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G. E. Zaikov^a; M. I. Artsis^a

^a Institute of Chemical Physics, Russian Academy of Sciences, Moscow, Russia

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Recent Advances in Flame Retardancy of Polymeric Materials: Materials, Applications, Industry Developments, Markets

G. E. ZAIKOV and M. I. ARTSIS

*Institute of Chemical Physics, Russian Academy of Sciences, 4 Kosygin str.,
117334 Moscow, Russia*

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The Fifth Annual Conference on Flame Retardancy was held on May 24–26 in Ramada Plaza Hotel, Stamford, Connecticut, USA. The Conference was organized by Business Communications Company, Inc., Norwalk, CT (President of company is Mr. Louis Naturman), conference coordinator—Mrs. Sharon D. Faust.

This year new materials (polymers, blends, composites), their applications, industry developments and markets were considered.

The focus of the presentations was on:

- introduction of new technological achievements and development in the field of flame retardancy (FR),
- review the current state of science and technology in FR,
- review the applications and markets for FR products,
- recent developments in local and global standardization and in testing technology,
- toxicity and environmental issues.
- unique opportunity for newcomers to FR research technology and marketing to become acquainted with FR field in all its aspects,
- halogen-based and non-halogen-based flame retardant chemicals, synergism, intumescence, FR mechanisms, modeling, flame parameters, inherently FR polymers and polymer blends.

About 120 experts from USA, Canada, Germany, Japan, Austria, England, Israel, Belgium, China, Poland and Russia contributed in this conference from 40 research centers of companies, universities and academies of sciences. About 40 plenary lectures were delivered at the conference and Technical Poster Sessions (6 posters) was conducted. The conference was opened by the Chairman Prof. Menachem Lewin, from the Hebrew University of Jerusalem.* Prof. Lewin described

*Prof. Eli Pearce (Brooklyn Polytechnic University), Prof. Charles A. Wilkie (Marquette University, Milwaukee) and Dr. Marcelo H. Hirshler (Safety Engineering Laboratories, Rocky River, OH) took part in organization of this conference.

the main purposes of the conference and gave a brief review of the four previous conferences.

The first part of conference was dedicated to new directions in FR technology and the FR industry. The design of flame retardants (a complete description of the interaction of transition metal halides and poly(methyl methacrylate) was covered in the lecture of Prof. Charles A. Wilkie (Department of Chemistry, Marquette University, Milwaukee, WI). The report of Prof. William Herbert Starnes, Jr. and his coworkers (J. P. Jeng, S. A. Terranova, E. Banaplata Revilla and K. Goldsmith) from Department of Chemistry, College of William and Mary, Williamsburg, VA considered a new approach to smoke suppression in vinyl chloride polymers. Prof. Eli Pearce (Director of Polymer Research Institute, Brooklyn Polytechnic University, New York) gave a general review of problems of flammability and flame retardancy.

The second part of conference was dedicated at advances in Fr Polymers. Prof. W. von Gentzkow (Siemens AG, Corp., Research and Development, Erlangen, Germany) reported on progress in the area of halogen free flame retardant thermosets for electronics. Effect of flame retardant structure and properties on styrenic polymer performance was the main subject of the lecture of Dr. John Uhemann from Dow Chemical Co., Midland MI. A new non-halogen technology for flame retardancy of ABS terpolymers based upon grafting was described in talk of Dr. Masanori Suzuki (Japan Synthetic Rubber Co., Ltd.) and Charles A. Wilkie. In this report the grafting of char-forming monomers such as methacrylic acid onto ABS and the flammability of the modified ABS were discussed.

The next part of conference covered the "Important Trends in Halogenated and Non-Halogenated FR Polymer Technology." The most important lecture in this part was given by Prof. Menachem Lewin who spoke about flame retardancy of polypropylene by intumescent systems. Some part of this talk was dedicated to problems of synergism and antagonism in actions of additives of polymers, char formation and application of cone-calorimetry for detecting of flammability of polymeric materials. Dr. Wolfgang Wanzke from Hoechst Co. (Frankfurt am Main, Germany) spoke about halogen free retardants for polymers which are produced by Hoechst.

