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Problems Associated with the Use of Urea-Formaldehyde Foam for Residential Insulation

Part IV: The Relevance of Materials Standards to Problems Associated with the Use of Urea-Formaldehyde Foam Insulation

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Part of
The National Program
for
Building Thermal Envelope Systems
and Insulating Materials

Prepared for the
U.S. Department of Energy
Conservation and Solar Energy
Office of Buildings and Community Systems
Buildings Division

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5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A02; Microfiche A01

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ORNL/SUB-7559/4

Contract No. W-7405-eng-26

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FOAM FOR RESIDENTIAL INSULATION

Part IV: The Relevance of Materials Standards to Problems Associated
with the Use of Urea-formaldehyde Foam Insulation

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Under Subcontract 7559

Part of
The National Program for
Building Thermal Envelope Systems and Insulating Materials

Research sponsored by the Office of Buildings and
Community Systems, Buildings Division
U.S. Department of Energy

Date Published - February 1981

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FOREWORD

This is one of a series of reports to be published describing research, development, and demonstration activities in support of the National Program for Building Thermal Envelope Systems and Insulating Materials. The National Program involves several federal agencies and many other organizations in the public and private sectors who are addressing the national objective of decreasing energy wastes in the heating and cooling of buildings. Results described in this report are part of the National Program through delegation of management responsibilities for the DOE lead role to the Oak Ridge National Laboratory.

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THE RELEVANCE OF MATERIALS STANDARDS TO PROBLEMS ASSOCIATED WITH THE USE OF UREA-FORMALDEHYDE FOAM INSULATION

Urea-formaldehyde foamed-in-place insulation is not a recent material arising from public concern for energy conservation in family dwellings. Foam insulation products were introduced to the American public in the early nineteen fifties and for the past several years have enjoyed a growing popularity. The popularity has not been without its problems. With the increase in usage there has been an attendant increase in odor and health problems attributed to the presence of formaldehyde.

The insulation industry is essentially self-regulated. Therefore, the question arises as to whether or not increased public regulation would be effective in controlling problems associated with the use of urea-formaldehyde foam as residential insulation. This paper discusses the relevancy of public regulation to controlling problems such as off-gassing of formaldehyde associated with the use of urea-formaldehyde foam products through the introduction of materials standards and quality assurance of manufacture and installation. For convenience and clarity one may divide the use of urea-formaldehyde insulation into three phases: The first of these being manufacture, the second being installation and the third being the behavioral phase.

The relevance of materials standards and quality assurance for each of these phases will be discussed in some detail. The first of these to be discussed is the manufacturing phase. Urea-formaldehyde foams are prepared from an aqueous solution of urea-formaldehyde resin and a foaming agent (surfactant). An acid catalyst (mineral acid) is employed to hasten the polymerization process and for curing the foam. The resin is usually formed from a mole ratio of 1:1.16 to 1:2 urea to formaldehyde. This solution is refluxed at pH 5-6 and to 80° to 100°C which causes the formation of methylolureas and methyleneureas. After neutralization at pH 7-9, the resin solution is dehydrated to a resin solids content of 50 to 70 percent in which state it may be stored for months at room temperature. Frequently additives are employed to provide for certain desired characteristics in relation to reduction of friability, improved structural integrity, to control moisture absorption and to block the off-gassing of formaldehyde. These additives include a variety of substances and vary greatly among proprietary products. Among these additives are various plasticizers, polyethylene glycols and glycolaldehydes, emulsions of acrylic resins and a variety of phenols and higher alcohols (1).

There are a number of reasons that argue for manufacturing control of the product. Inconsistencies in the manufacturing process that need control include but are not limited to variations in formulation during preparation and use of improperly aged materials.

