TASK B1. ADVANCED MATERIALS RESEARCH

1. ALTERNATIVE MATERIALS FOR CFC-B

ORNL/M--1330

DE91 004931

Monthly Progress Report

Building Thermal Envelope Systems
and Materials (BTESM)
Progress Report for DOE Office of
Buildings Energy Research

October 1990

Compiled by Gabrielle Burn
for
Jeffrey E. Christian, Program Manager
Energy Division

Prepared by the
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
for
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

MASTER

REPRODUCTION OF THIS DOCUMENT IS UNLIMITED

CONTENTS

I. BUILDING THERMAL ENVELOPE SYSTEMS AND MATERIALS (BTESM)	Page
HIGHLIGHTS.....	v
ABSTRACT.....	vii
A. IMPLEMENTATION	
1. Administration/Technical Support/Selected Projects.....	1
a. Management.....	1
b. Reports Published This Period.....	3
c. Conferences and Meetings of Interest.....	4
d. Consultants Report.....	5
B. BUILDING MATERIALS PROGRAM	
<u>Task B1. Advanced Materials Research</u>	
1. Alternative Materials for CFC-Based Foam Insulations.....	8
2. Thermal Resistance Measurements and Data Base of CFC-Replacement Thermal Properties for Foam Insulation Products.....	11
3. Investigation of the Substitution of Environmentally Acceptable Blowing Agents in Foam Insulation: Means to Achieve Equivalent or Approved Energy Efficiency.....	12
<u>Task B2. Performance of Currently-Used Materials</u>	
1. Models, Methods, Measurements.....	13
2. Thermal Insulation Studies.....	13
3. Standard Reference Material Development.....	15
4. Residential Insulation Corrosiveness.....	15
5. Residential Insulation Corrosiveness/Consultant's Report.....	16
6. Research and Development Data to Define the Thermal Performance of Reflective Materials Used to Conserve Energy in Buildings.....	17
7. Radiation Control Coatings.....	18
<u>Task B3. Building Materials Program Management Support</u>	
1. Support Activity.....	19
C. BUILDING ENVELOPE SYSTEMS	
<u>WALL PERFORMANCE</u>	
1. Thermal Mass Simplified Design Tool Assessment.....	22
2. Dynamic Evaluation of Thermal Bridges.....	23
3. Validation of Moisture-Transfer Model.....	24

C. BUILDING ENVELOPE SYSTEMS (cont'd)

ADVANCED WALL SYSTEMS

1. Moisture Control Handbook..... 25

FOUNDATION SYSTEMS

1. Building Foundations Research Agenda..... 26
2. Slab Foundation Benchmark Model..... 27
3. Foundation Thermal Performance Simplified
Prediction Tool..... 27

ROOF SYSTEMS

1. Roofing Research Center..... 28
2. Large Scale Climate Simulator..... 29
3. IEA Annex on Low Slope Roof Systems..... 29
4. Attic Testing on the LSCS..... 30
5. Field Testing of Isocyanurate Foams with Alternate
Blowing Agents..... 31
6. Roof Mechanical Properties Research Apparatus..... 32
7. Roofing Industry Committee on Wind Issues..... 32

D. COOPERATIVE PROJECTS

1. Cooperative Industry/Government Research Project
on Alternative Blowing Agents..... 33

HIGHLIGHT

SECOND SYMPOSIUM ON INSULATION MATERIALS-- TESTING AND APPLICATIONS

October 10-12, 1991

Gatlinburg, Tennessee

SPONSORED BY ASTM COMMITTEE C16

ON

THERMAL INSULATION

Call for Papers:	April 1, 1990
Abstracts Due:	August 1, 1990
Abstract Acceptance Notification:	September 1, 1990
Manuscripts Due:	January 2, 1991
STP Available:	October 10, 1991

<i>Session I:</i>	<i>Reflectives/Radiant Barriers/Radiation Control Coatings</i>
<i>Session II:</i>	<i>Economics and Energy Impact</i>
<i>Session III:</i>	<i>Long-Term Thermal Performance of Foams</i>
<i>Session IV:</i>	<i>Assessments and Properties of Foams</i>
<i>Session V:</i>	<i>Convection in Fibrous Insulation</i>
<i>Session VI:</i>	<i>Tests and Models</i>
<i>Session VII:</i>	<i>Performance Factors I</i>
<i>Session VIII:</i>	<i>Innovative Insulations</i>
<i>Session IX:</i>	<i>Test Methods and Comparisons</i>
<i>Session X:</i>	<i>Performance Factors II</i>

For more information, please contact Symposium Co-Chairmen:

Ron S. Graves
Oak Ridge National Laboratory
Post Office Box 2008
Building 4508
Oak Ridge, TN 37831-6092
615/574-5978
FAX 615/574-7721

Don C. Wysocki
Mobay Corporation
Penn Lincoln Parkway West
Pittsburgh, PA 15205
412/777-2574
FAX 412/777-2758

v/i

Building Thermal Envelope Systems and Materials (BTESM) Progress Report
for DOE Office of Buildings Energy Research

ABSTRACT

The Monthly Report of the Building Thermal Envelope Systems and Materials (BTESM) Program is a monthly update of both in-house ORNL projects and subcontract activities in the research areas of building materials, wall systems, foundations, roofs, and building diagnostics. Presentations are not stand-alone paragraphs every month. Their principal values are the short-time lapse between accomplishment and reporting and their evolution over a period of several months.

I. BUILDING THERMAL ENVELOPE SYSTEMS AND MATERIALS (BTESM)

A. IMPLEMENTATION

1. Administration/Technical Support/Selected Projects

This task includes overall management for the BTESM Program with the emphasis on assuring that individual R&D projects are performed via the best available expertise whether it be at universities, private labs, professional associations, or national labs (including ORNL). Also included are: implementation of major conferences, workshops and seminars, assurance of BTESM staff participation in committee work (BTECC, NIBS, ASTM, ASHRAE, etc.), BTESM National Program planning jointly with the total building community, technical support to DOE, and oversight of selected technical projects not delegated to other tasks.

a. Management (Jeffrey E. Christian/Pat M. Love, ORNL)

The BTESM Program was visited by several of the 73-member DOE Tiger Team, auditing ORNL for a six-week period. This unprecedented, detailed, independent review of environmental, safety, health, and quality assurance activities was requested by the Secretary of Energy. No problems were reported to us on any of our test facilities. The Large Scale Climate Simulator, RTRA, and ESRA facilities underwent numerous "walk-throughs" prior to the Tigers' arrival and one 3 hour quality assurance audit on October 12, 1990. The BTESM staff worked very hard preparing for this close inspection and preliminary indications are, "We're Grrrreat!"

