ORNL/TM-5515
(Addendum to ORNL/TM-5283)

Workshop on Technical Assessment of Industrial Thermal Insulation Materials—Summary

OAK RIDGE NATIONAL LABORATORY
OPERATED BY UNION CARBIDE CORPORATION FOR THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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METALS AND CERAMICS DIVISION

WORKSHOP ON TECHNICAL ASSESSMENT OF INDUSTRIAL THERMAL INSULATION MATERIALS — SUMMARY

S. Peterson, Editor

Prepared for
Division of Building and Industry,
Energy Research and Development Administration

JULY 1976

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
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UNION CARBIDE CORPORATION
for the
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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ABSTRACT

Over 80 participants representing 50 organizations met to discuss the report, *Industrial Thermal Insulation — An Assessment,* ORNL/TM-5283. Presentations on the performance of available materials, economic considerations, and measurement problems were followed by discussion. A final wrap-up session concluded that the report was valuable in pointing the direction for needed effort in the area, confirmed the indicated actions needed to further industrial application of insulation, and called for future meetings to continue the dialogue between the various facets of the industry.

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1. INTRODUCTION

The workshop whose proceedings are summarized here was held to provide a forum for a discussion of an assessment effort conducted by ORNL for the U.S. Energy Research and Development Administration and documented in *Industrial Thermal Insulation — An Assessment,* ORNL/TM-5283, by R. G. Donnelly, V. J. Tennery, D. L. McElroy, T. G. Godfrey, and J. O. Kolb. Following the study, which was conducted from September through December of 1975, the report was prepared and on March 2, 1976, was distributed to the industrial organizations providing input to the study as well as to other interested parties. This schedule provided those interested in attending the workshop on March 24 the time to study the report in advance.

The workshop, which was conducted in cooperation with ORNL's Office of Technology Utilization, was held to permit an on-the-spot critique of the assessment with participants representing insulation manufacturers, users, designers, specifiers, installers, measurement laboratories, and government. The agenda and list of attendees follow:

AGENDA

TECHNICAL ASSESSMENT OF INDUSTRIAL THERMAL INSULATION MATERIALS

Royal Scottish Inns, Oak Ridge, Tennessee
March 24, 1976

Morning Session — Chairman, R. G. DONNELLY

8:00 a.m.	Registration	
9:00	Call to Order	R. G. DONNELLY, ORNL
9:05	Welcome	M. W. ROSENTHAL, Associate Director, ORNL
9:15	Technology Utilization Opportunities at ORNL	M. E. KOONS, Executive Assistant to the President, UCC-ND
9:25	Sponsor Statement	R. W. ANDERSON, Division of Buildings and Industries, ERDA
9:35	Assessment Goals and Methodology	R. G. DONNELLY
9:45	Coffee Break	
10:00	Materials Assessment	V. J. TENNERY, ORNL
10:30	Discussion . . . . Leader	— W. C. TURNER III, Consultant
11:45	Lunch	

Afternoon Session — Chairman, T. G. GODFREY, ORNL

1:00 p.m.	Economic Considerations	J. O. KOLB, ORNL
1:30	Discussion . . . . Leader	— W. C. TURNER III
2:30	Coffee Break	
2:45	Thermal Properties Assessment	D. L. McELROY, ORNL
3:15	Discussion . . . . Leader	— R. P. TYE, Dynatech R/D Company
4:30	Wrap-Up . . . . Leader	— R. G. DONNELLY
5:00	Adjourn to Social Hour	

THERMAL INSULATION WORKSHOP

ATTENDEES

ERDA, Washington, D. C.

R. W. Anderson

CONSULTANTS

W. C. Turner III,
South Charleston, W. V.
Hayne Palmour III,
NC State University
Raleigh, N. C.

UCC-ND, Oak Ridge, Tenn.

C. J. Oen

ORGDP, Oak Ridge, Tenn.

G. L. Copeland

ERDA, Oak Ridge Operations, Tenn.

Lisbeth Sieberman, TIC

Y-12, Oak Ridge, Tenn.

John N. Turpin

ORNL, Oak Ridge, Tenn.

J. E. Cunningham
R. G. Donnelly
T. G. Godfrey
O. A. Kelly
J. O. Kolb
D. L. McElroy
C. J. McHargue
S. Peterson
M. W. Rosenthal
V. J. Tennery
T. N. Washburn
J. R. Weir, Jr.
K. A. Williamson

BABCOCK & WILCOX COMPANY

C. E. Zimmer, Lynchburg, Va.
L. C. Long, Augusta, Ga.
T. M. Sullivan, Alliance, Ohio

BADGER AMERICA, INC., Cambridge, Mass.

