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Hydrocarbon entrapment, whilst should always be considered is a very low risk, providing the existing system has been properly assessed and the correct installation methodologies are undertaken as recommended forthwith.

The quantification of hydrocarbons in bitumen-based waterproofing systems like SBS (Styrene-Butadiene-Styrene) and APP (Atactic Polypropylene) systems are largely dependent on ageing, degradation, environmental exposure and initial composition.

1) **Initial Hydrocarbon Content in Bitumen:** Bitumen consists mainly of hydrocarbons, with the precise composition depending on the source of crude oil and processing techniques. Typically, bitumen contains around 83-86% carbon and 9-11% hydrogen (John, A 2015). These hydrocarbons in bitumen exist in various molecular structures, including saturated hydrocarbons (CnH2n), aromatic hydrocarbons, and others.

2) **Ageing of SBS and APP Waterproofing Systems:** Over time, the hydrocarbon content of these systems diminishes due to oxidation, UV radiation, and thermal stresses. Ageing reduces flexibility, increases brittleness, and results in the loss of volatile components and the breakdown of long-chain hydrocarbons. This process affects SBS and APP systems differently. SBS, being more flexible, typically ages more slowly than APP, which can become more brittle over time *(Dalhat & Al-Abdul Wahhab, 2015)*.

3) **Loss of Hydrocarbons over Time:** Research indicates that the degradation of bitumen systems can cause a reduction in molecular weight and hydrocarbon chain length. For SBS-based systems, studies suggest a hydrocarbon loss of around 1-2% per year in typical environmental conditions *(González et al., 2010)*. APP bitumen systems also degrade but at a slightly faster rate due to APP's susceptibility to UV radiation *(Polacco et al., 2015)*.

Typically, waterproofing membranes have a bitumen content of around 70-80% by weight, with the rest being fillers and polymers. Assuming an average of 75% bitumen, the hydrocarbon content can be estimated as approximately 83-86% of that bitumen, translating to:

Total mass of the SBS system per m² (3mm underlay + 5mm cap sheet):

Approximate density of SBS-modified bitumen: ~1.1 kg/m² per mm thickness *(Dalhat & Al-Abdul Wahhab, 2015)*.

Total hydrocarbons content:

8.8kg/m² x 0.75 (bitumen content) x 0.85 (hydrocarbon content) = 5.61 kg/m²

Remaining Hydrocarbon Content = Initial Hydrocarbon Content × (1 - Percentage Loss Over Time)

Initial Conditions for both the SBS and APP systems:
Initial hydrocarbon content is approximately 5.61 kg per m² (based on an 8.8 kg/m² total mass, of which about 85% is hydrocarbons).

Assume a loss of 1 - 2% of hydrocarbons per year due to ageing (oxidation, UV exposure, etc.).

After 10 years, the bitumen system would have lost about 10-20% of its hydrocarbons:

- **At 10% loss:**
  Remaining Hydrocarbon Content = 5.61kg/m² × (1 - 0.10) = 5.61kg/m² × 0.90 = 5.05kg/m²

- **At 20% loss:**
  Remaining Hydrocarbon Content = 5.61kg/m² × (1 - 0.20) = 5.61kg/m² × 0.80 = 4.49kg/m²

Meaning hydrocarbon content would range between 4.49 kg/m² and 5.05 kg/m² after 10 years.

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After 15 years, we estimate a hydrocarbon loss of 15-30%:

- **At 15% loss:**
  Remaining Hydrocarbon Content = 5.61kg/m² × (1 - 0.15) = 5.61kg/m² × 0.85 = 4.77kg/m²

- **At 30% loss:**
  Remaining Hydrocarbon Content = 5.61kg/m² × (1 - 0.30) = 5.61kg/m² × 0.70 = 3.93kg/m²

After 15 years, the hydrocarbon content would range between 3.93 kg/m² and 4.77 kg/m².

After 20 years, the bitumen system could lose around 20-40% of its hydrocarbons:

- **At 20% loss:**
  Remaining Hydrocarbon Content = 5.61kg/m² × (1 - 0.20) = 5.61kg/m² × 0.80 = 4.49kg/m²

- **At 40% loss:**
  Remaining Hydrocarbon Content = 5.61kg/m² × (1 - 0.40) = 5.61kg/m² × 0.60 = 3.37kg/m²

After 20 years, the hydrocarbon content would range between 3.37 kg/m² and 4.49 kg/m².