The former includes such things as follows (2):

- o raw material quality (e.g. methanol content of formaldehyde, chemical grade of urea)
- o formaldehyde:urea molar ratio
- o batch vs continuous production
- o temperature of reaction stages
- o pH of reaction stages
- o type(s) of catalyst
- o concentration of catalyst
- o time of reaction stages
- o method and limit of endpoint
- o staging of the addition of raw materials
- o extent of evaporation, time and temperature
- o solids content
- o additives

The relationship of the factors in this list to quality assurance and materials standards is readily seen. What is not so clear is the role of product standards in relationship to the various additives that are determined on a proprietary basis. There is no question that there is a need for standardization among foam insulation products. The question reduces to how far should materials and product standards go and just what should they include. No doubt the factors listed above can and should be included in quality assurance standards. Until now at least the extent and enforcement of any quality assurance standard where they exist have been self-regulated by the industry with a resultant lack of uniformity in quality of product. The present state of the art argues for public control with respect to materials standards and quality assurance of installation of these products.

The following concept for manufacturing control of urea-formaldehyde foam insulation products is suggested from comments made by the National Bureau of Standards (3), quality assurance programs in use in other countries and inferences gathered from a variety of research reports and consultations with foam manufacturers and contractors. All companies marketing urea-formaldehyde foam insulation products be registered with a federal agency, e.g., Department of Energy, Department of Housing and Urban Development, etc. and this registration be predicated upon compliance with certain requirements. These requirements should include materials standards and adherence to a rigidly controlled quality assurance program for manufactured products. Such quality assurance programs should be approved by the agency as meeting quality assurance guidelines established for the industry. Additionally manufacturers should maintain records of quality assurance of manufacture which would

be open to inspection by the registering agency or their authorized representatives.

Factors relating to manufacture that are considered to affect the performance of urea-formaldehyde foamed-in-place insulation products that should be covered by materials standards include the following:

Cell structure	Mechanical properties
Cell content	Mold and vermin resistance
Wet and dry density	Odor
Dimensional stability	Free formaldehyde content
Durability	Methylol content
Electrical properties	Photodegradation
Corrosivity	Temperature and humidity stability
Thermal resistance	Water absorption
Combustibility	Water vapor transmission
Flame spread	Friability
Toxicity	Freeze and thaw resistance

There are a number of reasons for such control. The curing of the foam is dependent upon several factors inherent in the resin. These include the degree of condensation reflected in the amounts of methylol and methylene ureas, buffering effect of the surfactants and the pH. Surfactants normally employed include alkyl aryl sulfonate and alkyl naphthalene sulfonate. Rigid control of these relationships within a product line can assure a quality outcome. Public policy in the form of quality assurance of manufacture should require that manufacturers engage in such a program. Records of these quality assurance checks should be made available for inspection. Due to the nature of the product and the possible bearing on the evolution of formaldehyde, manufacturers should be required to list the ingredients on the label. Therefore, a labelling requirement should be instigated. Resin labels should also include a batch number, date of manufacture, inclusive dates for usage, physico-chemical measurements including free formaldehyde, methylol, methylene, methylene ether, methoxy and carbonyl carbon content as well as pH, viscosity and specific gravity.

While quality assurance as evidenced by labelling information will have some affect on the evolution of formaldehyde, it is no guarantee

that problems will not occur. Materials standards with respect to performance subscribed to by the manufacturer along with adherence to quality assurance of raw materials will have an impact on the evolution of formaldehyde and shrinkage but will have maximum impact only if coupled to the installation and behavioral phases. If one could exert rigid control over all three phases at the same time one can conceptualize a lessening of odor and shrinkage problems and a better performance by the product.

Phase two of the U-F use cycle is the installation phase which has a bearing on the formaldehyde issue but in a different context than that afforded by the manufacturing process. The urea-formaldehyde foam insulation product is unique among insulation materials. It simply does not exist as a shelf product as do other materials such as fiber glass, cellulose, etc. Because of this uniqueness it is extremely difficult to conceive why materials standards such as thermal efficiency, permeance, formaldehyde emission, corrosivity and water absorption, etc. established on a prototype product could be meaningful if a new product is created each time for installation in a structure. The only possible way there can be any relevance of materials standards to the application phase would be to develop a very rigidly controlled installation quality assurance program for applicators.

One may certainly question whether one could develop an installation quality assurance program of sufficient rigidity to permit the necessary control and yet be flexible enough for practicality. Such an assurance program would require certification of contractors and installers by a public agency rather than by industry. Such a certification program should require the successful completion of a competency examination that ideally would be administered at no greater intervals than 2 years. Those holding certificates should be required to take prescribed refresher courses at least twice during the two year interval.