Thomas N. Stein

BATTELLE-COLUMBUS, Columbus, Ohio

M. Jack Snyder

BREEDING INSULATION, CO., INC.

D. M. Cherry, Nashville, Tenn.
R. J. Myers, Chattanooga, Tenn.

THE CELOTEX CORPORATION, Tampa, Fla.

K. W. Holm

CERTAIN-TEED PRODUCTS CORP.,
Valley Forge, Pa.

W. T. Irwin

DIAMOND POWER SPECIALTY CORP.,
Lancaster, Ohio

James Schorr

DUKE POWER COMPANY, Charlotte, N. C.

Joe B. Stringer

DYNATECH R/D CO., Cambridge, Mass.

R. P. Tye

EBASCO SERVICES, INC., Norcross, Ga.

B. R. Adyanthaya

EXXON RESEARCH AND ENG. CO.,
Florham Park, N. J.

James E. Mossberg

FEDERAL ENERGY ADMINISTRATION, Washington, D. C.

Stephen W. Snyder

FIBER MATERIALS, INC., Biddeford, Me.

J. D. Theis

FIBREBOARD CORP., Emeryville, Calif.

H. L. Weber

FORTY-EIGHT INSULATION, INC.

Richard Gamble, Aurora, Ill.
Mike Keith, Geneva, Ill.
Thomas G. Cudd, Birmingham, Ala.

HAMMERMILL PAPER CO., Erie, Pa.

Daniel N. Murray

HARBISON-WALKER REFRACTORIES, Pittsburgh, Pa.

G. Hugh Criss

ICI, Wilmington, Del.

Stuart P. Hepburn

INTERNATIONAL VERMICULITE CO., Girard, Ill.

Max N. Orr

JOHNS-MANVILLE

C. M. Pelanne, Denver, Colo.
Larry R. White, Denver, Colo.
L. D. Sorrentino, Arlington, Va.
John Houston, Knoxville, Tenn.
Ms. L. J. North, Knoxville, Tenn.

MOBAY CHEMICAL CORP., Pittsburgh, Pa.

Donald Durdan
James Orefice
K. A. Pigott

MONSANTO COMPANY, St. Louis, Mo.

Kenneth L. McHugh
T. F. Stanley

NATIONAL BUREAU OF STANDARDS

Richard K. Kirby, Washington, D. C.

NATIONAL MINERAL WOOL CO., Summit, N. J.

Sheldon Cady

NEW ENGLAND INSULATION CO.

D. M. Coffin, Canton, Mass.
H. Alemazkoor, Norfolk, Mass.

NORTH BROTHERS COMPANY, Knoxville, Tenn.

Robert W. Smith

OWENS-CORNING FIBERGLAS

S. K. Heard, Jr., Washington, D. C.
F. C. Wilson, Granville, Ohio
Richard Hite, Toledo, Ohio
Wayne Haugen, Toledo, Ohio

PHILLIPS PETROLEUM CO., Bartlesville, Okla.

Walt W. Heinrich

PITTSBURGH-CORNING CORP., Pittsburgh, Pa.

R. W. Gerrish
C. P. Smolenski

REFRACTORIES RESEARCH CENTER, Columbus, Ohio

C. E. Semler

REFRIGERATOR SERVICES CO., Oak Ridge, Tenn.

Kenneth M. Davis

ROCKWOOL INDUSTRIES, Denver, Colo.

Stan Matthews

ROCKWOOL MANUFACTURING CO., Leeds, Ala.

E. F. Cusick, Jr.

SPRAYCRAFT CORP. Brooklyn, N. Y.

Paul S. Maco

TENNESSEE TECHNOLOGICAL UNIVERSITY, Cookeville, Tenn.

Charles J. Golden

TENNESSEE VALLEY AUTHORITY, Knoxville, Tenn.

Carl L. Mills

TEXACO, INC., Houston, Tex.

Kenneth E. Fonte

UNITED STATES GYPSUM COMPANY, Chicago, Ill.

John D. Ueber

UNION CARBIDE-TECH CENTER, S. Charleston, W. V.

E. C. Powell, Jr.

VIMASCO CORP., Nitro, W. V.

B. H. Duncan
J. W. Johnson

JIM WALTERS RESEARCH CORP.,

A. R. Koenig

YORK RESEARCH CORP., Stamford, Conn.