A new format for monthly reporting of interest items to industry has been drafted and is being reviewed.

All BTESM program areas are awaiting budget instructions from DOE/HQ.

The two Joint Work Statements for Cooperative Research and Development Agreements (CRADAs) for approval are still traveling through the signature chain but have reached the final step before ORO approval. One CRADA is with PIMA and will be used to obtain private industry funds for their share of the joint project on HCFC blowing agents for polyisocyanurate insulation. The other CRADA is with CISEP for conducting thermal performance measurements on cellulose blown insulation using the Attic Test Module and the Large Climate Simulator. CRADAs are a new provision recently adopted by DOE to permit research projects to bring in money from private industry to join with DOE money for cooperative ventures. The next step will be to submit the full CRADA containing detailed instruction.

Thermal Performance of the Exterior Envelopes of Buildings V Conference: The third planning meeting for this conference will be held on January 21, 1991 (9:00 a.m. - 12:00 noon), at the Hilton in New York, NY. A site selection presentation will be voted on and also final confirmation of chairs. A tentative program plan will be presented for comment and review. Other discussion will include topics for sessions.

Dave McElroy has announced his retirement from Oak Ridge National Laboratory effective November 16, 1990. Dave is the Group Leader of the Building Materials Group of the BTESM Program in the Metals and Ceramics Division of Oak Ridge National Laboratory. He performed research on nickel-based thermocouples at the University of Tennessee Engineering Experiment Station prior to joining ORNL in 1959. Dave is one of the founding fathers of the Energy Conservation Society, a proponent of vacuum panel technology, a strong project manager, and an active ASTM C-16 participant. He has been referred to by one admirer as a "National Treasure." His current research projects include leadership in developing foam insulation board slicing, CFC impacts, development of ASTM thin screen tester, and ASTM standards. Dave has a B.S. and M. S. in Metallurgy from the University of Alabama, and a Ph.D. in Metallurgy from the University of Tennessee. He is a Fellow in the American Society of Metals and is a member of the American Society for Testing Materials. We all wish Dave well and thank him for his many contributions to the program. Good luck Dave, we will miss you.

Dave will be succeeded by Dr. Thomas G. (Tom) Kollie, a member of the BTESM Program.

EVENTS

October 1-3	R. S. Graves and J. E. Christian presented technical papers at the Polyurethanes '90 Conference in Orlando, Florida.
October 4	Ron Graves and Jeff Christian presented status reports at the Cooperative Industry/Government Program for Testing of Laminate Boardstock Manufactured with HCFC Blowing Agents Steering Committee Meeting in Orlando, Florida.
October 8-9	D. L. McElroy and T. G. Kollie traveled to DOE/HQ in Washington, D.C. (Trip Report FY 1991-1).
October 10-11	T. G. Kollie attended the AHAM Meeting in Chicago, Illinois.
October 12	Three-hour QA audit of RTRA and ESRA facilities.

- October 14-17 D. L. McElroy, R. S. Graves, and D. W. Yarbrough attended the ASTM C 16 meeting in New Orleans, Louisiana (Trip Report FY 1991-2).
- October 18 Jacques Boudin, VISTA Scientific, met with Jeff Christian, Phil Childs, Bill Levins, and several other members of a Quality Incidence Review Team to discuss modification to the LSCS refrigeration system to alleviate excessive wear on one 75 hp compressor.
- October 24 Jeff Christian attended University of Minnesota Underground Space Center Foundation Test Facility Advisory Committee Meeting, and met with John Carmody to discuss the Builder's Foundation Handbook.
- October 25-26 Jeff Christian attended an ASTM Symposium on Water in Exterior Building Walls: Problems and Solutions. The meeting was held in Dearborn, Michigan.

b. REPORTS PUBLISHED THIS PERIOD

None.

C. CONFERENCES AND MEETINGS OF INTEREST*

1990

December 10-12: Third Brazilian Thermal Science Meeting, ENCIT-90, to be held in Itapema, SC, Brazil. For more information, contact Professor Alvaro T. Prata, Department of Mechanical Engineering, Federal University of Santa Catarina, P.O. Box 476, 88049 - Florianopolis-SC, Brazil, or call (0482) 335166, FAX (0482) 331519, or Telex 481 317 FUEG BR.

1991

January 19-23: ASHRAE 1990 Winter Meeting, to be held in New York, NY. For more information, contact Judy Marshall or Jan Young, ASHRAE Meetings, 1791 Tullie Circle, NE, Atlanta, GA 30329, or call (404) 636-8400.

April 17-19: Third International Symposium on Roofing Technology, sponsored by the National Institute of Standards and Technology; U.S. National Roofing Contractors Association; Canadian Roofing Contractors Association; National Research Council of Canada; International Waterproofing Association; CIB, and RILEM. The symposium will be held at the Montreal Convention Centre, Montreal, Quebec, Canada. For more information, contact Walter Rossiter, NIST, Center for Building Technology, Building 226, Room B-348, Gaithersburg, MD 20899, or call (301) 975-6719, FAX (301) 975-4032, TELEX TRT 197674 NIST WT.

October 10-12: Second Symposium on Insulation Materials--Testing and Applications, sponsored by ASTM Committee C 16, to be held in Gatlinburg, TN. For more information, contact Symposium Co-Chairmen: Ron S. Graves, Oak Ridge National Laboratory, P.O. Box 2008, Bldg. 4508, Oak Ridge, TN 37831-6092, (615) 574-5978; or Don C. Wysocki, Mobay Corporation, Penn Lincoln Parkway West, Pittsburgh, PA 15205, (412) 777-2574.

1992

December: Thermal Performance of the Exterior Envelope of Buildings V, to be held in the Florida area. Sponsors include DOE, ASHRAE, and BTECC. For more information, contact Pat M. Love, Co-Chairperson, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, Tennessee 37831-6070, or call (615) 574-4346.