A training program for certification of installers has been proposed by the National Association of Urea-Formaldehyde Foam Insulation Manufacturers (4). This suggested training program includes the principles of heat transfer and thermal insulations as well as chemical, physical, mechanical and thermal properties of foam insulation. Also included are manufacture and composition, chemical reactions and field manufacture of the foam. The course should also include a briefing on shrinkage, formaldehyde release, density relationships and factors affecting drying. The training program should provide in depth instruction on installation procedures with respect to review of construction types, vapor barriers and venting. Instruction should be provided on proper fill techniques for various types of construction. Instruction should include proper use, care and cleaning of application equipment, use of manufacturers certified equipment and the use of ratio monitoring devices. Additionally the program should include instruction on proper record keeping, disclosure statements and post installation follow-up inspections.

Ideally a good quality assurance program for installation of urea-formaldehyde foam insulation materials should include the following:

- o Every installer should be certified by examination and have served an apprenticeship. Certification examinations and apprenticeships should be in accordance with guidelines set forth by the agency registering the insulation product. To accomplish certification training programs should be conducted according to guidelines set forth by the certifying agency and approved by the agency registering the product if they are not one and the same.
- o Minimal requirements of training for certification should include:
 - 1) A simplified chemistry of U-F insulation products
 - 2) Structural and other problems identified with the use of the product
 - 3) Instruction on how to resolve problems
 - 4) Correct usage of materials with reference to the relationship of improper use and occurrence of problems
 - 5) Equipment maintenance and hygiene
 - 6) Ability to identify construction types and location and placement of vapor barriers
 - 7) Instruction on identification of structures that should not receive U-F foam insulation
 - 8) Instruction with respect to disclosures to the consumer concerning attributes of the product
 - 9) Instruction on implied and written warranties

The apprenticeship should be of sufficient length to permit the worker experience in the areas covered above. If an individual leaves the field for a period longer than six months, he must undergo re-certification by examination. Those that remain in the field should be re-examined every two years.

The qualification of installers through an assurance program by examination can be a step forward in reducing the frequency of low quality installations and the number of formaldehyde associated problems. This approach for phase 2 may be seen to have a greater impact on

reducing the number of adverse events than quality standards imposed on the manufacture of the raw materials. Both approaches with respect to phases one and two will have a greater impact than just controlling either phase alone. However great the impact, this approach will never reduce the number of formaldehyde associated problems to zero frequency without an understanding of the role of phase three.

Phase three is undoubtedly the most critical phase of all and is the least understood of the three. The behavior of finished foam in relation to formaldehyde emission from finished foam is an extremely complex process which we are only beginning to understand through current research. Current research (5) has revealed that there is a rapid high-level short-term release and a lower-level long-term release of formaldehyde exhibited by a number of commercially available foam insulation products. These two phenomena are only partially inter-related. The properties fundamental to this behavioral problem are the free formaldehyde content of the resin and fresh foam, the methylol and methylene contents and the methylene ether and methoxy groupings within the polymer. Other factors complicating the understanding and preventing it from being a straight forward chemical stoichiometric relationship are the effects of temperature, humidity and pH. The rate at which water is lost from the fresh foam and the subsequent equilibrium that is obtained after curing is a complex one highly dependent upon ambient conditions of temperature and humidity. All of which in turn may be modified by the nature of the building components to which the foam is in contact.

Contemplation of the available data with respect to formaldehyde release permits one to observe that there are two phenomena, an intrinsic one and an extrinsic one, both acting together with respect to formaldehyde release. The intrinsic one deals with the properties inherent within the foam polymer and the ingredients that are its precursors. These include, the degree of polymerization within the resin as reflected in the methylol and methylene ureas, methoxy, dimethylene ether, carbonyl carbon and free formaldehyde contents as well as total solids. Extrinsic factors include temperature, humidity, pH and building components.

