently available, obtaining a meaningful or accurate result can be difficult.

The combination of both issues above may result in unreliable validation.

The appropriate charts for the containers in question must be used to determine relationship between temperature / level and weight of the content.

12.2. Commentary on standards

12.2.1. British Standards

a) state that containers containing a liquefied extinguishant shall be replaced or refilled if the container is exhibiting a prescribed loss.
b) do not define any method by which the quantity of extinguishant shall be verified.
c) do not state, in parts dedicated to agent properties, temperature-density relationships; the extinguishant liquid density is only stated at 20°C.
d) do not state that the information required to be able to calculate the liquid level shall be made public and be freely available.
e) do not define the process by which the liquid level is determined and analysed to determine if the liquid level is correct.
f) do not address any of the shortcomings of the equipment, lack of, or ease of access to, published density data or operator training and specific competence.

12.2.2. Regulations
F-Gas regulation as enacted in the UK simply follows the practice indicated in the British standards.

12.2.3. Marine
Marine certification bodies may define their own requirements, but comply with the requirements of SOLAS regulations.

For liquefied extinguishants (e.g. CO₂ or FM200), the normal requirement is that each container is physically weighed annually (which can be by the complete removal of the container from the installation, or by the use of a local beam scale). Containers may also be fitted with continuous contents weight monitoring, but where these are employed, some classification societies still require that containers are removed and check weighed annually.

13. Conclusions

With the current limitations identified, the results obtained from liquid level testing may be unreliable. The only accurate means by which container contents can be validated is by weighing, using calibrated equipment. However, in many cases, this is impractical.

14. Recommendations

- To eliminate potential errors by field engineers in determining the theoretical liquid level of a container (due to issues of the indeterminable distance between the floor/datum level and the lowest point of the liquid and unknown volume of the dished end or container base), the liquid level of the agent should be marked on the container. This should be provided by the extinguishing system OEM or re-filler by means of a suitable permanent tamperproof marking. Its position must incorporate the distance between the lowest point of the liquid and the floor level and allow for the volume of the dished end or container base.

- To enable the testing to be carried out, it is essential that extinguishing system OEMs or re-fillers make available liquid level charts, tables or other means to the system owner, installer and maintenance provider.

- It would be beneficial that the accuracy of the liquid level devices currently available be improved and / or new technologies explored.

- Keeping banks of containers a minimum distance apart (e.g: 10cm) could assist with access (see 11.5). Care must however be taken to ensure that container stability is not compromised.

The standards should be reviewed in light of the current technologies and limitations of the equipment and techniques.
15. References and Bibliography

15.1. Requirements and Criteria for testing

a) EC Directives: F-Gas
b) Published standards: BS EN 15004 and BS 5306-4
Future development (NOT for publication)
15.1 Current equipment suppliers to be sought and contacted regarding possible measures which may be employed to increase the accuracy and repeatability of the liquid level sensors of all types currently available
15.2 Research could be conducted into alternative technologies for a device used in an entirely different industry which could be adopted or adapted.
15.3 A third party certification scheme could usefully be developed to include within container content TMV within its scope
15.4 Clarification of calibration requirements (if any) for container pressure gauges / switches would be beneficial (see: 7.9 (f))
15.5 Since the weight of the super pressurising gas (e.g.: nitrogen) may not be included within the fill weight and would need to be added by calculation using manufacturer’s data it would be preferable that the pressurising gas weight be recorded on the container alongside fill weight or included in the gross weight
15.6 There is a perception that echoes within relatively small diameter containers and / or containers with greater wall thicknesses may make determination of liquid levels difficult using ultrasonic devices