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**Seminar on Research in Energetic Materials**  
**Pardubice, April 24-25, 2002**

**Summary**

The 5<sup>th</sup> Seminar on “New Trends in Research of Energetic Materials” was held at the University of Pardubice on April 24-25, 2002. The author of this Report, who was a member of the Scientific Committee of the Seminar, attended as the representative of the Office of Naval Research International Field Office, which joined with the Air Force European Office of Aerospace Research and Development in providing financial support for the Seminar.

There were ~120 participants in the Seminar from 20 countries; the Seminar comprised 19 Lectures and 23 Posters, with 51 papers available in the Proceedings. Difficulties with visas prevented the participation of several scheduled attendees. Topics discussed covered a wide range of disciplines; in addition to the synthesis and characterization of energetic ingredients, numerous papers discussed the thermolysis, autoignition, combustion, and detonation of formulations. There were also discussions of safety-related issues and of the effective disposal of explosives. Details of some specific topics are discussed below.

**Seminar Details**

Of special interest was the coincident meeting of the Steering Committee of CEPA 14, which deals with the Second Generation of Energetic Materials, of the Western Armaments Group. As a result, there were several presentations dealing with uniform characterization of ingredients and formulations. The Seminar opened with a typically-thorough presentation by Dr. Adam Cumming on CEPA 14; in it, he reviewed the several Memoranda of Understanding (MOUs) that have been achieved, as well as the countries that have participated in each. Such MOUs are needed to achieve lower costs and lower risks while achieving higher performance. Thus far, topics covered have included “clean” propellants,

Insensitive Munitions, ignition systems, Low Vulnerability Ammunition (LOVA), and demilitarization of conventional munitions. Currently under discussion are flare compositions, synthetic chemistry of nitrocompounds, and fragment/bullet impact. The extent of International participation in these efforts is impressive and presages a great deal of positive results. Excellent examples of programs in individual countries were those from the Czech Republic; for instance, Marcel Hanus presented the methodologies currently being implemented in the Czech Republic to qualify explosive materials for the Army, and Juri Pachman discussed the techniques being established there to characterize the aging of solid propellants and explosives. Based upon the depth and scope of the several programs, the 2003 Seminar should contain a valuable database that could provide a starting point for the related programs in many countries.

The topic of detonations was covered both in presentations and in several valuable discussions in conjunction with the Seminar. For instance, sophisticated experiments to map the development of detonation waves are underway in Coimbra, Portugal (Prof. Campos), and the study of the thermodynamics of detonations continues at ICT (Dr. Volk). Both researchers question some of the usual assumptions regarding detonations and the reactions that drive them. For instance, the propagation of detonation waves does not always appear to follow generally-accepted behavior, and the products of detonations and, hence their yield, may not always match those of thermochemical calculations, even in detonations involving only gas-phase reactions. Some current research in Pardubice (Prof. Vavra) appears to be yielding some of the basic results required. Of particular interest is the extent of participation of aluminum in detonations and the factors that drive such participation; for instance, how does the presence of H<sub>2</sub>O in the reaction zone affect Al reactions, and what mechanisms are responsible for such effects? The recent rise in the application of nanoparticles to energetic materials has increased the need for better understanding of these issues, and it was recommended that they be a topic of the next Seminar.

The topic of propellant sensitivity continues to be evaluated at the University of Pardubice, led by Prof. Zeman. Extensive data on the impact sensitivity of

polynitro compounds were made available; details of chemical structure appear to play an important role in determining such sensitivity, and should help to direct ingredient-synthesis research. In a related research effort, an improved technique is being developed for the measurement of electric spark sensitivity, and molecular-structure effects have been identified. Of special significance in this effort is the capability to understand the differences between the data obtained with specific testers. A complementary theoretical effort by Prof. Vavra shows promise in understanding intermolecular effects on sensitivity.

An important aspect of Seminars of this type is the sharing of safety-related data that are applicable to all types of materials. For instance, two papers from the Warsaw Institute of Technology discussed the extent of overpressure that can be experienced during industrial processes. Professor Teodorczyk presented an analysis of a large-scale accident where 100 kgs of ethylene were released and then exploded, producing a yield nearly equivalent to a comparable amount of TNT! For instance, windows were broken as far away as 2 kilometers from the incident site. The analysis considered all of the mechanisms that could produce overpressures of this magnitude, and compared this accident with several previous ethylene-related incidents. As such, this manuscript is an important document in support of plant design and represents a very valuable reference.

