Hot Surface Ignition Testing of Low GWP 2L Refrigerants

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Outline/Agenda

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- HSIT – Hot Surface Ignition Temperature
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  - HSIT Test Method
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Introduction

• New environmental regulations require lower GWP refrigerants
• However, many of the new low/lower GWP refrigerants are ANSI/ASHRAE Class 2L flammable or “mildly flammable”
Typically, equipment and area standards have focused on:
- LFL and AIT as the basis for safety design when using flammable refrigerants
- ASHRAE 15-2013
- UL 60335-2-40,
- IEC 60335-2-40 and others

Would be appropriate ........:
- If all ignition energies were similar for all refrigerant classes
- If all leak events were similar to AIT conditions
Not all flammable refrigerant have the same ignition energy or MIE.
Autoignition Temperature (AIT)

- Autoignition temperature (AIT) of a gas mixture is the minimum temperature at which a gas mixture spontaneously ignites without an external ignition source.
- Autoignition is a balance between the heat production and heat loss.
- If the rate of heat production is higher than the rate of heat loss, the temperature of the gas mixture will increase and auto-ignition will occur.

*Autoignition testing *may not reflect* HVAC equipment leaks*
Autoignition Temperature (AIT)

AIT is not an intrinsic property of a mixture.

AIT depends on

• system volume
• pressure
• boundary conditions for heat transfer and
• time of contact between the hot environment and gas mixture.

*Not all leak events are similar to AIT
AIT conditions may be overly conservative*
Hot Surface Ignition Temperature

- Hot surface ignition (HSI) occurs when a substance impinges on a hot surface and it ignites.
- Hot surface ignition temperature (HSIT) is the lowest temperature at which the substance ignites when impinged upon a surface.
- This topic has been of interest to many different fields (automotive, aviation, mining) and now more recently in HVAC.
- Auxiliary heaters and other refrigeration systems can contain hot surfaces, which can be potential ignition sources.

*Hot surface phenomena may more appropriately reflect leak events in HVAC equipment than AIT*
Hot Surface Ignition Temperature

Previous HSIT conducted on:

- **Hot rod**
  - Temps up to 1000°C
  - Ref: 2009 Montforte et al

- **Heating element**
  - Temps 600-750°C
  - Ref: 2008 VDA, Hill

- **Flat plate**
  - Temps up to 800°C
  - Ref: 2008 VDA, Honeywell

- These HSIT tests all provided useful information to the industry
- However, they were not performed using a standard test method.

*Current work was to develop a standard HSIT method that can be used in the HVAC industry for class 2L refrigerants.*
HSIT Test Apparatus

Enclosed chamber used to house the hot plate

Hot plate
HSIT Test Apparatus

Top view of apparatus

Front view of apparatus

- Refrig spray line
- Planchett
- Insulation
- Ceramic hot plate
HSIT Test Method

- Planchet heated until desired temp was reached
- Five grams of liq refrigerant at room temperature was discharged directly onto planchett
- Planchett surface was observed for..  
  » initial liquid refrigerant hot surface ignition and
  » for an additional 2 min for possible refrigerant vapor ignition.
- If no visible ignitions
  » immediately or during the 2 minute observation time
  » the ventilation was turned on to clear the enclosure of refrigerant vapors.
- A corresponding “NO GO” result was also recorded for this refrigerant release.
- Process was repeated 5 times for each sample

*Neat 2L refrigerants did not ignite at 800°C.  
Therefore refrigerant blends at 825°C (1517 °F) and 850°C (1562 °F).*
Actual HIST Testing

- Planchet (round metal disc) heated to 800 °C (1472 °F).
- Disc is characteristically bright red

- Refrigerant is released at the center of the planchet.
- Disc is cooled due to refrigerant release and becomes duller color
Test Results (2L or expt 2L)

