FIRE PROTECTION PROBLEMS  
ASSOCIATED WITH  
CELLULOSE BASED INSULATION PRODUCTS  

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A Talk Presented at the  
1978 SFPE Fire Protection Engineering Seminar  
Anaheim Convention Center  
Anaheim, California  
May 16, 1978  

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60 Batterymarch Street  
Boston, Massachusetts 02110  
Price: $3.25
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ABSTRACT

A comprehensive, current (as of April 1978) and yet concise appraisal of fire protection problems associated with cellulose based insulation products. The authors first cover the basic manufacturing processes and installation practices, and then outline the fire problems presented by the products, such as: (1) the combustible properties of the materials as used for insulation; (2) the difficulties found in the manufacturing methods currently employed which do not guarantee fire retardancy; and (3) installation techniques which can introduce fire hazards with improper utilization.

The outlook for improving the technology is next discussed looking at various alternatives which have been offered by knowledgeable authorities. It is noted that pressures to cure the problems have led to a wide range of proposed regulations by federal, state and local authorities.

A highly significant portion of the text deals with the authors' evaluations of optimum testing techniques and criteria that may be used, followed by their personal conclusions.

Note: Abstract not prepared by the authors.
1.0 INTRODUCTION

The "small is beautiful" concept is currently popular with students of technology. Part of this popularity stems from a negative view of the complexity and lack of efficiency often found in large research and manufacturing institutions. As such, the concept favors small, independent organizations which assumedly operate in an efficient manner.

On the surface, the recycled cellulose insulation industry appears to fit the small is beautiful concept perfectly. It is composed of entrepreneurs operating with small plants utilizing raw materials from local areas and serving local markets. Investment costs to establish manufacturing facilities are relatively low and manpower utilization is efficient.

There is a drawback however. While these products can be made to perform in a generally satisfactory manner, the general level of technical expertise within the industry is such that they frequently do not. It is the objective of this paper to review the problems which exist with such materials and to report on efforts to improve the current situation.

Insulation materials based on newsprint and other recycled wood-fiber sources have been available for over three decades. Recently however these materials (like most other sources of insulation) have been enjoying booming markets as well as increased scrutiny from the media and regulatory bodies. The reasons for this stem from new interest in such materials caused by the energy crisis. Cellulose based products can be produced in small plants which can be put into operation rapidly. For this reason they have been more responsive to shortages for insulation than other materials which require high capital investment, long lead times for plant construction, and solid marketing projections that current use trends will be long-lived. In contrast to other cost effective materials, such as fibre glass, rock wall, or synthetic polymers (foams based on urethanes, polystyrene, or urea formaldehyde), cellulose insulations also require relatively little petro-chemical input either as energy for manufacture or as a raw material.

2.0 MANUFACTURING

Cellulose insulation is manufactured from recycled paper which is commonly combined with inorganic fire retardant chemicals. The paper portion is ideally composed of waste newsprint and other uncoated paper sources. Coated paper or fine paper are best avoided since coatings or smooth surface textures resist the addition of fire retardant chemicals. The fire retardant portion of the product is generally composed of a blend of chemicals such as borates (boric acid, borax, etc.), aluminum sulfate, and the ammoniophosphates. A typical manufacturing flow diagram is shown in Figure 1.

![Flow Sheet For Cellulose Insulation Manufacture](See Ref. 4)
The process begins with a sorting of incoming waste paper followed by conveying to a grinding station. Hammer-mills are generally used. During milling, fire retardant chemicals are metered in using a feeding device to intimately disperse chemicals and paperstock. (The use of two mills in sequence, I am told, results in optimum mixing of paper and chemicals.) Following milling, the pulverized product is conveyed to a bagging unit and dust collector. The former packages the product and the latter reduces both air pollution and dust hazards in the plant. The manufacturing process is relatively straight-forward.

3.0 INSTALLATION PRACTICES

The bulk of the resulting insulation is not used for new construction. Rather, the majority is sold for retro-fitting of private homes and small, multiple dwelling units. It can either be installed by consumers or by contractors by pouring into place (as in joist cavities in an attic space) or by pneumatic conveying using a blower device. Blowers are generally available on a loan basis to consumers when they purchase such insulation products from retail outlets. Contractors also install these materials in existing exterior walls by drilling holes in siding materials between wall studs and blowing the insulation into wall cavities. (Other techniques are available for new construction or for exposed installation of such insulation but these techniques will not be considered here.)

