ELECTRICAL AND INSTRUMENTATION

SAFETY

FOR CHEMICAL PROCESSES

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Electrical and Instrumentation Safety for Chemical Processes

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This text is dedicated to those involved in the design, operation, maintenance, and management of chemical and similar processes, with the goal that it will help them provide the safest facilities possible, and to those who live near chemical process facilities.

It is also dedicated to those who do not know what they do not know. In some chemical process units, there are no experienced electrical engineers, and someone else will have to make electrical safety decisions. This book will help that person to know what he or she does not know.

Preface

This text is about electrical and instrumentation safety for chemical processes. It covers a wide area of electrical and electronic phenomena and how they have and can significantly affect the safety of chemical processes. The importance of the subject is well known to anyone involved in the operation of chemical processes.

Lightning strikes can explode storage tanks, shut down electrical power systems, and shut down or damage computer and instrument systems. Static electricity can ignite flammable materials and damage sensitive electronic process control equipment. Electrical power system failures or interruptions can produce unsafe process conditions. Chemical processes use flammable and combustible vapors, gases, or dusts that can be exploded by electrical equipment and wiring. Even low-energy equipment like flashlights can ignite a flammable vapor. Interlock and equipment protection systems can cause safety problems.

How important is electrical and process control safety? A survey on "How Safe is Your Plant?", in the April 1988 issue of *Chemical Engineering* magazine, provided some answers. Among the results of this survey of chemical processes, it was found that over 800 respondents believed instrumentation and controls, shutdown systems, equipment interlocks, and other protection systems to be the least safe aspect of chemical industries. The survey also indicated that complying with OSHA and other regulations, process control software security, inspections, audits, and safety training are important safety issues.

Electrical and Instrumentation Safety for Chemical Processes covers the areas mentioned in the *Chemical Engineering* magazine survey, as well as many other important issues, including: hazardous areas; combustible dust safety; computer power and grounding; power system reliability for chemical processes; and process control safety.

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Introduction

The mission of this text is to present the principles and practice of electrical and process control safety as applied to chemical processes. The text accomplishes the following:

1. It presents the wide spectrum of electrical and process control areas essential to safety.
2. It presents the topics in an integrated approach that ties together key issues.
3. It takes unique and creative approaches to controversial issues.
4. It provides a safety course with practical, usable criteria. The text is prepared from actual experiences and work in chemical processes.
5. It presents a discussion, based on personal experience with work on codes and standards committees and with their application to new facilities and modifications of existing plants, of national and international regulations and standards; it describes what they are about and how to comply with them.
6. It provides recommendations concerning documentation, training, safety audits, inspections, and accident investigations.
7. It discusses the application of new techniques such as combustible gas detectors, fault-tolerant systems, and European hazardous area practices.
8. This test is a guide to good safety practice; however, applying the principles and practices in day-to-day situations requires good judgment and careful consideration of the factors involved. Alternatives and modifications should always be considered where justified and appropriate.
9. The National Fire Protection Association (NFPA), the Instrument Society of America (ISA), and other organizations' codes and standards are referred to throughout this text. It is essential to refer to the wording in the current code or standard in any situation.
10. The principles and practices described in this text are believed to

be safe and good practice and are intended to be used with proper engineering practice and application. Since there is a variety of conditions that can exist in any given situation that are beyond our control, the author, the author's employer, and the publisher assume no liability in connection with the application of the principles and practices described herein.

GENERAL SAFETY CRITERIA: PROTECTION OF PEOPLE, PROPERTY, AND THE COMMUNITY

The following is an excerpt from an article in the December 1988/January 1989 issue of *Chemical Manufacturers Association* (*CMA*) *News* titled "A Blueprint for Regaining Public Trust," which indicates that "in the following excerpts from a recent speech before the American Institute of Chemical Engineers, Harold J. Corbett, Senior Vice President of Monsanto Company, describes what industry must do to regain public trust."

The excerpt from the speech states that

> process risks will be reduced to the point where serious accidents do not occur and people living near the plant site will fully understand how the plant operates. Moreover they will have full confidence in the people operating the plant because they know that these people make safety the top priority.