Recently there has been an awakening as to the possible role of methylol, particularly in regard to free formaldehyde in the resin and eventual out-gassing from foam formed from it. Methylol groups serve a necessary function as a basis for crosslinking in the formation of the polymer. Undoubtedly some of the methylol undergoes hydrolysis to form formaldehyde. In seeking a source for free formaldehyde in fresh foam, one must ask the following question. Does free formaldehyde in freshly formed foam have free formaldehyde in the resin as its only precursor? The answer to this question is "probably not". Based upon some of the early research data from the Iowa group on behavior of formaldehyde emission (5), it was attractive to speculate that free formaldehyde in resin was the principal precursor of free formaldehyde in foam that

provides for an initial out-gassing lasting from 4 to 8 days while decaying rapidly to only a few parts per million dependent upon temperature and humidity. Recent findings provide for the following observations. The release of formaldehyde from U-F foam is intimately related to the water content and the removal of that water through the drying process. This earlier assumption is not entirely without support since Neusser and Zentner (6) after reviewing several studies on urea-formaldehyde resins expressed the opinion that formaldehyde release is proportional to the free formaldehyde content of the resin and that changes in temperature and humidity influenced the release of formaldehyde.

There is no doubt that the release of formaldehyde from U-F foam is intimately related to the water content and the removal of that water through the curing process. Based upon present information one may speculate on the sequence of events that may take place during the drying process. Freshly made foam contains a high percentage of closed cell structures and is approximately 70 percent water. Curing foam at ambient conditions of temperature and humidity results in a product with largely open cell structure. Rupture of the polymer membrane most probably results from pressure exerted on the membrane by water vapor and other gases trapped within the closed cell structure, by shrinkage resulting from both cell collapse and cross polymerization of the resin-formaldehyde polymer, hydrolysis of the membrane or possibly by thermal softening of the polymer. The release of formaldehyde is influenced by these phenomena and is associated with this loss of water. Research has shown that there is a more rapid release of formaldehyde at high temperature and low humidity. As the temperature is lowered and the humidity is increased there is less out-gassing of formaldehyde which is accompanied by a corresponding increase in extractable formaldehyde. Extractable formaldehyde is defined as being a combination of free formaldehyde and formaldehyde resulting from the hydrolysis of methylol and methylene urea groups with perhaps some methylene ether linkages being involved. While there is no data to support the following assumption, it would appear that a formaldehyde-water-temperature gradient exists with respect to cell rupture, extractable formaldehyde and formaldehyde out-gassing. Recent studies at Iowa support this idea in that findings on studies of one foam product indicate that shrinkage is considerably less if the foam is cured at low temperature and moderately elevated humidity. Concurrently formaldehyde out-gassing is lowered while extractable formaldehyde is increased. The gradient alluded to above is probably heavily influenced by pH and the type of building components in which the foam is placed.

One may conclude from the above remarks that materials standards and quality assurance will be ineffective for controlling mechanical and odor problems associated with the use of U-F foam insulation products unless they are viewed holistically in the context of the role played by manufacturing, installation and behavior of the product. Since the out-gassing of formaldehyde is one of the major issues, one may ask whether

such standards and assurance programs as suggested above would confine formaldehyde out-gassing to tolerable levels? The answer would be there is no guarantee that this would be the case based upon present data. Logically then, if reasonable and practicable materials standards and assurance programs were established for U-F foam manufacturing and use control and practiced fully, could one expect a reduction in formaldehyde out-gassing problems? One could expect a reduction in the frequency of occurrence of such problems but there is no way possible to predict how great this decrease might be, if any.

REFERENCES

1. Frisch, K.C. and Saunder, J.H. Plastic Foams Marcel Dekker, Inc. New York, 1973.
2. Prah, R.N. U-F Resins Chemistry. Technical Workshop on Formaldehyde U.S. Bureau of Standards. Washington, D.C. 1980.
3. NBS Technical Note 946. Urea-Formaldehyde Based Foam Insulations. An Assessment of Their Properties and Performance. U.S. Dept. of Commerce, National Bureau of Standards. 1977.
4. National Association of Urea-Formaldehyde Foam Insulation Manufacturers. Personal Communication. 1979.
5. Long, K.R., Pierson, D.A., Brennan, S.T., Frank, C.W., and Hahne, R.A. Problems Associated with Urea-Formaldehyde Foam for Residential Insulation. Part I: The Effects of Temperature and Humidity on Formaldehyde Release from Urea-Formaldehyde Foam Insulation. ORNL/SUB-75591. Oak Ridge National Laboratory. 1979.

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