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>Blend Composition</th>
<th>AIT, °C (°F)</th>
<th>HSIT, °C (°F)</th>
<th>HSIT-AIT, °C (°F)</th>
<th>BV, cm/sec (in/sec)</th>
<th>LFL, vol %</th>
<th>MIE, mJ (ft-lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-32</td>
<td>N/A</td>
<td>648 (1198)</td>
<td>&gt; 850 (1562)</td>
<td>202 (364)</td>
<td>6.7 (2.64)</td>
<td>14.4</td>
<td>30-100 (0.02 - 0.07)</td>
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<tr>
<td>R-1234ze</td>
<td>N/A</td>
<td>375 (707)</td>
<td>&gt; 850 (1562)</td>
<td>475 (855)</td>
<td>1.2 (0.47)*</td>
<td>7.0 **</td>
<td>61,000-64,000 (45 - 47)</td>
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<tr>
<td>R-1234yf</td>
<td>N/A</td>
<td>405 (761)</td>
<td>&gt; 850 (1562)</td>
<td>445 (801)</td>
<td>1.5 (0.59)</td>
<td>6.2</td>
<td>5,000-10,000 (3.7 - 7.4)</td>
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<tr>
<td>R-452B</td>
<td>R-32/125/1234yf (67/7/26)</td>
<td>N/A</td>
<td>&gt; 850 (1562)</td>
<td>N/A</td>
<td>4.2</td>
<td>7.5</td>
<td>est 100-300</td>
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<td>Pending</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>R-454A</td>
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<td>N/A</td>
<td>&gt; 850 (1562)</td>
<td>N/A</td>
<td>2.4</td>
<td>6.3</td>
<td>est 300-1000</td>
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<td>R-454C</td>
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<td>&gt; 850 (1562)</td>
<td>N/A</td>
<td>&lt;4* (2.5)</td>
<td>6.2</td>
<td>est 300-1000</td>
</tr>
<tr>
<td>Pending</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Submitted to ASHRAE</td>
<td>R-32/R-1234ze (21.5/78.5)</td>
<td>N/A</td>
<td>&gt; 850 (1562)</td>
<td>N/A</td>
<td>&lt;4*</td>
<td>~ 7.0</td>
<td>est &gt; 1000</td>
</tr>
</tbody>
</table>

*Denotes BV and **ETFL per ASHRAE Standard 34.

Two blends recently submitted to ASHRAE for safety classification; marked as R-pending.

All 2L refrigerants evaluated passed the test with no ignitions in any of the five replicates.
Test Results- HSIT Profile

- During refrigerant release, the surface significantly cooled within 5 sec after the release.
- Surface temperature decrease after refrigerant impingement is noted as “refrigerant surface-impingement cooling capacity.”
- Surface temperature rebounds back to the initial surface temperature and is noted as “surface temperature time lag.”
- ~30 seconds for the hot surface to come back to temperature and plateau.
Some refrigerants appear to be able to provide more cooling capacity.
Conclusions

• A new test method was developed to evaluate class 2L refrigerants for HSIT.
• All refrigerants evaluated (both 2L refrigerants and those containing 2L refrigerants) passed the test with no ignitions in any of the five replicates.
• HSIT > > AIT values due to the uncontrolled loss of vapor and heat after the refrigerant impinges upon the surface.
• Differences between HSIT and AIT were expected. As the ignition events become less than ideal (non-forced), the ignition temperature shifts to the right (increases).
• Delta HSIT – AIT values
  – ranged between 150-425°C (300-797 °F) and
  – could be even greater as test was limited to 800 °C (1472 °F) value.
• At this point, not enough 2L refrigerants were tested to make a general statement regarding the magnitude of the temperature shift between AIT and HSIT for 2L refrigerants.
Conclusions

• A data logger was used to collect temperature data for each refrigerant during the release event.
• During refrigerant release, the hot surface is cooled significantly within the first five seconds after the release.
• Depending on the refrigerant, the hot surface is cooled anywhere from 50°C to as much as 100°C.
  – This is noted as “refrigerant surface-impingement cooling capacity.”
  – Time it takes the surface to rebound is noted as “surface temperature time lag.”
• It appears that not all refrigerants have similar “surface impingement cooling capacity”.
• Some refrigerants appear to be able to provide more cooling capacity. It is important to note that
Bibliography


Bibliography

• UL 1995 “Heating and Cooling Equipment”, Underwriter’s Laboratory, Northbrook, IL 2012
• UL 60335-2-40 “Safety of Household and Similar Electrical Appliances, Part 2-40: Particular Requirements for Electrical Heat Pumps, Air-Conditioners and Dehumidifiers” Underwriter’s Laboratory, Northbrook, IL, 2012
Questions?

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