Another significant presentation discussed a joint (Czech-German) program to evaluate biodegradation as a technique for disposal of explosives, through a process known as phytoremediation. This program is studying means of decontaminating the soil and water involved and is also identifying the extent to which toxic products are produced in the plants employed; in some cases, the plants become deadly. Once again, this is an important document that should be referenced in the study of biodegradation as a viable disposal technique. A Polish paper discussed the possible application of waste energetic materials to improved blasting agents for mining; several practical issues in the preparation and use of such agents were identified.

Several papers discussed synthesis of energetic ingredients. Research is underway at Pardubice on the effects of reaction conditions on the purity and yield of the

insensitive high explosive known as TEX; valuable data on specific reactants were obtained. Swedish efforts on chemistry related to FOX-7 (diamino-dinitroethylene) continue. A paper by Latypov, et al. discussed the synthesis of derivatives with hydrazine; some derivatives were successfully prepared, but acid-base characteristics interfered with the synthesis of other derivatives. The results of work at Irkutsk on heterocyclic azidonitramines were presented in a paper by Prof. Medvedeva; her team has been able to synthesize six- and seven-membered heterocycles. Characterization of these compounds is underway. Three papers from the Peoples Republic of China describing ingredient synthesis were available in the Proceedings, even though the Authors were unable to attend. Techniques to desensitize the explosive known as BTENED were evaluated at CAEP; preliminary results indicated that some additives could produce materials with significantly-reduced sensitivity. Another program at CAEP is evaluating techniques to control the sensitivity of explosives produced through molding powders, and continuing research at Beijing Institute by Prof. Ou on compounds related to HNIW has produced some promising ingredients that could be employed as reaction intermediates or as end products.

Improved characterization of explosives was an integral part of many papers. An especially valuable presentation was made by Wilker, who discussed a technique to evaluate thermal-transport properties of explosives. Accurate knowledge of such properties is necessary for the prediction of the chemical stability of these materials. A "Hot Disk" method has been developed that allows for accurate measurement of thermal conductivity, a key parameter in establishing critical conduction for self-heating. The presentation clearly identified the experimental parameters that needed to be controlled in order to obtain accurate values of conductivity. It is hoped that the results in this presentation will lead to Standardization of this technique by the explosives community.

Several papers discussed the properties of emulsion explosives. Work in India, Croatia, Yugoslavia, and Poland was described; the Polish paper gave a thorough overview of the characteristics of the latest generation of these explosives, and the other manuscripts described the effects of environmental factors on the stability of

emulsions. Taken together, these documents represent an excellent summary of the state of the art related to emulsion explosives and their applications.

In addition to the technical details contained in the formal presentations and papers, valuable information was obtained from other sources at the Seminar. For instance, the technology being developed at the Beijing General Institute of Mining and Metallurgy for improved commercial emulsion explosives was described in an information package made available at the Seminar. The package described the range of materials that are now available, as well as the techniques that have been developed to apply them in order to produce optimum yields. Production at the rate of nearly 10,000 tons per year has been achieved, and trucks that can apply these explosives in a controlled manner are now being sold internationally.

Of special significance was the extent to which Explosia, a part of Synthesia (Pardubice), is expanding its range of synthesis capabilities. It was noted last year that CL-20 (HNIW) was being made available for sale by Synthesia; this year, Offering Sheets were handed out for several other ingredients, such as TEX, NTO, TAGN, ATZ, and GZT, and plans are underway to synthesize compounds such as TNAD and DADNE (FOX-7) and to manufacture linear nitramines for use as plasticizers. The latter compounds may be useful in reducing temperature sensitivity, and the other compounds mentioned can be applied to gas generators, insensitive explosives, and propelling charges. Most of the ingredients mentioned in the Offering Sheets appear to be available in scales typical of Pilot Plants.

Plans are already underway for the 6<sup>th</sup> Seminar next year, since 2003 is the 50<sup>th</sup> Anniversary year for the Institute of Chemical Technology. As mentioned above, the Seminar will represent the opportunity to share much of the data currently being obtained in the several programs underway. In addition, efforts will be made to organize sessions related to better understanding of detonations and of the participation of aluminum in detonations. It appears that some funding from the airbag gas-generator community will be available.

Another event of significance in 2003 is the planned World Conference on Explosives and Blasting Techniques, to be held in Prague in September. This Conference is being organized by the Czech Association for Blasting and Pyrotechnics and the European Federation of Explosives Engineers. When taken with the current activities of CEPA 14, it should represent an excellent opportunity to witness the progress being made to develop standards in explosives and their ingredients that are truly International.

In summary, this Seminar is an excellent opportunity to interact with an important portion of the Energetic Materials community, especially the younger researchers who do not have the financial resources to participate in the larger, more established Conferences. The financial support by from EOARD and ONRIFO played an important role in making the 5<sup>th</sup> Seminar successful.

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