*Please send notices to Gabrielle Burn.

d. CONSULTANTS

ACEC RESEARCH AND MANAGEMENT FOUNDATION

**Jack R. Warner
President
Washington, D.C. 20005
Subcontract ORNL/Sub-SE077/3
Deliver by: 05-31-90**

A new contract is pending.

**BTECC WORKSHOPS AND FEASIBILITY STUDY
BUILDING THERMAL ENVELOPE COORDINATING COUNCIL
NATIONAL INSTITUTE OF BUILDING SCIENCES**

**Bruce E. Vogelsinger
National Institute of Building Sciences
Washington, D.C. 20005
Subcontract ORNL/Sub-SC111/8
Deliver by: 12-31-90**

This contract has three tasks:

1. Feasibility of a Tracking System on Current Research and Publications on Building Thermal Envelopes.

A detailed scope of work was developed and distributed to potential subcontractors. Three proposals were reviewed and a subcontract was awarded to Energy Design Associates, Inc., Ansonia, New York. Work is under way, and the Materials RCC Committee of BTECC met on June 4 and reviewed the work of the subcontractor. A three-person review committee has been appointed. An interim report was submitted to the committee for review and comment on October 22. The report was reviewed by the Materials RCC Committee at a November 6 meeting. Comments on the draft report have been transmitted to Energy Design Associates and the final report is scheduled to be completed on December 28.

2. Workshop on Building Heat Flow Measurements.

The workshop was held at the Cold Regions Research and Engineering Laboratory, Hanover, NH on May 22-23, 1990. Twenty-three people attended the workshop. Papers from the authors were due September 1, 1990, and all but one paper has been received. Style editing has been completed, and the papers have been returned to the authors for review and final typing. Camera-ready papers are due back from authors on November 30. Publication of the proceedings is now scheduled for February 28, 1991.

3. Workshop on Preventing and Repair of Condensation Damage in New and Existing Housing.

The planning and conduct of this workshop has been assigned to BTECC's Research Coordinating Committee on Moisture Control. Erv Bales, New Jersey Institute of Technology, and Bill Rose, University of Illinois, volunteered to co-chair the workshop. The RCC met on November 6 and has developed a draft program and selected the data of May 20-21, 1991, for the workshop. Locations being considered for the workshop are Chicago, Newark, and Washington.

TASK B. BUILDING MATERIALS PROGRAM

The Building Materials Program includes work done at ORNL and work done by others on DOE-funded projects. The following pages include project reports for three areas:

B1. ADVANCED MATERIALS RESEARCH

Cooperative Government/Industry Project on Alternatives for
CFC-Based Foam Insulation
High-Resistance Powder-Filled Evacuated Panels

B2. PERFORMANCE OF CURRENTLY-USED MATERIALS

Determination of properties of materials
Improvement of test procedures

B3. MATERIALS PROGRAM MANAGEMENT SUPPORT

Technology transfer
Coordination of subcontracted research

**BUILDING
MATERIALS
PROGRAM****TASK B1. ADVANCED MATERIALS RESEARCH****1. ALTERNATIVE MATERIALS FOR CFC-BASED FOAM INSULATIONS**

D. L. McElroy, R. S. Graves, T. G. Kollie, and D. W. Yarbrough
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6092

This task is currently focused on two topics:

(1.1) The Cooperative Government/Industry Research Project for CFC Alternatives, and

(1.2) High-Resistance Powder-filled Evacuated Panels (PEPs)

1.1 Cooperative Project. We prepared the third draft of ORNL/TM-11645, entitled, "Thermal Resistance of Polyisocyanurate Foam Board Insulation Blown with CFC-11 Substitutes - A Cooperative Industry/Government Project." Copies of draft three were distributed to the Project Steering Committee for their review and comments by November 1. The report abstract was sent to the BTECM mailing list to prepare a report distribution list. R. S. Graves presented a paper at the Polyurethane 90 Conference that summarized testing of panels exposed in the Roof Thermal Research Apparatus (RTRA) and tests of thin specimens aging at 75°F and 150°F. These results and the ORNL results obtained from calculations using the MITB computer program for foam aging were presented to the Steering Committee. A subcommittee of the Steering Committee will meet in November to discuss development of foam aging models. The first draft of a proposed ASTM test procedure on thin specimen aging was discussed at the task group meeting of ASTM C 16.30 (Task Group 3.7). Comments are to be forwarded to A. O. Desjarlais, who will prepare a document for an ASTM C 16.30 ballot.

R. S. Graves made a presentation to ASTM C 16.30 entitled, "Interlaboratory Comparison of Four Heat Flow Meter Apparatuses on Planed Polyisocyanurate Boards Foamed with CFC-11." The participants discussed draft two of ORNL/TM-11720, and agreed to test planed specimens of greater thickness. Draft three of ORNL/TM-11720 is being prepared and will contain new values of thermal conductance. R. S. Graves prepared a presentation on foam aging for the November meeting of BTECC. We completed draft two of the paper on foam aging for the ASTM Symposium in October 1991.

Thermal conductivity tests were completed on the RTRA panels blown with 65/35 and 50/50 blends of HCFC-123/HCFC-141b. These panels have been exposed for approximately 10 months. The test results from the thin-heater apparatus and the heat flow meter apparatus agreed to better than 2% in the temperature range of overlap.

- 1.2 Panel. We, along with the DOE/HQ Program Manager, attended the October meeting of the insulation committee of the Appliance Research Consortium (ARC), which is a wholly owned subsidiary of the American Home Appliance Manufacturers (AHAM) Association. The ARC wants to develop a procedure to predict the lifetime of vacuum insulation. After extensive discussion, it was decided that ORNL had the technology needed for this development and that the newly established Cooperative Research and Development Agreements (CRADA) would be the best method to accomplish this technology transfer. To this end, we have prepared a Statement of Work (SOW) outlining our approach and the projected cost to the ARC. We will discuss the SOW with the insulation committee at their November meeting in Chicago.

