NBS TECHNICAL NOTE 982

U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

Criteria for Retrofit Materials and Products for Weatherization of Residences

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The National Bureau of Standards was reorganized, effective April 9, 1978.

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FOREWORD

This report is a revision of National Bureau of Standards Report NBSIR 75-795 issued in 1975. The revised report recommends criteria for materials and products which may be used as a resource document along with other information by the Department of Energy in the promulgation of standards for weatherization materials in their Weatherization Assistance Program (PL 94-385, Title IV, Part A, Section 413). The earlier report was submitted to public, industry and government review to solicit comments and suggestions regarding criteria for materials and products applicable for retrofitting residences to conserve energy. The revisions were based on available technical information on properties, performance and use of retrofit materials and products, and on the energy savings which may be achieved.

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ACKNOWLEDGMENT

The editors wish to thank the team of researchers in the Center for Building Technology and the Center for Fire Research at the National Bureau of Standards who participated in preparing the information and criteria in this report. Mr. Bradley A. Peavy, Jr. of the Building Thermal and Service Systems Division provided the criteria and information for thermal insulation and vapor barriers. Mr. Jenkins Washington and Mr. John S. Stroik of the Environmental Design Research Division provided the criteria and information for storm windows and doors. Mr. Arthur Hockman and Dr. Walter J. Rossiter of the Structures and Materials Division furnished the criteria and information for caulks and sealants, and weatherstripping and clock thermostats, respectively. Dr. Walter J. Rossiter and Mr. Robert G. Mathey prepared the criteria for replacement windows, replacement glazing and the suggested criteria for materials and products which were considered not eligible under the DOE Weatherization Assistance Program and are included in an Appendix. Mr. James M. Hicks of the Building Economics and Regulatory Technology Division reviewed the relationship between retrofitting and model building codes. Mr. Daniel Gross of the Center for Fire Research provided the requirements for fire and safety. The editors also acknowledge the assistance of Mr. S. Robert Hastings and Dr. Belinda L. Collins of the Environmental Design and Research Division in reviewing information which was submitted on windows and window accessories and in making suggestions regarding their use as possible weatherization materials and products. Dr. David A. Didion of the Building Thermal and Service Systems Division provided information on mechanical components and systems dealing with furnaces and heating equipment which may be applicable to the retrofitting of residences.

This report was sponsored by the Department of Energy, Office of Weatherization Assistance, under the direction of Mrs. Mary M. Bell. Coordination between the Office of Weatherization Assistance, DOE, and the Center for Building Technology, NBS, was provided by Ms. Sandra S. Monje and Mr. Heinz R. Trechsel, respectively.

Special thanks are expressed to Dr. Robert D. Stiehler and Mr. Paul R. Achenbach of the Center for Building Technology, NBS, for their many technical comments and suggestions concerning the criteria for retrofit materials and products and precautions to be followed in their application. Thanks are also extended to Dr. Ervin L. Bales and Ms. Shelley Launey, the Department of Energy, for their review of the report and noteworthy comments.

The editors express their appreciation to those industrial and government representatives who provided many useful comments and submitted pertinent product standards and specifications.

SI CONVERSION UNITS

In view of the presently-accepted practice in this country in this technological area, common U. S. units of measurement have been used throughout this paper. In recognition of the position of the U.S.A. as a signatory to the General Conference on Weights and Measures, which gave official status to the metric SI system of units in 1960, we assist readers interested in making use of the coherent system of SI units by giving conversion factors applicable to U.S. units used in this paper.

Length

1 in = 0.0254 meter* (m)
1 ft = 0.3048 meter* (m)

Area

1 in^2 = 0.000645 square meter (m^2)
1 ft^2 = 0.0929 square meter (m^2)

Volume

1 in^3 = 0.0000164 cubic meter (m^3)
1 ft^3 = 0.0283 cubic meter (m^3)

Mass

1 lb = 0.454 kilogram (kg)

Mass/Volume (Density)

1 lb/ft^3 = 16.02 $kilogram/meter^3$ (kg/m^3)

Temperature

degree celsius (°C) = 5/9 (°F - 32)

Pressure

1 psi = 6895 pascal (Pa)

Mass/Time (Flow)

1 perm (23°C) = 5.745×10^{-11} $kilogram/pascal\ second\ meter^2$ ($kg/Pa \cdot s \cdot m^2$)

Volume/Time (Flow)

1 cfm = 0.000472 $meter^3/second$ (m^3/s)

* Exactly

Velocity

1 mph = 0.447 meter/second (m/s)

Quantity of Heat

1 Btu = 1056 joule (J)

Energy/Area Time

1 Btu/ft^2 s = 1.134 x 10^4 $watt/meter^2$ (W/m^2)

Thermal Resistance

1 $°F \cdot h$ ft^2/Btu = 0.176 $meter^2$ kelvin/watt (m^2 K/W)

ABSTRACT

The Department of Energy requested the National Bureau of Standards to develop criteria for materials and products to be included in the DOE Weatherization Assistance Program. This program was established by Congressional legislation and was directed toward financially assisting low-income persons in retrofitting residences to conserve energy. In most cases, only energy-saving materials and products for which specifications and/or standards are available are to be included in the Weatherization Assistance Program. Because of statutory requirements labor costs for installing weatherization materials and products are not included in the program.

This report identifies criteria for materials and products considered eligible under the DOE Weatherization Assistance Program. The materials included are insulation and vapor barriers, storm windows and doors, caulking and weatherstripping, clock thermostats, replacement windows, and replacement glazing. The retrofit materials are listed by generic type and recommendations are made for their installation.

During the course of the investigation and based upon interactions with industry representatives, materials and products other than those considered eligible under the DOE Weatherization Assistance Program were also given consideration. Those materials and products having energy savings potential but which are considered not eligible are discussed in the Appendices.

Keywords: Caulks and sealants; clock thermostats; energy conservation; insulation; replacement windows; retrofitting; storm doors; storm windows; vapor barriers; weatherization; weatherstripping.

1. INTRODUCTION

1.1 BACKGROUND

In the past, homes were usually built to minimize first cost. Energy costs were low and little attention was paid to effective use of energy in homes. Many existing dwellings are inadequately insulated in the ceilings, walls and floors, are without storm windows (double glazing) and doors, and are in need of caulking and weatherstripping around windows and doors. It was estimated in 1973 that more than 40 million single family residences were inadequate in one or more of these ways and should be considered for retrofitting [1]*. More recently in 1977 in a study conducted by the Office of Business Research and Analysis, the U.S. Department of Commerce estimated that approximately 25.5 million housing units were in need of retrofitting [2]. This study also reported that approximately 8 to 9 million houses have been voluntarily retrofitted since 1973-74 which was the beginning of the energy crisis. Effective retrofitting of residences could save nearly 20 percent of the energy used for residential heating and cooling in the United States [3]. The term retrofitting, as used here, is the process whereby materials and products are permanently added to existing homes in order to reduce heating and cooling energy consumption.

The savings in both dollars and energy from effective retrofitting have been discussed in the literature [1-17]. Examples of savings cited from the literature are given in Appendix A. The reports cited show in general that a sound economic basis for retrofitting exists.

1.2 WEATHERIZATION ASSISTANCE FOR LOW-INCOME PERSONS

Retrofitting residences by the addition of insulation, storm doors and storm windows is costly and may be beyond the financial capability of low-income persons. The United States Congress passed legislation directing the Department of Energy (DOE)** to carry out a program of weatherization assistance for low-income persons, and in particular elderly and handicapped low-income persons [18]. Under this program, financial assistance would be provided for the purchase of weatherization materials. There are statutory limitations on the amount of assistance to be provided, particularily on expenditures for mechanical equipment. The intent of the program is to aid low-income persons in reducing their heating-fuel consumption while increasing their wintertime comfort. Thus, financial assistance would be granted only for

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* Figures in brackets indicate references listed in Section 5.

** The law specifically directed the Federal Energy Administration (FEA) to administer the Weatherization Assistance Program. Since passage of this law, the FEA has been incorporated into the Department of Energy.

those materials which would be purchased primarily to lower heating-fuel consumption, although some materials, such as insulation, may be beneficial in both winter and summer. Weatherization materials whose primary benefits are the reduction of cooling-energy consumption are not included under the scope of the program. Labor costs for installing the weatherization materials are also not included in the assistance program. Labor is provided by volunteers or public service employment workers.

The Weatherization Assistance Program includes energy-saving materials for which approval has been prescribed by the DOE. The DOE requested the National Bureau of Standards (NBS) to develop criteria by which energy-saving materials and products may be accepted in the DOE Weatherization Assistance Program. These criteria may be used along with other information by DOE in the promulgation of Standards for Weatherization Materials.

1.3 OBJECTIVES

The objectives of this report are to develop criteria for retrofit materials and products which may be included in the DOE Weatherization Assistance Program; to compile a list of retrofit materials and products by generic type and to indicate areas where they can be used; and to point out precautions which should be followed in the application of the retrofit materials and products.

1.4 SCOPE OF THE PROJECT

In 1975 at the request of the Federal Energy Administration (FEA), NBS published NBSIR Report 75-795 entitled "Recommended Criteria for Retrofit Materials and Products Eligible for Tax Credit" in anticipation of proposed federal legislation to grant tax credit to homeowners who retrofitted their residences [19]. It is noted that this proposed legislation was not passed at that time. That report recommended criteria for insulations, vapor barriers, storm windows and storm doors, caulks and sealants, weatherstripping and clock thermostats. It was agreed by DOE and NBS prior to the preparation of this present report that NBSIR Report 75-795 could provide a starting-point for the criteria for materials and products which may be included in the DOE Weatherization Assistance Program. Thus, NBSIR Report 75-795 was to be updated and revised, and expanded to include other retrofit items which were determined to be suitable for the Weatherization Assistance Program.

NBS asked industry and the public to participate in the project. Announcements of a public review of NBSIR Report 75-795 were placed in the Federal Register on May 13, 1977 and in the Commerce Business Daily on May 17, 1977. The public and industry were asked to submit comments to NBS on the NBSIR Report 75-795 and to suggest other energy-saving materials and products for inclusion in the DOE Weatherization

Assistance Program. Suggestions of other energy-savings materials and products were to be accompanied by technical information on properties and performance supporting their use and energy savings which may be achieved.

On June 24, 1977, a meeting was held at NBS, Gaithersburg, to explain the purpose of the project and to discuss the comments and suggestions received during the public review of NBSIR Report 75-795. Additional comments and suggestions concerning the NBSIR Report 75-795 were received during the meeting. NBS staff members requested that these additional comments and suggestions be submitted to them in writing.

An interdisciplinary team from the National Bureau of Standards was assembled to conduct the project. The team members included materials specialists, thermal engineers, a mechanical engineer, a fire safety engineer, research architects, a research psychologist and a building code expert. The team identified retrofit materials and products which were considered for inclusion in the DOE Weatherization Assistance Program and reviewed the comments, suggestions and technical information received during the public review of NBSIR Report 75-795. Many of those comments related to retrofit materials and products that are considered not eligible for the DOE Weatherization Assistance Program under the current legislative mandate.

The categories of materials and products considered eligible in the DOE Weatherization Assistance Program were insulation, vapor barriers, storm windows and storm doors, caulks and sealants, weatherstripping, clock thermostats, replacement windows and replacement glazing. These items are discussed in this report. Other commercially available materials and products may be suitable for retrofitting but are considered not eligible for the DOE Weatherization Assistance Program. Such products may be divided into two categories: those for which criteria may be suggested on the basis of available information and those for which criteria should be developed. Lists of such products are given in Appendices B and C. In developing the criteria for materials and products considered eligible for the DOE Weatherization Assistance Program and in developing the lists of products in Appendices B and C, the NBS team considered the information received from the public and industry during the public review of NBSIR Report 75-795.

1.5 ORGANIZATION OF THIS REPORT

Section 1 gives background information and the objectives and scope of the project.

Section 2 presents the criteria for determining the eligibility of retrofit materials and products for the DOE Weatherization Assistance Program.

Section 3 outlines precautions which must be taken to assure proper installation of the retrofit items.

Section 4 shows the relationship between the retrofitting process and model building codes, and the constraints which the codes impose upon retrofitting.

Section 5 lists references cited in this report.

Appendix A summarizes selected citations from the literature on retrofitting.

Appendix B gives suggested criteria for materials and products for retrofitting which are considered not eligible for the DOE Weatherization Assistance Program. These materials and products may be applicable in other programs.

Appendix C lists energy savings materials and products which are also considered not eligible for the DOE Weatherization Assistance Program and for which criteria are needed. These materials and products may also be applicable in other programs provided criteria are developed.

Appendix D includes information relevant to the properties, performance and use of caulks and sealants available for retrofitting.

Appendix E lists standards and specifications cited in this report.

2. RECOMMENDED CRITERIA FOR MATERIALS AND PRODUCTS TO BE INCLUDED IN THE DOE WEATHERIZATION ASSISTANCE PROGRAM

The materials and products considered eligible for the DOE Weatherization Assistance Program are insulation, storm windows and doors, caulks and sealants, weatherstrippping, vapor barriers, clock thermostats, replacement windows, and replacement glazing when used for retrofitting residences to save energy. This section gives criteria by which the eligibility of these materials and products is to be determined. It has been shown that proper use of these materials and products is effective in conserving energy and generally cost effective [1-17].

These criteria are based on factors such as thermal performance, fire safety, health safety, structural integrity, durability, quality, conformance to building codes, use and ease of installation. FOR ALL ITEMS WHICH MEET THE CRITERIA, THEIR USE IS ONLY ALLOWED IF THE MATERIALS, PRODUCTS AND INSTALLATION TECHNIQUES DO NOT VIOLATE APPLICABLE EXISTING LOCAL BUILDING-RELATED CODES.

Existing materials specifications and standards were reviewed for their suitability as a basis for the criteria. For most items, conformance to existing specifications or standards is given as the criterion for the DOE Weatherization Assistance Program. For others, for example weatherstripping, for which there are no available applicable specifications or standards, but which provide important energy savings when retrofitted to existing housing, the recommended criterion is that the material or product be labeled, identified or marketed as to its general category (e.g., weatherstripping) and properly installed. Regardless of the lack of standards or specifications for these items, they are eligible for the DOE Weatherization Assistance Program, since they have been cited as effective for conserving energy in heating residences [4, 5, 10, 12, 13].

The intent of the DOE Weatherization Assistance Program is to conserve energy through the encouragement of retrofitting. In cases where no applicable standards or specifications exist (e.g., weatherstripping), but where adequate experience is available to confirm the effectiveness of the retrofit items, the use of these items should not be hindered by requiring that new standards or specifications be written. Also, the problem of enforcing conformance to the criteria in evaluating the validity of claims for inclusion in the DOE Weatherization Assistance Program was kept in mind. Complicated technical criteria could make enforcement difficult, if not practically impossible.

All the materials and products considered eligible for the DOE Weatherization Assistance Program and criteria for determining their eligibility are summarized in table 1. All the standards and specifications cited in this report are listed in Appendix E.