4.0 FIRE PROTECTION PROBLEMS

The fire protection problems associated with cellulose insulation may be divided into three categories: material properties, manufacturing techniques, and installation practices.

4.1 FIRE PROBLEMS ASSOCIATED WITH MATERIAL PROPERTIES

The material properties which cause fire protection problems are the fuel value and high surface-to-mass ratio of the insulation. The paperstock used as a raw mate-
rial has a fuel value of approximately 14,390 cal/gm (3,800Btu/lb). During the manufacturing process, the paperstock is milled in order to produce a finished material having a high surface-to-mass ratio and a low KpC value. Thus, in its final form, if untreated, cellulose based insulation is a finely divided combustible fuel. Additionally, the low KpC value means that a small ignition source placed in contact with the insulation can raise the material's surface temperature above that required for ignition. For example, electrical shorts or low wattage incandescent light bulbs in close proximity to the material can lead to ignition. For this reason, the addition of fire retardants is mandatory if the material is to perform in a fire safe manner.

Effective inorganic fire retardants for wood based materials are well known and have a history going back to Guy-Lussac (2). Effectively fire retarded insulation must meet several criteria in terms of fire resistance and in terms of other factors which affect the use of the material. At present such criteria are based on ASTM Standard C-739 (3) which in turn forms a basis for current standards such as those of NACIMA (National Association of Cellulose Insulation Manufacturers), Underwriter Labs, and GSA. The standard deals with four performance areas basically. These are fire performance, moisture pickup, insulating ability (i.e. "R" Factor) and corrosiveness. The current fire criteria call for E-84 tunnel testing with the test material suspended on a screen above the test chamber. Flame spread, fuel contribution and smoke developed are measured variables.

Concerning fire retardants commonly used to achieve a flame spread rating of less than 25, industrial sources indicate that while several chemicals or chemical blends will perform at that level, smoke generation criteria are not generally met by blends containing large amounts of non-boron based materials (4). In addition, simply increasing amounts
of less costly inorganic additives to achieve fire safety goals, reduces "R" values and affects other areas of insulation performance.

Among such other areas of performance are corrosive effects of various retardants which can cause deterioration of exposed metal in insulated spaces such as electrical boxes, pipes, ducts, and vents. In addition, they can deteriorate fasteners and joist hangers for structural members. A recent ERDA report (5) showed corrosion to be a real problem with commercially obtained materials even though they currently meet the ASTM Standard. (One should be aware however that any insulation retrofit of an older building where vapor barriers are absent can lead to moisture related problems such as condensation in walls and attic spaces. This has been demonstrated by recent work at the U.S. Forest Products Laboratory. (6))

Beyond the problems associated with current ASTM criteria (i.e., flame spread, corrosion, insulating properties), two areas not addressed by the current standard are resistance to environmental attack (such as by rodents and fungal growth) and, perhaps most important, resistance to smoldering ignition.

4.2 MANUFACTURING PROBLEMS AREAS

In spite of the simplicity of the manufacturing approach described previously, problems exist in supplying consumers with a fire safe product. A major reason for this is the structure of the industry. With a currently booming market, the number of cellulose manufacturers nationwide has proliferated from under 200 a few years ago to as many as 400 according to which current estimate one believes. Within the industry, there are at least 4 trade associations (NASICA, SICUM, SACUM, MACI) which could theoretically monitor manufacturing and promote product quality since no mandatory federal standard exists currently. Apparently, however, none of these encompass more than a fraction of the manufacturers. Most current information indicates that NACIMA, one of the oldest, currently has only 13 members.

With vastly increased manufacturing output by the cellulose industry, the frequency of reports of fires caused by these materials has increased sharply. Areas, such as metropolitan Denver, have reported sizable increases in insulation related fires and groups, such as the Metropolitan Denver Task Force for Insulation Safety, have called for the application of comprehensive mandatory safety standards due to apparently poor product quality.

