GUIDELINES FOR

Vapor Release Mitigation

Prepared by
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for

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of the
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PREFACE

The American Institute of Chemical Engineers (AIChE) has a 30-year history of involvement with process safety and loss control for chemical and petrochemical plants. Through its strong ties with process designers, plant builders and operators, safety professionals, and academia, the AIChE has enhanced communication and fostered improvement in the high safety standards of the industry. Their publications and symposia have become an information resource for the engineering profession on the causes of accidents and means of prevention.

Early in 1985, AIChE established the Center for Chemical Process Safety (CCPS) to serve as a focus for a continuing program for process safety. The first CCPS project was the preparation of *Guidelines for Hazard Evaluation Procedures*. One of the CCPS projects for 1987 was the preparation of this document, *Guidelines for Vapor Release Mitigation*. The goal of this project was to

> publish available information on generic techniques designed to reduce the consequences of unplanned hazardous vapor releases. Sources of information will be major chemical companies as well as recent open literature, governmental agencies, transport systems, and engineering organizations. The CCPS will solicit information from major chemical companies and by so doing provide these companies a mechanism for making any special knowledge available to the engineering community and the public.

Thus, *Guidelines for Vapor Release Mitigation* is a survey of current industrial practice for controlling accidental releases of hazardous vapors and preventing their escape from the source area. To prepare this document, CCPS reviewed the available literature for de-

scriptions of existing and proposed vapor-control equipment and visited industrial sites. CCPS also obtained equipment designs and procedures for dealing with vapor releases from chemical and petrochemical companies.

These guidelines are intended to represent current industrial practice rather than theory. However, some of the suggested practices and equipment have not been fully tested; that is, they may not have been used to mitigate an actual vapor release. These guidelines present methods for attaining improvement and are a starting point for further development; however, they are not proposed as standards to be achieved by the industry, and companies are not expected to employ all of the methods presented.

Further, there are wide variations in toxicity (acute, chronic, and latent), resistance to corrosion and erosion, flammability (explosive limits and ignition energies), and physical properties (vapor pressure and vapor density) among the fluids involved. Therefore, the applicability of the guidelines should be evaluated or tested in terms of particular fluids and proposed construction materials.

Guidelines for Vapor Release Mitigation should be useful to both experienced and inexperienced engineers, but because of the rapid evolution in plant design and operation, it is unlikely that this volume includes all the useful methods for mitigating vapor hazards. Current literature--particularly the journals of AIChE and its British counterpart, the Institution of Chemical Engineers--contains additional guidance on existing and novel methods of vapor control.

Eliminating the cause of releases and reducing their frequency are effective mitigation methods, in the broader sense of the term. Techniques for analyzing processes to identify vapor release sources and evaluate their likelihood are presented in *Guidelines for Hazard Evaluation Procedures* and in a forthcoming CCPS volume, *Guidelines for Chemical Process Quantitative Risk Assessment Procedures*. Methods for preventing vapor releases are also addressed in *Guidelines for Safe Storage and Handling of High Toxic Hazard Material*. Although methods for reducing the likelihood of vapor releases are included in the present volume, these guidelines emphasize methods for reducing the size, duration, and consequences of vapor releases.

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The subcommittee acknowledges the assistance of the following people in commenting on various aspects of the drafts: D. E. Wade (Monsanto), R. A. Smith (Dow), R. F. Schwab (Allied-Signal), R. G. Holmes (Westinghouse), R. W. Ormsby (Air Products), P. Rasch (Celanese), R. J. Hawkins (Celanese), S. S. Grossel (Hoffman-LaRoche), and J. Hagopian (Arthur D. Little).

The principal author of *Guidelines for Vapor Release Mitigation* was Richard W. Prugh, a staff member of the Center for Chemical Process Safety, with significant technical and editorial contributions by Robert W. Johnson of Battelle Memorial Institute's Columbus Division. Important editorial contributions from William H. Goldthwaite of Battelle Columbus Division are gratefully acknowledged.

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SUMMARY

The purpose of this document is to make generally available the approaches and measures that are currently being used by many companies in the chemical process industry for mitigating the likelihood and consequences of vapor cloud releases.

