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A Progress Report from the Plastics Industry

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Based upon suggestions from inside and outside the industry, and in order to attack more directly mutual problems relating to fires and consumer safety, the technical programs of The Society of the Plastics Industry (SPI) have been altered to deal in a more direct manner with actual fire hazards that can be adequately defined. These programs are discussed in this article.

About a year ago, Ralph Harding, President of The Society of the Plastics Industry, in his address to the International Association of Fire Chiefs, cast out a challenge to the fire community. That challenge, in essence, stated:

> Tell us the needs, as you see them, and let us, in SPI, see how we might alter our present programs and/or establish new programs to find answers to those needs.

The response has been rapid and thoughtful. Individual members of many groups have contributed: the National Fire Protection Association (NFPA), the National Fire Prevention and Control Administration (NFPCA), the International Association of Fire Chiefs (IAFC), the International Association of Fire Fighters (IAFF), the Fire Marshals Association of North America (FMANA), the International Society of Fire Service Instructors (ISFSI), Underwriters Laboratories (UL), the Consumer Product Safety Commission (CPSC), International Conference of Building Officials (ICBO), the Factory Mutual Research Corporation (FM), the American Society for Testing and Materials (ASTM), the American Institute of Architects (AIA), the University of Utah, the National Bureau of Standards (NBS), the University of Michigan, Harvard University, and many others.

Based upon the responses, we in the plastics industry are placing increased emphasis, in our programs, on dealing with hazards of actual fire situations. To do so effectively, we are concentrating on known hazards and/or hazards that can reasonably be expected. Hazard analyses provide the guidance for our programs — for only when the problem has been adequately defined can we develop the proper solution.

The responses have been so meaningful, and so much interest has been shown, that we have asked for and received the help of representatives from various organizations to direct some of our programs. In fact, three of our newest and most important programs are being developed and administered by members of nonindustry groups, including the NFPA, NFPCA, IAFC, IAFF, FMANA, ISFSI, the California Fire Marshals and Fire Chiefs, and ICBO, with the SPI mainly supplying part or all of the funds.

Our own analysis and evaluation to date indicates that we must develop proper scale tests that will lead to controls for proven fire hazards in given product applications. This is also a principal concern of the Federal Trade Commission, as evidenced by the work of its Product Research Committee. Therefore, we are putting our greatest efforts into large-scale testing and trying to produce correlative results in smaller scale, rather than simply trying to improve such existing small-scale tests as ASTM D 635 and D 1692 and/or adding "let-the-user-beware" caveats. While caveats are required and may be appropriate in some cases, they really should be used only as a backstop until proper solutions are found.

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Our method of operation is to work on a mutual basis with all interested groups, reviewing all programs underway in the United States and Canada, and then to provide financial and/or technical support to those that have the most pertinent programs underway. If we determine that there is a need for additional effort in a specific area, we then consider initiating a specific SPI program. We have found this overall cooperative approach to be the most effective in producing the best results toward consumer safety in the shortest period of time. This approach minimizes duplication of effort and provides communications and discussions from the start, tending to reduce the time span between the end of experimentation and adoption of an adequate standard.

The major approach to combustibility research by the plastics industry is comprised of three steps:

1) Hazard analysis to attempt to determine all possible fire hazards;

2) Evaluation of the data to determine which hazards may be "unreasonable hazards" that warrant major action; and

3) Research to develop effective measurement and control methods for the defined major hazards.

Based on the results of this three-step approach, the plastics industry may modify its products, work for changes in standards or codes, or provide safe-use instructions and other information for consumers. Sometimes a combination of all three measures is required.

HAZARD ANALYSIS

A complete and technically sound analysis of the hazard is essential for any program aimed at true consumer protection. The problems must be properly defined first, if adequate solutions are ever to be found. For example, a slab of low-density foamed material lying in the center of a playing field cannot be envisioned as a hazard, except perhaps as a minor tripping hazard. On the other hand, that same low-density foam applied exposed to the ceiling of a nightclub (to make it look like a cave) where the occupancy may be high, the possible ignition sources numerous, and exits limited, can truly present an "unreasonable hazard."

Analysis of hazards must first be based upon a technically sound compilation of data, including case histories. The NFPA has always been first and foremost with fire statistics. Not only does it issue statistics on 30,000 fires, but it also makes compilations to indicate important trends.