Among the manufacturers composing the industry it appears that some individuals (either affiliated with trade associations or not) apparently do not make fire retardant additions to their products, do so erratically or apply these chemicals without attempting to meet the existing voluntary standard. For example, even in plants which attempt to meet such standards, lapses in operation of feeding devices concerned with fire retardant additions are not uncommon. Often such lapses go unnoticed with untreated material leaving the plants. While such labeled products are spot checked for quality, it would appear that such quality control schedules are inadequate for the volume of materials produced. In addition to unintentional lapses in manufacturing quality, production pressures such as costs of fire retardants, lead more unscrupulous operators to simply leave out these materials on occasion. Cost pressures exist because the major domestic borate sources have been selling these chemicals on an allocation basis for the past several years. Prices have risen from the neighborhood of $100 per ton a few years ago to the current range of $350 to $370 per ton. Foreign products are available on a COD basis for as much as $1,000 per ton, and not surprisingly, a black market for these materials has sprung up recently. Reducing quality due to high raw materials costs is no excuse for producing substandard products however and the authors have visited meticulously operated plants where
management checks quality with great frequency. The increasing number of home fires related to these products and the discovery of seemingly untreated material in the market place does demonstrate more than occasional lapses in manufacturing quality. (For example, while conducting home safety checks recently, the Santa Clara Fire Department located apparently untreated insulation in three homes. The authors have spoken with consumers as well, one of whom had a smoldering fire occur within a few hours of an attic installation of a labeled product.)

4.3 INSTALLATION PROBLEMS

Problems exist as well, with installation of cellulose insulation. When properly done, these materials are installed as should be done in new construction; i.e., adequate clearances are left between insulation and heated flues, vents, etc. In addition, recessed lighting fixtures are well isolated from contact with insulation, and sufficient ventilation space is left so that heat build-up and associated fire hazards are avoided.

Presently the number of businesses installing insulation have increased proportionally with the growth in number of insulation manufacturers. Because of this, poorly-trained installation personnel who frequently ignore the sources of smoldering ignition cited previously have been the cause of many problems. Uninformed homeowners also cause similar problems. Finally, if poor installation practices are combined with use of non-treated or poorly fire retardant-treated insulation products, the probability of an ignition increases markedly. In fact, fire records showing ignitions within twenty-four hours of installation are common in cases where both product quality and installation practices were sub-standard.

5.0 OUTLOOK FOR IMPROVED TECHNOLOGY

Looking at the overall technology base in the industry reveals scant information. Technical literature is basically non-existent, being restricted to promotional in-

formation and, at present, perhaps, a dozen current patents (See Refs 22 - 27). Several of these relate to production schemes involving wet application of chemicals to paper substrates. Although this is potentially a more effective technique than simple milling of retardant chemicals with paper, such techniques have proven non-cost effective for the small operators making up the bulk of the industry.

The EROA Report, cited earlier, is probably the most up to date document concerning such products, and is only a survey of their properties. It summarizes several of the problem areas as follows:

1. Re-evaluation of performance criteria are needed relating to:
   a. retention of fire-retardant additives after shipment, installation and in service
   b. moisture absorption
   c. corrosiveness
   d. fungal resistance

2. Specifications are needed to insure uniform product quality and performance

3. Methods of insuring compliance with standards are needed

In order to deal with these problem areas, a concerted effort will have to be made to develop realistic base-line data on performance criteria as well as new approaches to improve on such base-line performance. In addition, regulatory approaches based on appropriate testing scenarios, as well as effective and realistic enforcement practices, must be achieved.

Considering help with technical questions, a substantial literature exists in both the pulp and paper industry and the wood and textile chemistry areas dealing with fire retardant chemicals for these substrates (7, 8). Such classical information has not been systematically applied to this product area to date and other more innovative ideas, in terms of fire retardants or applications technology, do not appear to have
been tried.

On the manufacturing side, the addition of simple process-control equipment would go a long way to improve product quality. Requiring use of interlocks, for example, to stop milling of fiber during stoppages of fire-retardant feed to grinding mills could make an immediate impact. (Such equipment is mandated in the pending California State Insulation Quality Standards (9).) On-line instrumentation to monitor retardant levels as products are conveyed to the bagging station are unheard of currently but could be developed readily based on a variety of remote sensing techniques now available. These could be used in place of spot checks for quality assurance or in addition to such checks where they are currently used to meet guidelines for sampling. Seeing the fire performance records of these materials, it is our feeling that current execution of quality-control programs has been inadequate.

Finally, development of blending techniques, such as those used in the wood composite industry (i.e., partical board and fiberboard manufacturing) to add adhesives and other additives to fibrous raw materials should be considered. These might be useful in terms of both more effective use of retardant chemicals to attain fire safety objectives and more cost-effective use of chemicals as well.

Research to develop fire retardants for such insulation has been conducted recently by Dr. R. M. McCarter of the National Bureau of Standards, Center for Fire Research. Recognizing that insulation fires usually begin with smoldering ignition, he recently developed a combination of chemicals, one of which is included to eliminate smoldering ignition. This component is sulphur. The other chemicals are more familiar retardants, such as borates or phosphates which are felt to reduce and retard flaming ignitions. A patent application (10) was recently filed on the composition. The use of sulphur to suppress smoldering ignition follows its use in the fire-retarding of mattresses. Such a reasoned approach to insulation fire safety problems represents, perhaps, the first input directed toward this area from an outside source.