The interlaboratory comparison of measurements of the permeance (Γ) of three polymer films was completed. One of these films was SRM 1470 from the National Institute of Standards and Technology (NIST). Modern Controls, Inc. (MOCON), made measurements of the O_2 and He Γ 's of this SRM as did the K-25 Site, who also determined the Γ for N_2 . MOCON's O_2 Γ measurements were made with their OX-TRAN® instrument which has a sensitivity five orders of magnitude lower than the Γ of SRM 1470. As expected, their measurement was within 1.5% of the NIST value. The MOCON MULTI-TRAN® was used for the He measurements. While this instrument had sufficient sensitivity, the value was 7.7% high, which was acceptable but not as good as anticipated. The K-25 Site measurements demonstrated that they still have experimental problems with their technique. Their He Γ was 17% high, their O_2 Γ was erratic and as much as 57% low, and their N_2 Γ was erratic and as much as 49% high. This intercomparison demonstrated MOCON's ability to measure the permeance of O_2 , caused concern for their He measurements, and pointed to the need for improvement in the K-25 Site technique, which they are pursuing.

The He permeance of the General Electric (GE) barrier material was performed by these two laboratories as well as computed from our accelerated aging tests in He. The other two labs Γ 's for He were essentially the same even though the MOCON measurement was performed at a temperature 5.4°C below that of the K-25 measurements. Such a temperature difference should have caused at least a 15 to 20% difference because permeation is an activation controlled process and thus has an exponential increase with temperature. The ORNL value was a factor of two lower than the others and was obtained at temperature lower than the others by 2°C and 7°C, which accounts for some of the difference. Specimens

were obtained from the same lot of GE panels. In fact the MOCON and K-25 specimens were from the same panel. The ORNL measurements were the mean of six panels. At the 99.5% confidence level, only a 30% difference in I 's would be expected due to differences in specimens, if the standard deviation of the ORNL measurements is associated only with differences in specimens. The I of He for the GE barrier material is only a factor of 30 above the sensitivity, and the K-25 Site measurements on the SRM demonstrated that their measurements could be off by 50% for I 's in this range. We are continuing to pursue a resolution of these differences.

The first rough draft of our summary report that reviews the ORNL efforts in panel technology has just been completed.

2. THERMAL RESISTANCE MEASUREMENTS AND DATA BASE OF CFC-REPLACEMENT THERMAL PROPERTIES FOR FOAM INSULATION PRODUCTS

R. Zarr
National Institute of Standards and Technology
Gaithersburg, Maryland 20899

ORNL/IA-21513/27

Progress Report for September 1990:

FY 1990 Milestone 1 (Calibrate Small HFM). To review: a small heat-flow-meter (HFM) apparatus (plate size 305 millimeters) was obtained in January 1990 from a member of the NIST foam advisory panel. Calibration measurements using an in-house standard have been on-going since late March 1990.

FY 1990 Milestone 2 (Measure Materials using GHP and HFM). Repeatability tests were conducted by a member of the Heat Transfer Group using the small HFM described above. Five tests were conducted with one specimen of fibrous-glass board and one specimen of molded-beads expanded polystyrene. Prior to each measurement, the HFM was calibrated using a specimen of fibrous glass-board.

The remaining work effort for this month was diverted to the 1990 ASTM C 687 Loose-Fill Round Robin.

1. The apparent thermal conductivity of four specimens of unbonded glass-fiber and four specimens of rockwool was measured using the NIST one-meter guarded hot plate. At the conclusion of the GHP tests, the apparent thermal conductivity of some of the specimens was determined in the large heat-flow-meter apparatus under the same test conditions.

FY 1989 Task B, Milestone 3 (Round-Robin with ORNL and JWRC). Work for this task was diverted to the above tasks.

Miscellaneous:

1. Galley proofs of the paper, "Summary of Low-Density Glass-Fiber Reference Materials at NIST: 1989-1989," were returned to the Journal of Thermal Insulation.

**3. INVESTIGATION OF THE SUBSTITUTION OF ENVIRONMENTALLY ACCEPTABLE
BLOWING AGENTS IN FOAM INSULATION: MEANS TO ACHIEVE EQUIVALENT
OR APPROVED ENERGY EFFICIENCY**

Glicksman, Burke, Lanciani, Mozgowiec, Page
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

ORNL/Sub-09099/17

The Bepex Corporation will soon process samples of PMMA, nylon, teflon, and PPO micropowders in their Hybridization system in order to coat them with graphite. These samples will then be analyzed using the FTIR spectrometer, and they will be added to PV foam. The resulting foam insulation will then be tested for its effective thermal conductivity.

Toners are being considered as candidate composite micropowders, which may be added to PV foam to reduce radiative heat transfer. Samples are currently under analysis.

Samples of rigid foam prepared using a unique formulation devised through a joint venture between Mobay and Union Carbide were obtained. Testing of these samples is soon to commence.

A new method to cut foam samples was discovered. The instrument is called Microtone and it is used for cutting biological tissue. The new technique shall have the advantage of cutting and not tearing its way through the spectrometer tested sample. It is expected that the problem of a torn cell wall "skin" on the exterior face of the sample will be alleviated.

New methods of forming vacuum insulation panels using a glass encapsulant are being studied. Current attention is being focused on using a mold to perform the glass to the shape of the powder. This shell will then be filled with a compressed powder brick and then sealed, under vacuum, with a thin layer of microsheet glass.

Several materials have been tested for use as possible molds. Thus far, graphite has proven to be the most appropriate material. In the critical range of 600°C to 750°C the molten glass does not stick to the graphite. However, at these high temperatures, the graphite oxidizes quickly unless kept under vacuum or in an inert atmosphere.

TASK B2. PERFORMANCE OF CURRENTLY-USED MATERIALS**1. MODELS, METHODS, MEASUREMENTS - ORNL**

This task is currently focused on three topics:

1. Development and use of analytical models for heat transfer.
2. Development and use of flat insulation testers: the Unguarded Thin Heater Apparatus (UTHA) and the Advanced R-Matic Apparatus.
3. Measurement of the behavior of loose-fill attic insulation.

1.1 Models-ORNL

The predictions of a finite difference model for transient tests show the need to decrease the thermal mass ratio (TMR) of the thin heater to the specimen. We are planning tests with a stainless steel screen wire heater to decrease the TMR for a polystyrene specimen from 0.17 to 0.040.