The IAFF and the NBS published an excellent and comprehensive report on fire-fighter mortality in May 1976. And of course, one of the most comprehensive programs of data collection is the National Electronic Injury Surveillance Systems (NEISS) used by the Consumer Product Safety Commission (CPSC). Data relating to fabrics are included in the Flammable Fabrics Accident Case and Testing Systems (FFACTS), developed at NBS and now maintained by the CPSC.

The SPI wholeheartedly supports these efforts on data accumulation and encourages additional work now underway to improve the overall quality of detailed reporting.

Work within the SPI program that specifically relates to this area of data collection includes the following:

1) A proposed program conducted jointly by the Harvard University School of Public Health, the NFPCA, the Boston Fire Department, and the SPI that will analyze combustion gases at more than 100 actual fires to determine what products of combustion are being produced and whether they may present major hazards to either fire fighters or occupants. This excellent program, developed by Dr. William Burgess of Harvard, would be financed by the NFPCA and the SPI. The fire gas samples would be obtained at the fire location by members of the Boston Fire Department and subsequently analyzed at Harvard. Gases would be collected by instruments worn by the fire fighters during their first entry at the fire scene and also during cleanup operations. These would be analyzed for carbon monoxide, carbon dioxide, oxygen, nitrogen dioxide, hydrogen cyanide, hydrogen chloride, aldehydes (acrolein), etc., and their concentrations determined. In addition, the major combustible materials involved in each fire would be reported. A formal proposal has been submitted by Harvard to NFPCA and SPI for funding this program.

2) An independent "toxicity review" conducted with top personnel of key government, code, fire protection, and medical organizations, etc., through personal interviews. The objective of the review is to obtain a better "definition of the problem" and to adjust our programs accordingly. The review is expected to be completed during the last quarter of 1976, with any necessary changes in SPI programs coming by the summer of 1977.

3) The loan of an SPI scientist to the NBS as a research associate assigned by the NBS to the group whose responsibility is hazard analysis (analyzing fire statistics and causes).

4) The investigation of fires by independent consultants who have had many years of investigative experi-

ence. Such investigations sometimes become necessary when news reports implicate plastics. The investigations often show that plastics were not involved, or that the material used was not installed in accordance with codes or good standard practice.

5) The funding of a fire injury incidence study being conducted by Professor Irving Einhorn's group at the University of Utah. A detailed initial report presented in July 1975 at the University of Utah Polymer Conference series[1] analyzed 103 fires in Salt Lake City. The data obtained were similar to national data on causes of fires.

EVALUATION OF HAZARDS

Programs should be aimed at the elimination of defined "unreasonable hazards." Materials themselves cannot be correctly and technically defined as "hazardous," but must be evaluated in their specific end use. They can become hazardous only in respect to the degree of risk involved in the use of a material in a specific application. Many of the most hazardous situations result from the misuse of a material — that is, a use that is outside the original intent of the material supplier or fabricator. For example, common unmodified cellular foams are not intended to be used as a sprayed-on decoration, applied to and left exposed on the ceilings of a nightclub.

The plastics industry usually finds it difficult to obtain true findings of "unreasonable hazards" regarding its specific products. While data lead us to believe that misuse of cigarettes, alcohol, matches, gasoline, firecrackers, guns, etc., creates at least a severe degree of hazard, what is the true extent of hazards for items such as furniture stuffed with foam, and occasional furniture or kitchen cabinets made of plastics?

It is confusing at times to our SPI technical groups when they observe that relatively weak action is being taken against known hazards such as ignition sources (cigarettes, matches, cigarette lighters) or extremely flammable materials such as gasoline, etc. Yet there are a few who would indiscriminately ban the use of polyvinylchloride (PVC) in electrical conduit — "due to the hydrogen chloride toxicity problems." To date, there has not been one substantiated reported death, proven by autopsy, related to hydrogen chloride produced by combustion of PVC. Leading toxicologists tell us that hydrogen chloride is so irritating that a human cannot physically remain in a room in which it exists in the 50 ppm range, and the dangerous levels for hydrogen chloride are generally above 2000 ppm.[2] While data obtained to date indicate that hydrogen chloride is not an "unreasonable hazard" in ordinary fire situations, we are aware that special care should be taken if an unusually heavy concentration of PVC is involved in a fire — for example, in a telephone exchange or computer room. In this case, hydrogen chloride, being acidic, can contribute to irritation of the lungs, leading in severe cases to pulmonary edema generally one to three days following exposure.

The same precautions should be taken in any situation where large quantities of a single material are present, such as a storeroom full of wool clothing that can produce large amounts of hydrogen cyanide when it burns. This is particularly important when the space is totally enclosed. This is the situation as we see it to date; however, we are continually looking for and would appreciate any additional input based upon sound technical data.