Table 1. Summary of Recommended Criteria

Material or Product	Recommended Criteria for Weatherization Assistance[1]
Insulation-Mineral Fiber	
Blanket/Batt	Conformance to F.S.[2] HH-I-521E and ASTM C 665-70, and fire safety requirements[3]
Board	Conformance to F.S. HH-I-526C and ASTM C 612-70 or C 726-72, and fire safety requirements
Duct Material (Industrial Type)	Conformance to F.S. HH-I-558B and fire safety requirements
Loose-fill	Conformance to F.S. HH-I-1030A and ASTM C 764-73, and fire safety requirements
Insulation-Mineral Cellular	
Aggregate Board	Conformance to F.S. HH-I-529B and fire safety requirements
Cellular Glass	Conformance to F.S. HH-I-551E and ASTM C 552-73
Perlite	Conformance to F.S. HH-I-574A and ASTM C 549-73
Vermiculite	Conformance to F.S. HH-I-585B and ASTM C 516-67
Insulation-Organic Fiber	
Cellulose	Conformance to F.S. HH-I-515D and fire safety requirements
Board and Block	Conformance to F.S. LLL-I-535A and ASTM C 208-72, and fire safety requirements
Insulation-Organic Cellular	
Polystyrene Board	Conformance to F.S. HH-I-524B and ASTM C 578-69, and fire safety requirements
Urethane Board	Conformance to F.S. HH-I-530A and ASTM C 591-69, and fire safety requirements
Urea-Based, Foamed-in-Place	Conformance to HUD Use of Materials Bulletin No. 74, and fire safety requirements
Flexible Unicellular	Conformance to F.S. HH-I-573B and ASTM C 534-70, and fire safety requirements

Table 1 (Cont'd)

Material or Product	Recommended Criteria for Weatherization Assistance
Insulation-Air Spaces	
Reflective	Conformance to F.S. HH-I-1252A and fire safety requirements
Storm Windows	
Aluminum Frame	Conformance to ANSI/AAMA 1002.9-1977
Wood Frame	Conformance to Section 3 of ANSI/NWMA I.S. 2-73
Rigid Vinyl Frame	Conformance to NBS Product Standard PS 26-70 and performance guarantee
Frameless Plastic Glazing	Required Minimum Thickness, 6 mil (0.006 in)
Storm Doors	
Aluminum	Conformance to ANSI/AAMA 1102.7-1977
Wood	
Pine	Conformance to Section 3 of ANSI/NWMA I.S. 5-73
Fir, Hemlock, Spruce	Conformance to Section 3 of FHDA/6-77
Rigid Vinyl	Conformance to NBS Product Standard PS 26-70 and performance guarantee
Caulks and Sealants	Conformance to the applicable Federal Specification and ASTM Standard(4)
Weatherstripping	Commercial availablity
Vapor Barriers	Conformance to ASTM C 755-73
Clock Thermostats	Conformance to NEMA DC 3-1978 or DC 15-1972 and performance test requirements(5)

Table 1 (Cont'd)

Material or Product	Recommended Criteria for Weatherization Assistance
Replacement Windows	
Aluminum	Conformance to ANSI/AAMA 302.9-1977
Steel	Conformance to SWI Recommended Specifications for Steel Windows, 1977, and maximum air infiltration of 0.5 cfm per linear foot of sash crack length
Wood	Conformance to ANSI/NWMA I.S. 2-73
Replacement Glazing	Commercial availability for other than safety glazing; for safety glazing conformance to CPSC Part 1201(6)

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(1) For all items, assistance should be allowed only if the items are installed as stated in Section 2 and installation does not violate any existing applicable building-related code. In cases where Federal Specifications or ASTM Standards are revised, the revisions should be reviewed to determine their applicability to the Weatherization Assistance Programs. If the revised Federal Specification or ASTM Standard is determined to be applicable, the recommended criteria for acceptance in the Weatherization Assistance Program should include the latest revision.

(2) F.S. - Federal Specification

(3) For fire safety requirements, see Section 2.1.3.1.

(4) For the applicable Federal Specifications or ASTM Standards, see table 5 in Section 2.4.3. The recommended criteria for inclusion in the Weatherization Assistance Program should include the latest revision of the Federal Specification or ASTM Standard, if the revisions are determined to be applicable.

(5) For performance test requirements, see Section 2.7.3.

(6) For safety glazing requirements, see Section 2.3.5 and Section 2.9.3.

2.1 INSULATION

2.1.1 Definition. Thermal insulation is a material or assembly of materials used primarily to provide resistance to heat flow.

2.1.2 Materials. The materials listed below are those considered suitable for use in residences to provide increased thermal resistance through retrofitting.

2.1.2.1 Types. Insulation is available in the following types:

- o Mineral fibrous materials such as glass, rock or slag wool.
- o Mineral cellular materials such as perlite and vermiculite.
- o Organic fibrous materials such as wood, paper, or synthetic fibers.
- o Organic cellular materials such as polystyrene, polyurethane, or urea-based.
- o Air spaces with either nonreflective or metallic or metallized organic reflective surfaces.

2.1.2.2 Physical Forms. Insulation is available in the following physical forms:

- o Loose-fill. Loose-fill insulation consists of fibers, granules or nodules which are usually poured or blown into attics, walls or other enclosed spaces.
- o Flexible and Semirigid. These are materials with varying degrees of compressibility and flexibility, generally blanket, batt or felt insulation. They are available in sheets or rolls of many types and varieties. Coverings and facings may be fastened to one or both sides to serve as reinforcing, vapor barriers, reflective surfaces or surface finishes. Thickness and shape of insulation may be of any dimension conveniently handled, although standard sizes are generally used.
- o Rigid. These materials are available in rectangular dimensions called block, board or sheet, and preformed during manufacture to standard lengths, widths and thicknesses.
- o Foamed-in-Place. These materials are available as liquid components which may be poured, frothed or sprayed in place to form rigid or semirigid foam insulation.

2.1.3 Criterion. Materials used for thermal insulation should meet requirements for heat flow resistance, fire safety and quality. Federal Specifications and ASTM Standards are available which state requirements for heat flow resistance and quality of the insulations, but which are in most cases incomplete in regard to fire safety. In retrofitting residences by the addition of

thermal insulation, it should be accomplished in such a manner so as not to decrease the overall fire safety of the residence. This involves considerations of installation, burning characteristics such as ignitability, rate of heat release, smoldering and surface flame spread, and flame resistance permanency.

In general, materials conforming to the Federal Specifications, ASTM Standards, and the HUD Use of Materials Bulletin listed in table 2 are considered to meet only the requirements for heat flow resistance and quality, since these specifications do not in most cases contain adequate fire safety requirements. As such, the insulation materials listed in table 2 should be acceptable for the Weatherization Assistance Program only if they:

(a) conform to the applicable fire safety requirements listed in Section 2.1.3.1 and given in table 2,

(b) conform to the requirements other than fire safety of the applicable Federal Specifications, and ASTM Standards, or HUD Use of Materials Bulletin given in table 2, and

(c) are properly installed as designated in Section 2.1.4 and table 2.

Each insulation should be labeled as conforming to the applicable specifications, standards, fire safety requirements, and areas of application.

2.1.3.1 Fire Safety Requirements for Thermal Insulation Materials

Some Federal Specifications and ASTM Standards currently require that the fire performance of the various insulation materials be evaluated according to the test procedures described in ASTM E 84 "Surface Burning Characteristics of Building Materials," or ASTM D 1692 "Rate of Burning or Extent and Time of Burning, or Both, of Cellular Plastics Using a Supported Specimen by a Horizontal Screen." It is considered that these procedures are not appropriate for assessing the response of insulations to flame and heat in all applications. Thus, it is recommended that the test procedures given herein be used in lieu of or in addition to ASTM E 84 or ASTM D 1692 for each insulation material as noted in table 2.

The fire safety requirements for insulation materials are given in Section 2.1.3.1.1, Section 2.1.3.1.2, and Section 2.1.3.1.3. As can be seen from table 2, they differ for the various materials. They also differ according to the area of application, depending whether the insulation is installed in an attic or an enclosed space (e.g., walls, floors) or installed exposed on a wall or ceiling.

Table 2. Thermal Insulating Materials Considered Eligible for the Weatherization Assistance Program

Type of Insulation	Federal Specification[1] Number	Federal Specification[1] Title	ASTM Designation[1]	Fire Safety Requirements[2] Area of Application: Attics (Above Ceilings)	Enclosed Spaces	Exposed Walls or Ceilings
Mineral Fiber	HH-I-521E	Insulation Blankets, Thermal (Mineral Fiber, for Ambient Temperature)	C 665-70	A, B	B	C
	HH-I-526C	Insulation Board, Thermal (Mineral Fiber)	C 612-70 C 726-72	A, B	B	C
	HH-I-558B	Insulation, Blocks, Boards, Blankets, Felts, Sleeving (Pipe and Tube Covering), and Pipe Fitting Covering, Thermal (Mineral Fiber Industrial Type)	-	A, B	B	C
	HH-I-1030A	Insulation, Thermal (Mineral Fiber for Pneumatic or Poured Application)	C 764-73	A, B	B	D
Mineral Cellular	HH-I-529B	Insulation Board, Thermal (Mineral Aggregate)	-	A, B	B	C
	HH-I-551E	Insulation, Block and Board, Thermal (Cellular Glass)	C 552-73	none	none	none
	HH-I-574A	Insulation, Thermal (Perlite)	C 549-73	none	none	none
	HH-I-585C	Insulation, Thermal (Vermiculite)	C 516-67	none	none	none
Organic Fiber	HH-I-515D	Insulation Thermal (Loose-fill for Pneumatic or Poured Application) Cellulose or Wood Fiber	-	A, B	B	D
	LLL-I-535A	Insulation Board, Thermal and Insulation Block, Thermal	C 208-72	A, B	B	C
Organic Cellular	HH-I-524B	Insulation Board, Thermal (Polystyrene)	C 578-69	D	B, E	D
	HH-I-530A	Insulation Board, Thermal (Urethane)	C 591-69	D	B, E	D
	HH-I-573B	Insulation, Thermal (Flexible Unicellular Sheet and Pipe Covering)	C 534-70	D, F	D, F	D, F
		Urea-Based, Foamed-in-Place[3]	-	D	B, E	D
Air Spaces	HH-I-1252A	Insulation, Thermal, Reflective (Aluminum Foil)	-	A, B	B	C

(1) In cases where Federal Specifications or ASTM Standards are revised, the revisions should be reviewed to determine their applicability to the Weatherization Assistance Program. If the revised Federal Specification or ASTM Standard is determined to be applicable, the recommended criteria for acceptance in the Weatherization Assistance Program should include the latest revision.

(2) Fire safety requirements and tests are given in Section 2.1.3.1. The letters in this table have the following designations:
- A: Critical Radiant Flux $\geq$ 0.12 W/cm^2 (1200 W/m^2)
- B: Smoldering Combustion Test
- C: Flame Spread Classification $\leq$ 150
- D: Not recommended in this application
- E: Flame Spread Classification $\leq$ 75
- F: This insulation when used in residences is intended for pipes and ducts; flame spread classifications $\leq$ 150.

(3) No Federal Specification nor ASTM Standard is available for this insulation material. Eligibility is based on conformance to HUD Use of Materials Bulletin No. 74. It is noted that this Bulletin states that urea-based, foamed-in-place insulation is accepted for use only in enclosed building cavities such as walls, partitions and floors.

2.1.3.1.1 Attic Floors

- o Critical Radiant Flux. Critical radiant flux is the level of incident radiant heat energy on the attic floor insulation system corresponding to the furthest point at which flame propagation ceases. For insulations, the critical radiant flux should be equal to or greater than 0.12 W/cm^2.*

  The critical radiant flux shall be determined by the test procedure described in Federal Specification HH-I-515D [20]. This method of test provides a basis for evaluating the surface flame spread behavior of an attic floor insulation in a building attic. The fundamental assumption inherent in the test is that "critical radiant flux" is one measure of the sensitivity to flame spread of installed attic floor insulation.

- o Smoldering Combustion. This test determines the tendency of the insulation to support and propagate smoldering combustion subsequent to exposure to a standard localized ignition source.

  When tested for smoldering combustion, the insulation should meet the following requirements:

  a) weight loss should not exceed 15 percent of the initial weight
  b) no evidence of flaming combustion shall be observed.

  The smoldering combustion test shall be conducted according to the procedure described in Federal Specification HH-I-515D [21].

- o Flame Resistance Permanency. Chemical retardant insulations should retain their flame resistance throughout their service lifetime. At the present time it is considered that an adequate test procedure is not available for assessing this property of insulations.

2.1.3.1.2 Enclosed Spaces

- o Smoldering Combustion. Insulations installed in enclosed spaces should meet the smoldering combustion requirements summarized in Section 2.1.3.1.1.

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* Unit given in the test method; 0.12 W/cm^2 = 1.2 kW/m^2

- o Surface Burning Characteristics. The flame spread classification of plastic foam insulation should not exceed 75.*

  The ASTM E 84-77 flame spread test method shall be the basis for evaluating the surface burning characteristics of plastic foam insulations when used in enclosed spaces.

2.1.3.1.3 Exposed Walls and Ceilings

- o Surface Burning Characteristics. The flame spread classification index of mineral fiber blanket, mineral fiberboard, mineral aggregate and cellulosic-fiber boards, industrial mineral fiber, and reflective insulations should not exceed 150.

  The ASTM E 84-77 flame spread test method shall be the basis for evaluating the surface burning characteristics of insulation materials used in exposed locations on walls and ceilings. Where blankets or boards with facings are to be used exposed in rooms, attics, crawl spaces, garages and other locations, the surface burning characteristics of the membrane-faced insulation shall be measured.

2.1.4 Areas of Application. Materials used for thermal insulation may be applied in residences as outlined in table 2 to the following areas: walls, roofs, attics, ceilings, floors, pipes, ducts, vessels and equipment exposed to the external environment. It is noted that the HUD Use of Materials Bulletin No. 74 states that urea-based, foamed-in-place insulation be accepted for use only in enclosed building cavities such as walls, partitions and floors.

Exposed plastic foams (non-faced or faced, untreated or fire-retardant treated) shall not be permitted in habitable or occupiable areas. These materials shall be protected by a layer of gypsum board of 1/2 inch thickness or greater, or an equivalent fire barrier.

Installed insulation and vapor barrier shall not make contact with recessed lighting fixtures, motors, fans, blowers, heaters, flues, and chimneys. In the case of lighting fixtures, the 1978 National Electrical Code prepared by the National Fire Protection Association states that "thermal insulation shall not be installed within 3 inches of the recessed fixture enclosure, wiring compartment or

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* Plastic foams are difficult to evaluate in ASTM E 84-77. The requirement of a flame spread classification of 75 maximum for these foams, in conjunction with a smoldering combustion test will provide safety assurance as is possible with current test methods. A flame spread classification of 75 (or any other numerical classification) shall not be construed as the equivalent of "noncombustible."

ballast and shall not be so installed above the fixture as to entrap heat and prevent the free circulation of air unless the fixture is otherwise approved for the purpose." When insulating ceilings, the thermal insulation should not be placed over lighting fixture enclosures (unless approved for the purpose), electrical junction boxes, exposed frayed wiring, or wiring which contains damaged electrical insulation. In addition, precautions should be taken when installing insulation over any exposed wiring in ceilings, even that in good condition. To retain loose-fill and foamed-in-place insulations from making contact with other energy-dissipating objects, a minimum of 3 inches of air space should be provided and assured by the use of blocking. After addition of loose-fill or foamed-in-place insulation to cavity walls, electrical outlet boxes within those walls should be examined for the presence of insulation. If found, the insulation should be removed from the electrical outlet boxes.