6.0 REGULATORY ASPECTS

As stated previously, the pressures for more reliable products from the cellulose insulation industry have been building with their increased use by consumers. Because of service failures by such products, regulations are currently being prepared or revised on federal, state, and local levels. On the federal level, the General Services Administration has for some years had a standard (GSA-HHI-515) which mandated performance of cellulose insulation products purchased by government agencies. This current standard (revision 515-C) is quite similar in fire safety aspects to the ASTM-C-739 specifications. A recent proposed revision (HHI-515-D) makes a major break with the older standard (11). This new specification, prepared in cooperation with the National Bureau of Standards, if adopted will significantly change the criteria used to judge fire performance of such products. In place of the familiar E-84 Steiner Tunnel Test, a radiant panel test originally developed at NBS for rug testing is prescribed. This device (see Figure 2) provides a decreasing flux gradient along horizontally exposed samples such that a heat flux level (0.08 watts/cm²) similar to a 160°F attic temperature (not uncommon in the southern and western United States) will serve as the flame-spread cut-off. In addition, a smoldering ignition test is included with ignition by cigarette. According to NBS personnel, of seven "off-the-shelf" fire-retardant treated insulations tested, four passed the radiant panel flame spread criteria and only two passed the smoldering ignition test (12, 13). It would appear that either these new tests are more stringent than existing ones or the majority of products tested were sub-standard.
Figure 2: Side Elevation of Radiant Panel Tester. (See Reference 11)

On the federal level, other regulatory activities are taking place, which, if carried through, will have far more widespread impact in the public sector. Chronologically, these began with Consumer Product Safety Commission (CPSC) activity. This was prompted by a petition submitted to the agency in October, 1976. This document alleged a variety of health and safety hazards to be associated with all major insulation types (i.e., fiberglass, polymeric foam, cellulose, etc.). Since the CPSC is frequently mentioned in the news and in industrial information, a description of how it operates, with the insulation petition as a case in point, will be given.

The CPSC was established by Congress to protect the public where questions of product safety are at issue. It is required by statute to respond to petitions submitted by individuals in 150 days. It does not conduct research but must rely on evaluation of outside information supplied to it or uncovered by investigators. On receipt of the insulation petition, it was submitted to the CPSC Office of General Council for consideration and went as well to the Office of Program Management. The latter has responsibility for matters associated with household products and structures. In addition, CPSC engineering staff members prepared a report based on information in the petition and from other outside sources. In June 1977, the commissioners considered the assembled report (14), and concluded that a general lack of information existed. A public hearing was then scheduled and held in August, 1977 (15). Finally, by early 1978, the commissioners decided that a safety standard was necessary for cellulose insulation materials. Claims against the other insulating materials were disallowed as presented (16). In its most recent action on the subject, the commission prepared an offer for standard development, which was circulated in the Federal Register (17). Such an offer solicits interested elements in the public sector (such as ASTM or industrial bodies) to prepare an appropriate standard. As of now, this is where the matter rests.

Meanwhile (1/24/78) in Congress a bill relating to safety of insulating materials was proposed by Senator Ford and Representative Moffit (18). As written, it mandates the CPSC to adopt the existing GSA standard (i.e., revision 515-C) as an emergency, national standard within 120 days of the bill's passage.

The proposed bill also calls for an extensive research effort into fire and health hazards associated with all insulation materials to be conducted by the CPSC. The impact of this legislation, should the bill survive, would be to put the CPSC in the research business directly.

Meanwhile, efforts to control insulation quality are being carried forward on the state level as well. Here in California, Senate Bill 459, passed last year (19), mandates establishment of fire safety standards which substanti-
ally increase quality control criteria and certification labeling programs. The State Energy Department will administer the program and attainment of specified performance levels will result in a state seal being issued to a manufacturer's product. No bag of insulation will be permitted to be sold in the state without this seal. Certification will be carried out by third party plant inspection and testing. The standard utilizes the E-84 tunnel test for flame spread criteria and the proposed GSA smoldering test. Unfortunately, the radiant panel test in that standard will be included on an information only basis for the first six months, after which the state will decide whether to make it a mandatory provision or not (20).