Five recent programs on the evaluation of fire hazards appear to be extremely helpful. First is the excellent *Fire Fighter Mortality Report*[3] that was done by the IAFF for the NBS. This in-depth, 165-page investigation of the in-line-of-duty deaths of 101 fire fighters is an excellent example of hazard analysis. Forty-five of the 101 cases were related to heart attacks (which were brought on by: a) exposure to smoke/toxic fume inhalation, b) stress, and c) overexertion). The *Report* concluded that: "The case investigations have uncovered numerous problems of fire fighter's health and safety which require immediate attention. Solutions to several of the problems are evident. . . ." Because of the pertinent information presented, this *Report* should be "must reading" for each of us in the fire community. But the *Report* itself is only the beginning. While the *Report* lists only two deaths directly related to toxic fume inhalation, toxic fumes — particularly carbon monoxide, with its effect on the oxygen-carrying capability of the blood — must be considered as a factor in many of the 45 heart attack cases and in the nine cases attributed to smoke inhalation. The *Report* emphasizes that fire fighters should wear self-contained breathing apparatus "in all fire situations."

The second good example of hazard analysis is the report "Fire Death Scenarios and Firesafety Planning,"[4] developed by the NBS and the NFPA. This report discusses the use of fire scenarios and lists the 14 top fire

[1] I. N. Einhorn and Newman, Polymer Conference Series, Flammability Research Center, University of Utah, July 1975

[2] Y. Henderson and H. W. Haggard, *Noxious Gases*, Second Edition, (American Chemical Society, Monograph Series No. 35, 1943).

[3] Thomas Balanoff, *Fire Fighter Mortality Report*, produced by the International Association of Fire Fighters for the National Bureau of Standards, May 1976.

[4] F. B. Clarke, III and John Ottoson, "Fire Death Scenarios and Firesafety Planning," FIRE JOURNAL, Vol. 70, No. 3 (May 1976), p. 20.

scenarios that account for 66 percent of the fire deaths in the United States. Key conclusions of the report include the facts that: a) 27 percent of all fire deaths are related to fires in residential furnishings caused by cigarettes and other smoking materials; b) 54 percent of all residential fires involved the ignition of furnishings (one-half of them in mattresses and/or bedclothes; one-half in upholstered furniture); and c) *all* scenarios involving 2 percent or more of the fire deaths occur in the home. This report provides us with many important points.

A third example of good hazard analysis is the study conducted by Dr. Radford and others at the Johns Hopkins University Applied Physics Laboratory,[5] where the survey of 206 fire deaths in Maryland (from 1971 to 1974) showed definite carbon monoxide poisoning in 50 percent of the deaths. In 52 percent of the deaths, the cause of the fire was a cigarette or other smoking material. Dr. Radford further explains the extreme hazards of carbon monoxide. If an adult is exposed to a 5 percent concentration of carbon monoxide, which may frequently be encountered in fire situations, it will take only ½ to 1½ minutes to reach a 50 percent carboxyhemoglobin concentration in the blood. Compared to carbon monoxide, hydrogen cyanide is very soluble and will be taken up by body fluids. Dr. Radford indicates that for that reason, it is "probably relatively rare" to have a concentration of hydrogen cyanide in a fire sufficiently large to cause significant injury. Irritant gases such as aldehydes, on the other hand, will have an immediate effect because they become concentrated in the lungs, instead of being distributed throughout the body.

As a fourth example, Dr. Zikria of the Columbia-Presbyterian Medical Center of New York City has done some excellent studies[6] relating to the cause of death after arrival of the fire victim at the hospital. This work provides information on how gases and heat cause respiratory burns, and on injuries caused by inhalation of smoke and fumes — including carbon monoxide, aldehydes, and acidic and basic gases. Dr. Zikria's work has also involved studies with the irritating aldehydes in wood, specifically acrolein. Dr. Zikria has previously stated that: "It is likely that the agents causing tracheobronchial and pulmonary parenchymal damage of smoke poisoning in man are also the aldehydes which are found in large quantities in smoke and combustion of wood, cotton, furniture, and nonsynthetic structural materials." This type of investigation is important in regard to the possible damage caused by the more unusual aspects of gases produced during fire situations.

Professor Einhorn's group at the University of Utah[7] is evaluating additional independent data based upon the Fire Injury Surveys. This program is placing its major emphasis on the physiological and toxicological effects of combustion products.