2.1.5 Commentary. Although a degree of material combustibility is allowed, the intent of these fire safety requirements is to allow insulating materials which are not more combustible (or flammable) than acceptable existing construction and insulation materials, and to preclude any increased fire hazard due to the retention of heat from energy-dissipating objects.

In areas where occupants are likely to be engaged in normal activities, the insulation should perform its intended function without the increased risk of ignition, rapid flame spread, and heat and smoke generation. Insulation in concealed spaces may be a particular fire problem due to its susceptibility to smoldering and its inaccessibility for fire fighting.

Although the primary fire safety properties of insulation relate to ignitability and rate of heat release, at the present time standard test methods for these properties do not exist. It is recommended that the critical radiant flux, smoldering combustion and flame spread classification test methods be used to judge fire performance. Federal Specificaton, HH-I-515D, has incorporated the critical radiant flux and smoldering combustion tests. Federal Specifications, HH-I-521E and HH-I-1030A are presently undergoing revision, and it is anticipated that the critical radiant flux and smoldering combustion tests will be incorporated in the revisions.

Many insulation materials, including those consisting of cellulose, plastic foam and fibrous glass (containing organic binder) are combustible materials which will burn and release heat, smoke and gases, especially when exposed to continuous large fire sources. Additional information on the rate of heat release and on performance of these insulation materials in full-scale room fire tests should be developed.

The urethane plastic foam industry recommends that urethane foam used in all interior and/or ceiling construction should be covered with at least 1/2 inch of cement plaster or fire-rated gypsum

wallboard or an equivalent barrier providing a finish fire rating of 15 minutes or more [22]. This recommendation has been incorporated in building codes and federal regulations for organic cellular insulations for various types of buildings.

With regard to the installation of urea-based foamed-in-place insulation, the HUD Use of Materials Bulletin No. 74 states that each manufacturer shall certify that his approved applicators of urea-based foamed resin insulation are licensed as such and carry a current certificate of qualification and an identification card.

No general test method exists for evaluating the flame resistance permanency of all chemical retarded insulations. The test procedure in ASTM C 739-77, Section 10.4, has been used for cellulosic loose-fill insulation, but is not recommended at this time because of unresolved questions concerning its applicability. Additional information based on research, laboratory testing and field experience should be developed.

Proper retrofitting requires the installation of adequate amounts of insulation to reach desirable levels of heat flow resistance. The prudent homeowner who retrofits should upgrade his home, whenever possible, to these levels. The homeowner should realize that heating and cooling costs vary with energy prices. The amount of insulation that is economically justified based on energy costs increases with fuel prices [4]. For the various geographical locations as designated by heating degree-days, the total thermal resistance, R_t, resulting from retrofitting thermal insulation to opaque portions of walls, roofs, ceilings and floors should lie within the ranges of values given in table 3. The retrofitting of insulation at the edges of slab floors to reduce slab edge heat loss should give resultant thermal resistances, R-values, and total depths of insulation at the slab edges as listed in table 4.

Air ducts, plenums, pipes and other surfaces installed in unheated spaces (e.g., attics, unheated garages, crawl spaces, etc.) should be thermally insulated to provide a metal surface to outside surface thermal resistance of not less than $R = \Delta T/15$, where ΔT is the maximum temperature difference (°F) between the duct (or other enclosure) and the surrounding air, or should be insulated to a value of $R = 4$, whichever is greater.

The thermal resistance of building and insulating materials may be obtained or calculated from values given in table 3 of Chapter 20 of the ASHRAE Handbook of Fundamentals [24]. Where calculation is necessary, the thermal resistance is the thickness of a material divided by its thermal conductivity in consistent units. The thermal resistances of air spaces may be obtained from table 2 of Chapter 20 of the ASHRAE Handbook of Fundamentals [24] for various orientations and effective emissivities of the air space.

Table 3. Desirable Ranges of Total Thermal Resistances, R_t[1], of Walls, Roofs, Ceilings and Floors, for Ranges of Heating Degree-Days[2]

Heating Degree-Days[3]	0 - 4500	4501 - 8000	8001 or more
Flat roof deck	12 - 20	20 - 30	20 - 40
Ceilings	20 - 30	30 - 40	40 - 50
Masonry wall construction	4 - 11	10 - 12	11 - 17
Frame wall construction	12 - 15	12 - 20	12 - 25
Floors[4]	1 - 11	12 - 20	20 - 25

(1) Values of total thermal resistance are given in units $°F \cdot h \cdot ft^2 \cdot Btu^{-1}$. To obtain transmittance, $U = 1/R_t$.

(2) In retrofitting many residences, it may not be possible to upgrade the total thermal resistance of a wall, roof, ceiling or floor to the greatest desirable value for a given degree-day range because of limitations in building construction. Thus, there is overlap in some of the ranges of total thermal resistance for the ranges of heating degree-days.

(3) Values of degree-days for many geographical locations are given in Chapter 43 of the ASHRAE Systems Handbook [23].

(4) Total resistance values for floors over basements, unheated garages or crawl spaces with no positive heat supply.

Table 4. Minimum Total Thermal Resistance of Insulation at Edges of Slab-On-Ground Floors

Heating Degree-Days	Thermal Resistance, R $°F \cdot h \cdot ft^2 \cdot Btu^{-1}$	Depth of Insulation inches
2500 - 4500	4.0	18
4501 - 8000	5.0	24
8001 or more	7.0	24

The thermal resistance of surfaces exposed to still (inside) and moving (outside) air and various positions and directions of heat flow must be used in calculations for total thermal resistance. R-values of surfaces are given in table 1 of Chapter 20 of the ASHRAE Handbook of Fundamentals [24].

The total thermal resistance to heat flow through a flat wall, roof, ceiling or floor is equal numerically to the sum of the individual resistances in series of the components comprising the opaque portions of the walls, roofs, ceilings or floors, and the resistances of the air films on the inside and outside surfaces of the wall, roof, ceiling or floor. Table 4 of Chapter 20 of the ASHRAE Handbook of Fundamentals [24] gives examples for computation of total thermal resistance, R_t.

2.2 STORM WINDOWS

2.2.1 Definition. A storm window is an extra window, normally installed to the exterior of the primary or ordinary window to increase resistance to heat flow and to decrease air infiltration. Less commonly, storm windows are installed on the interior of the primary windows.

2.2.2 Materials. Storm windows may be constructed of aluminum, wood or rigid vinyl [poly(vinyl chloride)] frames, with glass or plastic glazing. Flexible and rigid plastic sheeting may also be used.

2.2.3 Criterion. Storm windows for retrofitting should conform to the standards or special provisions listed below, and be installed as stated in Section 2.2.4. Each storm window should be labeled as conforming to the applicable standard or special provision.

2.2.3.1 Aluminum Combination and Frame Storm Windows. Aluminum combination storm windows should conform to the American National Standard Institute ANSI/AAMA 1002.9 - 1977 "Voluntary Specifications for Aluminum Combination Storm Windows for External Applications." Aluminum frame storm windows should conform to Sections C1.2, C1.3, C1.4 and C1.6 of ANSI/AAMA 1002.9 - 1977.

2.2.3.2 Wood Frame Storm Windows. Wood frame storm windows should conform to Section 3 of the American National Standard Institute ANSI/NWMA I.S. 2-73 "Wood Windows."

2.2.3.3 Rigid Vinyl Frame Storm Windows. Rigid vinyl frame storm windows should be constructed with vinyl profile extrusions which

conform to NBS Voluntary Product Standard PS 26-70, "Rigid Poly(Vinyl Chloride) (PVC) Profile Extrusions." These windows should be equal in quality to aluminum and wood frame storm windows. The manufacturer should assure their quality and guarantee that they will perform as well as aluminum and wood frame storm windows.

2.2.3.4 Frameless Plastic Glazing. Plastic glazing used as frameless storm windows should consist of either rigid or flexible sheets, a minimum of 6 mil (0.006 in) thick.

2.2.4 Areas of Application. Storm windows used for retrofitting may be installed on residences to existing primary windows. Installation should not violate any applicable existing local building-related code. A minimum of 1/2 inch of air space should be provided between the glazing of the primary and storm windows.

2.2.5 Commentary. Some storm windows are installed in a fixed position which may create a ventilation problem. Also, fixed position storm windows may hinder or prevent egress in case of emergency. When installing any type of storm window, the installed storm window should not restrict the existing capacity and access required for occupant egress via windows. It is normally expected that one (or more) bedroom and living room windows can serve as emergency means of exit and will be easily openable and of suitable dimensions and area (5 sq. ft). Local building codes should be consulted for regulations regarding retrofitting with storm windows, particularly those installed in a fixed position.

Installation of storm windows may cause moisture build-up between the outer and inner windows. This moisture build-up may be reduced or eliminated by the use of small ventilation openings (generally called weep holes) in the outer window sash.

Storm windows may not always provide a significant decrease in air infiltration. The reduction in air infiltration depends upon the relative tightness of the original primary window and the storm window.

2.2.5.1 Aluminum Combination and Frame Storm Windows. The intent of the criterion is to assure the quality of storm windows which are used for energy conservation. Section C 1.10 of ANSI/AAMA 1002.9-1977 gives an option for certification of a storm window to show compliance with the standard. It is not the intent to require certification to the standard; however, labeling that the storm windows meet the provisions of the standard is recommended.

2.2.5.2 Wood Frame Storm Windows. ANSI/NWMA I.S. 2-73 was not developed for storm windows, but rather for primary windows. Section 3 of the standard is used as the criterion in retrofitting to assure the quality of the materials and the quality of the construction of the windows.

2.2.5.3 Rigid Vinyl Frame Storm Windows. NBS Voluntary Product Standard PS 26-70 is concerned with the quality of vinyl profile extrusions, and not completed windows. Since there are no standards to assure the the quality of these windows, the manufacturer should guarantee that they perform as well as aluminum and wood frame storm windows described in Sections 2.2.3.1 and 2.2.3.2.

2.2.5.4 Frameless Plastic Glazing. Flexible and rigid plastic sheeting can be effective in reducing heat flow and are acceptable for use as storm windows. Flexible sheeting offers an economical method for retrofitting but has a short life, usually lasting one season.

In the installation of frameless plastic glazing, consideration should be given to the fact that interior installation is easier and provides greater protection to the plastic. Condensation on the interior of the primary window may appear and may be difficult to remove. To reduce the possibility of condensation, the plastic glazing installed on the interior should be sealed continuously along its perimeter and not contain weep holes. In addition, the plastic glazing should have a low water vapor permeability.

Outside installation is more difficult (e.g., 2 story houses) and damage to the plastic is more likely from the elements. Flexible sheeting installed outside may pose a noise problem due to fluttering caused by wind. In the case of outside installation, condensation which occurs on the plastic glazing can in general be removed from the inside by opening the windows. Condensation may be reduced or prevented if the exterior plastic glazing is not installed airtight, and limited air infiltration is permitted.

2.3 STORM DOORS

2.3.1 Definition. A storm door is an extra door, installed to the outside of an exterior primary or ordinary door, to provide greater resistance to heat flow and to reduce air infiltration.

2.3.2 Materials. Storm doors may be constructed of aluminum, wood or rigid vinyl frames with glazing, or of wood without glazing.

2.3.3 Criterion. Storm doors installed for retrofitting should conform to the standards listed below, and be installed as stated in Section 2.3.4. Whenever storm doors contain glazing, safety glazing is required in conformance to Part 1201 - Safety Standard for Architectural Glazing Materials. Storm doors should be labeled as conforming to the applicable standard, as well as the CPSC Standard for safety glazing, whenever the storm doors contain glazing.

2.3.3.1 Aluminum Frame Storm Doors. Aluminum frame storm doors should conform to ANSI/AAMA 1102.7-1977 entitled "Voluntary Specifications for Aluminum Storm Doors."

2.3.3.2 Wood Storm Doors With or Without Glazing

- Pine storm doors should conform to the requirements for exterior doors listed in Section 3 of ANSI/NWMA I.S. 5-73 entitled "Ponderosa Pine Doors."

- Fir, hemlock and spruce storm doors should conform to the requirements for exterior doors listed in Section 3 of the Fir and Hemlock Door Association Industry Standard FHDA/6-77 entitled "Industry Standard for Douglas Fir, Western Hemlock, and Sitka Spruce Doors and Blinds."

2.3.3.3 Rigid Vinyl Frame Storm Doors. Rigid vinyl frame storm doors should be constructed with vinyl profile extrusions which conform to NBS Voluntary Product Standard PS 26-70, "Rigid Poly(Vinyl Chloride) (PVC) Profile Extrusions." These doors should be equal in quality to aluminum and wood frame storm doors. The manufacturer should assure their quality and guarantee that they will perform as well as aluminum and wood frame storm doors described in Sections 2.3.3.1 and 2.3.3.2.

2.3.4 Areas of Application. Storm doors used for retrofitting may be installed on residences to any existing exterior door. Installation should not violate any applicable existing local building-related code.

2.3.5 Commentary. The addition of storm doors should not endanger the safety of the occupants of the dwelling. Doors are the normal means of exit from a residence, and an installed storm door should not restrict the existing capacity and access for occupant egress.

To reduce the risk of bodily injury due to accidental impact with storm doors containing glazing, safety glazing should be used whenever storm doors contain glazing. The Consumer Product Safety

Commision (CPSC) requires that safety glazing be used in storm doors or combination doors, doors used for human passage (both exterior and interior) and sliding or patio-type doors. These safety glazing materials must meet the requirements of Part 1201 - Safety Standard for Architectural Glazing Materials established by the Consumer Product Safety Commisssion and issued in the Federal Register January 6, 1977. The requirements of this CPSC Safety Standard were effective on July 6, 1977 and are mandatory and supersede local and national code requirements.

2.3.5.1 Aluminum Frame Storm Doors. The intent of the criterion is to assure the quality of the storm doors necessary for satisfactory performance and that energy savings will be realized through their use. Section C 1.10 of ANSI/AAMA 1102.7-1977 gives an option for certification of a storm door to show compliance with the standard. It is not the intent to require certification to the standard; however, labeling that the storm doors meet the provisions of the standard is recommended.

2.3.5.2 Wood Frame or Wood Storm Doors. The standards ANSI/NWMA I.S. 5-73 "Ponderosa Pine Doors" and FHDA/6-77 "Industry Standard for Douglas Fir, Western Hemlock, and Sitka Spruce Doors and Blinds" were not developed for storm doors, but rather for primary wooden doors. Section 3 of each standard is used for criteria in retrofitting because there are no existing performance standards or specifications that have been developed specifically for wooden storm doors.

Conformance to the requirements given in Section 3 of each standard assures the quality of the materials and construction of the storm doors.

If woods other than those listed in Section 2.3.3.2 are used to construct storm doors, the quality of these doors shall be equal to the quality of the doors listed in Section 2.3.3.2.

2.3.5.3 Vinyl Frame Storm Doors. NBS Voluntary Product Standard PS 26-70 is concerned with the quality of vinyl profile extrusions, and not completed doors. Since there are no standards to assure the quality of these doors, the manufacturer should guarantee that they perform as well as aluminum and wood frame storm doors described in Sections 2.3.3.1 and 2.3.3.2.