1.2 Methods-ORNL

The third draft of ORNL/TM-11629 was prepared from comments by a group of reviewers. This report, entitled, "Steady-State and Transient Tests Using the Unguarded Thin-Heater Apparatus (Thermophysical Properties of Building Materials)," is ready to be delivered to the Records Office for final preparation. The abstract was sent to the BTESM mailing list to prepare a distribution list for the report. This report forms the basis for a paper for the ASTM Symposium in 1991 and draft one of this paper was prepared and sent to a group of reviewers at ORNL.

We ordered a second high-capacity, temperature-controlled, circulating bath for the bottom plate of the Unguarded Thin-Heater Apparatus (UTHA). Obtaining this bath will allow tests with the UTHA to as low as 30°F. We anticipate testing a new set of specimens from Lawrence Berkeley Laboratory in November. These specimens will include a new gas barrier material that should reduce the rate of permeability to air components.

1.3 Loose-Fill Attic Insulation-ORNL

An ORNL Central Files Memo, ORNL/CF-90/292, entitled "1990 Loose-Fill Insulation Interlaboratory Comparison Test Plan," was prepared by the Records Office and is at reproduction.

ORNL test results for the 1990 ASTM C 687 Interlaboratory Comparison on the Thermal Resistance of Loose-Fill Insulations were delivered to Dr. D. R. Smith, NIST, for analysis and reporting.

A paper entitled, "Thermal Performance of Conventional and High-Density Fiberglass Batt Insulations under Compression," by R. S. Graves and D. W. Yarbrough was prepared for the November 1990 Conference on Fire Safety and Thermal Insulation, St. Petersburg, Florida, November 5-8, 1990.

2. THERMAL INSULATION STUDIES

D. W. Yarbrough, S. Wudhapitak, and M. Said
Department of Chemical Engineering
Tennessee Technological University
Cookeville, Tennessee 38505

ORNL/Sub-7715/90

No progress to report for the month of October.

3. STANDARD REFERENCE MATERIAL DEVELOPMENT

D. R. Smith
Chemical Engineering Science Division
National Institute of Standards and Technology
Boulder, Colorado 80303-3328

ORNL/IAA-21428/63

No progress to report for the month of October.

4. RESIDENTIAL INSULATION CORROSIVENESS

E. E. Stansbury
Consultant
5800 Woodburn Drive
Knoxville, Tennessee 37919

ORNL/Sub-B8240/29

Six of the eight participants in the ASTM round robin program to evaluate an electrochemical method for assessing the corrosiveness of residential building thermal insulation have reported their results. These results were correlated, a preliminary report was prepared and the report was presented to the ASTM 16.31 Corrosion Task Group at the meeting in New Orleans on October 15, 1990. Also presented was an overview of results of investigations at the University of Tennessee on corrosiveness measurements on thirteen cellulosic, three mineral fiber, and four foam insulations. There was general agreement that the results of the round robin evaluation indicated that development of a satisfactory electrochemical method applicable to the three types of insulation was questionable. There was sufficient interest in a partial immersion test developed at the University of Tennessee to plan a round robin of three participants to further evaluate its potential as a general corrosiveness test method.

5. RESIDENTIAL INSULATION CORROSIVENESS

**E. E. Stansbury
Materials Science and Engineering Department
University of Tennessee
Knoxville, Tennessee 37919**

**Martin Marietta Energy Systems, Inc.
99732PAX/14
Consultant's Report**

A procedure of partial immersion of 2 in. x 2 in. x 0.003 in. low carbon steel in wet cellulosic, mineral fiber and foam insulations for evaluation of their corrosiveness has been tentatively standardized. Following exposure of two weeks with 1.5 in. immersion in the wet insulation, specimens are removed and cleaned. Corrosion is concentrated at the metal-air-wet insulation interface due to the availability of oxygen to support the cathodic reaction. The severity of corrosion is evaluated initially by examination for complete penetration along the interface. If penetration has not occurred, the corrosion can be estimated by a survey of thickness using ball-tipped micrometers. In an investigation of seven wet insulations, two were penetrated and the corrosion rate corresponding to maximum penetration for the others, always near the air interface, ranged from 6.1 to 9.8 mpy. It is difficult to detect a change in thickness of the specimens over positions deeply immersed in the insulation; the minimum rate detectable would have been -.5 mpy. Corrosion rates under conditions of total immersion in leachates from these insulations ranged from 0.45 to 2.0 mpy.

**6. RESEARCH AND DEVELOPMENT DATA TO DEFINE THE THERMAL
PERFORMANCE OF REFLECTIVE MATERIALS USED TO
CONSERVE ENERGY IN BUILDINGS**

**A. O. Desjarlais
Thermatest Division of Holometrix, Inc.
Cambridge, Massachusetts 02139**

ORNL/Sub-SA835/23

Requests for ORNL/Sub/88-SA835/1 have exhausted our supply. We obtained the photomasters from Bonneville Power Administration to allow 150 additional copies to be prepared.

7. RADIATION CONTROL COATINGS

Robert W. Anderson
Robert W. Anderson and Associates, Inc.
Boulder City, Nevada 89005

ORNL/Sub-SE791/6

Analysis of computerized simulations of the annual thermal performances of roofs with and without RCCs were continued for five climatic areas. The analyses show the effect of RCCs on:

- (a) heating and cooling loads for roofs with various levels of thermal insulation, and
- (b) roof surface temperatures and ceiling temperatures.

The application of the RCCs on black insulated roofs significantly reduces the cooling loads and the relative effect on cooling and heating loads varies with climatic conditions. The maximum surface temperature of black roofs can exceed 170°F; the application of RCCs reduces the maximum surface temperatures to about 10°F above outside air temperatures; the effect of the RCCs on maximum roof temperatures is relatively insensitive to different climatic areas. Likewise, the application of RCCs can significantly reduce ceiling temperatures during the cooling season.

Upon the availability of test data from the ORNL RTRA summer test of RCCs, measured heat flow and surface temperature data will be compared to the values calculated with the BLAST program.

19/20

**BUILDING
MATERIALS
PROGRAM**

Task B3. BUILDING MATERIALS PROGRAM MANAGEMENT SUPPORT

1. SUPPORT ACTIVITY - ORNL

This task is focused on two topics:

- (1.1) Exchange of technical results with the building materials community.
- (1.2) Coordination of subcontracted research at other facilities.