All five of these studies provide us with some items on which to take immediate action. It is evident that toxicity is a major problem. There are so many unknown factors relating to toxicity, whereas the characteristics of ignition, heat release, and flame spread are defined more easily. All combustible materials (cotton, wool, wood, etc., as well as synthetics) present a hazard in regard to the toxicity of combustion products when involved in a fire situation. All of these materials produce carbon monoxide, which is the major cause of fire deaths. Furthermore, additional gases such as acrolein (wood), hydrogen cyanide (wool and urethanes), and hydrogen chloride (polyvinylchloride) may be produced. It is essential, therefore, that we determine whether these or any other materials may present an "unreasonable hazard." For this reason, a major part of the research effort being conducted by many groups, as well as by the SPI, is at present aimed at developing a testing method for evaluating materials and the toxicity of their combustion products in order to determine which, if any, of them may present an "unreasonable hazard."

Within the SPI: 1) the principal job of hazard evaluation is conducted by the Coordinating Committee on Consumer Safety (CCCS), which is comprised of representatives of 20 operating divisions concerned with various categories of plastics products. This Committee, which meets quarterly, assembles information on hazard analysis, searches out potential problems, reviews ongoing research, and determines directions for new research. Research programs may be conducted directly under the supervision of the Committee or by one of the operating divisions.

2) At the request of the National Bureau of Standards, the SPI has been supplying it with commercially significant materials for toxicity review and bioscreening of combustion products. This program, funded by the NBS, has to date evaluated at the Flammability Research Center of the University of Utah nearly 140 samples of materials with and without flame-retardant additives. Included are polyurethane foam (rigid and flexible), polyvinylchloride, polystyrene (expandable and rigid), polyolefins, and polyesters. Thus far, there has been no reported indication that any of these commercially significant materials presents an "unreasonable hazard" when subjected to heat or combustion.

[5] Edward P. Radford, "CO Is Still Worst of Lethal Cases, Fire Casualties Seminar Learns," *Fire Engineering*, Vol. 128, No. 9 (September 1975), p. 31.

[6] B. A. Zikria, et al., "A Clinical View of 'Smoke Poisoning,'" a paper given at Physiological and Toxicological Aspects of Combustion Products: an International Symposium held March 18-20, 1974, at the University of Utah, (Published by the National Academy of Sciences, Washington, D.C. in 1976).

[7] See opposite page of this article.

RESEARCH EFFORTS

Technical development efforts on combustibility are continuing at several locations, where many groups are now conducting full-scale testing. These include the NBS, Underwriters Laboratories Inc., Factory Mutual, the Federal Aviation Administration (FAA), the National Aeronautics and Space Administration (NASA), the Rubber and Plastics Research Association (RAPRA) of England, the National Research Council (NRC) of Canada, the Southwest Research Institute (SWRI), the University of California, etc. A key effort on fire research by the Product Research Committee is now underway. This Committee, set up as a result of the 1974 Consent Agreement between the Federal Trade Commission, 25 plastics manufacturers, and the SPI, is spending $5 million over a five-year period on fire research relating to cellular products. Recent reports of large-scale testing include such reports as *Fire Hazards of Plastics in Furniture and Furnishings Fires in Furnished Rooms* (Palmer, Taylor, and Paul, RAPRA, February 1976); and *Flammability Studies of Cellular Plastics and Other Building Materials Used for Interior Finishes* (Underwriters Laboratories, 1975).

Much of the concern in this area focuses on toxicity of combustion products, and one example of an important pertinent report is *The Physiological and Toxicological Aspects of Combustion Products* (International Symposium of the National Academy of Sciences, 1976).

Technical efforts of the SPI include the following:

1) A committee on *Fire Services Full-Scale Testing* has been developed that includes members of the California fire fraternity and the SPI. The purpose of this committee is to develop guidelines, rationale, procedures, etc., for future full-scale testing — including full-scale building burns. This committee is being directed by members of the California Fire Chiefs Association, the International Association of Fire Chiefs, the California State Fire Marshals, and the International Conference of Building Officials. Its concept, although ambitious, has the potential to help identify the many dynamic variables in actual fire situations in multistory buildings.