Robert Curt
Robert D. Rinehart

ZIRCAR PRODUCTS, INC., Florida, N. Y.

B. H. Hamling

2. INTRODUCTORY PRESENTATIONS

In his remarks of welcome on behalf of ORNL, Murray Rosenthal, Associate Director for Advanced Energy Systems, emphasized the breadth of interests in ORNL's programs. Although the major mission remains the development of nuclear energy, the Laboratory has for several years had programs on health, ecology, conservation, and nonnuclear energy, and the extent and diversity of these programs are increasing, particularly in coal technology and energy conservation. Rosenthal concluded with an appeal for frank contributions from the visitors.

Carol Oen, Technology Utilization Officer at ORNL, substituting for M. E. Koons, presented a brief but encouraging invitation to the industrial representatives to examine and hopefully take advantage of Government-developed technology. She pointed out ERDA's increased program of technology transfer and noted that this workshop was a first in obtaining a critique of an ORNL-conducted assessment.

The sponsor's statement, presented by R. W. Anderson of ERDA, started with words of welcome and appreciation for participation and interest. His main point was that conservation is being given high priority by ERDA, particularly for the immediate term. The report shows an immediate possibility of saving the equivalent of two to four million barrels of oil per day by increased and more effective industrial use of insulation. The study is a first step toward overcoming the various barriers to greater energy conservation in the industrial sector. ERDA is interested in overcoming these barriers.

Ralph Donnelly, chairman of the ORNL study group, reviewed the goals and objectives sought and the sources and methods used, as outlined in the introduction to the report. Three main goals of the study were to (1) identify the industrial energy savings potential of thermal insulation, (2) assess the status of industrial insulation technology, and (3) identify the areas requiring additional research and development.

3. MATERIALS ASSESSMENT

3.1 Presentation by V. J. Tennery

In his remarks of appreciation for industrial input to the study, Tennery singled out the three trade associations as being a key to other sources:

National Mineral Wool Insulation Association
The Refractories Institute
Thermal Insulation Manufacturer's Association.

The maximum surface temperature for possible personnel contact is not an OSHA standard, as stated in the report on page 38, but is a guideline in selected industries. A similar Underwriters' standard is pending.

In his presentation of insulation materials following Table 3.1, page 12 of the report, Tennery singled out a few types for which particular concern had been expressed. Shortcomings of *organic foams* are their combustibility, vapor toxicity, permeability to water vapor and the inadequacy of the barriers used to protect them. *Calcium silicate* is important because of its wide use on steam lines, which are widely used in industrial plants for energy transport. Recent calcium silicate insulation is mechanically inferior to products made before the ban on asbestos. *Foam glass* is favored over other massive insulation for low-temperature use if the joint design is good enough to prevent penetration of water vapor. *Firebrick* is more difficult to get except in the higher temperature grades, and these are more heat conducting than brick that would be satisfactory in applications at less extreme temperatures. Despite premium prices, the *evacuated cryogenic insulation* systems that are designed and built for a prescribed performance are well thought of by many industrial users. The technology upon which these systems are based was developed in the space program, and the lack of comparable Federal development support is blamed for the lack of use of the designed systems approach in other areas of insulation application. *Ceramic fiber insulations* are attracting great interest for high-temperature applications. Despite sparse data, new alumina and zirconia fiber products appear to have superior properties to previously available aluminosilicate fiber products. Perhaps a government-sponsored demonstration of their performance would be valuable.

Many other properties from the list in Table 3.2 of ORNL/TM-5283 are often overriding compared with thermal conductance in many applications. For example, in the organic chemical processing industry, properties related to flammability are important. The need appears to be for systems with guaranteed performance; this includes supports, jackets, mastics, etc.

Tables 3.3 and 3.4 (pages 23 and 24 of the report) were explained to present the potential for energy conservation. One area where other considerations thwart heat conservation is in very high-temperature furnaces that contain molten metals or glass. Insulation would raise the wall temperatures and drastically reduce the furnace lining life.