Drs. H. Horacek and R. Grabner from Chemie Linz, Linz, Austria gave information about recent advances of nitrogen based applied to RP's and blends. A new look at some old FR's (melamine and melamine phosphates) was the main subject of the Prof. Edward D. Weil lecture (Brooklyn Polytechnic University, New York) and his coworkers (Oliver Huang, N. Patel, Weiming Zhu and V. Choudhury). This lecture comprised a literature and patent review, together with some new observations and insights based on experimental work in progress at Brooklyn Polytechnic University.

"More on FR Chemicals and Systems"—was the title of the next session of the 5th conference. Pyrolysis and char formation, kinetics, thermodynamics and mechanism of chemical reactions—was the main topic of Prof. G. E. Zaikov and Dr. S. M. Lomakin lecture (Institute of Chemical Physics, Moscow, Russia). Fire retardant polyester fibers and other products containing a new fire retardant were described in the lecture of Dr. Mark Haggard from Albright and Wilson America,

Richmond, VA. New results on mechanisms and performance of molybdenum and zinc containing flame and smoke suppressants were discussed by Dr. Larry Mus-selmann from VP Technology and Operations (Polymer Additives Group, Appolo, PA). Dr. Joseph Green (FMC Corp., Princeton, NJ) discussed the synergy of phosphorus-bromine flame retardants in polycarbonate blends. The lecture contained convincing evidence of phosphorus-bromine synergy in polycarbonate-PET blends. Flame retardancy of PAN and its copolymers was reported by Drs. J. Zhang and T. J. Shields, Fire SERT Center, University of Ulster, Carrickfergus, UK. Effectiveness of a range of flame retardants was studied using TGA, DSC, LOI and con calorimetry. For the flame retardants tested, retardancy was closely related to char formation.

The final session of FR chemicals and systems included 4 lectures. FR-polypropylene, a novel approach in the road to flame retardance was reported in the lecture of Dr. Ramon A. Mount from Ram-Tech, St. Louis, MO. Mineral fibers have been used to extend the physical properties of thermoplastics. This report documents a rather surprising effect on the flame retardant and smoke suppressant properties of mica-filled polypropylene. The lecture of Drs. Kelvin K. Shen and Donald J. Ferm, U.S. Borax Inc., Valencia, CA was concerning with recent advances on the use of borates as fire retardants in polymers, and Dr. Richard S. Rose reported (Great Lakes Chemical Corporation) about novel inherently flame retardant latexes for coating and adhesives applications. The last talk of this session was dedicated to the major criteria for choosing a flame retardant (Dr. P. Georlette, Plastic Additives Division, Dead Sea Bromine Group, Israel).

Session 6 concerned the problems in FR in the transportation industry. A part of these lectures was related to the effect of instrument response time on heat release rate measurements (Drs. Richard E. Lyon and Allan Abramowitz, FAA Technical Center, Atlantic City, NJ). A fractional effective dose model for post crash aircraft survivability was covered by Dr. Louise S. Speitel, FAA Technical Center, Atlantic City, NJ and thermally reversible gelation of hydrocarbons was discussed by Dr. Mark Green, Department of Chemistry and Herman F. Mark, Polymer Research Institute, Polytechnic University, NY.

Next session was dedicated to "Consumer Focus-Industrial, Military Applications." Dr. C. J. Abraham from Inter-City Testing and Consulting Corporation, Mineola, NY spoke about linseed oil—a hazardous but necessary ingredient. A review of plastic materials for building environmentally conscious products was presented by Dr. Ray Kirby (the coauthor was Inder L. Wadehra) from the Engineering Center for Environmentally Conscious Products, IBM Corp., Research Triangle Park, NC. The problems of flame retardancy of chemical protective gloves and overboots was discussed by Drs. D. Gulliami, A. Galezewski and Wilusz (U.S. Army Natick Research, Development and Engineering Center, Natick, MA).