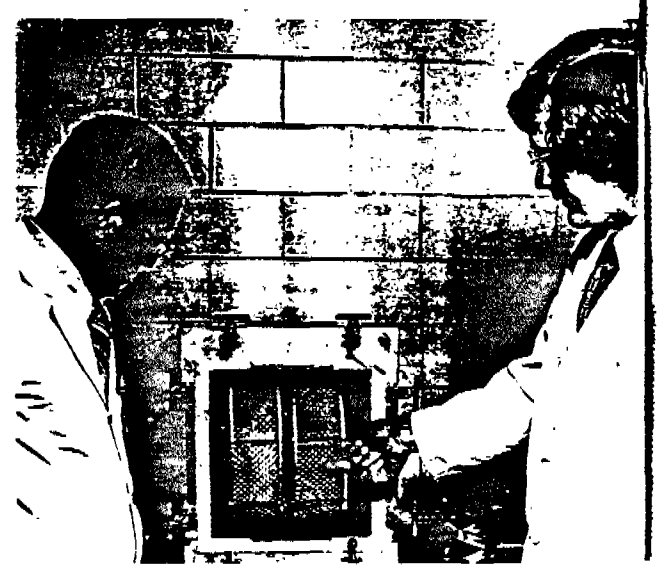
2) The second two-year period of the cooperative *SPI-NBS Research Associate Program* has been initiated. Six more scientists have been assigned to the Bureau to help develop firesafety technology. The group contributes to investigation of such areas as ignition toxicity of combustion products, flame spread, rate of heat release, and analysis of real fires. During the previous two years, the SPI's first six Research Associates, who have now returned to their respective companies, contributed to the NBS development of a radiant panel test for flooring and carpets, the extensive review of the furniture markets with a view toward establishing firesafety guidelines for furniture manufacturing and material suppliers, the development of the modified smoke density measurement chamber, the refinement of a method to measure the rate of heat release from materials, and the establishment of a rationale and technique for the analysis of combustion gases.

3) The NBS has stated that there is "no standard test method" available for adequate evaluation of hazards relating to combustion products from burning materials. At the same time, however, the NBS announced — as a projected target — the development of a standard method for evaluating materials as an "unreasonable hazard" with respect to toxicity of combustion products. Following development of such a method, a second phase will attempt to develop a more refined and definitive test for evaluations. The SPI now has two Research Associates at the NBS assisting in this important project.

4) One SPI Research Associate is assisting in an aggressive NBS program aimed at designing and building a new calorimeter for *measurement of rate of heat release* (BTU/min) — a parameter considered by many to be important with respect to "flashover." The NBS reports that the design has been completed. Installation and demonstration of the equipment is scheduled for 1977.

5) At the University of Michigan, the SPI is conducting a joint program with the Manufacturing Chemists Association (MCA) to develop a system to evaluate the toxicity of combustion gases using a bioscreening technique (rats) response to death and/or incapacitation. The

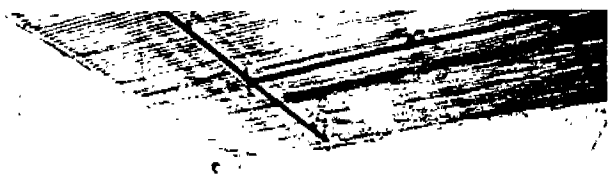
At Du Pont's Haskell Laboratory for Toxicology, Dr. J. B. Terrill (right) discusses with Dr. K. P. Lee, DVM, the loss of hind leg function in exercised rat resulting from carbon monoxide-induced anoxia. Experimentation of this type is being conducted in many laboratories to determine the effects of products of combustion in fires.



ultimate aim is a system to determine which, if any, materials might present an unusual hazard. Considerable progress toward this objective has been made. At present, the work is concentrating on improving the techniques used in the past for determination of "incapacitation." Many of the old techniques (such as the tumble cage) require prior training of the rats and/or make it difficult to determine the point of incapacitation (falling versus sliding, etc.). A roto-rod technique shows good potential as being less subjective.

6) Eight full-scale tests have been conducted to determine what type of fire protection is needed for warehousing of short life-cycle plastics (e.g., polyethylene bottles, foam trays and cartons, and polystyrene cups) commonly stored in commercial warehouses. Results of those tests, conducted at Factory Mutual, have demonstrated sound methods of storage configurations and sprinkler protection for plastics commodities. Additional tests are planned to further refine the information that is being provided to insurers, the fire service, and standards-making groups.

Engineers at Factory Mutual Research Corp. study installation of foam plastic insulation in preparation for a fire test on large-scale corner wall Such tests have been conducted for the plastics industry since 1972.



Factory Mutual's large-scale corner wall is 25 feet high with 50-foot and 40-foot-long walls. Wall materials are tested in conditions simulating a factory installation. The fire source is a 750-pound crib of wood generating temperatures of over 1000°F.

