37th Meeting of the Open-ended Working Group of the Parties to the Montreal Protocol – Side Event

Complying with international standards when using flammable refrigerants without being obstructed with archaic charge size limits

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Introduction

Existing charge requirements for ACs

Evolution of knowledge

Concluding remarks
Lots of options available to satisfy MP rules

- Options are limited when filtering out for cost, efficiency, GWP and “future proofing”
- HCs most viable for some major applications such as room ACs
- But safety standards arbitrarily obstruct their use
Standards lag; not lead!

But to ensure fluidity, alternative approaches can be adopted... E.g.:

“An appliance employing materials or having forms of construction differing from those detailed in the requirements of this standard may be examined and tested according to the intent of the requirements and, if found to be substantially equivalent, may be considered to comply with the standard.”

Must be able to demonstrate how this is satisfied – to self or preferably a third party
**Existing requirements**

**GG.2 Requirements for charge limits in unventilated areas**

This clause is applicable to appliances with a charge amount \( m_s < M \leq m_1 \) and to non-fixed factory sealed single package units with a charge amount of \( m_s < M \leq 2 \cdot m_1 \).

Reference Figure GG.1.

For non-fixed factory sealed single package units with a charge amount of \( m_s < M \leq 2 \cdot m_1 \), the requirements of GG.2.1 apply.

For other appliances with a charge amount of \( m_s < M \leq m_2 \) (A1), the required minimum floor area \( A_{\text{min}} \) to install an appliance with refrigerant charge \( M \) (kg) shall be in accordance with following:

\[
m_{\text{max}} = 2.5 \cdot \left( \frac{LFL}{A} \right)^{0.4} \cdot h_0 \cdot (A)^{1/2}
\]

or the required minimum floor area \( A_{\text{min}} \) to install an appliance with refrigerant charge \( M \) (kg) shall be in accordance with following:

\[
A_{\text{min}} = \left( \frac{M}{2.5 \cdot \left( \frac{LFL}{A} \right)^{0.4}} \cdot h_0 \right)^2
\]

where:

- \( m_{\text{max}} \) = allowable maximum charge in a room in kg;
- \( M \) = refrigerant charge amount in appliance in kg;
- \( A_{\text{min}} \) = required minimum room area in m²;
- \( A \) = room area in m²;
- \( LFL \) = Lower Flammable Limit (LFL) in kg/m³;
- \( h_0 \) = installation height of the appliance in m:
  - 0.6 m for floor location;
  - 1.8 m for wall mounted;
  - 1.0 m for window mounted;
  - 2.2 m for ceiling mounted.

where the LFL is in kg/m³ from Annex BB and the molecular weight of the refrigerant is greater than 42.

**NOTE 1** This formula cannot be used for refrigerants lighter than 42 kg/m³.

**NOTE 2** Some examples of the results of the calculations according to the above formula are given in Tables GG.2 and GG.3.

**GG.3 Requirements for charge limits in areas with mechanical ventilation**

This is applicable for appliances with a charge amount of \( m_s < M \leq m_1 \).

Reference Figure GG.2.

Mechanical ventilation applies to fixed appliances only.

Mechanical ventilation occurs when the appliance enclosure or the room is provided with a ventilating system that, in the event of a leak, is intended to vent refrigerant into an area where there is not an ignition source and the gas can be readily dispersed. The appliance enclosure shall have a ventilation system that produces airflow within the appliance enclosure and meets the requirements of 3.1 or is intended to be installed in a room that meets the requirements of 3.2.
Existing requirements

There are numerous implicit assumptions, that dictated formulation

GG.2 Requirements for charge limits in unventilated areas

The maximum charge in a room shall be in accordance with the following:

\[ m_{\text{max}} = 2.5 \times (LFL)^{(5/4)} \times h_0 \times (A)^{1/2} \]

or the required minimum floor area \( A_{\text{min}} \) to install an appliance with refrigerant charge \( M \) (kg) shall be in accordance with following:

\[ A_{\text{min}} = \left( \frac{M}{2.5 \times (LFL)^{(5/4)} \times h_0} \right)^2 \]

