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Technical Report Summary

R-2000
SUPER ENERGY EFFICIENT HOME PROGRAM

Polyethylene Vapour Barriers: Recent Research into their Long-Term Durability

Introduction

Current construction practice relies heavily on polyethylene (PE) films for use as air barriers and vapour diffusion retarders (air-vapour barriers). In recent years, there has been some concern about the long-term durability of these materials. Reports coming out of Sweden, and follow-up research on material samples from Canadian homes, indicate that there are some cases where sections of PE film showed degradation with time. This degradation is by no means widespread and, in fact, the isolated nature of the problem makes it difficult to define the root cause or causes of the degradation.

The concern, however, was sufficient to prompt research by a number of organizations into the causes of the problem and the potential solutions. The R-2000 Home Program of Energy, Mines & Resources Canada (EMR), in view of the emphasis placed on quality assurance for R-2000 homeowners, is one organization with a particular concern. To meet the airtightness requirements of the program, an R-2000 Home must have a continuous air barrier. In most cases, this has been accomplished by the use of PE films. If premature aging occurs, the long-term performance of the house may be affected.

This report summarizes the findings of research initiated by the R-2000 program to investigate aging effects on PE film air-vapour barriers, and the initiatives taken to minimize the problems associated with the material.

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Background: Polyethylene Films for Use as Air-Vapour Barriers

In recent years, particularly since the early 1970s, polyethylene has become widely used as an air-vapour barrier in houses. It is light, tough, relatively inexpensive, manufactured in usable sizes, and is fairly easy to work with.

Like many plastics, polyethylene can be 'engineered' by controlling the production process and using particular additives to create products with a wide variety of physical characteristics. In general, the PE sheet materials used for air-vapour barriers are a low density polyethylene containing very few additives. The sheets are usually formed by forcing the material through dies or blow-moulding the resins at relatively high temperatures to form sheets of a variety of widths and thicknesses.

Only a small fraction of the total PE sheet production is destined for use as air-vapour barrier material in housing. From the perspective of the manufacturers, the production of material for the building industry is a small, low-cost, low-profit item in their product line. Consequently, until the recent concern with aging, not much attention has been directed towards engineering materials to meet the special needs of the building industry.

Currently, there is no significant regulation of the process used to produce the PE films used in housing. There are some acceptance standards, notably a Canadian General Standards Board standard and Canada Mortgage and Housing Corporation's approved building material standards. To meet these standards, products must have certain physical characteristics with respect to flexibility and toughness. These tests and approvals do not consider the durability of the product over time.

Energy, Mines and Resources Canada
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Material Degradation

Polyethylene films are susceptible to degradation over time as a result of a number of different mechanisms. Some of these mechanisms, however, are of minor concern in air-vapour barrier applications. These include:

- Chemical attack. While there is ongoing research with respect to the potential for chemical attack on PE films when used in the building industry, no incompatibility of particular concern has been identified to date.
- Radiation. While ultraviolet radiation from sunlight definitely has an effect on PE materials, air-vapour barriers are not generally exposed to this form of energy. It is possible that a problem could arise if the material is exposed to sunlight for long periods during shipping, storage or installation.
- Bacterial action. This has not been a significant problem.

The mechanisms which are of most concern are:

- The possibility of mechanical failure due to single or cyclic stresses.
- Thermal effects. Like most plastics, polyethylene compounds have temperature limits. Heat changes the physical characteristics of the material and accelerates structural and chemical changes, such as oxidation. However, the susceptibility of a particular compound to thermal degradation depends greatly on the additives used. Certain additives, known generally as stabilizers, greatly increase the resistance of the polyethylene material to thermal oxidation.

Investigation by the R-2000 Home Program into the problem of PE film aging has been coordinated by the Ontario Research Foundation and has focused on the issue of thermal oxidation of PE films. Concern about PE air-vapour barriers was initially raised by some Swedish reports which indicated that isolated areas had been found where polyethylene had become brittle with age. This was particularly evident in areas subjected to relatively high heat, such as behind electric heating elements.

In response to these findings, Sweden developed a standard which made use of an accelerated aging test to approve PE materials for use as air-vapour barriers.

In Canada, a preliminary investigative study by CMHC of a small number of houses, ranging in age up to twenty-three years, did find some isolated instances of degraded PE material. In some cases, the degradation was confined to areas of the sheet not necessarily associated with a heat source. This would indicate that the problem could be related to the manufacturing process, perhaps due to inconsistent compounding resulting from the use of recycled materials. There was also an indication that some recently manufactured materials were more susceptible to aging than older PE films. This could be attributed to the reduced use of stabilizers or a change in the film manufacturing process which, in more recent years, has involved the use of higher pressures and temperatures.

