Barrier Development and Testing for Warm Applications

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Introduction

- It is know that higher temperature increases the rate that VIP performance decreases
- Thus the focus of VIP has been mainly on cold applications.
  - Substantial progress has improved barrier performance for cold applications
    - Most cold applications now have acceptable VIP life
- There is now interest in potential warm (55º C to 100º C) applications of VIP such as hot water heaters
  - Maintaining VIP performance over time is much more difficult
- This presentation will cover a test method and results for barrier performance for warm applications

Warm Application Test Method

- Typical warm application
  - One side of VIP 55º C to 100º C
  - Other side room temperature

- Heat seals of VIP can be folded to room temperature side
  - Reduces the diffusion through the seals

- The test duration is long (weeks to months) to obtain sufficient change to predict rate of performance decrease
  - Known methods of accelerating the testing such as reduced internal VIP thickness can be used
    - If thickness reduced too far, the room temperature side of VIP will be above room temperature

Warm Application Test Method

- Desire to test many VIP at ounce
  - Long duration of test
  - More data points per barrier material (performance scatter)
  - Test multiple barrier materials at the same time
- Test panel size
  - 300 mm x 300 mm x desired panel thickness
    - This testing was done at 17 mm thickness
    - Panels periodically conductivity tested
- Tester area
  - 610 mm x 914 mm
    - Six (6) panels tested at one time

Warm Application Test Method

- Tester Construction
  - 6.35 mm thick aluminum plate
  - Full coverage electrical heaters under plate
  - Plate with heaters resting on 51 mm thick foam insulation

Fig 1: Tester hot plate that can test 6 panels at one time

Warm Application Test Method

- Temperature control
  - Plate temperature measured by calibrated thermocouple
  - Digital DC power supply
    - Power adjusted to obtain and maintain the desire temperature
    - More accurate control for this application

Fig 2: Adjustable DC power supply to electrical heaters

Barrier Films Tested

- Three layer metalized barrier film
  - This is a commonly used film
  - It is often used for panels that are small or poor aspect ratio panels
    - Almost eliminates the thermal shorts from hot side to cold side
- Hybrid barrier
  - Aluminum foil based barrier with one metalized layer on hot side and 3 metalized layer barrier on cold side
  - Used so the thermal short from hot to cold side is reduced
  - Used where longer life is required and/or higher temperature environment
- Proprietary barrier
  - Metalized barrier layers and chemical barrier layers

Test Panel Preparation

- All panels produced with a fiberglass core material
- Oven dried
  - A small amount of moisture attaches to the fiberglass surface and the oven drying removes this moisture
- The panels are evacuated and sealed at 2.0×10^{-2} torr
- Sufficient barrier film to fold seal flaps to cold side of panel
  - Seal flaps at room temperature (21.7º C)

Test Procedure

- Thermal Conductivity measurements were made before, midway through, and at the end of testing
  - Test duration 2 weeks
- Hot Plate temperature 100º C
  - Panel cold side is room temperature (21.7º C)
- Room temperature aging was previously conducted
  - Room temperature change with time known

Test Results and Analysis

- Three layer metalized PET barrier
  - Performance decrease in two weeks 19%
    - Performance decrease is linear with time based on the one week and two week results
    - Monthly about 38%, annually 456%
  - Temperature dependency to be 1.6 times for every 10º C increase in temperature

Test Results and Analysis

- Hybrid barrier (aluminum foil on hot side and 3 metalized barrier on cold side)
  - Test duration continued on this barrier to 4 weeks
  - Performance decrease in 4 weeks 3%
    - Performance decrease is linear with time based on the one week, two week, and four week results
    - Annually 39%
  - Temperature dependency 1.4 times for every 10º C increase in temperature
  - Some hot to cold side thermal edge effect but not as severe as aluminum foil barrier in both sides

Test Results and Analysis

- Proprietary barrier
  - Metalized barrier layers and chemical barrier layers
- Performance decrease in 2 weeks 13%
  - Performance decrease is linear with time based on the one week and two week results
  - Annually 338%
  - Temperature dependency 1.8 times for every 10º C increase in temperature

Conclusions

- Three layer metalized PET barrier
  - Calculated decrease in performance at 70º C is 110% per year
  - If continuous operation at warm temperatures (55º C to 100º C), performance decrease over time would not be acceptable
  - Note this is with a fiberglass core
  - Conclusions for fine powder core would be very different
    - Fiberglass requires substantially harder vacuum levels

Conclusions

- Hybrid barrier (aluminum foil on hot side and 3 metalized barrier on cold side)
  - Calculated decrease in performance at 70º C is 13% per year
  - If continuous operation at warm temperatures (55º C to 100º C), performance decrease over time would be marginal for a few year life application and unacceptable for a long life (10 year application)
  - Note this is with a fiberglass core
  - Conclusions for fine powder core would be very different
    - Fiberglass requires substantially harder vacuum levels

Conclusions

- Proprietary barrier (Metalized barrier layers and chemical barrier layers)
  - Calculated decrease in performance at 70º C is 58% per year
  - If continuous operation at warm temperatures (55º C to 100º C), performance decrease over time would be unacceptable for most applications
  - The chemical barrier layers at room temperature are very effective
  - As temperature rises the effectiveness decreases faster than other barrier technology
  - Note this is with a fiberglass core
  - Conclusions for fine powder core would be very different
    - Fiberglass requires substantially harder vacuum levels

Short Exposure to High Temperature

- Panel high temperature exposure
  - Occurrence – 1 to a few times
  - Duration – minutes to a few hours
  - May occur one side or both sides

- Oven testing of panels
  - Test duration 3.5 hours
  - Panel conductivity tested before and after oven exposure
  - Panels based on fiberglass core
  - Fiberglass oven dried
  - The panels are evacuated and sealed at 2.0 x 10^{-2} torr
  - Seal exposed to oven temperature

Calculations

- It is typically assumed that short duration exposure to high temperature would not be a problem
- Based on the previous Hot plate testing the **calculated** decrease in performance results are below for 3 hours exposure

Temperature	3 metalized	Hybrid	Metalized + chemical
100º C	0.17%	0.005%	0.12%
130º C	0.69%	0.014%	0.68%

- Eventually a temperature will be reached where the prediction is not valid

Panels Oven Tested

- Three layer metalized PET barrier
- Proprietary barrier (Metalized barrier layers and chemical barrier layers)
- Panel size 300 mm x 300 mm x 17 mm
- Full panel exposure to temperature

Test Results and Analysis

- Oven temperature increased 5º C for each consecutive test
- New panel used for each test temperature
- For both the three layer metalized PET barrier and the proprietary barrier (Metalized barrier layers and chemical barrier layers):
  - The conductivity before and after oven exposure did not significantly change until 130º C oven temperature was reached.

Test Results and Analysis

Decrease in Performance

Oven Temperature	3 Layer Metalized	Metalized + chemical
130º C	10%	10%
135º C	12%	19%
140º C	14%	35%

- Comparing the previous calculated expected change in performance to the actual 130º C performance decrease, a new mechanism occurred.
- As the oven temperature increased beyond 130º C the barrier with metalized and chemical barriers decreased performance faster than the 3 layer metalized barrier

Overall Conclusions for "Warm" Applications

- Hot flat plate testing shows that even at warm temperature applications barrier performance must improve
- Oven testing has shown that even a single short duration (3.5 hours) exposure to 130º C or above can significantly decrease the panel performance.
  - A new mechanism that decreases the barrier starts to occur at about that temperature
- Chemical barrier layers are good a cold temperature but decrease performance as the temperature rises
- Barrier technology development will be critical to VIP use for warm applications