2.4 CAULKS AND SEALANTS

2.4.1 Definition. Caulks and sealants are nonrigid materials placed in joints of buildings to prevent the passage of heat, air, moisture and dust. The terms caulk and sealant are often used interchangeably. On the other hand, many producers and contractors refer to the lower performance materials as caulks, and to the better performance materials as sealants.

2.4.2 Materials. Materials used as caulks and sealants are grouped in three classifications according to their performance. The materials in each class are listed below. Information relevant to properties, performance and use of the materials is given in Appendix D.

2.4.2.1 Basic Performance.

- o Oil and Resin Base Caulks
- o Polybutene Compound

2.4.2.2 Intermediate Performance.

- o Latex Caulks
- o Acrylic (Solvent Type) Caulks
- o Butyl Rubber Sealant (or Caulk)
- o Chlorosulfonated Polyethylene

2.4.2.3 High Performance.

- o Polysulfide
- o Polyurethane
- o Silicone

2.4.2.4 Putty and Glazing Compounds. There are two types of compounds generally used for sealing relatively small glass panes. The two types are putty and glazing compounds. For larger glass windows (e.g., picture windows) sealants from the intermediate and high performance classes are used.

2.4.3 Criterion. Caulks and sealants for retrofitting residences should conform to the applicable Federal Specification and ASTM Standard given in table 5.

Table 5. Specifications for Caulks and Sealants

Performance Classification	Caulk or Sealant	Federal Specification	ASTM Designation
--	Putty	TT-P-00791B	---
	Glazing Compound	TT-G-410E	---
Basic	Oil and Resin Base	TT-C-00598C	C 570-72
Intermediate	Acrylic (Solvent Type)	TT-S-00230C	---
	Butyl Rubber	TT-S-001657	---
	Chlorosulfonated Polyethylene	TT-S-00230C	---
	Latex Sealing Compounds	---	C 834-76
High	Polysulfide		
	single component	TT-S-00230C	---
	multi-component	TT-S-00227E	---
	Polyurethane		
	single-component	TT-S-00230C	---
	multi-component	TT-S-00227E	---
	Silicone	TT-S-001543A	---

2.4.4 Areas of Application. Caulks and sealants used for retrofitting should be installed in joints of residential housing such as those associated with the following:

- o Window frames
- o Door frames
- o Window and door glazing
- o Joints between walls and foundations or slabs
- o Wall to wall joints
- o Siding joints
- o Skylights
- o Ducts, vents and other penetrations through walls
- o Air conditioners to window joints
- o Attic floor/chimney/siding gaps
- o Fuel-oil pipe and other similar designed breaks in the exterior surface
- o Window frame/storm window joint.

2.4.5 Commentary. The level of performance of a caulk or sealant is related to the cost of the product. A more expensive product will in general last longer. Thus, a high initial investment may more than pay for itself by eliminating additional expense at a later date because of re-installation costs. Even a low quality caulk or sealant will save energy by reducing air infiltration, if properly applied. Guidelines for applying caulks and sealants are given in Section 3.4

Caulks and sealants should be labeled on the containers or cartridges as conforming to the applicable Federal Specification and ASTM Standard so that the homeowner may determine compliance to the criterion stated in Section 2.4.3.

2.5 WEATHERSTRIPPING

2.5.1 Definition. Weatherstripping consists of narrow strips of material placed over or in moveable joints of windows and doors to reduce the passage of air and moisture.

2.5.2 Materials. Various types of weatherstripping are available for retrofitting. In general most can be applied to both windows and doors. However, others are made specifically for doors. Examples of weatherstripping include the following:

2.5.2.1 Weatherstripping for Both Windows and Doors

spring bronze strips
felt strips

adhesive backed foam strips
adhesive backed sponge rubber strips
bristle brush strips
hollow vinyl cord
sponge rubber gasket
metal wrapped vinyl strips
metal wrapped felt strips

2.5.2.2 Weatherstripping for Hinged Doors

door bottom strips
door bottom sweeps
door shoes
vinyl bulb threshold
interlocking threshold
magnetic strips

2.5.3 Criterion. Any commercially available material which is marketed as weatherstripping is eligible. It is not required that the weatherstripping conform to any specification or special provision.

2.5.4 Areas of Application. Materials used as weatherstripping may be applied to all windows and exterior doors in residences or to doors between heated and unheated rooms.

2.5.5 Commentary. This report is concerned with weatherstripping normally sold in building supply houses, hardware stores and home improvements centers. Weatherstripping is one of the easiest retrofit materials or products to install. The only requirement for acceptance in the DOE Weatherization Assistance Program is that the material be commercially available and be labeled as weatherstripping.

There are no test methods for demonstrating the efficiency of weatherstripping used for retrofitting. The amount of reduction of air flow will depend upon the tightness of the door or window being weatherstripped, and the degree to which compression or deflection of the weatherstripping seals the air gap of the door or window. Certain weatherstripping may not be suitable for all doors and windows because of the gap size of the joint. Proper selection and installation of weatherstripping are important to achieve maximum reduction of air flow.

There is a range of quality among the various weatherstrippings that the homeowner may purchase. In general, the foam plastics are inferior to the metal strips or vinyl cord [25]. Even an inferior quality

product will save energy by reducing air infiltration at windows and doors. Such materials are, therefore, recommended for acceptance. The homeowner should be aware that inferior quality weatherstripping may not perform as well as better quality products and may have to be replaced more frequently. Better quality products are more durable and tend to retain their ability to reduce air infilitration for a longer period of time.

2.6 VAPOR BARRIERS

2.6.1 Definition. A vapor barrier is a material which provides a high resistance to the transmission (flow) of water vapor through building and insulating materials due to water vapor pressure difference. The principal purpose of vapor barriers is to preclude or reduce appreciably the possibility of moisture accumulation including condensation of water vapor within insulation and other building materials.

2.6.2 Materials. The materials listed below, when installed as recommended, provide water vapor barriers. Vapor barrier materials should be water resistant, puncture resistant, abrasion resistant, tear resistant, fire resistant, noncorrosive, rot and mildew resistant, and of sufficient tensile strength, in addition to a high resistance to water vapor transmission.

2.6.2.1 Membrane Barriers are flexible and nonload bearing, and are supplied in a roll form or as an integral part of thermal insulation. These include metal foils, coated felts and papers, laminated foil and treated papers, and plastic films and sheets. Accessory items, such as tape and adhesives, may be required for sealing joints. Membrane barriers should have a water vapor permeance not greater than 1 perm (see Commentary, Section 2.6.5).

2.6.2.2 Mastic, Coating and Paint Barriers are field applied semi-liquid compositions having high resistance to water vapor transmission after curing. The ingredients of these barriers include bitumens (asphalts), resins or polymers, pigments, fillers, and volatile solvent or water. Paints which have been used as vapor barriers include alkyds including aluminum pigmented alkyds, polyurethanes, epoxies and rubber based paints. Paints used as vapor barriers should have a water vapor permeance not greater than 1 perm. It would be desirable to have the water vapor permeability of paints stated on the containers.

2.6.2.3 Structural Barriers may be formed from rigid or semi-rigid materials of low permeability which from a part of a structure. They include reinforced plastics, aluminum, stainless steel and insulating materials which are relatively impervious to water

vapor flow due to their physical structure and composition. They require careful sealing of joints and seams. These materials are generally not used as vapor barriers in residential housing.

2.6.3 Criterion. The materials used for water vapor barriers should conform to provisions cited in ASTM C 755-73, "Standard Recommended Practice for Selection of Vapor Barriers for Thermal Insulation," and be installed in areas listed in Section 2.6.4. Vapor barrier materials should have a permeance not greater than 1 perm, when tested according to the dessicant methods described in ASTM E 96-66(72) or ASTM C 355-64(73).

2.6.4 Areas of Application. Materials used for water vapor barriers may be applied in residences to the following areas: (1) warm (winter) side of opaque exterior walls, (2) warm (winter) side of flat roofs and ceilings under ventilated attic spaces, (3) generally on the warm (winter) side of floors over unheated basements and crawl spaces depending on the moisture and temperature in these areas, and (4) over ground or soil in crawl spaces. Membrane vapor barriers, when installed in habitable or occupiable areas, should be covered to prevent damage or an increased risk of fire. Vapor barriers should not be applied over existing insulation in cases where the existing insulation is covered with new insulation.

2.6.5 Commentary. Increased amounts of insulation in the walls, roofs or ceilings and floors to reduce heat flow during winter heating and/or summer cooling of residences requires attention to the increased possibility of excessive accumulation of moisture in these elements. This may be prevented by one or more of the following measures:

- o providing a vapor barrier to limit vapor entrance
- o ventilating the residence to reduce vapor pressure
- o making the cold side of walls, roofs or ceilings, and floors more permeable to the escape of water vapor.

These measures should not be regarded as equal alternatives or as equally beneficial in conserving energy.

The deleterious effects of moisture accumulation in building and insulating materials may include:

- o deterioration of materials by chemical, physical and biological changes and by freeze-thaw breakdown of materials.
- o reduction of thermal resistance of insulating materials and a decrease in their effectiveness as insulation.
- o significant dimensional changes occur in many building materials with changes in moisture content.

As stated in the criterion, vapor barrier materials installed for retrofitting purposes should have a permeance not greater than 1 perm. Permeance values for typical vapor materials are given in table 1 of Chapter 18 of the ASHRAE Handbook of Fundamentals [24]. (A perm unit is one grain $h^{-1} \cdot ft^{-2} \cdot in^{-1}$ of mercury vapor pressure difference.)

Exact values for permeance should be obtained from the manufacturer of the material under consideration or, if necessary, secured as a result of laboratory tests. The permeance of vapor barrier materials should be determined by the dessicant method (Procedure A) described in ASTM E 96-66(72), "Standard Method of Test for Water Vapor Transmission of Materials in Sheet Form," or by the dessicant method described in ASTM C 355-64(73), "Standard Method of Test for Water Vapor Transmission of Thick Materials." Permeance of a material generally varies with temperature and with the mean of the relative humidity levels on the two sides of the vapor barrier.

2.7 CLOCK THERMOSTATS

2.7.1 Definition. A clock thermostat is a temperature control device for interior spaces incorporating two adjustable temperature control points and a clock or timer for switching from one control point to the other. Only one control point regulates the interior space temperature at one time. A temperature control point is the mean value of the air temperature at the thermostat under specified operating conditions.

2.7.2 Products. Clock thermostats and clock thermostat systems may be classified as follows:

2.7.2.1 A Clock and Two Individual Thermostats. In this system, two thermostats are connected through a time clock to the heating system. The clock automatically switches from the normal temperature controlled by one thermostat to the setback (lower for heating, higher for cooling) temperature controlled by the other. The duration of the setback is determined by the clock. This system has the advantage that more than one setback period may be chosen in a 24 hour period. Also, different types of clocks may be used to control switching. For example, 24-hour and 7-day clocks are commercially available. By using a 7-day clock, the setback time can be programmed for a whole week. Commercially available clock thermostats of this type include products which contain two thermostats and a clock in one unit used for replacing the existing thermostat, and those which combine a thermostat and a clock in one unit used for supplementing the existing thermostat. This type of clock thermostat may also be used with central air conditioning.

2.7.2.2 Fully Automatic Clock Thermostat. This is a thermostat which combines two temperature control points and a clock in one unit. After the setback period is fixed, the thermostat automatically switches between the normal and setback temperatures generally once every 24 hours, although some newer units allow more than one setback every 24 hours. Fully automatic clock thermostats may also be used with central air conditioning systems.

2.7.2.3 Semi-automatic Clock Thermostat. This is a thermostat which combines two temperature control points and a wind-up timer in one unit. With this unit, the setback is manually activated by setting the timer. The duration of setback is also fixed manually each time the setback is activated. The thermostat automatically switches from setback to normal temperature. This device may be activated more than once every 24 hours.

2.7.3 Criterion. For a clock thermostat or clock thermostat system, the thermostat portion should conform to the provisions prescribed in National Electrical Manufacturers Association (NEMA) Standards Publication DC 3-1978 entitled, "Low-Voltage Room Thermostats," or NEMA Standards Publication DC 15-1972 entitled "Residential Controls: Line-Voltage Room Thermostats," depending upon the type of thermostat. In addition, when the thermostats are tested according to the methods described in Part 4 of NEMA DC 3-1978 or NEMA DC 15-1972, the following requirements should be met:

- o the operating differential should not exceed 2°F,
- o the cycling rate at 50 percent maximum load should not exceed six cycles per hour, and
- o the effective operating droop should not exceed 4°F.

The thermostats should be labeled as meeting the provisions of the standards as well as those for operating differential, cycling rate and effective operating droop.

2.7.4 Areas of Application. Clock thermostats may be applied in residential housing as replacements of or additions to existing thermostats which control interior space temperatures.

2.7.5 Commentary. NEMA Standards Publications DC 3-1978 and DC 15-1972 were not developed specifically for clock thermostats. The standards do allow for auxiliary thermostat components for resetting or for changing temperature control points, as described in Section 2.03 of NEMA DC 3-1978 and Section 2.04 of NEMA DC 15-1972, respectively.

Part 4 of NEMA DC 3 or NEMA DC 15 gives performance tests including differential, cycle rate and droop tests to be conducted on thermostats. However, levels of performance have not been specified in

these NEMA Standards. Levels of performance are specified within the criterion for eligibility of clock thermostats in the DOE Weatherization Assistance Program. These levels of performance specified herein were based on the performance of some presently-available thermostats. For example, the cycling rates of 50 percent maximum load of typical thermostats used for furnaces, boilers and air-conditioner are five, three and three cycles per hour, respectively.

It has been reported that substantial energy savings can be achieved through temperature setback at night [6, 7]. Temperature setback of a thermostat can be accomplished manually. There is no technical reason for requiring the use of clock thermostats. However, there are practical reasons to consider such as convenience and comfort to the homeowner. For example, he may forget at night to use manual setback or may not want to rise in a cool house in the morning. Automatic control of the setback eliminates the human element and assures regular night setback with its resulting energy savings. Although some fully automatic clock thermostats may only function on one cycle (setback) a day, they may be nevertheless set back manually at other times whenever the need arises. The cost-effectiveness of a clock thermostat varies with the amount of space or heating capacity it controls and the duration of the heating season.

2.8 REPLACEMENT WINDOWS

2.8.1 Definition. A replacement window is a thermally improved primary window, including the frame, sash and glazing. It is installed in the wall of a residence after removal of the existing window and frame assembly to increase resistance to heat flow and to decrease air infiltration.

2.8.2 Materials. Replacement window frames and sash may be constructed of aluminum, steel or wood, with glass or plastic glazing.

2.8.3 Criterion. Replacement windows for retrofitting should conform to the standards and special provisions listed below, and be installed as stated in Section 2.8.4. In addition replacement windows should have multiple glazing, and metal frames should contain a thermal break to reduce heat flow.

2.8.3.1 Aluminum Frame Replacement Windows. Aluminum frame replacement windows should conform to ANSI/AAMA 302.9-1977, "Voluntary Specifications for Aluminum Prime Windows."

2.8.3.2 Steel Frame Replacement Windows. Steel frame replacement windows should conform to "Recommended Specifications for Steel Window," Steel Window Institute, 1977. Allowable air infiltration should not exceed 0.5 cfm per linear foot of sash crack length when tested with the window sash closed and latched in accordance with ASTM E 283-73 at a static air pressure of 1.56 psf.

2.8.3.3 Wood Frame Replacement Windows. Wood frame replacement windows should conform to ANSI/NWMA I.S. 2-73 entitled "Wood Windows."