1.1 Exchange - ORNL

R. S. Graves, ORNL, and D. Wysocki, Mobay, are Co-Chairmen of the ASTM C 16 Second Symposium on Insulation Materials. Manuscripts are due January 2, 1991, to allow the Symposium proceedings to be available by October 10, 1991. Session Chairmen have been asked to obtain reviewers for each paper.

1.2 Coordination - ORNL

We placed a subcontract on research on advanced foams at MIT and we initiated placement of a subcontract to continue the Radiation Control Coating Project in FY 1991. We held discussions with DOE/HQ staff on the ORNL Statement of Work for FY 1991. We participated in the Fall meeting of ASTM C 16 in New Orleans, Louisiana, and we revised ASTM C 1058 for a C 16.30 ballot. We are planning to create an advisory panel to help revise the DOE Insulation Fact Sheet during FY 1991.

C. BUILDING ENVELOPE SYSTEMS

ORNL Staff:

**J. E. Christian, K. E. Wilkes, R. L. Wendt,
G. E. Courville, P. W. Childs, and K. W. Childs**

This task includes work done at ORNL and work by others on DOE-funded projects on Building Envelope Systems and is divided into Wall Performance, Advanced Wall Systems, Foundation Systems, Roof Systems, and Building Diagnostics. Each of these project areas is treated separately on the following pages.

WALL PERFORMANCE

1. THERMAL MASS SIMPLIFIED DESIGN TOOL ASSESSMENT

**J. E. Christian
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6070**

No significant progress for the month of October.

2. DYNAMIC EVALUATION OF THERMAL BRIDGES

D. Burch
National Institute of Standards and Technology
Gaithersburg, MD

ORNL/IA-21513/27

Progress Report for September 1990:

Milestone 3 (Prepare Final Report): The final report for this project, entitled, "Dynamic Evaluation of Thermal Bridges in a Typical Office Building," is undergoing review at the National Institute of Standards and Technology. All other milestones for this project have been completed.

In this report, a finite-difference model is used to predict the steady-state and dynamic thermal performance of thermal bridges in a typical office building. The thermal bridges evaluated include: a built-up roof system with ceiling fasteners, a roof/wall interface, an insulated masonry cavity wall with metal studs, a floor slab that penetrates wall insulation, and a window frame/wall interface.

The steady-state analysis reveals that the thermal bridges increased the overall envelope heat transfer coefficient for the office building by 33%. A thermal bridge is found to have a large effect when it has a large cross sectional area that short circuits the thermal insulation of the building envelope.

In the dynamic analysis, a finite-difference model is used to numerically determine a complete set of conduction transfer function (CTF) coefficients for each of the thermal bridges. The mathematical procedure is to predict the heat transfer response of a thermal bridge excited by a ramp excitation function. The heat transfer response for a triangular pulse is subsequently obtained by superimposing the responses for three ramp excitation functions to form a triangular pulse. A recursive relation employing the common ratio is applied to the triangular-pulse response to determine first-order CTF coefficients. The validity of the CTF coefficients is demonstrated by accurately predicting the heat transfer response of each of the thermal bridges to a diurnal excitation function.

3. VALIDATION OF MOISTURE-TRANSFER MODEL

D. Burch
National Institute of Standards and Technology
Gaithersburg, Maryland 20899

ORNL/IA-21513/27

Progress Report for September 1990:

Milestones 1 and 2. Complete Diffusion and Sorption Isotherm Measurements for Ten Materials: During this reporting period, NIST carried out moisture property measurements for five materials. The five materials included vinyl-covered gypsum board, asphalt-impregnated kraft paper, wafer board siding with latex paint applied to the exterior surface, foam core sheathing, and wood fiber board. These property measurements are needed as input to the NIST Moisture Transfer Model which will be used to generate recommended good practices for controlling moisture in wall constructions as a function of indoor humidity conditions and outdoor climatic conditions. A progress report on these property measurements is given below.

Sorption Isotherm Measurements

A sorption isotherm is a plot of the equilibrium moisture content of a materials versus ambient relative humidity. Adsorption and desorption isotherm measurements for the five materials were completed with the exception of the desorption isotherm for wafer board siding. Here measurements had to be repeated because mold grew on several of the specimens. The vinyl-covered gypsum board specimens were observed to absorb a comparatively small amount of water vapor in the hygroscopic range. When exposed to a relative humidity of 97%, the equilibrium moisture content was less than 5%. On the other hand, the other four materials absorbed considerably larger amounts of moisture. When exposed to a relative humidity of 97%, the other four materials attained an equilibrium moisture content above 20% by weight.

Diffusion Measurements

Permeance measurements of the five materials as a function of relative humidity were completed at ambient temperatures of 76°F and 44°F, with the exception of two materials at 44°F which are currently under way. For each material, a correlation of permeance as a function of relative humidity was obtained. The permeance measurements were observed to be independent of temperature. The wood-fiber board was found to be very permeable, whereas the other four materials had a permeance less than 1 grains/h·ft²·in.Hg, thereby indicating that these materials would essentially function as vapor retarders.

ADVANCED WALL SYSTEMS**1. MOISTURE CONTROL HANDBOOK**

Joseph Lstiburek
Dames & Moore, Trow
Park Ridge, Illinois 60068
ORNL/Sub-SD350/6

All of the revised text for the Moisture Control Handbook has been sent to John Carmody at the University of Minnesota for incorporation into the software package used to format this book. The only writing left is to prepare the executive summary. The references requested by the review panel also have to be added. The section on wetting and drying rates is part of this draft material. This was missing from the earlier review copy. A hard copy of the revised text was sent to ORNL on Friday, November 9, 1990.

FOUNDATION SYSTEMS**1. BUILDING FOUNDATIONS RESEARCH AGENDA**

J. E. Christian
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6070

The heat flux transducer guards for six transducers have been assembled. The PVC laminate used to protect the HFT and guard assembly have arrived. The sensors will be mounted in several foundation insulation specimens which will be tested in the North wall of the ESRA. Prior to installation, the insulation will be characterized in the thermal properties laboratory. The heat flux transducers will also be calibrated in-situ.