No airflow is present

Room is gas-tight

Leak at constant flow rate

Entire charge leaks in 4 mins

Leak source is low momentum diffuser

Entire charge goes

There are numerous implicit assumptions, that dictated formulation
Evolution of knowledge

Initial draft requirements

Increasing testing, data and experience
Evolution of knowledge

Room is gas-tight

No occupied spaces are ever tight!
- Not only very difficult
- Also against the law

Building Research Establishment database; air leakage results for 471 dwellings
Evolution of knowledge

Leak source is low momentum diffuser

Wall unit
1.52 m
310 g ±3%
60 g/min ±4%

Max concentration [g/m³]

<table>
<thead>
<tr>
<th>Component</th>
<th>Concentration [g/m³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>diffuser</td>
<td>67</td>
</tr>
<tr>
<td>Behind, conn fitting</td>
<td>40</td>
</tr>
<tr>
<td>IDU, LHS return bends, base</td>
<td>30</td>
</tr>
<tr>
<td>IDU coil centre</td>
<td>20</td>
</tr>
<tr>
<td>IDU, RHS coil</td>
<td>30</td>
</tr>
<tr>
<td>IDU, RHS coil base</td>
<td>40</td>
</tr>
<tr>
<td>IDU, RHS return bends, base</td>
<td>50</td>
</tr>
<tr>
<td>IDU, RHS return bends, base, up</td>
<td>60</td>
</tr>
</tbody>
</table>
**Evolution of knowledge**

**For 4 min leak time, release from IDU gives 3/5ths concentration of diffuser release**
Evolution of knowledge

Also address effect of indoor unit geometry – experiments on mock indoor unit with varying geometries.

Since max concentration and thus allowable charge can be so sensitive to geometry of enclosure, need to account for this:

- No easy way to anticipate, so should provide option for performance test
Evolution of knowledge

Leak at constant flow rate

When a leak happens, it either
- Grows larger over time (from nothing)
- Occurs instantaneously and pressure decays over time

Growing leak or decaying leak always results in lower concentration
Evolution of knowledge

Entire charge leaks in 4 mins

Approximately 4 minute leak time
- Not impossible, but extremely improbable!
- Consider also improvement in leak tightness technology over past 20 years

Frequency of leak hole sizes approximated from process industry models
Evolution of knowledge

No airflow is present

The purpose of an AC is to mix negatively/buoyant air in a room
- Utilise to mix leaked refrigerant
- Tests show concept is extremely effective

Gas sensor – setting: 20% of LFL

450 g R290, 15 g/m³ (35 % LFL), 150 g/min, 11 m² room, airflow 800 m³/h
Evolution of knowledge

Entire charge goes

Some charge always stays inside the system

- 10 – 15% under normal circumstances
- Up to 90% retained with use of safety valves

\[ M_{\text{charge}} = M_{\text{retained}} + M_{\text{max}} \]
Evolution of knowledge

Other negative uncertainties?

- Effect of highly congested room

Maximum concentrations are about 10% higher

(Not conclusive, just a qualitative impression)
Concluding remarks

So how to employ larger charge sizes, whilst demonstrating equivalent level of safety?

- Basis of formula is to avoid LFL in event of a leak
- So do a leak simulation test in a given room size
- If concentration does not exceed 100% of LFL then the refrigerant charge in tested equipment provides equivalent safety
Concluding remarks

For example

- Current formula in 12 m² test room allows 260 g of R290 (assuming 65 g/min)
- Test with similar leak rate (60 g/min) shows 480 g before LFL is reached
- With lower leak rate of 30 g/min (i.e., system has enhanced leak tightness) even 610 g is well below LFL
Concluding remarks

Historically, limited investigation into the topic
- Charge limits based on pessimistic uncertainties

E.g., background fire frequency (USA) of ACs: $2 \times 10^{-5} \text{ y}^{-1}$
Concluding remarks

With a bulk of testing, data and analysis
- Higher charge amounts known to result in less severe risks
Concluding remarks

Furthermore, risk reducing measures have been developed
- Needed charge amounts will not lead to unacceptable risk levels
Concluding remarks

So why not just change the standards?

- Yes, of course
- But the process is potentially extremely drawn-out

3, 4, .... 9, 10 years!
Thank you for your attention!