7) The Urethane Safety Group has just published a new bulletin on four large-scale corner wall tests, conducted at Factory Mutual, that involved spray-on thermal coatings over spray-on polyurethane foams. Those tests followed 12 corner wall tests that involved exposed and metal-clad polyurethane foam panels and control materials. Some of the test materials were rated acceptable by Factory Mutual and some failed, providing a great deal of guidance on sound applications.

8) The Plastics Pipe Institute of SPI has sponsored a number of tests at the research facilities of Ohio State University and the University of California at Berkeley. These tests, based on ASTM test method E 119, are designed to determine the effect of penetration with plastics pipe on fire-rated walls and floors. The data gathered thus far indicate that, when properly installed, plastics pipe will not reduce the endurance rating of fire-resistant construction, nor will it serve as a vehicle for the spread of fire through a structure.

9) All Research Applied to National Needs (RANN) programs related to firesafety have been transferred to the National Fire Prevention and Control Administration by the National Science Foundation. One ongoing, significant, sophisticated program at the University of Utah involved bioscreening analysis of traditional materials (wood-cellulosic) and synthetics (PVC, urethane). The SPI funds all six graduate students who are working on this program.

10) Recently, the Expanded Polystyrene Block Molders Committee has been conducting fire tests of its products in a dwelling-size corner at Underwriters Laboratories Inc. They also are conducting, at Factory Mutual, large-scale warehousing tests on materials used as packaging insulation for appliances.

11) A fellowship has been awarded to Johns Hopkins University for the development of methodology on toxicity, in conjunction with the NBS.

12) Our work at the Southwest Research Institute (SWRI) has shifted to determination of the effects of density on the rate and quantity of off-gas evolution. This program is nearing conclusion. Although the program

Representatives of the fire services at a working session with the Society of the Plastics Industry to devise a training program for fire fighters on plastics and combustibility. First phase of the program has been completed and development of training materials is underway.

was originally intended to be of relatively short duration, the complexity of analyzing products to determine the toxicity of their combustion off-gases presented a number of technical difficulties that were not easily solved.

13) The Polystyrene Safety Group has work underway at SWRI relating to methodology that, while specific to their products, will add to the overall technology.

14) In cooperation with the State Fire Marshal of Ohio and Patton Life Safety Systems, the SPI sponsored a series of burns in which sprinkler systems were tested for possible residential use. Work in this area, and on smoke detectors, is expected to be continued and expanded under the direction of the NFPCA.

CONTROL OF FIRE

The results of all this analysis, evaluation, and research obviously would be meaningless if the steps ended there. But they do not.

Members of the plastics industry are constantly analyzing results obtained from these programs and field experience in order to modify their products and develop new ones.

In addition, SPI members are and have been participating for many years, with many others in the fire community, in developing proper standards and building code provisions in recognition of the fact that fire is an enemy to all of us.

It is becoming increasingly obvious that our abilities to control unwanted fires through design of materials and assemblies, while improving all the time, will never provide the total answer because combustibles will always be with us in the built environment. Therefore, it is essential that adequate systems for rapid detection and suppression also be used — for true life safety.

One of the best examples of this type of system is Disney World in Florida, where a planned combined system of detection / alarm / suppression / smoke venting, coupled with compartmentalization, permits widespread uses of combustible materials (treated wood and plastics) in an area of greatest concern — one of the most densely populated (with children) areas in the world.

Another very important step involves education and communication. Specific efforts within the SPI include:

1) Distribution by the SPI and its member companies of many safe-use bulletins describing proper methods for handling and installing their products, and encouraging adherence to building code provisions that prescribe proper uses.

2) A project now underway at the NFPA to develop a training program concerning plastics for fire fighters. The project is being developed by the NFPA staff with guidance from members of the IAFC, IAFF, FMANA, ISFSI, and SPI, who meet regularly. The first phase, involving research and design, has been completed and the program should be ready for distribution and use by early 1977.

The use of plastics in the built environment has grown very rapidly in the past quarter century, and projections indicate that it will continue to grow. The SPI is concerned that this be a proper growth, not accomplished at the expense of firesafety. In 1977, we should begin to see results from many of the programs described in this article, and these will be passed along to the fire community. We believe that, with the help of the fire community, we are on the right track with our programs, but obviously a great deal of additional work needs to be done. The SPI welcomes constructive criticism and suggestions on how changes can be made in its constant reevaluation of its programs. △

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