Many of the major chemical accidents that have occurred recently have involved the release of toxic or flammable vapors in quantities sufficient to have severe health and environmental impacts. The release of dangerous amounts of toxic and flammable vapors can be minimized and the severity of their effects can be reduced by a variety of mitigation measures. The choice of mitigation measure depends upon the particular hazard of concern, the amount of material involved, the siting of the facility, the processes involved, and other characteristics of the facility in question. Nevertheless, there is a hierarchy or preference order to the approaches that should be considered in choosing an approach for any particular mitigation concern.

The mitigation approach which is generally most effective is to make the plant inherently safer. A chemical process facility will be inherently safer if, for example, the inventory of hazardous material can be eliminated by substitution of a nonhazardous material in the process, or reduced to a level where total release would not pose a threat to employees or the public. This is being done in several facilities by manufacturing the hazardous material in situ and limiting the inventory to that which is in the pipes and reaction vessels. Another approach that is sometimes possible with new plants is to choose a site far enough removed from populated or sensitive areas that it would be impossible for a hazardous concentration to develop there. It fol-

lows that this buffer zone must somehow be kept inviolate for the life of the plant or process.

There are a variety of engineering approaches to mitigation of hazardous vapor releases that are next in order of preference. The first is to ensure plant integrity so that the probability of a release is minimized. Attention to design and construction codes is an important aspect of this. Ensuring that materials of construction are chosen to maintain plant integrity while containing the process materials under the process conditions and under process upset conditions is essential. Inspection and testing of materials and equipment before start-up and at intervals during operation of the process are also necessary.

"Process integrity" is also high on the preference order of approaches to mitigation. Process integrity involves the chemistry of plant design and operation, and includes ensuring that only the proper reactants and solvents are used and that they are of the required purity for the process and equipment. Knowing and maintaining the conditions of operation within limits that are known to be safe is also essential to process integrity. Avoiding processes that are sensitive to parameter deviations and providing measurement and control of those parameters are helpful in avoiding upsets that lead to loss-of-containment accidents. Pressure relief systems, properly chosen and configured and venting into other containment or disposal systems such as scrubbers, stacks, and flares, are another way of enhancing process integrity.

The approaches to mitigation that have been mentioned above are at the top of the preference order because they can work toward preventing the release of dangerous amounts of hazardous vapors. However, mitigation after loss of containment can also be effective and usually must be provided for in the process design stage. Secondary containment by concentric piping, double-walled vessels, or enclosures may be warranted. In the event of the release of a volatile liquid to the environment by a leak or a rupture of a line or vessel, containing the liquid in a restricted area or minimizing its surface area can reduce the quantity of material released as vapor. This can be accomplished by using dikes, curbs, and trenches leading to strategically located impoundments. An added incentive is to help keep the liquid source of the vapor away from sensitive areas with respect to people, process, and the environment.

There are other effective mitigation measures that are more concerned with the start-up, operation, and maintenance of the facility than with facility and process design. These include procedure development and communication, training, inspections and tests, documentation and the protocol for maintenance and modifications. In each

instance, accuracy and clarity of procedures are important to avoid errors which could lead to upsets and vapor release accidents.

Should loss of containment develop, there are methods for temporarily stopping a leak through patching or, with some materials, freezing that may be useful. Mitigation by early detection and warning can be effective in preventing on-site health effects and in limiting the off-site release to nonhazardous levels. There are several detection methods ranging from various types of sensors to detection by personnel by odor or sight. Warning may involve alarms, communication systems, and accident analysis systems.

Lower on the preference order, but still important, are the systems or equipment that can be provided for mitigation by countermeasures. These provide mitigation by controlling, to as great a degree as possible, the dilution and dispersion of the hazardous vapors. Systems such as water curtains, steam curtains and water sprays have been studied and used, to a limited extent, to control the movement and concentration of the vapor. If the spilled liquid has been confined by a dike or impoundment, reducing the vapor generation rate can often be done by covering the liquid source with foams, with compatible liquids, and, in some cases, with granular solids.

On-site and off-site emergency response can provide effective mitigation of health effects in many instances if adequately planned and effectively implemented. This requires both equipment and training--both tailored to the materials and types of accidents that are most likely to be involved.

The preference order of mitigation measures that have been mentioned and are described in this volume is important to selection of the most appropriate measures for a particular facility. Also important is an understanding of the types of accident that can occur and result in a vapor release and the possible consequences of such a release. Methods for identifying and evaluating accident scenarios, both with and without particular mitigation measures, can be valuable in the selection process. Other AIChE-CCPS volumes, referenced in this text, describe these identification and evaluation procedures.

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