Fundamentals of Insulation and their effect on building sustainability

A.S.H.R.A.E. (Qatar Chapter) Presentation

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Sekisui Foam International
Sekisui Chemical Co, Japan

- Large Japanese multinational company
- Multi-discipline
  - Housing
  - Urban Infrastructure & Environmental Products
  - High Performance Polymers
- Markets: Housing, Construction, Chemical, Foams, Automotive, Pharmaceutical, Medical
- Turnover: USD $10 billion
- Employees: 20,000, (23 countries)
- Pioneered the Physically Crosslinked Polyolefin foam technology
- World’s largest Polyolefin foam manufacturer
  - Sekisui Foam International
    - Manufacturing plants in Japan, USA, Europe, Australia, Thailand Korea, China
    - Manufacturers of Thermobreak™ Physically Crosslinked Insulation range
- ISO 9000 - ISO 14000 and extensive environmental initiatives.
- Video (Sekisui)
Sekisui Chemical Co.

...Prominent Technology Insulation Products

Thermobreak Thermal Insulation

- Physically Crosslinked Technology
- Introduced the first “ALL-IN-ONE” insulation range with factory applied reinforced foil and repositionable acrylic adhesive system
- Superior Thermal Conductivity – lowest for any flexible insulation
- Superior Vapour Permeability resistance
- Extensive Fire & Smoke testing to International Standards
- Environmentally friendly GREEN STAR rated products
- Third Party Certification systems
“Climate Change and Energy Usage is one of the most significant issues of our time...”
Green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by:

- Efficiently using energy, and other resources
- Protecting occupant health and improving employee productivity
- Reducing waste, pollution and environmental degradation
# Insulation – Central to Energy Efficiency

- **Global Energy**
  - Buildings consume between 25%-40% of total global energy consumption. (OECD Report)
  - Crucial to improve energy efficiency of buildings

- **Building Energy**
  - Cooling and heating account between 40%-70% of a building’s energy consumption.

- **Energy reduction**
  - Energy efficient equipment
  - Automation advances
  - Legislation by regulatory authorities. (Green Building Councils)

- **Insulation Benefits**
  - One of the easiest and most efficient technologies available today to significantly reduce energy costs.
  - Other benefits include personal comfort, sound control, condensation control, fire protection and personnel protection.
  - It has become the focus, and it is central to the Green Building concept.
Global Energy Reduction initiatives

Mandatory Governments schemes to reduce energy by enforcing R values for duct, pipe, wall, roof and floor insulation

**USA & Canada**
- National grid map based on prevailing weather conditions.
- Each zone requires min R values for insulation such as pipe, duct, wall etc.
- Thickness of insulation is determined by regulatory authorities to ensure energy reduction and building sustainability levels.
- **Installed thickness v’s supplied thickness R values**

**Australia**
- Follows the same Zone system with min R values for duct, pipe, wall and roof insulation.
- Introduction of Commercial Building Disclosure program through Building Energy Efficiency Certificate (BEEC). Owners must disclose energy efficiency of the building to prospective owners and lessors.
- Imminent Carbon Tax system (2011) for buildings that use excessive energy.
Global Energy Reduction initiatives

- New Zealand is also very similar to the system adopted in Australia (Zones)
- Min R values apply

- Europe 2020 vision to increase energy efficiency in buildings by 20%.
  - Minimum energy performance requirements set in respect to AC systems, insulation etc.
  - Energy performance of existing buildings to be upgraded at renovation to meet minimum requirements.
  - Building Energy Certificate program introduced 2010 including AC system efficiency.
Implications of global trends

1. Insulation will become the focus of energy reductions

2. Insulation properties will come under increasing focus. Includes both performance and health & safety (eg VOC)

3. Shift from up-front cost to long term performance value to comply with building sustainability directives.

4. Building certification systems means that insulation suppliers **MUST** be able to verify technical properties and guarantee performance.
Insulation – Changing key selection criteria

- Thermal efficiency
- Short term & long term
- Factors that affect performance
- Sustainability

- Cost Vs. value
- Long term operating cost
- Cost to comply with energy reduction initiatives

- Environmentally safe products
- VOC requirements
- Global Warming potential (EPA)
- Certification requirements (LEED)

- Fire & Smoke Standards
- Health related issues such as bacterial growth
- Indoor air quality
Insulation types

Two broad categories

TRADITIONAL TECHNOLOGY

- **Open Cell** or fibrous insulation
- Fibreglass
- Mineral wool (Rockwool)

NEW TECHNOLOGY

- **Closed Cell**
- Crosslinked Polyolefin (flexible)
- Elastomeric
- Rigid cellular (PU, Phenolic)
What is Crosslinking technology?