One of the most important sessions was dedicated to problems of testing and standardization. Dr. Marcello Hirschler from Safety Engineering Laboratories, Inc., Rocky River, OH, discussed the use of the cone calorimeter to determine smoke corrosivity. Dr. Pravinray and D. Gandhi from Underwriters Laboratories Inc., Northbrook, IL compared the results of cone calorimeter with the UL94 classification for some plastics. Current regulatory activities in textile flammability

were discussed by Dr. Phillip J. Wakelyn, National Cotton Council, Washington, DC. In the second part of this session were presented lectures about the fire spread and growth model and its incorporation in the FMRC flammability apparatus for the evaluation of flame retardant materials (Dr. A. Twearson, Factory Mutual Research Corp., Norwood, MA), design of fire-test-response burn room calorimeter facility (Drs. King-Mon Tu and Alan Aaronson, AKZO Chemicals, Inc.), use of barriers and fire blocking layers to comply with fuel-scale fire tests for furnishings (Dr. Gordon Damant, Inter City Testing and Consulting Corp., Sacramento, CA) and a cone-calorimeter study of the effects of heat flux on the flammability of flame-retarded cross-linked polyethylene (Dr. M. D. Sawyer, Raychem, Ltd., England).

The next session was dedicated to environmental and toxicity issues. Participants of conference discussed with great interest the lecture of Dr. Gordon L. Nelson from Florida Institute of Technology (Melbourne, FL) who reported on the effect of carbon monoxide and fire exposure. Carbon monoxide is common to almost all fire atmospheres. This report summarized current comprehensive studies on CO toxicity to humans in both fire and non-fire incidents. Real fire toxicity is almost solely determined by CO.

The evaluation of ecotoxicological properties from incineration of new duroplastic materials without halogen as flame-retardant was presented in a lecture of group of authors (D. Lenoir, L. Becker, W. Thumm, A. Kettrup) from Institute of Ecological Chemistry, GSF Research Center, Oberschleibheim, Germany. Very important data were presented in the lecture of Prof. Ryszard Koslowski from Institute of Natural Fibers, Poznan, Poland about influence of flame retardant on the emission of toxic products from fabrics during thermal decomposition and combustion.

The last lecture of this session was dedicated to the status of regulations affecting brominated flame retardants in Europe and United States (Dr. Marcia L. Hardy, Health and Environment, Ethyl Corporation, Baton Rouge, LA).

The last report was about synthesis and applications of poly(diphenylsulfone phenylphosphonate)—Drs. Yuuzhong Wang, Changyi Zheng and Dacheng Wu from Textile College, Chengow University of Science and Technology, Chengow, China.

Poster session included information of Drs. E. Clausen, D. Lenoir, E. Wirfelder, A. Kettrup from Institute of Ecological Chemistry about thermolytic rate, reactivity and ecotoxicological behaviour of phosphorus compounds used as reactive flame retarders in casting resins. Prof. W. von Gentzkow, Drs. K. Kretzchmar, H. Markert, M. Schreyer (Siemens AG, Germany) presented data on halogen free flame-retardant molding compounds for the encapsulation of electronic components. Prof. W. von Gentzkow, Drs. J. Huber, H. Kapitzka, W. Roger (Siemens AG) covered halogen free flame-retardant laminates for printed circuit boards. Drs. A. Hauk, M. Sklorz, G. Bergmann, O. Hutzinger, University of Bayreuth, Chair of Ecological Chemistry and Geochemistry, D 95440 Bayreuth, Germany, reported on analysis and toxicity testing of new halogen-free flame retardant polymers for electronics. Drs. J. Cyrys, D. Lenoir, G. Matuchek, A. Kettrup, Institute of Ecological Chemistry, Germany discussed the application of thermal analysis of new

halogen-free flame retardant duroplastic materials. Drs. A. Richard Horrocks, Subhash A. Anand, Diane Sanderson and Baljinda Kandola, School of Textile Studies, Bolton Institute, Bolton, UK covered the fibre-intumescent-interactions and enhanced heat and flame resistance.

The conference has reviewed in depth the current interest in problems of flammability and fire retardancy of polymeric materials. This interest can be explained by the wide application of polymeric materials in industry, agriculture, transport and ordinary life, and by the development of laws regarding environmental protection and requirements for chemical additives for polymers. For these reasons, chemists (scientists and engineers) must continue the search for new non-toxic flame retardants for polymeric and composite materials.

Some academic scientists could not participate at this conference because of very high registration fee (850 US \$).

The 6th conference will be held in May 1995 in Stamford, Connecticut, USA.