Tennery used the information in Table 3.4 to assess the immediate-term savings in the energy-intensive industries. He noted that feedstock energy for the chemical industry was not included; in previous tables it had been. About 8.5% of the total process energy is the total savings estimated from the assumption of 10% fuel saving in direct fired processes by better use of insulation. This amounts to potential savings of about $3 billion, half in steam distribution. Credit for much of this information was given to a previous study by the Dow Chemical Company.[1]

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[1]J. T. Reding and B. P. Shepard, *Energy Consumption: The Primary Metals and Petroleum Industries*, Dow Chemical Company, PB-241-990 EPA 650/2-75-032-b (April 1975); ibid: *The Chemical Industry*, Dow Chemical Company, EPA-650/2-75-032-a (April 1975); ibid: *Paper, Stone, Clay, Glass, Concrete and Food Industries*, Dow Chemical Company, EPA-650/2-75-032-c (April 1975); ibid: *Fuel Utilization and Conservation in Industry*, Dow Chemical Company, EPA-650/2-75-032-d (August 1975).

Insulation system performance measurements are not available. Apparently systems are overdesigned to ensure or prolong satisfactory performance. Certification of installers should be considered, although how to do it is not clear. Capital for insulation installation is apparently lacking despite excellent prospects for return of investment. Permeation of barriers by vapors in low-temperature insulation systems can result in serious undetected degradation.

3.2 Discussion led by W. C. Turner

The need for a way to measure insulation performance as installed was raised again by an installation contractor. One user tried using steam flow meters; results were enlightening but not highly satisfactory. The problem has been discussed in the ASTM, and it appears that a combined effort of user, manufacturer, and installer is needed. Available properties of insulation, while meaningful, are idealized and difficult to use to predict performance. ERDA could help provide a clearing house where small manufacturers and contractors could have access to expertise now available only to large companies.

Dimensional tolerance problems were pointed out. Changes in pipe sizes have contributed to this problem. Also, larger shrinkage and expansion of the insulations are leading to gaps in them; multilayer applications are necessary to avoid large heat losses through these gaps.

The lack of installation contractor input to the report was pointed out. Another item not covered was the subject of mastics and barriers used in insulation systems. Also underground heat distribution systems were not included in the report.

Legislation on Federal loan guarantees for installation was reported to be under consideration. Some users believe rapid write-offs would be better.

The question was raised as to the energy required to produce the insulation used to save energy. A manufacturer cited a saving of 40 to 200 Btu/year per Btu consumed in manufacture of industrial insulation, based on an association study for the FEA. Another cited a similar savings factor of 20 for residential use.

Another question raised concerned design methods criteria and property codes analogous to the *ASME Piping and Pressure Vessel Code*. The National Insulation Contractors Association works closely with TIMA on studies related to this. Some local application manuals exist, for example in the Boston area. Canadian recommendations for building insulation exist. More coordination between applicators, users, etc. is needed. Techniques for evaluating applicators are varied. Architect-engineers normally write specifications and try to be selective. Supervision of installation is varied depending on the personnel available. Examples were cited in which wrong mastics and vapor barriers were specified, and the applicator, despite knowing better, had to follow the specification.

Some discussion was concerned with applications by the power generating companies. This was not included in the tabulations, but some interest was found as energy conservation directly increases the product output. Sometimes increasing the insulation is hampered by existing designs, such as restricted spacings in piping systems.

The report had indicated a feeling that insulation manufacturers were witholding more favorable products pending more favorable demand. A user representative said that "industry would beat their doors down" if the manufacturers could provide insulation that would give the same heat loss with less thickness.

Examples were given of successful applications of insulation to a number of processing systems. In one case, installing fiber in a ceramic kiln not only gave the predicted energy saving but so increased the uniformity and quality of the product that production was substantially increased. Optimization of the process and energy use together thus can lead to more savings than just that in fuel.

Some discussion concerned the ability of the manufacturer, installer, and architect-engineer to come up with quality systems, only to have cost cutting by the user lead to an inferior system and low quality. One user reported a contrasting example: this company last year had two major insulation installations. Most of the contractors that had been interested at first dropped out when the user insisted on performance guarantees. Eventually a contract was reached in which the user got his guarantees, but at a higher cost than initially planned. Discussion later in the meeting brought out that these installations are in a location frequently subjected to rather adverse weather and that considerable negotiation on specifications between user and contractor preceded the actual installation.

4. ECONOMIC CONSIDERATIONS

4.1 Presentation by J. O. Kolb

Kolb introduced the economic survey with a listing of three purposes:

1. assess investment analysis methods used for insulation,
2. determine economic criteria currently used, and
3. evaluate effects of degraded performance on insulation economic value.