The two work statements contributed by the BTESM staff and submitted to separate ASHRAE technical committees for ASHRAE funding have been approved and are now on the street. The RFP indicates that the potential bidders must deliver their proposals to ASHRAE Headquarters by mid-December. One of these work statements is entitled, "Energy Calculations for Basements, Slabs, and Crawl Spaces." This work will produce algorithms based on existing methods for incorporation into standard hourly building computer energy simulation models. The second work statement is entitled, "Development of Soil Thermal Property Database." This work will provide guidance to users of a soil database produced by this research and enable site-specific classification of soil thermal properties for use in foundation energy calculations.

2. SLAB FOUNDATION BENCHMARK MODEL

D. Wasserman and Jeff Christian
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6070

Ken Wilkes will be helping to develop the foundations models capabilities to simulate coupled moisture mass transfer. The conduction portion of the model has been completed by David Wasserman, who will be concentrating on research in other areas. The model was transferred to Ken this month.

3. FOUNDATION THERMAL PERFORMANCE SIMPLIFIED PREDICTION TOOL

Jeff Christian
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6070

Additional comments from the DOE review of the *Builder's Foundation Handbook* are being worked into the final mattes. The subcontract with John Carmody has been extended to accommodate some of the suggested additions. An example illustrating the use of the worksheets has been added to the handbook.

ROOF SYSTEMS

1. ROOFING RESEARCH CENTER

R. L. Wendt and J. E. Christian
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6070

The Cooperative Research and Development Agreement (CRADA) projects continue to work their way through the system. One covers additional work on polyisocyanurate insulations developed under the joint government/industry research project. The other is to test the performance of cellulose insulation in the Attic Test Module and LSCS under severe winter conditions.

R. L. Wendt presented an update of the Center's activities at the Federal Roofing Committee meeting held at NIST on October 16-18.

The Single Ply Roofing Institute, Technical Committee met on October 23-24. The recover subcommittee requested that R. L. Wendt prepare a preliminary proposal for review to determine the rate of change in moisture content of low-slope roof systems that have become wet and are then recovered with new membranes. Knowing the "drying rate" of various systems and the parameters that impact it could lead to significantly more prudent decision making with regard to when it is appropriate to recover existing roofs. It is envisioned that this project would be accomplished as an industry/government collaborative research project.

The Center's Industry Advisory Panel met on October 25 at the National Roofing Contractor's Association Headquarters near Chicago. Eleven of the Panel members attended. K. E. Wilkes and R. L. Wendt described the Center's activities since the last meeting. T. L. Smith, NRCA, described the application of the roof on the RMPFRA. Response from the panel was positive, particularly with regard to the quality of the work being accomplished.

The RTRA summer data letter report on the Radiation Control Coating (RCC) was completed. It not only provides detailed data of the RCC over 1.5 in. plywood compared to a plain black EPDM over 1.5 in. plywood, but also is compared to an R-18 insulated roof system under a plain black and plain white EPDM. This report is undergoing internal review. Hourly tabulated data are provided in anticipation of its use to validate algorithms in whole building energy simulation models. This draft material was sent to Bob Anderson for inclusion in an ASTM paper to be presented in Gatlinburg, Tennessee, in October 1991.

2. LARGE SCALE CLIMATE SIMULATOR

**P. W. Childs, K. E. Wilkes, and J. E. Christian
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6070**

Further analysis of the climate chamber compressor revealed wear on some of the remaining pistons from the unloaded cylinders.

Jacques Bodine of Vista Scientific visited ORNL and met with various ORNL staff regarding the single-stage compressor problems. It was determined that the single-stage compressor cannot last running at the unloaded conditions that we normally operate under. Alternatives to the current design were discussed. The consensus was for the addition of a three ton separate refrigeration unit for use during runs when no load is on the chamber. Jacques will provide a design and an estimate for the addition.

3. IEA ANNEX 19 ON LOW SLOPE ROOF SYSTEMS

**George E. Courville
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6070**

No progress to report for the month of November.

4. ATTIC TESTING IN THE LSCS

Kenneth E. Wilkes and Agnes Delmas
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6070

Attic Seal, Inc., has defined a new series of testing on their products based on the findings from the initial testing. Included will be the re-insulation of the Attic Test Module with blown fibrous glass insulation to the R-19 level and the replication of testing which identified the existence of convection within the insulation. Discussion with industry continued on the initial findings.

A representative of MIMA has requested that we submit a statement of proposed work that entails testing the attic module with foam insulation installed. This test has been requested to confirm that apparent convection will not be detected in a material which is unlikely to permit any substantial amount of convective heat transfer through the foam.

5. FIELD TESTING OF ISOCYANURATE FOAMS WITH ALTERNATE BLOWING AGENTS

J. E. Christian and G. E. Courville
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6070

An article on the CFC alternatives was published in Construction Specifier News in the November 1990 issue. A technical paper was presented at the Polyurethanes '90 Conference. This paper is available in the conference proceedings and in an SPI publication entitled, "CFCs & the Polyurethane Industry: Volume 3, 1990." A status report was presented to the Cooperative Industry/Government Project Steering Committee. Field data up to September 24 was presented. After 460 days since production, aging has clearly slowed on all test specimens. Several of the field samples are beginning to enter the transition zone from air component diffusion dominance to the more stable region when blowing agent diffusion or solubility begins to dominate any further thermal drift. Several of the full thickness 1.5 in. field samples are tracking the aging curve predicted by the accelerated slicing tests remarkably well. The blends have been pulled from the RTRA and laboratory tested for steady state k-value and to develop k-value vs temperature relationship needed to normalize field k-value data to that at 75°F. The blends have both been reinstalled in the RTRA. The 141b specimens have also been pulled from the RTRA. They are expected back from the laboratory on November 12, 1990. The CFC-11 and HCFC-123 specimens will also be checked in November.

The Cooperative Industry/Government Project Steering Committee formed a Task Force to (1) evaluate the data collected thus far on the existing set of experiments; (2) examine whether or not to modify any of the remaining work in light of findings to date; and (3) prepare a list of recommendations for Phase II. This task force will be headed by Bob Blanpied of Atlas Roofing. A meeting will be scheduled prior to the next steering committee meeting.