Summary of hydrocarbons;

- **At 10 years:** 4.49 to 5.05 kg/m²
- **At 15 years:** 3.93 to 4.77 kg/m²
- **At 20 years:** 3.37 to 4.49 kg/m²

New Systems Based on 3mm Underlay + 5mm Cap Sheet;

All have a similar bitumen content, around 70-80% by weight.

Total mass per m² = Density × (Underlay thickness + Cap sheet thickness)

Total Mass of waterproofing system:
Total mass per m² = 1.1kg/m²/mm × (3mm+5mm) > 1.1kg/m²/mm × 8mm = 8.8kg/m²

Bitumen content per m² = Total mass × Bitumen percentage
Bitumen content per m² = 8.8kg/m² × 0.75 = 6.6kg/m²

Total hydrocarbons content:
Initial hydrocarbon content is approximately 5.61 kg per m² (based on an 8.8 kg/m² total mass, of which about 85% is hydrocarbons).

This means that the total amount of hydrocarbons (CnH2n) in the new APP system is 5.61 kg per m².

Summary of hydrocarbons;
- Total mass per m² (3mm underlay + 5mm cap sheet) = 8.8 kg/m²
- Bitumen content (75% of total mass) = 6.6 kg/m²
- Hydrocarbon content (85% of bitumen) = 5.61 kg/m²

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Overlaying a bitumen flat roofing system with a new bitumen waterproofing system;

- **Off-gassing from Existing Layers**
  Older bitumen layers can release volatile organic compounds (VOC's), including hydrocarbons, over time as they degrade. When a new waterproofing layer is applied over the old one, the existing bitumen can continue to off-gas. Without adequate ventilation or escape routes, these vapours can become trapped.

- **Application of Hot or Torch-applied Systems**
  If the new bitumen system involves the use of heat (e.g., torch-applied systems), the heat can cause the old bitumen to soften or release additional hydrocarbons. This could further increase the potential for vapour entrapment.

- **Moisture Trapped Underneath**
  Moisture that is present in the old bitumen or within the roofing substrate can also become trapped during the overlay process. When this moisture heats up, it can vaporise and, depending on the type of moisture, may carry some hydrocarbons with it. Vapour pressure build-up can result in blisters or bubbles forming within the roof system.

- **Compatibility Issues**
  Compatibility between the old and new bitumen materials is crucial. Incompatibility may result in poor adhesion, creating air pockets or gaps where vapours or hydrocarbons can accumulate.

- **Lack of Ventilation or Venting Design**
  When a new waterproofing system is added, the design may not include sufficient venting for the layers beneath. Without adequate ventilation, vaporised hydrocarbons or other gases have no way to escape, leading to potential build-up and eventual system failure.

- **Thermal Cycling**
  The roof surface experiences regular thermal cycling (heating during the day, cooling at night), which can cause expansion and contraction of the materials. This movement may drive trapped hydrocarbons or moisture through weak points in the system, potentially leading to blistering or damage over time.

- **Potential Impacts of Hydrocarbon Trapping**

  - **Blistering:** The build-up of vapour can result in blisters between the layers, which can eventually compromise the roof's integrity.

  - **Membrane Damage:** Pressure from trapped gases can weaken the membrane, leading to tears, cracks, or delamination.

  - **Odours and Health Concerns:** Trapped hydrocarbons may also release odours, and depending on the type of hydrocarbons, there could be health and environmental concerns, though these risks are typically low with modern roofing materials.

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Mitigation Measures;

To prevent hydrocarbon trapping during the overlay process:

1. 100% certainty that the existing roofing system is in a suitable condition and can be overlaid. If in any doubt the existing roof, or questionable layers must be removed before a new system is installed.
2. Surface Preparation: Ensure proper cleaning and drying of the old bitumen layer to remove any loose material, debris, or moisture that could cause problems during the overlay.
3. Third parties independent chemical testing if concerns are raised.
4. Ventilation Design: Incorporate vents or breathers into the system to allow trapped vapours to escape. Use partially bonded underlays to allow moisture to escape.
5. Compatibility Checks: Use materials that are compatible with the existing bitumen layer to prevent chemical reactions that could increase off-gassing.
6. Use of Cold-applied Systems: Consider cold-applied systems that do not require heat, reducing the likelihood of excessive off-gassing during installation.
7. Proper Installation Practices: Ensure that the new system is installed under optimal conditions (temperature, humidity) to minimise the risk of trapping vapours.

References:

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