Much of his investment analysis presentation centered about the left drawing of Fig. 4.1 on page 48 of the report, which schematically illustrates the balance of insulation cost against the value of energy saved. Kolb discussed the investment analysis methods and economic criteria used by industry, essentially as presented in Chapter 4 of the report. He cited a related study[2] by York Research Corporation for FEA. The lack of capital was pointed out as a serious restraint. He concluded with these recommendations:

1. Discounted cash-flow investment analysis should be included in evaluations of insulation thickness.
2. ERDA should encourage economic analysis of insulation investment to (a) establish sensitivity to cost factors and (b) validate through case studies.
3. Economic incentives should be considered to promote increased insulation use:

   (a) accelerated tax write-off of investment
   (b) low-interest-rate loans.

4.2 Discussion led by W. C. Turner

The economic feasibility of potential energy savings discussed earlier was questioned. The discussion centered around Fig. 4.1 of the

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[2] R. D. Rinehart, J. Coyne, and J. Hoffbauer, *Final Report FEA Contract No. Co-04-50169-00 Economic Thickness for Industrial Insulation*, York Research Corp. Report 2=8755.

report. The figure was criticized as inaccurate and not representative of current computerized methods of economic analysis; yet there was essential agreement that it is a good qualitative representation. Turner claimed responsibility for the much-used graph and explained that the last half inch of the indicated optimum thickness corresponds to a 20% return on investment, and the prior increments correspond to a much greater return. The representation of the insulation cost as linear with thickness is admittedly a simplification; the correct curve would be steeper for low and high thicknesses. The minimum in the cost curve is broad. The discussion cited one study that included the depreciation period as a variable and showed that the optimum thickness was not affected by cost of money in the range 10 to 50%. The consensus reached was that most of the technically feasible energy savings were possible with a 30 to 50% return. Another point made was that in fuel-short areas, regardless of return on investment, the energy savings could be necessary to avoid a plant shutdown from fuel shortage.

Kolb's statement in connection with effects of degraded performance, "Increased conductance increases economic thickness," was questioned as illogical. Several individuals tried with graphical, numerical, and verbal arguments to clarify the statement. A York Research Corporation representative was asked to comment on the basis of York's recent study for the FEA; the response was that increased conductance does indeed increase the calculated economic thickness of insulation.

A view was expressed recommending computer input rather than handbook type tables as in RECON. The new study by York Research takes into account more of the known complexities, but it still is unable to consider the variation in the value of heat with quality (such as steam at different temperatures and pressures).

A question was raised on whether economic analyses include the possibility of catastrophic loss of insulation quality in service. The solution appears to be to factor a statistically probable lifetime into the analysis. An example given was a possible penetration of the 4-mil coating on polyurethane insulation. A manufacturer pointed out the present practice calls for 20 to 40 mils of a very high-quality coating.

5. THERMAL PROPERTIES ASSESSMENT

5.1 Presentation by D. L. McElroy

The presentation was a condensation of Chapter 5 of the report and related appendices. First McElroy described ASTM activities in this area, essentially abstracted from section 5.2 of the report. Then he described the guarded hot plate (ASTM C 177-71) and heat flow meter (ASTM C 518-70) methods. Most of the information on these methods is reported in the ASTM symposia described in Appendix B of the report. A noteworthy example is the 1951 round robin comparison of 20 guarded hot plates on 1-in.-thick corkboard. In the 1973 symposium the ASTM Committee C-16 opined that the measurement methods seldom give values of true thermal conductivity, and the results are better reported as thermal conductance. The ASTM equipment survey showed considerable capacity for measurement, but reference materials are lacking.

McElroy presented information on sources of thermal property data, a comparison of thermal conductivity as a function of temperature for many materials (Fig. 5.3 of the report), and mechanisms of heat transport (as covered in Appendix F of the report and illustrated by Fig. F-8). He listed the following major concerns in the area of thermal property measurement:

1. Measurement quality is questionable because methods can be misapplied.

2. Realistic data are often not available.

3. Applicability of methods can be questioned because of such effects as in-service pickup of water and use of nonrepresentative samples.

4. Specification is needed for the performance of measurements.

5. High-temperature data require difficult tests, and the results are less than ideal.

6. Round-robin tests are needed to increase validity of data.

7. ASTM subcommittees C-8.04 and C-16.30 differences are delaying measurements on refractory fiber blankets to high temperatures.

8. Magnitudes of property changes are unknown.

9. Conductance rather than conductivity is the property to be measured.

10. Heat transmission data are needed.

11. As one goes from materials to subassemblies to field installations the data become scarcer; cross communication is needed between those concerned with these areas.