2.8.4 Areas of Application. When warranted because of excessive air infiltration, any residential primary window and frame assembly may be replaced. Installation should not violate any applicable existing local building-related code.

2.8.5 Commentary. Comparison of the cracks around existing windows with the values cited in the ASHRAE Handbook of Fundamentals, 1977, Chapter 21 for "poorly fitted" and "average" windows will provide some guidance in evaluating the need for replacement. Any warping, poor fitting or damage that could not be overcome by weatherstripping would suggest a need for replacement. Installation of weatherstripping and storm windows are alternative methods to reduce heat flow and air infiltration through windows. In cases where it is not possible to install storm windows to primary windows, replacement windows may be warranted. As compared to storm windows, the potential of replacement windows to reduce energy consumption is related to the decrease in air infiltration which is achieved through the replacement of windows.

Thermally improved windows incur low rates of heat flow and air filtration. Multiple glazing and thermal breaks in metal window frames are intended to provide low rates of heat flow and therefore increased benefits for energy conservation. The ASHRAE Standard 90-75, "Energy Conservation in New Building Design," recommends that the air infiltration through windows not exceed 0.5 cfm per linear foot of sash crack length. ANSI/AAMA 302.9-77 for aluminum windows and ANSI/NWMA I.S. 2-73 for wood windows have air infiltration requirements the same as recommended by ASHRAE 90-75. The "Recommended Specifications for Steel Windows," Steel Window Institute, 1977, has no requirement for maximum allowable rate of air infiltration, and thus the criterion in Section 2.8.3.2 includes a maximum air infiltration requirement.

Replacement window frames should be properly caulked and sealed into the wall of the residence to prevent air infiltration at these locations.

Replacement windows should be labeled as manufactured to conform to the applicable provisions given in Section 2.8.3. It is not required that they be certified by independent laboratories as meeting these provisions. However, test results may be needed to assure conformance to the applicable criteria.

2.9 REPLACEMENT GLAZING

2.9.1 Definition. Replacement glazing denotes the replacement of broken or missing glazing from primary windows and exterior doors. Excessive air infiltration through broken windows will reduce the effectiveness of other retrofit measures. Consequently, broken or missing glazing should be replaced before retrofit measures are considered.

2.9.2 Materials. Replacement glazing should be window glass or plastic. Safety glazing may be used or required in some applications.

2.9.3 Criterion. It is not required that replacement glazing conform to any specification or special provision unless safety glazing is required. Safety glazing is required in storm doors or combination doors, exterior doors and sliding or patio-type doors, and must conform to the requirements of CPSC Part 1201 - Safety Standard for Architectural Glazing Materials. Replacement glazing should have a minimum thickness of 1/16 inch.

2.9.4 Areas of Application. Replacement glazing may be applied to repair any broken or missing window pane in a primary window or exterior door.

2.9.5 Commentary. The requirements of CPSC Part 1201 - Safety Standard for Architectural Glazing Materials are mandatory and supersede local and national code requirements. It is noted that the CPSC Safety Standard does not cover glazing materials used in the manufacture and construction of architectural products such as prime windows and storm windows.

Replacement glazing should be properly secured in the sash and puttied or sealed to prevent air infiltration. Thickness of replacement glazing greater than 1/16 inch may be necessary for some applications.

3. INSTALLATION PRECAUTIONS

This report is not intended to be a manual for installing retrofit materials and products. The Federal Energy Administration prepared "Project Retro-Tech, Instructor's Kit for Home Weatherization Course" to train and guide applicators and consumers in the proper installation of retrofit materials and products for residences [26]. The kit consists of four documents: "Home Weatherization Instructor's Guide," "Home Weatherization Job Book," "Home Weatherization Manual," and "Home Weatherization Charts." Other installation manuals are: The U.S. Department of Housing and Urban Development report "In the Bank... Or Up the Chimney?" [5] and the NAHB Research Foundation's "Insulation Manual - Homes/Apartments" [10] which discusses all aspects of insulation including proper installation. The NBS report "Retrofitting Existing Housing for Energy Conservation: An Economic Analysis" [4] and "Making the Most of Your Energy Dollars in Home Heating and Cooling" [5] give the levels of retrofitting which are cost effective for the homeowner. In addition, many manufacturers and trade associations have available pamphlets describing the correct installation of their products.

Section 2 of this report presents recommended criteria for acceptance of retrofit materials and products to assure their quality and safe use. However, proper retrofitting requires more than quality materials and products. Proper installation of retrofit materials and products is a necessity. A superior material may be less effective in saving energy if improperly installed.

This section points out certain precautions that must be taken in the installation of retrofit materials and products. Following these precautions will assist the homeowner in correctly installing the material.

3.1 INSULATION

- When a vapor barrier is attached to the insulation, and the insulation is being applied to an uninsulated wall or ceiling, the vapor barrier must be applied towards the warm (winter) side of the wall or ceiling.
- When adding insulation on top of existing ceiling insulation, do not use a vapor barrier over the existing insulation.
- For air conditioning applications, duct insulation should contain a vapor barrier on the outside (warm-side) surface to prevent condensation on the duct and in the insulation. For heating and air conditioning applications, ducts should be sealed with aluminum duct tape or similar material prior to adding insulation.
- When insulating attics, do not cover air vents in attic floors, soffits and gables. Insulated attics should be vented. In general, the net ventilation area for attics should be at least 1/300 of the ceiling area if a vapor barrier is provided and

1/150 of the ceiling area if there is no vapor barrier. Net ventilation area refers to the total of all openings free from obstructions.

- When insulating floors over unheated crawl spaces where earth is uncovered, provision should be made for adequate natural ventilation. For crawl spaces where the earth is uncovered, the net ventilation area should be at least 1/150 of the ground area. Whenever possible, the earth should be covered with a vapor barrier. Less ventilation is required if the earth is covered with a vapor barrier or concrete slab. Crawl spaces should have a net ventilation area of at least 1/1500 of the ground area when the ground surface is covered with a vapor barrier. Crawl spaces should be cross-ventilated, and the openings should be screened against birds, insects and animals and protected against the penetration of rain and snow. It is noted that vents in crawl spaces should be closed during the heating season, but it is essential that they be opened after the heating season.
- Retrofitting walls by the addition of loose-fill or other insulations may increase the possibility of moisture accumulation in the insulation, siding and sheathing, particularly in cold climates [27]. Water vapor permeation through the exterior wall from the inside may cause blistering and peeling of exterior paints having low water vapor permeability. Application of a vapor barrier paint or vinyl wall paper with a permeability not exceeding 1 perm on the inside wall surface will reduce the moisture accumulation hazard. The exterior of walls retrofitted with loose-fill or other insulations should not be painted with oil-base or other coatings of low moisture permeability, unless means are provided to allow moisture vapor to escape through the exterior wall.
- Retrofitting walls with loose-fill or other insulations requires the use of special equipment. Operators of this equipment should be familiar with their use to assure proper application. Installation of urea-based foam insulation should only be performed by applicators trained and approved by the urea-based foam insulation systems producer.
- Loose-fill insulation added to ceilings and walls should be of the proper fill density. The installed insulation should not contain excess voids or air spaces. Densities normally recommended by industry are as follows: the fill density of cellulose insulation should be 2-3 lb/ft^3 for ceilings and 3-4 lb/ft^3 for walls; for glass fiber insulation 0.7 and 2 lb/ft^3 for ceilings and walls, respectively; for slag and rock wool insulations 2 lb/ft^3 and 2.5 lb/ft^3 for ceilings and walls, respectively. These values can be used to calculate needed amounts of these insulations.
- For fire safety, installed insulation should not contact recessed light fixtures, motors, fans, blowers, heaters, flues and chimneys. In the case of lighting fixtures, thermal insulation shall not be installed within 3 inches of the recessed fixture enclosure, wiring compartment or ballast and shall not be so installed above the fixture as to entrap heat and prevent the free circulation

of air unless the fixture is otherwise approved for the purpose. When insulating ceilings, the thermal insulation should not be placed over lighting fixture enclosures (unless approved for the purpose), electrical junction boxes, exposed frayed wiring, or wiring which contains damaged electrical insulation. In addition, precautions should be taken when installing insulation over any exposed electrical wiring in ceilings, even that in good condition. To prevent loose-fill insulation from making contact with energy dissipating objects, a minimum of 3 inches of air space should be provided and assured by use of blocking.

- After addition of loose-fill or foamed-in-place insulation to cavity walls, electrical outlet boxes within those walls should be examined for the presence of insulation. If found, the insulation should be removed from the electrical outlet boxes.

3.2 STORM WINDOWS

- Storm windows should be securely fastened in place and should be straight, plumb, level and without distortion to assure satisfactory contact to the primary window frame.
- Storm windows should be sealed according to the manufacturer's instructions. Proper caulking between the storm window frame and the primary window frame is necessary to assure water tightness and to limit air infiltration. Some air exchange between the outdoors and the space between the primary and storm windows is desirable to prevent condensation on the window on the exterior of the house.
- Weep holes in the storm window frame should not be blocked.

3.3 STORM DOORS

- Storm doors when fastened in place should be straight, plumb, level and without distortion to assure satisfactory contact to the primary door frame.
- Storm doors should be installed according to the manufacturer's instructions. Proper installation is necessary to minimize air infiltration and assure watertightness.

3.4 CAULKS AND SEALANTS

- Follow manufacturer's directions as indicated on label of the cartridge or can, or in a brochure. Pay particular attention to precautions given for safety in handling the material.
- Remove from the joint to be caulked all dust, dirt, particles, oil, grease, loose caulking and loose paint before placing the new compound into the joint.
- Manufacturers often recommend a primer or surface conditioner for certain surfaces. This is done to produce a strong bond of the sealant to the surface. Use only the recommended primer.

- o Whenever possible, do not caulk joints at temperatures below 40°F since at low temperatures poor adhesion of the sealant may result.
- o Do not apply sealant on wet or damp surfaces, including those on which condensation is present.
- o If the joint is 1/4 inch wide or more, use a backup or filler material, if possible. The filler may be any foam or sponge type nonstaining material which is pressed into the joint without completely filling it. A space with a depth of at least 1/4 inch should be left for application of the sealant.
- o Tool the sealant with a putty knife or smooth wooden stick to force the sealant against the sides of the joint.
- o The placing of paper masking tape on each side of the joint before the caulking operation will leave a neat looking joint. Peel the tape off as soon as each section of work is finished.
- o Do not add any liquid or powder to a sealant to change its handling property unless specific instructions are given by the manufacturer.
- o Do not heat the sealant unless there are printed instructions to do so.

3.5 WEATHERSTRIPPING

- o Follow manufacturer's directions as printed on the package or in a brochure.
- o Assure that the surface is smooth by removing old weather-stripping, dirt particles, loose paint, etc.
- o Apply adhesive backed weatherstripping to clean and dry surfaces only.
- o Apply weatherstripping in one continuous strip along each joint of the door or window.
- o Assure that weatherstripping is tight at corners.
- o For both door and window applications, assure that the applied weatherstripping makes contact with the fixed and movable sections of the joint (for example, window sash and frame). In general weatherstripping should be slightly compressed when the door or window is in a closed position.

3.6 VAPOR BARRIERS

- o Apply vapor barriers on the warm (winter) side of ceilings and walls.
- o Do not puncture, rip or tear vapor barriers.
- o Punctured, ripped or torn vapor barriers should be repaired. Repairs can be made by covering the damaged area with a piece of vapor barrier material secured with kraft paper tape or covering the damaged area directly with a low permeability tape such as aluminum duct tape or PVC tape.

- o Combustible vapor barriers such as asphaltic kraft paper should not be left exposed after installation but should be covered to reduce the risk of fire.
- o Fit vapor barriers carefully around all joints and penetrations such as duct openings, electrical fixtures and switches, and window or door frames, and seal joints, if possible.

3.7 CLOCK THERMOSTATS

- o Follow the manufacturer's instruction for installation.
- o Prior to installation the installer should determine whether the characteristics of the device are compatible with the requirements of the heating and/or cooling system with regards to voltage, current ratings and modes of operation.
- o Thermostats should not be installed near heat sources, cold areas or areas that receive poor air circulation.
- o When the installation requires any electrical connections, additional wiring, or electrical components, all and any circuits supplying electrical power to the thermostat and electrically connected devices (i.e., heating and or cooling unit) should be disconnected at the supply. Some clock thermostats may require installation by a qualified electrician.
- o Do not wire the clock into the temperature limit or fan control circuits of the furnace. Whenever the limit control is activated, the clock will stop and lose time. An inaccurate clock may discourage the homeowner from using the clock thermostat.

3.8 REPLACEMENT WINDOWS

- o Follow the manufacturer's instructions for installation.
- o Seal or caulk joints between the replacement window frame and the wall of the residence to eliminate this path of air and water penetration.
- o Check that operable sashes open easily after installation and painting.

3.9 REPLACEMENT GLAZING

- o Use proper size and tightly install using mechanical fasteners, and putty or glazing compound to prevent air infiltration.
- o Use safety glazing in doors containing large sections of glass, as required by the CPSC Safety Standard for Architectural Glazing Materials.

4. RETROFITTING AND MODEL BUILDING CODES

To determine the relationship between retrofitting residences to conserve energy and the model building codes, the Standard Building Code, Basic Building Code, the One and Two-Family Dwelling Code and the Uniform Building Code were examined. The study produced the following information:

- o None of the model codes, per se, is retroactive unless substantial repairs or alterations are performed on existing buildings; this is especially the case with existing single family dwellings and therefore building permits are generally not required for retrofitting.
- o In their adoption of model codes by reference, some local jurisdictions change certain aspects of the requirements of the model code to conform to specific local conditions, and therefore may require building permits for retrofitting.
- o Local jurisdictions may have contractor licensing laws which require the issuance of building permits for all work performed on single family dwellings.
- o Since the model codes in general do not require the issuance of building permits, inspections of the installation of insulation, weatherstripping and/or storm windows and doors in existing single family dwellings accordingly are not required. Again, local regulations may require permits and inspections.
- o All three of the model codes have requirements which prohibit certain types of foam plastic insulations unless certain encapsulation conditions are satisfied. This poses a problem wherein the installer can be in violation of a law although no permit or inspection is required.
- o The question of the installation of storm windows over openings necessary for required natural ventilation or emergency exits in existing single family dwellings will not arise in the case of model codes, per se, but may be a problem in specific local jurisdictions.

While model building codes and building officials, as noted above, do not presently enforce energy conservation provisions retroactively, they now have in many instances adopted energy conservation provisions which apply to new buildings and may also apply to additions to existing buildings. These provisions are basically adaptations of the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) Standard 90-75. A further development of this Standard into an American National Standard is now underway. In addition a new energy conservation code based on the ASHRAE Standard was issued in December 1977 by the National Conference of States on Building Codes and Standards (NCSBCS), Inc. for acceptance and use by state and local jurisdictions.