Crosslinking is forcing the linear polyolefin molecules to attain a 3D structure.

- Crosslinking can be achieved by
  - Physical means (irradiation) or
  - Chemical means.

Physically Crosslinked technology results in:
- Smaller cell size > **lowest thermal conductivity than any other flexible insulation**
- Extremely high vapour permeability resistance
- Better fire resistance, higher temperature resistance
- Better compression and tensile strength.
- More flexible
- Precise technology > no chemicals used
Critical Insulation Performance factors

- **Thermal Conductivity** (k) defines how good a material insulates (W/mK).
  - It is independent of thickness. The lower the k value the better a material insulates.
  - It varies according to mean temperature.
  - ASTM C518 most common test method. (fixed conditions)

- **Vapour Permeability** is the diffusion of water VAPOUR into the insulation (gas phase).
  - It varies with Temperature and Relative Humidity.
  - ASTM E96 most common test method. (Ng/s) (fixed conditions)

- **Water absorption** is the amount of water (liquid) a material can absorb.
  - Water in any insulation material decreases its thermal conductivity significantly (up to 10 times).
  - Very important in cases where condensation occurs – some materials like closed cell do not allow spread of water.
Fire & Smoke Standards are formed by safety committees and experts to ensure public safety.

There is currently no Standard that requires non combustible materials to be used as duct or pipe insulation.

### BS 476 Parts 6 & 7

- Most widely used in ME, Asia and India.
- Part 6 – Combustability (ignition) measured by $i_1$ indeces, and FPI total
- Part 7 – Spread of flame : Class 1-4
- Class 0 Classification : $i_1<6$, FPI<12, Class 1 in Part 7

- Does not test for smoke density or toxicity!
- Test is conducted by the accredited facility on the sample submitted by the manufacturer / supplier.
- No facility inspection or follow up program
- No verification system to ensure sample origin or manufacturer!
ASTM E84 (UL 723, NFPA 255)
- US / CANADA Standard
- 8m tunnel test
- Test both Fire spread (FSI Index) and Smoke development (SDI)
- Insulation pass requirements under US Building Code:
  - Flame Spread Index MAX : 25
  - Smoke Developed Index MAX : 50

- Test is conducted by the accredited facility on the sample submitted by the manufacturer / supplier.
- No facility inspection or follow up program
- No verification system to ensure sample origin or manufacturer!

NFPA 90A & 90B
- Not a Fire standard but insulation requirements referenced to ASTM E84
- The new Standard also requires ASTM C411 High Temperature test (120 C)
Smoke Density and Toxicity Standards

ISO 5659 with Gas Analysis

- International Smoke Standard
- 25 KW, 25KW with flame burner, 50 Kw exposure
- Tests for smoke density and Toxicity (6 common combustion gases with low IDLH values, HCL, SO2, HCN, HBr, HF, CO, NOx)
- Pass requirements:
  - Smoke Density: $D_s < 200$ (50 KW/m2 exposure)
  - Emissions levels of above gases have MAX values

BS 6853

- Test conducted in tube furnace at 600 C, 40 min duration
- Tests concentrations of CO, CO2, HF, HCN, HBr, NO2 and SO2 gases
- Average of each gases used to determine the R index, and comparison to IDLH values (Immediately Dangerous to Life and Health)
AS 1530.3

- Building Code of Australia / New Zealand
- Derived from BS 476 but extended to include smoke, and heat evolved
- Insulation pass requirements under AS/NZ Building Code:
  - Spread of Flame Index 0 max (Range 0 - 10)
  - Ignition Index 0 max (Range 0 - 10)
  - Smoke Developed Index 3 max (Range 0 - 10)
  - Heat Evolved Index 0 (Range 0 - 20)

- Test is conducted by the accredited facility on the sample submitted by the manufacturer / supplier.
- No facility inspection or follow up program
- No verification system to ensure sample origin or manufacturer!