The Memorandum of Understanding on (MOU) Roofing Research at ORNL is now available for review. ORNL has reviewed it and has urged DOE to sign it. We understand that the EPA lawyers are "looking at it." Jean Lupinacci has urged the EPA lawyers to sign. PIMA has told us that they will not enter into a CRADA with ORNL until this MOU is signed. The PIMA CRADA is being "fast tracked." This being a new instrument for transferring money on cooperative projects, some growing pains are being experienced.

6. ROOF MECHANICAL PROPERTIES RESEARCH APPARATUS

**Robert L. Wendt
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6070**

The roof containing the five different polyisocyanurate insulation formulations was installed June 26-27, 1990. Three blisters have been previously noted on the roof platform. They have remained stable in size during October.

Site grading was completed. Work remaining to be accomplished includes the installation of the initial series of foundation experiments.

7. ROOFING INDUSTRY COMMITTEE ON WIND ISSUES

**George E. Courville
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830-6070**

No progress to report for the month of November.

D. COOPERATIVE PROJECTS

1. COOPERATIVE INDUSTRY/GOVERNMENT RESEARCH PROJECT ON ALTERNATIVE BLOWING AGENTS

**G. E. Courville, D. L. McElroy, J. E. Christian, and R. L. Wendt
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831**

This project is jointly supported by the Department of Energy, the Environmental Protection Agency, The Society of the Plastics Industry, the Polyisocyanurate Insulation Manufacturers Association, and the National Roofing Contractors Association. The objective of the project is to conduct comparative laboratory and field studies of isocyanurate foam roofing boards blown with conventional CFC-11 and with alternative blowing agents. The purpose is to identify performance differences, if any, between foams with alternative blowing agents and foam blown with CFC-11.

1. MEETINGS AND PRESENTATIONS

On October 1-3, R. S. Graves and J. E. Christian presented technical papers at the Polyurethanes '90 Conference in Orlando, Florida.

Ron Graves and Jeff Christian presented status reports at the Cooperative Industry/Government Program for Testing of Laminate Boardstock Manufactured with HCFC Blowing Agents Steering Committee Meeting in Orlando, Florida, on October 4.

2. LABORATORY TESTING

We prepared the third draft of ORNL/TM-11645, entitled, "Thermal Resistance of Polyisocyanurate Foam Board Insulation Blown with CFC-11 Substitutes - A Cooperative Industry/Government Project." Copies of draft three were distributed to the Project Steering Committee for their review and comments by November 1. The report abstract was sent to the BTESM mailing list to prepare a report distribution list. R. S. Graves presented a paper at the Polyurethanes '90 Conference that summarized testing of panels exposed in the Roof Thermal Research Apparatus (RTRA) and tests of thin specimens aging at 75°F and 150°F. These results and the ORNL results obtained from calculations using the MITB computer program for foam aging were presented to the Steering Committee. A subcommittee of the Steering Committee will meet in November to discuss development of foam aging models. The first draft of a proposed ASTM test procedure on thin specimen aging was discussed at the task group meeting of ASTM C 16.30 (Task Group 3.7). Comments are to be forwarded to A. O. Desjarlais, who will prepare a document for an ASTM C 16.30 ballot.

R. S. Graves made a presentation to ASTM C 16.30 entitled, "Interlaboratory Comparison of Four Heat Flow Meter Apparatuses on Planed Polyisocyanurate Boards Foamed with CFC-11." The participants discussed draft two of ORNL/TM-11720, and agreed to test planed specimens of greater thickness. Draft three of ORNL/TM-11720 is being prepared and will contain new values of thermal conductance. R. S. Graves prepared a presentation on foam aging for the November meeting of BTECC. We completed draft two of the paper on foam aging for the ASTM Symposium in October 1991.

Thermal conductivity tests were completed on the RTRA panels blown with 65/35 and 50/50 blends of HCFC-123/HCFC-141b. These panels have been exposed for approximately 10 months. The test results from the thin-heater apparatus and the heat flow meter apparatus agreed to better than 2% in the temperature range of overlap.

3. FIELD TESTING

An article on the CFC alternatives was published in Construction Specifier News in the November 1990 issue. A technical paper was presented at the Polyurethanes '90 Conference. This paper is available in the conference proceedings and in an SPI publication entitled, "CFCs & the Polyurethane Industry: Volume 3, 1990." A status report was presented to the Cooperative Industry/Government Project Steering Committee. Field data up to September 24 was presented. After 460 days since production, aging has clearly slowed on all test specimens. Several of the field samples are beginning to enter the transition zone from air component diffusion dominance to the more stable region when blowing agent diffusion or solubility begins to dominate any further thermal drift. Several of the full thickness 1.5 in. field samples are tracking the aging curve predicted by the accelerated slicing tests remarkably well. The blends have been pulled from the RTRA and laboratory tested for steady state k-value and to develop k-value vs temperature relationship needed to normalize field k-value data to that at 75°F. The blends have both been reinstalled in the RTRA. The 141b specimens have also been pulled from the RTRA. They are expected back from the laboratory on November 12, 1990. The CFC-11 and HCFC-123 specimens will also be checked in November.

The Cooperative Industry/Government Project Steering Committee formed a Task Force to (1) evaluate the data collected thus far on the existing set of experiments; (2) examine whether or not to modify any of the remaining work in light of findings to date; and (3) prepare a list of recommendations for Phase II. This task force will be headed by Bob Blanpied of Atlas Roofing. A meeting will be scheduled prior to the next steering committee meeting.

The Memorandum of Understanding on (MOU) Roofing Research at ORNL is now available for review. ORNL has reviewed it and has urged DOE to sign it. We understand that the EPA lawyers are "looking at it." Jean Lupinacci has urged the EPA lawyers to sign. PIMA has told us that they will not enter into a CRADA with ORNL until this MOU is signed. The PIMA CRADA is being "fast tracked." This being a new instrument for transferring money on cooperative projects, some growing pains are being experienced.

4. ROOF MECHANICAL PROPERTIES RESEARCH APPARATUS

The roof containing the five different polyisocyanurate insulation formulations was installed June 26-27, 1990. Three blisters have been previously noted on the roof platform. They have remained stable in size during October.

Site grading was completed. Work remaining to be accomplished includes the installation of the initial series of foundation experiments.

END

DATE FILMED

02 / 27 / 91