As no present standards for energy conservation in existing buildings are available, ASHRAE is now undertaking development of the following energy conservation standards for existing buildings:

ASHRAE 100.1P	Low Rise Residential (up to 3 stories)
ASHRAE 100.2P	High Rise Residential
ASHRAE 100.3P	Commercial Buildings
ASHRAE 100.4P	Industrial Buildings
ASHRAE 100.5P	Institutional Buildings
ASHRAE 100.6P	Public Assembly

Under the standards development process each of the proposed standards is developed and drafted by an ASHRAE subcommittee, sent out for public review and comment before final approval by ASHRAE as a standard. Once a standard is approved, model code groups may adopt the standard by reference and code regulatory authorities may either adopt the model codes or the standards directly. So while presently there exists no nationally approved standards for energy conservation in existing buildings their future development is anticipated. To aid in the administration and enforcement of the energy conservation standards in existing buildings, the National Conference of States on Building Codes and Standards (NCSBCS) is planning, in conjunction with the model code groups, development of a companion model code.

Regarding glazing materials in products used for retrofitting, there are mandatory requirements for glazing used in storm doors or combination doors, exterior doors and sliding patio-type doors which were established by the Consumer Product Safety Commisssion (CPSC). As previously mentioned these requirements supersede local and national codes.

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APPENDIX A. SELECTED CITATIONS FROM THE LITERATURE ON RETROFITTING

This appendix is a limited survey of the literature. It is included in this report to show that a sound basis for retrofitting exists. The reports cited demonstrate that retrofitting existing housing not only conserves energy, but is also economically desirable for the homeowner.

The National Mineral Wool Insulation Association (NMWIA) conducted a study to determine the extent to which the requirements for improved thermal performance of living units could alleviate the shortage of energy for heating and cooling in the decade 1973-1982 [1].* The study considered two techniques for retrofitting existing housing; the upgrading of existing ceiling insulation, and the installation of storm windows and storm doors. It was estimated that there were 42.6 million single family units built before 1973 to consider for retrofitting. For the computations an "average" home** was defined with an assumed level of ceiling insulation, U = 0.10 Btu/h·ft^2·°F. If the ceiling insulation of these "average" homes was upgraded with a R-11 insulation, the potential energy savings per week in the U.S. would be 562 trillion Btu. For the year 1982, this would amount to a savings of 1,124 million dollars. The 1972 estimated cost of the ceiling insulation retrofit was $144 per dwelling. The recovery of this investment would take 5.45 years.

The retrofitting of storm doors and storm windows alone was considered for 21.3 million single family residences by the National Mineral Wool Insulation Association. In this case, the total energy savings would be 818 trillion Btu per year, and the dollar savings, 1,635 million per year. The 1972 cost of installing storm doors and windows was $240 per dwelling. The NMWIA reported that the recovery of the investment would require 3.1 years.

According to NMWIA the total energy savings achieved by the retrofitting of ceiling insulation to the 42.6 million units and of storm doors and windows to 21.3 million units would be 1380 trillion Btu per year [1].

The National Bureau of Standards (NBS) published a report which considered the economic aspects of retrofitting existing housing for energy conservation [4]. The study identified economically optimal combinations of selected energy conservation techniques for reducing heating, ventilating and air conditioning (HVAC) costs. The study maximized potential dollar savings achieved with certain retrofitting

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* References cited in this Appendix are listed in Section 5 of the report.

** floor area, 1200 ft^2; doors, 40 ft^2; windows 160 ft^2; location, in degree day range of 4700-5000.

techniques by comparing total savings versus total costs. Climatic, architectural and economic variables were used in the analysis. The retrofitting techniques considered were:

1) attic insulation
2) wall insulation
3) floor insulation over an unheated space
4) duct insulation in unheated space
5) storm windows
6) storm doors
7) weatherstripping

The optimal combination of each of these techniques varies with fuel costs and climatic conditions. The optimal level of retrofitting increases as the cost of fuel increases and the climatic conditions become more severe. Levels of retrofitting are greater for homes that are both heated and air conditioned than for homes with heating only. Some general results of the NBS study follow.

The NBS report [4] showed that even in areas of low fuel costs and mild climates, it is economically desirable to add insulation to attics where none previously existed. Moreover, in areas of high fuel costs and severe climates, it is economically desirable to add more than the currently recommended six inches of attic insulation. For example, about 10 to 12 inches is optimal for oil heated homes and about 12 inches for electrically heated and cooled residences in certain climates. The figures vary slightly depending on the type of insulation.

It is also cost effective to blow insulation into existing walls and to wrap exposed heating and cooling ducts in most climatic conditions regardless of the cost of fuel. Insulating over unheated spaces, generally crawlspace, garage or basement, becomes cost effective in mild climates where fuel costs are high. It is cost effective in all other climates regardless of the price of fuel.

The economic desirability of retrofitting with storm windows depends upon window size as well as fuel costs and climate conditions, according to NBS [4]. In general, it is economically advantageous to to add storm windows in most climates. The exceptions are mild climates where fuel costs are low. Even here, the addition of storm windows over large windows (minimum size 4 x 5 ft) becomes cost effective. On the other hand, the addition of storm doors is only cost effective in areas of high fuel costs and severe climates, assuming that a screen door must be replaced.

Weatherstripping of doors and windows to reduce air infiltration was shown in the NBS report to be cost effective in all cases. The effect of sealing and caulking around doors and windows was not examined.

The U.S. Department of Housing and Urban Development (HUD) prepared a report on the economics of retrofitting existing homes to reduce energy

energy consumption [6]. This report is intended to help the homeowner calculate how much money he can expect to save by spending money to retrofit. The report states that if each homeowner spent $400 to retrofit his home, he would, in most cases, recover that money in less than 5 years.

The retrofit techniques discussed in the HUD report include those in the NBS report. In addition, the HUD report takes into account other energy saving techniques such as caulking, servicing of furnaces and air conditioners and thermostat setback.

Lowering the thermostat setting to reduce interior house temperature and thus heating fuel consumption is called setback. A lower thermostat setting during the sleeping hours than during the daytime is called night setback. The Oak Ridge National Laboratory examined the potential energy savings that may be achieved through thermostat setback [7]. It was concluded that, if temperatures of homes were reduced from a typical 72°F to 68°F during the day and residential heating could be reduced by 14%. The reduction in energy consumption is dependent upon the climate. The percentage of energy savings is greater in mild climates than in severe climates. The absolute energy savings are greater in the more severe climates. For a home maintained at 68°F and located in an area of 4000 degree days, a night setback to 55°F could produce an energy savings of 22%. Savings from night setback for homes located in other areas can be estimated from the method given in the report.

The energy savings gained from night setback had been previously reported [8]. This paper showed that a night setback of 5°F produced an energy savings of 5 to 12% depending upon the location. For a setback of 10°F, the percentage savings was 9 to 16%. As in the Oak Ridge report, the more severe climates give a smaller percentage, but a greater absolute savings.

Another example of energy saved by retrofitting has been given by the Consumers Power Company of Jackson, Michigan [9]. It was estimated in 1975 that there were in the service area 665,000 gas heated residences which have inadequate ceiling insulation. If all customers were to install 6 inches or the equivalent of R-19 of ceiling insulation, natural gas consumption would be reduced by an estimated 14,725,000 Mcf per year. That was enough gas to heat 125,850 homes in their area for one year.

The NAHB Research Foundation prepared a business guide for retrofitting homes [10]. The basic retrofitting techniques considered in the guide were insulation, storm windows and doors, sealants, weatherstrippping, clock thermostats, heating and air conditioning tune-ups, and lower hot water heater temperatures. Additional techniques such as exhaust fans, awnings and replacement heating systems were listed as optional, depending on the homeowner's preference to install them.

In June 1977, the National Bureau of Standards published a report presenting 33 design stategies, which were classified in 6 major groups, for improving the thermal performance of windows [12]. The six groups were the site, exterior appendages, frame, glazing, interior accessories and building interior. Windows were shown to effect energy consumption of a building through six possible functions: solar heating, daylighting, shading, insulation, air tightness and ventilation. In addition to the 33 design strategies, the report also presented an explanation for the physical phenomena responsible for each strategy's energy performance, energy and non-energy related advantage and disadvantages of the strategies, aesthetic considerations, approximate cost, and examples of installations of the various design strategies. Laboratory studies regarding energy performance of windows were quoted.

In stating their conclusions, the NBS authors pointed out [12] that a window may act as a solar collector introducing energy into a building to lower winter heating costs and may provide a source of illumination which can substitute for artifical lighting to lower electricity costs. It was further mentioned that windows can provide a means of natural ventilation which can postpone the need for air conditioning in the spring and fall, and substitute for air conditioning on cool summer evenings.

The NBS authors concluded [12] that the design strategies could minimize the window thermal load on mechanical systems. In the winter, heat loss could be reduced by the use of double glazing, storm sash or edge-sealed transparent roller shades. Night-time heat loss could be minimized with tight-fitting draperies, opaque roller shades, or insulating shutters. It was shown that, for the summertime, numerous means were available for blocking solar heat gain, the most effective being exterior appendages, such as roller blinds and awnings, or site solutions. Air infiltration through windows could be greatly lowered through the use of good quality windows and weatherstripping, and by landscaping or other means to reduce the force of the wind [12].

The Federal Energy Administration (FEA) with the assistance of the National Bureau of Standards prepared a pamphlet to increase consumer awareness of methods to improve the thermal performance of windows [13]. The pamphlet stated "properly designed, located and used windows can actually reduce heating and air conditioning costs; poorly designed, located and used windows will increase these costs." Methods for improving thermal performance of windows included those described in the previously mentioned NBS report on window design strategies [12], although they were described in less detail. The FEA pamphlet advised readers to: trap the sun's warmth for winter heating, insulate against heat loss, minimize infiltration at windows, take advantage of natural ventilation and shade against summer solar heat gain.

A study was conducted at the Illinois Institute of Technology (IIT) under the sponsorship of the Window Shade Manufacturers Association to evaluate the effectiveness of roller shades in conserving

energy in residential heating and cooling [14]. In this laboratory study, a test window to which roller shades could be mounted was constructed between a test (indoor) room and a control (outdoor) room. The test room was maintained at 75`F, while the temperature of the control room varied from 20 to 50`F for winter tests and 85 to 95`F for summer tests. Solar radiation was simulated using arc and incandescent lamps.

According to the IIT study, the use of window shades on a typical residence in a moderate climate would reduce heating costs by as much as 8 cents per dollar and cooling costs by as much as 21 cents per dollar [14]. The conclusions were based on a well insulated home with an average amount of glass and no shading devices prior to the installation of the roller shades. In regard to the conclusions of the IIT Study, it is noted that most windows of existing residences may contain some type of shading devices and when retrofitting the residence their replacement may not be warranted. Draperies and venetian blinds were also tested in the IIT Study, and were found to be less effective than roller shades for reducing energy consumption, under the conditions of the test.

The National Bureau of Standards published the findings of a comprehensive survey to assess the properties and performance of urea-formaldehyde based foam insulations [15]. In summarizing the results, advantages and disadvantages associated with the use of the foams were given and problem areas of significance to the homeowner were also identified. It was shown in this report that the use of foams as cavity wall insulation conserves energy through reduced fuel consumption. This NBS report recommended that laboratory and field studies be initiated to gather data on the performance of foams, since performance data for for many properties were found to be lacking or contradictory.

An experimental study was conducted at the National Bureau of Standards to evaluate the energy conservation achieved in retrofitting a wood-frame residence [16]. The residence was retrofitted in 3 stages: reduction of air leakage, addition of storm windows, and installation of insulation in the floor, ceiling and walls. Before the house was retrofitted; it contained some insulation in the attic.

It was found in this NBS study [16] that techniques used to reduce air leakage did not produce measurable reductions in the heating energy requirements, since the house was tightly constructed in its original state. The addition of storm windows acheived a heating energy reduction of about 25 percent. The installation of insulation reduced the heating energy consumption by about 33 percent. In all, the total reduction in heating energy requirements was found to be about 58 percent. The seasonal energy requirement was reduced by a greater percentage than the heat loss in the coldest weather, because the retrofit measures appreciably lowered the outdoor temperature (balance point) at which heating was first needed.

In the strictest sense, the results obtained in the NBS Study [16] apply only to that house. However, it may be anticipated that the addition of insulation and storm windows would result in significant savings in most existing houses and that weatherstripping and sealing would be effective in conserving energy in many existing buildings.

In a recent NBS report, the results of a simplified analysis for annual heating, cooling and lighting requirements associated with windows were presented [17]. The analysis was based upon a computer simulation of these requirements for typical commercial and residential modules located in a climate such as found in Washington, D.C. The analysis included the effects of window size, heat transfer, solar shading, compass orientation, selective fenestration heat-transfer management, and off-hour temperature setback. Three different modes of operation with respect to heating and cooling requirements were assessed: external loads only; external and internal; and external, internal, and daylight. The analysis assumed that daylight could replace or supplement artificial light whenever it could supply a specified minimum level of illumination.

The results of the study [17] demonstrated that a properly designed and operated window system could reduce operating costs below those for a solid wall for the types of rooms simulated in the given climatic conditions. It was found that reducing operating costs for windows required careful consideration of orientation, the balance between annual heat gains and losses, use of daylight whenever sufficient, and good management practices including off-hour temperature setback. The use of daylight rather than artifical light had the most impact. It was noted that experimental verification of the results were needed. It was also found that unless window management and daylight are used, windows will increase heating and cooling requirements when compared to an equivalent wall area. When all the options for reduction of heat loss and gain are utilized and daylight is substituted for electric light, whenever practicable, the best performance in terms of heating, cooling and lighting requirements are obtained.

APPENDIX B. SUGGESTED CRITERIA FOR MATERIALS AND PRODUCTS CONSIDERED NOT ELIGIBLE UNDER THE DOE WEATHERIZATION ASSISTANCE PROGRAM

The materials and products which are presently considered eligible for the DOE Weatherization Assistance Program are insulation, storm windows and storm doors, sealants and caulks, weatherstripping, vapor barriers, clock thermostats, replacement windows, and replacement glazing. However, other energy-saving materials and products are available for retrofitting. As previously mentioned, NBS had requested the public and industry to suggest additional energy-saving materials and products. Suggestions of other energy-saving materials and products were to be accompanied by technical information on properties and performance supporting their use and energy savings which may be achieved.

A number of suggestions for additional materials and products was received by NBS, primarily from manufacturers and trade associations. These suggestions were reviewed along with others proposed by NBS staff members. It was determined that criteria could be written for some additional materials and products which are considered not eligible under the DOE Weatherization Assistance Program. Items in this category are replacement doors, insulation/sheathing, window accessories including roller shades, venetian blinds and draperies, and whole house fans. Although considered not eligible under the DOE Weatherization Assistance Program, this supplementary list of suggested criteria are presented in order to assist in assuring that these materials and products, when used, meet minimum criteria relating to energy conservation effectiveness, safety, serviceability and durability.

Materials and products listed in this Appendix are considered not eligible under the DOE Weatherization Assistance Program primarily because of the statutory requirements, limits on expenditures for retrofit items and their energy conservation effectiveness. Greater emphasis was placed on reducing heating-energy consumption than on cooling-energy consumption. It is thought that these statutory limits on expenditures may be reached when installing basic retrofit items such as insulation, storm windows and doors, sealants and caulks, and weatherstripping.

B.1 REPLACEMENT DOORS

B.1.1 Definition. A replacment door is a thermally improved exterior primary door which is installed to increase resistance to heat flow and decrease air infiltration after removal of the existing door. Such doors may be classified as either hinged doors or sliding patio doors. Replacement of a hinged door may or may not require replacement of the frame whereas replacement of a sliding patio door normally requires replacement of the frame.