UL 94 HF

- Horizontal Fire Test specifically designed for foams.
- Spread Classification as HF1 – HF2- HF3

- Under UL follow up inspection program
- UL collects samples from factory. Regular un-announced inspections and testing.
**FM Global**

- Global Loss Prevention company with increasing influence
- Any property insured by FM Global needs to use FM Approved products
- FM Philosophy is that laboratory scale fire tests are not adequate
- Utilise large scale fire tests to simulate actual fire situations. The most demanding fire tests.
- Aproval for insulation is based on [FM 4924](#)
  - Factory audit by FM (Quality procedures and materials)
  - Witnessing of manufacturing of materials
  - Material sent directly to FM headquarters for testing.
- Annual audit and inspection.
- Approved materials carry the FM logo
Third Party Approvals – Ensuring Product Conformity

- Third Party approvals under ISO Guide 67
- Certification body must hold accreditation to EN45011 / ISO Guide 65
- Dubai Civil Defence approvals for insulation material (BS 476) now falls under this system.
- Warrington Exova is such a certification body.
- Procedure for Civil Defence Approval includes the following:
  - Manfacturing facility audit by approved certification body (e.g. Exova)
  - Quality Systems audit
  - Product witnessing and testing at approved laboratory.
  - Annual audit and verification.

**Things You Should Know**

- ALWAYS ASK FOR TEST CERTIFICATES BY ACCREDITED LABORATORIES
- NEVER ACCEPT SUPPLIERS CLAIMS AT FACE VALUE
Thermal Conductivity (k)

- Thermal Conductivity varies with mean temperature.
  - The higher the mean temperature the higher the k value
  - Comparisons should be done at the same mean temperature.
- Thermal conductivity is affected by vapour permeability and water absorption.
  - If fiberglass absorbs 1-1.5% moisture, its insulation performance is reduced by 36% (HVAC manual – 10.6 McGraw Hill)
- Thermal conductivity of a material is defined by its structure and density and how heat is primarily transferred through the material. Hence differences is fibrous V’s cellular material of the same density.
- Thermal conductivity in fibrous material decreases with increasing density but the opposite is true for cellular materials.
- Cell size is a determining factor of thermal conductivity in cellular materials, even at the same density.
  - Physically Crosslinked foam (25Kg/m3) - 0.032 W/mK @ 23C
  - Chemically Crosslinked foam (25 Kg/m3) - 0.038 WmK @ 23 C

_Smaller cell size means thinner cell wall, therefore primary heat transfer is via Convection….but air is an excellent insulator._
### What is water vapour?
- Water exists in the atmosphere in two forms:
  - Liquid
  - Gas
- Vapour permeability is concerned about the GAS form of water.

### What affects vapour permeability?
- Vapour permeability depends on vapour pressure
- Vapour pressure is determined by:
  - Temperature
  - Relative Humidity
- Vapour pressure increases both with Temperature and Relative Humidity

### What is the affect on insulation?
- Vapour permeability is one of the leading causes of condensation.
- The condensation is more critical in systems where ambient conditions are severe in terms of high temperature and high Relative Humidity (%RH)
The higher ambient temperature and Relative humidity as compared the lower conditions on the inner interface set up as Vapour Pressure differential. Vapour will permeate through the insulation until it reaches due point conditions. It will CONDENSE at those conditions forming water and saturating the insulation. Vapour permability will seriously affect thermal conductivity.

The selection of insulation in areas where high temperature or humidity exist should take vapour permeability into serious consideration.
Implications of Vapor Permeability on thermal performance and sustainability.

1. Vapour Permability is measured by ASTM E96 at controlled laboratory conditions.

2. They **bare no relation** to the ACTUAL ambient conditions that prevail in a region (e.g., high temperature in the Middle East).

3. Thermal conductivity will be affected resulting in severe loss of thermal performance and increasing energy costs. (Ref ASHRAE Study- *Far East Conference on Air Conditioning in hot climates*).

4. Building sustainability and energy savings are compromised!
A closer look at Vapor Permability of common insulation materials

Figure 3. Permeance for various insulation materials (25mm thickness unless otherwise indicated).
Measure Vapour permeability data do not reflect observations under actual conditions.

**Figure 3. WVTR versus changing ambient relative humidity at a constant 30°C ambient temperature.**

- **PVC Nitrile Rubber 25-mm**
- **Physically Crosslinked Polyolefin -25mm**
A closer look at Vapor Permability at common climatic conditions in ME

Figure 2. WVTR versus changing ambient temperature at a constant 80% ambient humidity.
A closer look at changes in Thermal Conductivity over time due to Vapour Permability at typical climatic conditions.

Figure 6. Change in insulation thermal conductivity over time at 30.2°C, 83% RH ambient conditions.
Implications of Building Sustainability on insulation selection.

1. Published data on insulation key selection criteria DO NOT reflect actual conditions in severe climates.

2. Key performance criteria such as Thermal conductivity are influenced by many factors and continuously change over time.

3. Designers of HVAC systems will now have to take a more cautious approach, taking into consideration how these factors affect energy costs.

4. Shift from “up-front cost” philosophy to “long-term operating cost” with health & safety also influencing decision making.
Do You Have Any Questions?

We would be happy to help.