McElroy presented the conclusions:

1. Lack of publication and information feedback limits effective use of knowledge.

2. The ASTM insulation activities are very valuable.

3. Tests are costly but very important.

4. Standards to evaluate methods are lacking.

5. Data extrapolation from thin samples to actual systems is of concern.

6. Proper application of techniques is not enforced.

7. No single unbiased data source exists; few repeated measurements are available.

8. Mechanistic studies are lacking.

9. Tests of in-service variables are lacking.

He recommended the following:

1. Develop realistic tests to obtain results on current insulations, develop standards, evaluate variations in insulations, define product variability, improve material specifications, increase mechanism understanding;
2. Perform field tests to evaluate installation variables;
3. Create an information center to critically evaluate property data.

5.2 Discussion Led by R. P. Tye

A representative of the chemical processing industry remarked that in analogy to the need for in-service measurement of insulation performance, a need exists for measurement of properties of materials in process. Starting materials and products can be measured, but properties of materials in process are unknown. Perhaps when one of these problems gets solved, the solution will help with the other.

Before any further discussion from the floor, Tye presented some of his own remarks. He pointed out that action was under way on several questions McElroy had raised, and that he felt he could in some cases contribute to the definition or solution of the problems presented. His position as chairman of the ASTM subcommittee C-16.30 on Thermal Properties enabled his remarks, which centered on ASTM activities.

He cited an additional round robin — the Institut International du Froid (international Institute of Refrigeration) study in 1967 on the National Physical Laboratory (British) fiber glass. It showed reasonably good agreement at room temperature between most measurements, but wide divergence was seen in the temperature dependences.

Tye presented an explanation of the ASTM committees, particularly subcommittee C-16.30, and invited those present to join. Initially interest in and capability of thermal property measurement was limited to room temperature. Increasing industrial application has extended the temperature range of interest. Changes under way in ASTM Standard C-177 are more philosophical than technical, principally eliminating the idea of thermal conductivity. The idea is that measuring conditions should better approximate conditions of use. Foreign standards are often restricted to small temperature gradients (0.3 K/mm), which are better for conductivity measurement but poorer for performance measurement (20 K/mm). Tye cited a need for international standards, and announced that he and some colleagues would be attending a meeting in Stockholm in April to start this. This was the meeting of the International Standards Organization, April 5—7, 1976, and the other attenders from the U.S. were F. Powell of the National Bureau of Standards, F. Wilson of Owens-Corning, F. Govan of York Research, and J. Barnhart of TIMA.

Tye cited that the main virtue of the report under discussion is that it is a first step in getting people to realize what needs to be done in the difficult problem of thermal property measurement. Much work is buried in company archives. Proprietary considerations prevent release in many cases.

The basic measurement standards are in pretty good shape; if used correctly they can give good results over a pretty wide temperature range. Reference materials are needed for any improvement.

Another problem discussed was the measurement of systems rather than materials. Such work is just getting started. It requires going up in size and complexity. Standardizing such measurements is hampered by the lack of equipment to perform them. The guarded hot box is a sort of system tester, although it applies more to building insulation than to industrial insulation. It needs drastic revision. Some question how we can evaluate systems when materials are not well understood. The calibrated hot box under development will be an important advance, allowing examination of moisture and air infiltration effects. Moisture, both vapor and impingement, are ever-present problems. Mastics and vapor barriers are important parts of the system.

ASTM Committee C-16 wants accreditation for measurement laboratories, and in preparation it is doing another equipment survey. Such accreditation is impossible without standard reference materials, and these do not exist. Their development has first priority. The National Bureau of Standards is expected to and should take a lead in this development. Suitable materials for the purpose are available, and a lot of careful measurement is needed to make them into reference standards. This should require about a year.

Another activity of the ASTM C-16.30 committee is, in conjunction with a committee on building construction, looking into a measurement of heat transmission along with infiltration of moisture and air.

Another deals with dynamic methods, aimed at field testing. A transportable hot box exists, but it is expensive and little in demand, perhaps ahead of its time. The infrared camera is useful but only qualitative. It needs to be used in conjunction with other methods. Patterns shown by typical flaws should be collected for comparison with actual installations.

Tye concluded by repeating his call for more participation in ASTM committee work and by repeating his evaluation of the ORNL report that it "points us in certain very necessary directions." He then reopened the discussion.