Since polyethylene films can be engineered to provide a wide variety of physical properties, there is no fundamental reason why manufacturers cannot produce materials which are more resistant to degradation, provided:

- they know about the problem,
- they know the cause of the problem,
- there is some reliable test method of determining whether the material is resistant to aging. This method or test must be relatively inexpensive and of short enough duration to allow adjustment to the manufacturing process.

Consultation between regulatory authorities and manufacturers' representatives indicated that some kind of standard which includes the determination of the resistance to aging would be acceptable if realistic test procedures could be developed. The Society of Plastics Industries (SPI) established a Steering Committee and a Technical Subcommittee to address the problem on behalf of the industry. EMR and CMHC participated and provided assistance in identifying the problems and determining the ways to resolve them.

Testing Methods

The standard already developed in Sweden requires that samples of vapour barrier material be aged for 25 weeks at 100°C. After this accelerated aging process, the materials are subjected to a tensile elongation test. The aging period is meant to simulate a fifty-year exposure to the 35°C temperatures which could be expected in a building application.

The current CGSB standard, CAN2-51.33-M80, Vapour Barrier, Sheet, for Use in Building Construction, includes non-tested requirements such as appearance, sheet dimensions, packaging and labelling. There are specified tests to determine pliability, tensile strength and elongation and water vapour permeance. None of these tests determine resistance to degradation with time.

Any test to determine the aging characteristics of Canadian PE films must meet certain criteria:

i) It must give a reliable indication of the actual resistance to aging of the material under the conditions to which it will be subjected in actual use.

ii) It must be consistent enough to be a realistic pass/fail test.

iii) The duration of the test must be sufficiently short to ensure that a manufacturer does not have to hold large quantities of product prior to release, or, better still, short enough to allow adjustment of the manufacturing process if problems arise.

Obviously, the third criterion means that a six-month test, such as the one used in Sweden, is far from ideal.

The R-2000 Home Program contracted with the Ontario Research Foundation (ORF) to perform testing on PE materials using the Swedish approach as well as some other methods. These tests included:

- The testing of tensile strength and the elongation of samples aged for fifteen weeks at 95°C. This is similar to the Swedish test method.
- Infrared spectroscopy to study the chemical composition of PE films heat-aged at 99.5°C. Samples were periodically removed from the oven for measurement of the infrared spectrum. As thermal oxidation occurs, the spectrum changes, showing absorption of a particular wave-length. This is known in the industry as 'carbonyl absorbance'. The length of time before onset of this absorbance pattern provides a measure of the resistance of the material to thermal oxidation. This time can vary from days to months.
- Oxidation induction time (OIT) testing is another standard test method used in the plastics industry. In this test, a sample is brought up to a relatively high test temperature (in this specific case 180°C, 190°C or 200°C) in an inert, nitrogen atmosphere. After stabilizing at the test temperature, the atmosphere is switched over to oxygen. The onset of thermal oxidation is measured with a Differential Scanning Calorimeter and occurs in a period of minutes. The length of time before the onset of thermal oxidation is a measure of the material's resistance to oxidation.

  This test has the obvious advantage of being very short, and it is recognized in the industry as providing a reasonable measure of the resistance of a particular material to thermal oxidation. Experience has shown, however, that some materials which perform very well in longer duration, lower temperature tests do not necessarily have high OIT test values.

In general, it can be stated that the realism and the duration of these test procedures decline in the order in which they are listed. While the OIT test is the most difficult to perform and farthest removed from actual usage conditions, it has a relatively short duration, which is an important consideration for the plastics industry.

Proposed New Standards

Builders, regulatory agencies and manufacturers all recognize the need for long-term durability of polyethylene air-vapour barrier materials. They are, therefore, very interested in methods of ensuring that the air-vapour barrier materials available to builders are resistant to the effects of age.