Local municipalities obviously vary widely in approach to insulation products. While insulation installation in new construction is dealt with by the various model building codes, most municipalities do not become involved with insulation retrofit of existing structures. Santa Clara, California, is an example of one which is becoming involved. The example cited earlier, in which several houses were found with non-retardant treated insulation as well as substandard installation, has led Sanata Clara to consider an ordinance which will make permits for such retrofits and inspections of installation mandatory.

Should all of these rules become effective, (as well as possible actions, such as standards development by the federal Department of Energy and/or labeling and advertising rules by the Federal Trade Commission), quite a maze of legislation will exist. In one sense it appears to be a potentially costly duplication of effort both on the federal level and where proposed federal and existing state legislation overlap as in California.

7.0 TESTING TECHNOLOGY AND CRITERIA

In several places the CPSC documents associated with their investigation comment that present flame spread tests (i.e., the E-84 as currently run) are not "realistic." (14) Questions revolve largely around a suspension of materials on a wire screen in the Steiner Tunnel for testing as compared to the actual configuration of such insulation products in service. (Tests run in Canada have recently led to inclusion of flame spread classifications in building code documents which are based on the exposure of insulation materials on the Steiner-tunnel floor. This testing configuration has frequently led to flame spread ratings considerably higher than those obtained for the same materials when tested on the tunnel ceiling. (21)

Similarly, other tests, such as the proposed GSA standard are open to criticism for one reason or another. In the case of the smoldering provision, the ignition source specified (cigarettes) might better take the form of a hot object, such as a wire or metal plate or even a hot light bulb. Such devices are more consistent with in-service hazards and fire records indicate them to have been ignition sources in the past. The radiant panel provision is in our opinion superior to the existing flame spread test. The use of a controlled heat flux seems most appropriate, but the absence of a smoke generation criteria is disappointing. (The existing ASTM-E-162 radiant panel test utilizes a photocell for such testing for example.) The logic behind not having such a criteria apparently stems from an assumption that successful suppression of ignition (as tested for in the smoldering provision) will prevent open flaming. However, if one envisions a scenario where fire starts elsewhere (as in clothing stored in an attic or in compartments adjacent to the insulated one), a source of ignition is assured. At this point smoke generation criteria become important in terms of both life safety of building occupants and fire-fighting personnel.

Finally, realistic criteria to evaluate retention and longevity of retardant chemicals in such insulation have yet to be proposed. Problems that should
be considered involve leaching of chemi
cals due to relative humidity cycling and
possible condensation moistening of in-
sulation as well as long term aging ef-
fects and heat cycling effects on such
insulation in the field. Confusion ex-
ists for example in cases of fires in
installations more than several years old
where fire retardant longevity may have
been affected by leaching or fall-off.
Of course the possibility also exists that
such insulation was not properly treated
originally. Finally, considering tests
for such properties as flame-spread and
potential for smoldering ignition, condi-
tioning and/or accelerated aging schedules
prior to testing of materials seems appro-
priate.

8.0 CONCLUSIONS

At the time of writing this paper, much
activity is occurring related to the utili-
ization of cellulosic insulation. Regula-
tions to unify performance standards for
such insulation materials are in flux and
may be expected to remain so for at least a
calendar year. A wide range of approaches
are open to overcome the technical problems
associated with these insulation materials.
However, there is a lack of committed cap-
itl, technological expertise, and develop-
ment-oriented personnel in the field. It
would appear that either an industry com-
mitment of funds for research and develop-
ment or a government effort in this direc-
tion will be necessary to advance the level
of technology if such an advance is truly
needed. A research and development fund
based on a tax from each bag of material
sold may be a valid approach, so that re-
sponsibility for such research is not
shifted to the government sector for the
attendant costs. Alternatively, if a con-
tinuing market appears to exist, larger
companies may enter the field and generate
new technology with their larger capital
bases.

Finally, it may be that regulatory
over-kill is occurring. New applications
of available manufacturing technology, mod-
est but well-reasoned extensions of fire
retardant technology, and appropriate fire
performance and quality control criteria
may suffice in place of large, non-cost
effective research and development and
regulatory efforts. In any case, it is
our opinion that the manufacturing units
composing this industry now present a
viable approach to solving the increas-
ing national need for insulation mate-
rials. With proper regulation and en-
forcement such materials can be made
fire safe for use by the general public.
REFERENCES

(1) The authors would like to thank the various people whose information was invaluable in preparing this report. These include Phil Stern of the Boulder, Colorado District Attorney's office, John Liskey and Howard Cohen of the Consumer Product Safety Commission and Gene O'Neill of Western Weathercheck, Santa Clara, California.