A question came up on specifications on refractory blanket insulation. A new specification is in preparation. The present specification allows the use of either ASTM C 177 or ASTM C 201. For lower conductance, C 201 needs modification. It was originally developed for high-conductivity materials. Development of standards, as it is done by voluntary committees, is necessarily a slow process, and speeding it up is expensive.

The discussion questioned a research firm's service on surveys with an infrared camera. The firm's representative revealed that the service had been contemplated but abandoned because of poor demand. One user's experience was that the infrared camera showed faults in the installation, such as poor joints. Further discussion confirmed Tye's conclusion that the method can be valuable but is subject to much uncertainty if used alone.

A Battelle representative reported a similar but shorter study[3] for the same sponsor on building insulation. Conclusions were similar:

> The major conclusion of the study is that very little information is available to accurately predict the in-service behavior of building-insulation materials. The greatest needs exist in this area. There is a lack of adequate test methods and laboratory facilities for conducting such evaluations. The limited information gathered indicates that facilities are needed for evaluating both existing and new insulation materials.

In connection with discussion on the prospects for field testing, Tye pointed that there is nothing in ASTM C 177 to require dry samples or 1-in. (25-mm) samples. One person reported a laboratory simulation of operating conditions on a segment of Alaska pipeline. He pointed out the greater ease of testing effects of system alterations in the laboratory than in the field. A consultant suggested use of existing instrumentation, such as steam meters, to determine insulation performance from a heat balance. The high cost of system or field testing was pointed out, but a high value was also put on the energy savings.

In answer to a question on high-temperature capabilities of instruments, Tye indicated the existence of two guarded hot plates capable of 1500°C (hot face). This limit is one reason for going to

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[3]J. R. Schorr, *Summary Report on Identification of Problem Areas Associated with Building-Insulation Materials to Energy Research and Development Administration ERDA*, Battelle Columbus Laboratories, Columbus, Ohio, Oct. 17, 1975.

the ASTM C 201 method for refractory blankets. The line source method can go higher and is simple, but it sometimes gives poor results. Laser flash methods are inadequate because of the low density of insulation.

Data on insulation were said to be often inadequate for design. Rather than typical, data presented by manufacturers are often biased for favorable conditions.

An installation contractor commented on the desirability of performance contracts. He pointed out the effects of uncertain material properties, unfavorable installation conditions, lack of manufacturers' instructions for installation, and haste demanded by the customer as contributing to uncertainty in performance. He questioned whether the responsibility for performance should be on the manufacurer, installer, designer, or user. A design engineer employed by a user bases his designs on his knowledge and experience. He selects suppliers and contractors and holds the contractor responsible only for following his specifications, and then he assumes responsibility if the system fails. His opinion was that the user should assume responsibility. He pointed out that heat balances may not give a good measure of performance because pumps and other system components may be degraded in performance. In one case, ammonia barges were reaching port very seriously overheated, and the blame was put on the insulation. The problem was finally traced to a faulty compressor. A manufacturer of high-temperature insulation explained the difficulty in guaranteeing performance because of uncertainties in installation and use. An installer cited an example of a utility preparing very strict specifications for insulation, insisting on a guaranteed performance, spending millions of dollars, and then having inferior fireproofing installed to save $50,000. Another user-employed designer agreed that it was his responsibility to design for required performance and the contractor was responsible only for following specifications. However, he added that another requirement for a proper installation is constant inspection by the customer; the quality of the construction reflects the quality of the inspection. A shortage of qualified inspectors restricts the ultimate performance.

Other factors pointed out as affecting performance of an insulation system were the lack of maintenance and the low quality of installation labor — workmanship has degraded greatly in the last ten years despite a tripling in cost.

A measurement expert pointed out that measurements of apparent conductivity on mineral wool from many manufacturers all fell in a narrow band as a function of density and temperature. However, one unnamed manufacturer consistently reported substantially lower values. Yet when his product was measured in the same laboratory the values fell in the same band with the other similar materials. His reported values could be brought into agreement if. on his specification sheets, the words "mean temperature" were changed to "hot face temperature."

Another example from the same man dealt with the thermal conductivity of concrete. In the guarded hot plate apparatus when used on samples having as high conductance as concrete, most of the thermal resistance is at the interface between the sample and the plates, so the measuring thermocouples should be on the sample rather than on the plates. The measurements gave conductivities higher than usually reported, particularly for the more conducting denser concretes, when the temperature gradient was measured in the sample. Traditional values were obtained if the plate temperatures were used in the conductivity calculation.