The Canadian General Standards Board has a committee of interested parties, including members of the SPI Technical Subcommittee, which is developing a new standard for PE air-vapour barrier materials for houses. This will provide some assurance that the materials entering the market will last the lifetime of the house. This standard will take the form of an updating of the current standard, CAN2-51.33-M80, and will be entitled CGSB Standard CAN2-51.34-M, Vapour Barrier, Polyethylene Sheet, for Use in Building Construction. The proposed additions to the existing standard include:

- Testing to a modified ASTM procedure, D3895 ''Oxidation Induction Time of Polyolefins by Thermal Analysis''. Specifically, the proposed requirement is an OIT of 30 minutes at 190°C.
- A requirement that the material be stabilized against ultraviolet light, achieving a three-month life when exposed to sunlight.
- A specification on the properties of the resins used, including a requirement that only virgin resin be employed. Reprocessed resin is not permissible.
- A requirement that the average thickness be at least 150 microns (6 mil), with no point less than 120 microns.
- A requirement for a test to measure impact strength.
- A requirement that the packaging protect the material from ultraviolet radiation.

The industry's view is that this standard is stringent but reasonable. The OIT test requirement is the most difficult to meet, but it is attainable, at an acceptable cost, by the use of appropriate additives. This view is supported by in-house testing by some major manufacturers and testing carried out at ORF.

ORF Testing

Energy, Mines and Resources Canada contracted with the Ontario Research Foundation to perform a series of tests on samples of different PE air-vapour barrier materials. Testing included the aging test, infrared spectroscopy testing and the OIT test previously discussed. The tests were performed on samples of:

- PE air-vapour barriers that had already been in service for varying lengths of time in Canadian houses.
- Recently manufactured material, typical of PE films currently available in Canada.
- Some foreign products, some of which were developed to meet the Swedish aging test standard.
- Some 'prototype' air-vapour barrier sheets produced by Canadian manufacturers using higher stabilizer content in order to meet the OIT test requirement proposed in the new standard.

This testing had to meet three fundamental objectives:

- To determine an appropriate proposed Canadian standard.
- To determine how close the samples were to meeting the 'Swedish standard' and the proposed Canadian standard.
- To correlate the results of different tests on the same samples. Obviously, if a reasonable correlation was not obtained between the short-duration OIT test and the longer duration, more realistic aging tests, the reasonableness of basing the standard on the OIT testing would have to be questioned.

Test Results

The two figures illustrate the results of two of the test procedures carried out by the Ontario Research Foundation. Figure A-1 shows the results of the oxidation induction time testing and Figure A-2 shows the results of the infrared spectroscopy testing.

The results from the various samples are grouped in the following classifications:

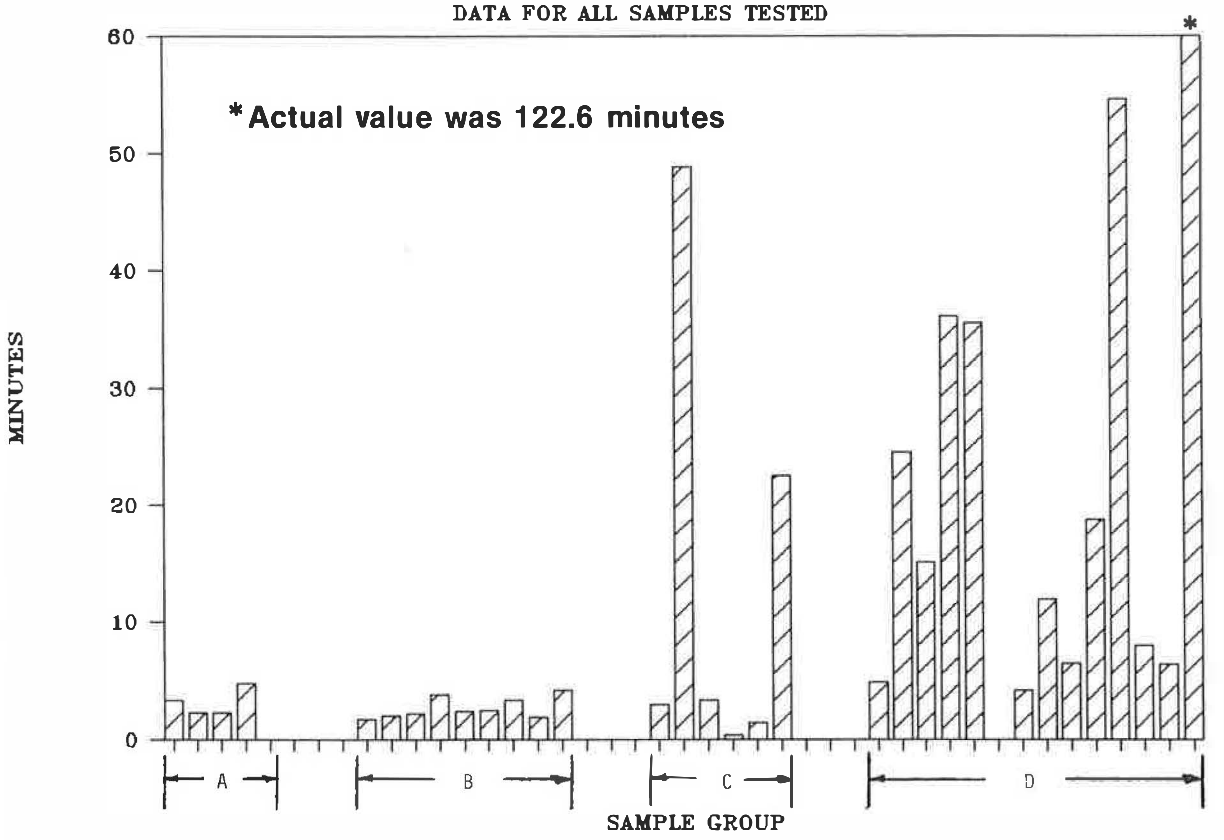
Group A: aged-in-place films taken from CMHC-inspected homes. Age varies up to twenty-three years.