B.1.2 Materials. Replacement doors may be constructed of a wood with glass or plastic glazing, or of solid wood, or of a metal or wood exterior skin with an insulated core. The metal doors are either aluminum or steel and may contain glazing.

B.1.3 Criterion. Replacement doors for retrofitting should conform to the standards and special provisions listed below, and should be installed as stated in Section B.1.4. Where glazing is used it should conform to the requirements of Part 1201 - Safety Standard for Architectural Glazing Materials established by The Consumer Product Safety Commission. These doors should be labeled as being manufactured to conform to the criterion.

B.1.3.1 Hinged Doors. The coefficient of thermal transmittance (U-value) for replacement hinged doors should not be greater than 0.45 Btu/h·ft^2·°F as determined by the method for calculating overall coefficients of heat transmission given in Chapter 20 in the ASHRAE Handbook of Fundamentals [23]. In addition, replacement hinged doors should conform to the applicable specification as follows:

- Steel replacement doors should conform to Steel Door Institute (SDI) Recommended Specifications 100-76 entitled "Standard Steel Doors and Frames."
- Pine replacement doors should conform to the provisions for exterior doors listed in ANSI/NWMA I.S. 5-73 entitled "Ponderosa Pine Doors."
- Fir, hemlock and spruce replacement doors should conform to the provisions for exterior doors listed in the Fir and Hemlock Door Association Standard FHDA/6-77 entitled "Industry Standard for Douglas Fir, Western Hemlock, and Sitka Spruce Doors and Blinds."
- Hardwood veneered flush doors should conform to the provisions for exterior doors listed in National Woodwork Manufacturers Association Industry Standard I.S. 1-75 entitled "Hardwood Flush Doors."

B.1.3.2 Sliding Patio Doors. Sliding patio doors should have multiple glazing and metal frames should contain a thermal break to reduce heat flow. In addition, replacement sliding patio doors should conform to the application specification as follows:

- Aluminum sliding patio doors should conform to ANSI/AAMA 402.9-1977 entitled "Voluntary Specifications for Aluminum Sliding Glass Doors."
- Wood sliding patio doors should conform to ANSI/NWMA I.S. 3-70 entitled "Wood Sliding Patio Doors."

B.1.4 Areas of Application. When warranted because of excessive heat flow and air infiltration, any residential exterior door, or door and frame assembly, may be replaced. Installation should not violate any applicable existing local building related code.

B.1.5 Commentary. Guidelines are not available to assist the homeowner in deciding whether or not an exterior door, or door and frame assembly, should be replaced with a thermally improved door. In analogy with Petersen's findings [4] that in many cases storm doors are not cost-effective, it may be assumed that replacement doors may in many cases not be cost-effective, when installed only for energy conservation purposes. Installation of weatherstripping and storm doors are alternative methods to reduce heat flow and air infiltration through exterior doors.

Thermally improved doors require low rates of heat flow and air infiltration. The requirements for a 0.45 $Btu/h \cdot ft^2 \cdot °F$ thermal transmittance in the case of hinged doors, or for multiple glazing and thermal breaks in metal frames in the case of sliding patio doors are intended to provide low rates of heat flow, and therefore increased benefits for energy conservation.

ASHRAE Standard 90-75, "Energy Conservation in New Building Design," recommends that the air infiltration rates through hinged doors and sliding patio doors not exceed 1.25 and 0.5 ft^3/min per square foot of door area, respectively. ANSI Standards ANSI/AAMA 402.9-1977 and ANSI/NWMA I.S. 3-70 have requirements for maximum allowable rate of air infiltration through sliding patio doors. These requirements may be specified since sliding patio doors are normally installed as a door and frame assembly. The assembly including weatherstripping may be manufactured to provide a tight seal between the sliding door and the frame.

It may be difficult to attain the ASHRAE recommended maximum rate of air infiltration for replacement hinged doors, or door and frame assemblies. In either case, the air infiltration will depend upon the quality of installation. The door should be installed straight, plumb, level and without warping. It should fit tightly in the frame and be properly weatherstripped, including placement of a threshold. Proper installation of hinged doors is required if the ASHRAE recommended maximum rate of air infiltration of 1.25 ft^3/min per square foot of door area is to be attained.

New door and frame assemblies should be properly caulked and sealed into the wall of the residence to eliminate this path of air infiltration.

B.2 INSULATION/SHEATHING

B.2.1 Definition. Insulation/sheathing is a procedure for retrofitting residences whereby rigid board insulation is installed on the exterior of the walls of the residence over the existing siding or facade to reduce heat flow through the walls. Siding must be added to the residence after installation to cover and protect the rigid board insulation.

B.2.2 Materials. Insulation materials used as insulation/sheathing may be rigid boards fabricated from organic cellular insulations such as polystyrene, polyurethane or polyisocyanurate, or other suitable materials of low thermal conductivity.

B.2.3 Criterion. Rigid board insulation materials used as insulation/sheathing should have a thermal resistance (R) of not less than 4 for their installed thicknesses and conform to the applicable specifications and standards, and the fire safety requirements for insulations given in Section 2.1.3. The R value should be based on tests conducted according to ASTM C 177 at a mean temperature of 75°F.

B.2.4 Areas of Application. When warranted because of difficulties in improving the heat flow resistance of walls of residences through other means such as cavity wall filling, exterior walls of residences may be retrofitted with an insulation/sheathing system. Installation should not violate any applicable existing local building-related code, particularly with regard to the use of cellular plastic insulation in residences. Consideration should be given to existing walls which are required to have a fire resistive rating such as proximity to other building and their contents.

B.2.5 Commentary. Installation of an insulation/sheathing system for retrofitting residences may in many cases be less effective for energy conservation than other methods of retrofitting such as the addition of insulation to wall cavities. Installation of loose fill insulation into wall cavities normally 3-1/2 inches thick will in general provide considerably higher values of total thermal resistance as compared to insulation/sheathing systems. It is noted that the minimum desired R value for frame wall construction given in table 3 is 12. Insulation/sheathing systems may be more expensive than other methods of retofitting walls since siding must be installed over the insulation to protect it. Careful consideration should be given to the benefits for energy conservation and the relative costs of alternative systems before choosing an insulation/sheathing system.

In some cases, the installation of an insulation/sheathing system may be the only practicable means of improving the thermal resistance of an exterior wall of a residence. For example, the wall may not have a cavity and insulation may not be readily installed on the interior surface. The intent of the inclusion of insulation/sheathing systems in this supplementary list of retrofit material and products is to have available a system for improving the thermal resistance of walls of residences in those cases where other means of retrofitting walls are not practicable.

It is necessary in general to keep the thickness of the sheathing to a minimum to facilitate installation of siding and trim at doors, windows, eaves and other locations. Insulation thickness can be minimized by using materials having low values of thermal conductivity such as foamed plastics.

For homeowners who are considering the replacement of siding because of deterioration, consideration may be given to the installation of an insulation/sheathing system. This may provide a means of improving the thermal resistance of the residence at a minimum additional cost.

The use of an organic cellular insulation of low water vapor permeance may retard the flow of water vapor and may cause moisture accumulation between the insulation and the wall. Unwanted moisture accumulation in walls may lead to their deterioration. A vapor barrier on the interior surface of the wall, such as low permeability paint or vinyl wall covering, will lessen the possibility of condensation within the wall. Manufacturers' instructions relative to providing spaces, cracks or openings for breathing should be followed.

B.3 WINDOW ACCESSORIES

B.3.1 Definition. A window accessory is a product installed to improve the thermal performance of a window assembly by reducing solar heat gain in the summer and reducing heat loss in the winter.

B.3.2 Products. The products listed below are those considered acceptable for use in residences to provide improved thermal performance of a window assembly through retrofitting:

- o Roller shades
- o Venetian blinds
- o Draperies

B.3.3 Criterion. A window accessory for retrofitting should conform to the specifications and special provisions listed below, and be installed as stated in Section B.3.4.

B.3.3.1 Roller Shades. Roller shades should conform to Federal Specification DDD-S-251d "Shade, Roller, Window; Roller, Slat, Cord, and Accessories" or Interim Federal Specification L-S-001787 "Shade, Window, (Vinyl), with Roller, Slat, Ring Pull and Accessories and Vinyl Film (In Piece Goods)." The shades should be classified as white (opaque) or light (translucent) according to ASHRAE Handbook of Fundamentals, 1972 Edition, Chapter 22, table 15.

B.3.3.2 Venetian Blinds. Venetian blinds should conform to Interim Federal Specification AA-V-00200B "Venetian Blinds." The color of the slats should be classified as light according to ASHRAE Handbook of Fundamentals, 1972 Edition, Chapter 22, table 15.

B.3.3.3 Draperies. Draperies should be fabricated from cloth conforming to Interim Federal Specification CCC-C-001703A "Cloth, Drapery, Glass Fiber" or Interim Federal Specification CCC-C-01766 "Cloth, Drapery, Other Than Glass." The cloth should have a fabric classification III_L (closed weave and light color) according to ASHRAE Handbook of Fundamentals, 1972 Edition, Chapter 22, figure 10.

B.3.4 Areas Of Application. Window accessories used for retrofitting may be installed in residential housing on the interior of any primary window. The window accessory should be installed at least 1/2 inch from the window and should fit tight at the top, bottom and sides of the window frame to entrap air and minimize the circulation of air between the window and accessory. The energy conservation potential of roller shades, venetian blinds, and drapes for non-solar heat transfer will be largely lost, if these accessories do not fit the top, bottom and sides of the window frame sufficiently to approximate a dead air space.

B.3.5 Commentary. Window accessories should be used properly to obtain maximum energy conservation. During hot, sunny summer days the accessories should be closed or drawn to reduce solar heat gain into the room. During cold weather, window accessory products on the sunny exposures should be open during the day to allow heat gain by solar radiation, and closed during evenings and nights to reduce heat loss through the window. In the case of draperies, the track should be installed, if possible, to allow the open draperies to clear the window so that maximum sunlight penetrates into the room during the winter. Draperies should hang in contact with the floor or window

sill to prevent or reduce the circulation of room air behind the drapery and back to the room.

The ability of a window accessory product to reduce solar heat gain is measured according to the concept of the shading coefficient. The shading coefficient is defined in the ASHRAE Handbook of Fundamentals, 1972 Edition, page 397, as the ratio of the solar heat gain through a glazing system under a specific set of conditions to the solar gain through a single light of double strength sheet glass under the same set of conditions. Window accessory products which meet the criteria in Section B.3.3 have shading coefficients of about 0.5 or less, depending on the type of glazing.

Window accessories are included herein to conserve energy. The amount of solar radiation absorbed and transmitted by the product and the amount of air passing through the product should be kept to a minimum. Therefore, the criteria are necessarily restrictive with regards to color of the product and in the case of draperies the closeness of the weave of the fabric.

B.4 WHOLE HOUSE FANS

B.4.1 Definition. A whole house fan is an exhaust fan capable of exchanging air throughout the entire residence at a rapid rate.

B.4.2 Products. Whole house fans are manufactured products intended to circulate air throughout a residence for purposes of removing heat from an occupied space and creating an improved sensation of comfort by means of a high rate of ventilation. They consist of revolving blades attached to a rotary hub and are operated by an electric motor.

B.4.3 Criterion. Whole house fans for retrofitting should conform to the following provisions:

- o the capacity of the fan should provide one air change per minute for the cubic feet of the house to be ventilated at one time, when operated with the manufacturer's smallest recommended shutter at 0.1 inch water static pressure, and
- o the fan should be listed by Underwirters Laboratories.

B.4.4 Areas of Application. Whole house fans may be installed in ceilings, attics or walls so that the air throughout the residence can be exchanged with outside air.

B.4.5 Commentary. Whole house fans may offer an energy-savings alternative to air conditioning in many climates during mild summer weather. Whole house fans may provide comfortable indoor temperatures whenever the outdoor temperature is about 80°F or lower.

The Home Ventilating Institue has issued the "Whole House Ventilating Fan Standard." The provisions cited in the criterion in Section B.4.3 are contained in the Home Ventilating Institute Standard.

APPENDIX C. MATERIALS AND PRODUCTS TO BE CONSIDERED FOR RETROFITTING FOR WHICH CRITERIA ARE NEEDED

While compiling the criteria for materials and products considered eligible for the DOE Weatherization Assistance Program and a selected group which were considered not eligible, additional items, other than those listed in Section 2 and Appendix B, were given consideration as means for reducing the energy consumption of residences. These items have been listed in this Appendix because they were judged to have significant potential for energy conservation. They were not included in the recommended DOE Weatherization Assistance Program criteria because they are beyond the scope of the program as defined by legislation and because standards or other acceptable means do not exist for assessing materials quality or performance. It is noted that the criteria which were developed for retrofit items not only address their energy savings but also the performance parameters such as durability, serviceability and safety.

This Appendix suggests materials and products which may be considered for inclusion in retrofit programs. Manufacturers and trade associations suggested many materials and products that they believed applicable as retrofit items for inclusion in weatherization programs. Other suggestions resulted from conversations between NBS personnel and outside researchers who were familiar with energy conservation measures.

The following lists of suggested additional retrofit items include a brief comment as to why each item was suggested. The two lists present general retrofit items and mechanical equipment items associated with furnances and heating equipment. The Appendix has been included in this report to present the additional retrofit items that have been suggested. It is recommended that the criteria for eligible materials and products included in the DOE Weatherization Assistance Program be reviewed periodically and revised when technical information becomes available on which criteria for additional materials and products may be based provided they comply with the statutory requirements.

C.1 GENERAL RETROFIT ITEMS

C.1.1 Awnings. Awnings with side panels shade the windows of a residence, reducing the summer solar heat gain of windows. They should be removable or retractable so that in the winter the sun's rays may penetrate into the residence.

C.1.2 Reflective Glass. Reflective glass rejects the radiation of the sun which normally penetrates into the home. The interior remains cooler, thus less energy is consumed in air conditioning

the residence. The use of reflective glass as the exterior pane of a double glazed window (insulating glass) may reduce the radiation of heat across the air space and reduce winter heat losses.

C.1.3 Reflective Coatings Or Films. Reflective or low-emissivity films on the inside surface of glass reflect much of the incoming solar energy while still permitting a tinted view outside the window. Some films may increase the window's reflectivity of infrared heat from within the room, thus the winter U-value of the window may be slightly reduced.

C.1.4 Solar Screens. Solar screens, installed on the outside of windows, shade the windows and reduce solar heat gain in the summer. They may or may not significantly reduce winter solar heat gain. An external solar screen installed close to a window may create a layer of nearly still air which may slightly insulate the window against winter heat loss.

C.1.5 Shutters. Exterior operable shutters shade windows in the summer during the day and reduce heat loss and possibly air infiltration in the winter during the night.

C.1.6 Setbacks/Timers. Setback/timers are mechanical devices, other than clock thermostats, for automatically starting electrical equipment when needed and shutting it off when not needed. This may conserve energy by running equipment only when necessary.