A representative from the National Bureau of Standards explained the bureau's procedures for adopting reference materials. Three levels exist: (1) Standard Reference Material (SRM) quality, (2) Research Materials (not certified), and (3) General Materials (handled by NBS as a disinterested third party). With sufficient information a material can advance from level (3) to (1).

A consultant brought out that properties (not only thermal) need to be known for the use temperature. Another person pointed out the need for extensive mechanical and physical data, much nonexistent, for design calculations.

6. WRAP-UP SESSION

Several of the participants offered statements summarizing the principal conclusions coming out of the meeting.

Several points involved the measurement area. Three interrelated needs are for accreditation of laboratories, for reference materials, and for further round robins. Direct contact with the Department of Commerce was suggested to accelerate accreditation actions. To expedite accreditation and reference material development, priority should be given to the temperature range from liquid nitrogen to 1000°C. Min-K materials should make suitable reference materials. A means is needed to distinguish reliable testing laboratories from nonreliable ones. Participation in round robins should be forced. Better international communication is also needed; the Stockholm meeting should provide a start. Finally, methods are needed for systems measurements. The size and complexity of such measurements will make them expensive, perhaps too expensive to undertake, despite an urgent need. This might be an area where ERDA support would be valuable.

One materials question raised was in an area not covered by the report: mastics and vapor barriers. These should be studied as well as the insulation materials. Also, the availability of advanced materials was brought up; if available they would be much in demand, but what would they cost? Some of the better materials are a compromise between performance and cost. Another materials problem, which is related to measurement problems, is the variability of properties of nominally one material.

Economic problems were also cited. The present business climate discourages investment; capital where available is needed elsewhere. Also, uncertainty about government actions inhibits investment. Government inducements would be helpful.

The most frequent conclusion was that a meeting like this is a valuable confrontation of the different parties interested in insulation and such a meeting should be repeated, possibly in about two years, with greater participation by contractors and specifying engineers. Possible subjects for future meetings would be interim progress reports and presentation of industrial test cases showing energy conservation. On the subject of meetings, Tye announced that another ASTM symposium would probably be held in 1977.

7. FOLLOW-UP LETTERS

Two participants, one manufacturer and one consultant, responded to the invitation to send letters to be summarized in this report. Summaries of these letters follow.

7.1 Letter from Manufacturer

The Manager of Technical Services of an insulation manufacturer offered his comments on the subject of performance specifications. He essentially outlined the responsibilities of the owner, designer, contractor, and component supplier. Essentially, the owner-designer team should specify the materials and installation to give the required performance, and provide inspection to ensure adherence to specifications. The installation contractor and the supplier should be responsible for providing workmanship and materials to meet these specifications. Although better knowledge of the rates and mechanisms of heat transfer through insulation materials is desirable, the main key to better performance is design of the system for energy conservation. Reiterating the importance of components other than the insulation, the writer expresses the following belief:

> I have an unsubstantiated conviction that energy losses through supports, attachments, open joints at fittings, etc. due to pipe or equipment expansion, and workmanship are presently the major contributors to the stated difference between systems operation and the "theoretical" value attributed to the advice of insulation manufacturers. Perhaps too little attention is being paid to the heat transfer in parallel heat flow conditions found in actual service design and construction. When these parallel heat transfer paths are in the system, then first priority should be to reduce the heat transfer through them. Then, differences within the insulation materials may be the critical item to receive attention.

He lists the following steps toward "successful performance of the 'insulation system'":

1. Attention to details on all heat transfer paths within the system.
2. Attention to details on all factors that could lead to performance degradation in the intended service.

3. Choice of suitable components to meet the performance requirements. This includes much more than the type and thickness of the thermal insulation.
4. Preparation of the job specification, which not only calls out the components, but how these components are to be combined within the system without ambiguities or omissions.
5. Attention to detail during installation that the components are properly installed with the required levels of workmanship.
6. Attention to detail (after installation) that the system is operated within the boundaries of the design.
7. Attention to detail (after installation and during service) that the system is maintained to assure proper operation and service life.

7.2 Letter from Consultant

The consultant presented feelings expressed by several participants that he interviewed after the meeting as well as his own. Principal shortcomings of the report expressed by the interviewees were lack of presentations on overall systems, materials other than insulation, and studies on correct testing methods. The consultant noted that the scope of the study precluded their inclusion. All agreed that the meeting was excellent but attendance should have been broader: more contractors and consumers, unions, and management of manufacturers and large users. The investigation should continue. In general, the report and meeting served to point out the ills of the industry and are essential to the start of progressive action.