Group B: commercial films currently being used in Canadian home construction.

Group C: assorted films, varying in source and physical composition. Films C1 and C2 are Swedish materials, while C3 to C6 are cross-laminated films from American sources.

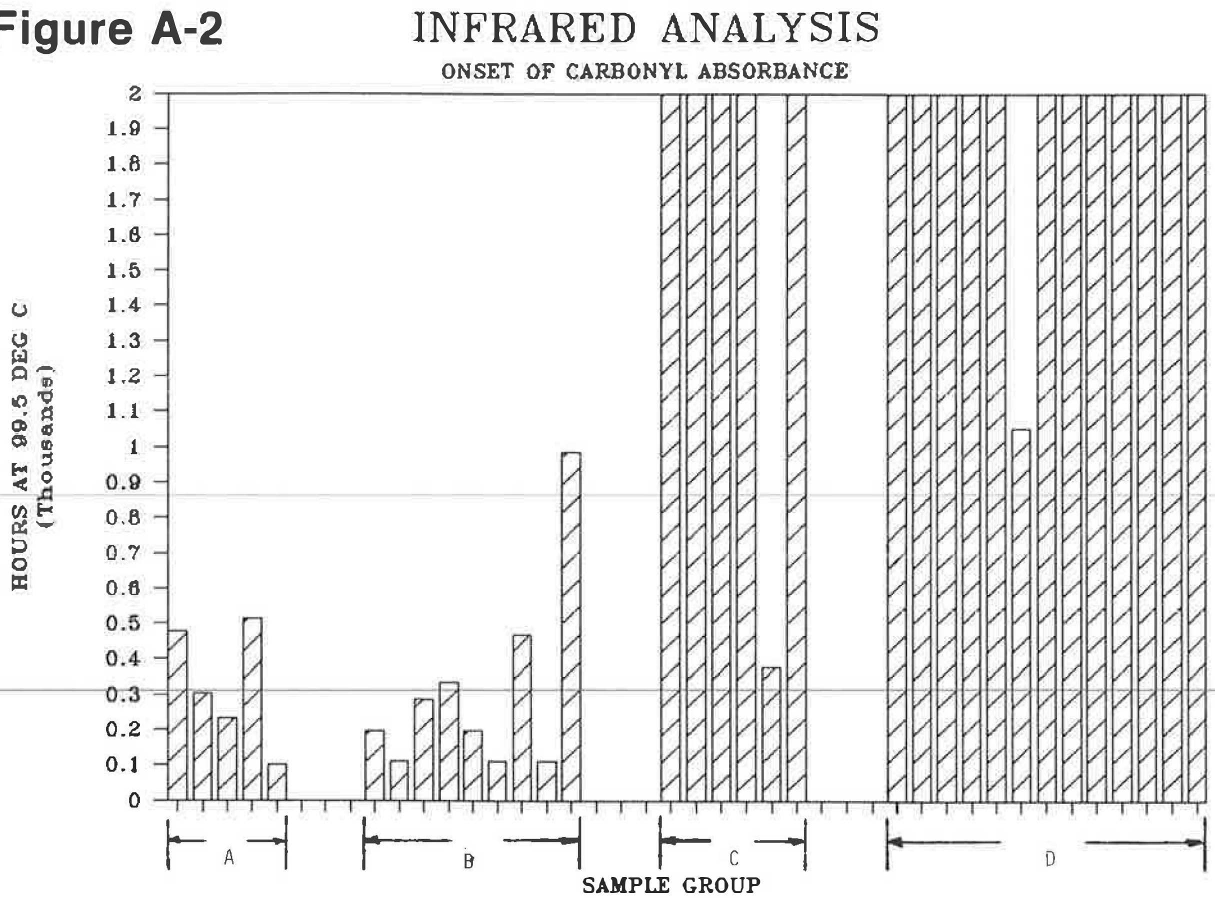
Group D: prototype films from a number of Canadian manufacturers, formulated to meet the proposed new standard for thermal oxidative stability.