C.2 MECHANICAL EQUIPMENT ITEMS

C.2.1 Fuel Oil Burners For Furnaces And Boilers. Recent DOE/NBS field tests have shown that annual tuneups of oil burners increase the average unit's performance by 3% over one season, and by 7% for a 3-year tuneup interval. These tests have also shown that almost all of the oil burners examined (over 400) were oversized. Oversizing means that the furnace burns oil at a faster rate than necessary to maintain a comfortable house temperature. Even on the coldest days of the year, oversized burners may not operate for long periods, maybe running less than 30 percent of the time. During these long off-periods, heat is lost up the chimney, greatly reducing the overall efficiency. The tests on oversized burners demonstrated that reducing the nozzle size and modifying burner air handling parts may save up to 14% in seasonal operating costs. A 30% savings is possible by replacing inefficient burners with new, high efficiency burners that have a reduced firing rate. Additional data are available for evaluating the merits of separating the boiler and potable water heater.

C.2.2 Gas Furnaces. Theoretical and laboratory studies conducted jointly by Carrier Corp., Honeywell Corp. and NBS have evaluated the energy savings resulting from several new design options for residential gas furnaces. Some of these options may become available on a retrofit basis and resultant savings could be expected to be similar in magnitude. For example, calculations indicate that automatic vent dampers applied to a typical residential gas furnace system located in Washington, D.C. would save 8% on a furnace's fuel and electric energies. The installation of ducts to allow for direct intake of combustion air which is reheated by the flue gas exhaust will result in a 5% reduction in furnace operating costs. Intermittent ignition devices save 7% in operating costs.

Committee Z21 of the American National Standards Institute has been engaged over the last two years in developing standards for three types of automatic vent dampers for gas-fired equipment. An ANSI Standard, Z21.66 for electrically-activated vent damper was issued in November, 1977. Proposed ANSI Standards, Z21.67 and Z21.68, for mechanically-activated and thermally-activated vent dampers have received approval of the Z21 Committee and have been submitted for approval by the ANSI Board of Standards Review. Several electrically-activated vent dampers have been certified by the American Gas Association for compliance with ANSI Standard Z21.66.

The Underwriters Laboratories has completed an initial draft of a standard applicable to vent dampers for oil-fired equipment. This document is identified as Subject 17, Proposed First Edition of a Standard for Vent or Chimney Connector Dampers for Oil-Fired Appliances. This draft document is being distributed for public review. The approved standard may be expected in about six months. Underwriters Laboratories is currently testing electrically-activated vent dampers for oil-fired heating equipment and has listed a few such vent dampers.

C.2.3 Heat Pumps. An important benefit of the heat pump lies in the fact that, except in very cold weather, the amount of heat energy delivered to the indoor air is greater than the amount of electrical energy put into the system. The ratio of the annual heat delivered to the annual electrical energy input is called the seasonal performance factor (SPF) which is typically between 1.5 and 2.2 for much of the country. As a result a heat pump operating in these regions may annually use 30% to 55% less electrical energy than an electrical resistance heating system (i.e. baseboard or furnace) which has a nominal efficiency of 100% (SPF = 1). Comparison with fossil fuel heating systems is not so well defined and highly climate dependent. A regional or climate-dependent table of seasonal performance factors for heat pumps is presently under development by DOE.

APPENDIX D. CAULKS AND SEALANTS AVAILABLE FOR RETROFITTING

This Appendix presents information relevant to the properties, performance and use of caulks and sealants available for retrofitting.

D.1 BASIC PERFORMANCE

D.1 Oil and Resin Base Caulks. General purpose caulking compounds formulated to seal exterior or interior nonmoving or very slightly moving joints between various building materials; they form a skin which can be painted to prolong performance; may function for several years if applied properly; and are available in cartridges for use in caulking guns, in flexible tubes and sometimes in cans for putty knife application.

D.1.2 Polybutene Compound. Available in preformed shapes such as rope, cord or tape; suitable for temporary seals around window air conditioners and storm windows, for example; performance is extended when used in areas where it is protected from the elements.

D.2 INTERMEDIATE PERFORMANCE

D.2.1 Latex Caulk. General purpose sealant designed for exterior or interior joints; responds to small joint movements; flexes with the joint to provide a resilient seal; extrudes smoothly from a gun, can be painted almost immediately after application; available in standard cartridges and in cans.

D.2.2 Acrylic (Solvent Type) Caulk. For general purpose caulking in joints with moderate movement; excellent adhesion to most building materials without the use of a primer; estimated service life up to 20 years; strong odor restricts use to exterior joints; available in cartridges and cans and in numerous colors.

D.2.3 Butyl Rubber Sealant (or Caulk). An all-purpose sealant with greater service life and performance than the oil base caulks and about equal in overall quality to the latex acrylic types; forms a skin which can be painted; responds to joint movements up to about 10 percent of the original width; adheres to all building surfaces and retains a high degree of flexibility; available in cartridges and cans in numerous colors.

D.2.4 Chlorosulfonated Polyethylene. An all-purpose sealant with a relatively slow cure to a rubbery compound; provides good durability, flexibility and adhesion as well as easy application; responds to somewhat larger joint movements than the butyl or latex caulks; for use on exterior joints only; available in cartridges and cans in standard colors.

D.3 HIGH PERFORMANCE

D.3.1 Polysulfide. A sealant which cures to a rubbery compound with exceptional flexibility, recovery and adhesion to most building surfaces. The sealant has the ability to respond to joint movements up to plus and minus 25 percent of the installed width. When properly installed, the service life can be 20 years or more. It is available as a one-component material which is packaged in standard cartridges for caulking guns; also available in a multi-component type which is mixed on the job just before application; also available in a pourable type for deck joints. The cured sealant has practically no shrinkage. Primers are used when recommended by the producer. Several colors are available. Joint design and preparation are of great importance for durability.

D.3.2 Polyurethane. The characteristics and performance properties of this class of sealant are essentially the same as those of the polysulfides when properly installed in accordance with the manufacturer's instruction. The sealant is particularly known for high abrasion resistance and tear strength and is often used for joints in plaza and decks with heavy foot traffic. It is available in single and multi-component types, the latter in both nonsag and pourable grades.

D.3.3 Silicone. A class of single component sealants known for its versatility as a joint filler with exceptional performance under very high and low temperatures. It has exceptionally strong adhesion to glass as well as to other building materials. Ease of extrusion from the caulking gun is unaffected by cold temperature. It forms a skin in less than a hour and cures in a few days to an elastic compound. It is available in cartridges and cans in several colors including clear. One variety is used for joints with exceptionally large movements.

D.4 COMPOUNDS FOR SEALING GLASS PANES

D.4.1 Putty. This name is usually applied to a soft dough-like, knife-applied compound formulated by blending oils, solids and pigments. It is used for face glazing (application around the edges of a pane of glass, and for the bedding application to the inner side of the sash). After the putty is set, painting extends its performance life. It is available for wood or metal sash. Putty hardens and cracks with age and needs replacement periodically.

D.4.2 Glazing Compound. Different from putty in that the formulation is modified to enable the compound to remain plastic over a long period. It performs well as an effective seal between the glass and the framing. Several types are available for specific purposes. It is a general purpose glazing compound which will bed and face glaze glass to both wood and metal frames. It is available in standard cartridges and cans.

APPENDIX E. STANDARDS AND SPECIFICATIONS CITED IN THIS REPORT

1. Federal Specifications
Specification Sales (3FRSBS)
Building 197
Washington Naval Yard
General Services Administration
Washington, DC 20407

AA-V-00200B - Venetian Blinds (6-5-73)
CCC-C-001703A - Cloth, Drapery (2-5-73)
CCC-C-01766 - Cloth, Drapery, Other Than Glass (11-8-72)
DDD-S-251D - Shades, Roller, Window; Roller, Slat, Cord, Slat, Cord, and Accessories (4-12-62)
HH-I-515D - Insulation Thermal (Loose-Fill for Pneumatic or Poured Application): Cellulose or Wood Fiber (6-15-78)
HH-I-521E - Insulation Blankets, Thermal (Mineral Fiber, for Ambient Temperatures) (7-24-72)
HH-I-524B - Insulation Board, Thermal (Polystyrene) (11-6-72)
HH-I-526C - Insulation Board, Thermal (Mineral Fiber) (10-17-68)
HH-I-529B - Insulation Board, Thermal (Mineral Aggregate) (2-12-71)
HH-I-530A - Insulation Board, Thermal (Urethane) (11-22-71)
HH-I-551E - Insulation Block and Boards, Thermal (Cellular Glass) (3-11-74)
HH-I-558B - Insulation, Blocks, Boards, Blankets, Felts, Sleeving (Pipe and Tube Covering), and Pipe Fitting Covering, Thermal (Mineral Fiber Industrial Type) (1-9-73)
HH-I-573B - Insulation, Thermal (Flexible Unicellular Sheet and Pipe Covering) (2-20-68)
HH-I-574A - Insulation, Thermal (Perlite) (5-31-66)
HH-I-585C - Insulation, Thermal (Vermiculite) (10-17-74)
HH-I-1030A - Insulation, Thermal (Mineral Fiber, for Pneumatic or Poured Application) (2-23-73)
HH-I-1252A - Insulation, Thermal, Reflective (Aluminum Foil) (3-4-71)
LLL-I-535A - Insulation Board, Thermal and Insulation Block, Thermal (1-19-70)
L-S-001787 - Shade, Window, (Vinyl) with Roller, Slat, Ring Pull and Accessories and Vinyl Film (In Piece Goods) (3-9-73)
TT-C-00598C - Caulking Compound, Oil and Resin Base Type (for Building Construction) (6-23-70)
TT-G-410E - Glazing Compound, Sash (Metal) for Back Bedding and Face Glazing (Not for Channel or Stop Glazing) (4-21-69)
TT-P-00791B - Putty: Linseed-Oil Type, (For Wood - Sash - Glazing) (10-16-69)
TT-S-00227E - Sealing Compound: Elastomeric Type, Multi-Component (For Caulking, Sealing, and Glazing in Buildings and Other Structures) (11-4-69)
TT-S-00230C - Sealing Compound: Elastomeric Type, Single Component (For Caulking, Sealing, and Glazing in Buildings and Other Structures) (2-2-70)

TT-S-001543A - Sealing Compound: Silicone Rubber Base (For Caulking, Sealing, and Glazing in Buildings and Other Sturctures) (6-9-71)
TT-S-001657 - Sealing Compound -- Single Component, Butyl Rubber Based, Solvent Release Type (For Buildings and Other Types of Construction) (10-8-70)

2. NBS Voluntary Product Standards
National Bureau of Standards
Washington, DC 20234

NBS Voluntary Product Standard PS 26-70 Rigid Poly(Vinyl Chloride) (PVC) Profile Extrusions (4-1-70)

3. HUD Use of Materials Bulletin
Department of Housing and Urban Development
Washington, DC 20410

Use of Materials Bulletin No. 74 - Thermal Insulation, Urea-Based, Foamed-in-Place

4. CPCS Safety Standard
Consumer Product Safety Commission
Washington, D. C. 20207

Part 1201 - Safety Standard for Architectural Glazing Materials

5. ASTM
American Society for Testing and Materials
1916 Race Street
Philadelphia, Pennsylvania 19103

C 208-72 - Insulating Board (Cellulosic Fiber), Structural and Decorative
C 355-64(73) - Water Vapor Transmission of Thick Materials
C 516-67 - Vermiculite Loose-Fill Insulation
C 534-70 - Performed Flexible Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form
C 549-73 - Perlite Loose-Fill Insulation
C 552-73 - Cellular Glass Block and Pipe Thermal Insulation
C 570-72 - Oil and Resin-Base Caulking Compound for Building Construction
C 578-69 - Preformed, Block-Type Cellular Polystyrene Thermal Insulation
C 591-69 - Rigid Preformed Cellular Urethane Thermal Insulation
C 612-70 - Mineral Fiber Block and Board Thermal Insulation

C 665-70 - Mineral Fiber Blanket Thermal Insulation for Wood Frame and Light Construction Buildings
C 726-72 - Mineral Fiber Roof Insulation Board
C 739-77 - Cellulosic Fiber (Wood-Base) Loose-Fill Thermal Insulation
C 755-73 - Selection of Vapor Barriers for Thermal Insulations
C 764-73 - Mineral Fiber Loose-Fill Thermal Insulation
C 834-76 - Latex Sealing Compounds
E 84-77 - Surface Burning Characteristics of Building Materials
E 96-66(72) - Water Vapor Transmission of Materials in Sheet Form
E 283-73 - Rate of Air Leakage Through Exterior Windows, Curtain Walls and Doors

6. ANSI
American National Standards Institute
1430 Broadway
New York, New York 10018

ANSI/NWMA I.S. 2-73 - Wood Windows
ANSI/NWMA I.S. 3-70 - Wood Sliding Patio Doors

ANSI/NWMA I.S. 5-73 - Ponderosa Pine Doors
ANSI/AAMA 302.9-1977 - Voluntary Specifications for Aluminum Prime Windows
ANSI/AAMA 402.9-1977 - Voluntary Specifications for Aluminum Sliding Glass Doors
ANSI/AAMA 1002.9-1977 - Voluntary Specifications for Aluminum Combination Storm Windows for External Applications
ANSI/AAMA 1102.7-1977 - Voluntary Specifications for Aluminum Storm Doors

7. NEMA
National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, D.C. 20037

DC 3-1978 - Low-voltage Room Thermostats
DC 15-1972 - Residential Controls Line-voltage Room Thermostats

8. NWMA
National Woodwork Manufacturers Association
400 West Madison Street
Chicago, Illinois 60606

NWMA Industry Standard I.S.1-73 - Wood Flush Doors

9. FHDA
Fir & Hemlock Door Association
Yeon Building
Portland, Oregon 97240

Industry Standard FHDA/6-77 - Douglas Fir, Western Hemlock, and Sitka Spruce Door and Blinds

10. SDI
Steel Door Institute
1230 Keith Building
Cleveland, Ohio 44115

SDI 100-76 - Recommended Specifications Standard Steel Doors and Frames.

11. SWI
Steel Window Institute
2130 Keith Building
Cleveland, Ohio 44115

Steel Window Institute Recommended Specifications for Steel Windows 1977

12. Home Ventilating Institute
230 North Michigan Avenue
Chicago, Illinois 60601

Whole House Ventilating Fan Standard

13. ASHRAE
The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
345 East 47th Street
New York, New York 10017

ASHRAE Standard 90-75 - Energy Conservation in New Building Design

14. NCSBCS
National Conference of States on Building Codes and Standards, Inc.
1970 Chain Bridge Road
McLean, Virginia 22101

Model Code for Energy Conservation in New Building Construction, 1977

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The Department of Energy requested the National Bureau of Standards to develop criteria for materials and products to be included in the DOE Weatherization Assistance Program. This program was established by Congressional legislation and directed toward financially assisting low-income persons in retrofitting residences to conserve energy. For most cases, only energy-saving materials and products for which specifications and/or standards are available are to be included in the Weatherization Assistance Program. Because of statutory requirements labor costs for installing weatherization materials and products are not included in the program.

This report identifies criteria for materials and products eligible under the DOE Weatherization Assistance Program. The materials included are insulation and vapor barriers, storm windows and doors, caulking and weatherstripping, clock thermostats, and replacement windows, and replacement glazing. The retrofit materials are listed by generic type and recommendations are made for their installation.

During the course of the investigation and based upon interactions with industry representatives, materials and products other than those considered eligible under the DOE Weatherization Assistance Program were also given consideration. Those materials and products having energy savings potential but which are considered not eligible are discussed in the Appendices.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)* Caulks and sealants; clock thermostats; energy conservation; insulation; replacement windows; retrofitting; storm doors; storm windows; vapor barriers; weatherization; weatherstripping.

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