Figure A-1 OIT VALUES AT 190 DEG C



(Proposed Standard is 30 minutes at 190°C)

Figure A-2


INFRARED ANALYSIS
ONSET OF CARBONYL ABSORBANCE
HOURS AT 99.5 DEG C
(Thousands)
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
A
B
C
D
SAMPLE GROUP

Conclusions

The basic conclusions drawn from the testing program were:

1) With one exception (a new 2 mil film), both currently acceptable polyethylene air-vapour barrier sheets and the used samples taken from a number of houses met the tensile strength and percentage elongation requirements of the proposed new specification.

2) While there was some variation in the performance of different films during the OIT testing, used samples and new, currently acceptable materials exhibit the same characteristics and tendencies.

3) Current polyethylene vapour barrier materials do not meet the proposed requirement of a 30-minute OIT value at 190°C.

4) Some prototype PE films which incorporate stabilizers met this proposed requirement. This indicated that manufacturing PE air-vapour barriers with sufficient thermal stability to meet the standard is feasible.

5) Some films which yield low OIT values appear to perform very well during lower temperature tests, indicating that the OIT test is not an absolute measure of long-term stability in normal usage for all types of film.

6) The converse of conclusion 5 was not found, i.e. there were no samples which yielded high OIT times but showed low durability in other tests carried out at lower temperatures.

In summary, the OIT test proposed for the new standard seems reasonable. There are some discrepancies in its correlation with tests which use more realistic exposure conditions, but these differences are in the conservative direction. For example, a Swedish sample failed the OIT test but did well during the lower temperature Swedish test.

Consensus in the industry indicates that the advantages of having a simple, short-duration test outweigh the disadvantage that some materials which could be deemed acceptable as a result of long-duration testing would not pass the OIT test. There is also a consensus that PE air-vapour barrier materials can be produced which meet the stringent proposed standard at an acceptable incremental cost.

The concept of a standard based on OIT testing, seems, therefore, to be accepted. The adoption of this standard would result in the production of materials which have a very high expectation of lasting as long as the building envelope.

Implications For Builders

Before being adopted, the proposed standard for polyethylene vapour barriers for use in building construction must go through a number of approval processes. The final approval and implementation of the standard cannot be expected before the end of 1986. After acceptance, manufacturers will mark all air-vapour barrier materials conforming to the standard in a manner similar to the following:

(Trade name)
Polyethylene sheet vapour barrier
Complies with CGSB Standard CAN2-51.34-M

For the remainder of 1986, the R-2000 Home Program, through the EMR/CHBA technical department, will be setting up a mechanism to identify polyethylene films that meet the new standard.

A number of manufacturers who produced prototype materials for the test program described earlier are considering the production of materials which would meet the standard prior to its implementation. At the time of writing, this prospect seems likely but not certain. A builder can check the availability of materials with local distributers of PE air-vapour barrier sheeting produced by the major Canadian manufacturers.

Another potential source of information on the manufacturers' plans is:

Society of the Plastics Industry of Canada
1262 Don Mills Road, Suite 104
Don Mills, Ontario
M3B 2W7
(416) 449-3444
Contact: Charmian Entine

Special orders are also possible. Some manufacturers would consider producing special batches as small as 2300 kg (approximately 16 000 m^2 of 6 mil film). This may be impractical for a single builder, but suppliers or a group of builders could consider this option.

In any case, the new formulations will be more expensive to produce than currently available films. At the time of writing, the actual incremental cost had not been determined by the manufacturers, but indications are that this will not have a significant impact on the material cost of a house.

If the stabilized materials are not available, builders should use a 6 mil thickness of the currently acceptable material.

For more information, contact:
Technical Reports
Super Energy Efficient Home (SEEH) Program
580 Booth Street
Ottawa, Ontario K1A 0E4
(613) 995-1118