The results of a survey on "How Safe is Your Plant?" in the October 10, 1988, issue of *Chemical Engineering* indicate that 90% of the respondents feel safe on the job, despite the fact that 44% of their plants had a major accident within the last 5 years and 70% think a similar accident may happen again. Safety is a major concern in all industries but especially the chemical process industry because of the hazardous nature of the materials that are used. It is absolutely essential to avoid catastrophic incidents like Flixborough. Flixborough refers to an explosion that occurred at a caprolactam facility in the United Kingdom in 1974. The explosion occurred when 50 tons of cyclohexane was released into the air, killing 28 employees, injuring many, and causing $100 million in property damage. Such incidents like this and the 1989 explosion at a Phillips Petroleum plastic plant in Pasadena, Texas, could result in additional regulatory legislation on the state and federal level. In many states, hazop analyses are already a part of state regulations for certain high hazard materials. Recent oil spills have resulted in significant federal and state legislation to regulate storage tanks and pipelines.

It is important to recognize that environment and safety issues share a common ground. Explosions, fires, and malfunctions of process equipment can cause the release of materials outside the plant boundary. Furthermore, public perception and opinion is critical in today's regulatory environment.

Fires, explosions, injuries, and fatalities within the plant that are not in the Flixborough category are equally damaging. Each incident, no matter how large or small, is another bad mark against the plant, company, and industry. The individual and aggregate impact on the individual process unit, plant, and company can be significant. Safety is good business. This is as true today as it has ever been, especially in the competitive environment. Companies cannot afford accidents. Fires and explosions can render a process unit or plant inoperative. The replacement of facilities at today's inflated costs may be too high to justify replacement, and the unit may be shut down. Lost production results in lost sales and unhappy customers who may buy from competitors.

As an example, a product testing lab had a fluorescent lighting fixture fire (not an uncommon event) that shut down the lab, and the product had to be shipped outside the plant to be tested. As another example, a static spark ignited a cotton-like plastic that burned the building. The unit was shut down permanently because rebuilding was not justified. A fire in a process control room or computer room can be particularly devastating because it can result in the loss of process control or interlock design that may not be recoverable.

Personnel injuries or fatalities are particularly devastating, especially if they involve fellow employees and friends. In addition to personal tragedy, which is bad enough, Occupation and Safety Health Administration (OSHA) citations and lawsuits can follow. The average cost of a disabling injury in 1987 was approximately $23,000, which represents a 22% increase over 1986.

Personnel injuries or fatalities can occur in electrical systems without explosions or fires. Thirty volts AC (or in some situations even lower voltage) can electrocute a person. For example, an improperly grounded limit switch or instrument transmitter could be the cause. As another example, an electric arc is the hottest temperature on earth next to a nuclear reaction. A spark between the wiring terminals in a control panel could damage the eyesight of an electrician looking closely at the source to troubleshoot a circuit but not wearing safety glasses. Arcs in power equipment, which can release significant thermal energy, have burned maintenance electricians severely.

If the costs and consequences of accidents in chemical processes are understood, why do they occur? The following are possible reasons.

Production and Costs

The safety survey in *Chemical Engineering* magazine (October 1988) indicates that although safety is often said to be paramount, in reality production often reigns in many Chemical Process Industries plants. One respondent indicated that safety is talked about, but production and costs are always the important factors.

It Can't Happen Here

The tendency to think that an accident cannot happen in your plant is not peculiar to chemical process safety. It might be associated with a failure to appreciate what can happen and inexperience with the fact that it *has* happened here. Dusts are an example of something that is familiar and appears to exist in a rather harmless condition in day-to-day operations. In certain conditions, however, dust can produce violent explosions and fires, as grain-processing people can testify.

Poor Design and Installation

Good engineering is an essential element of chemical process safety, or any type of safety. Well-engineered plants produce the quality and quantity of products needed in a safe manner. They can be operated or maintained without undue effort or safety risks. They start up and operate well.

Operator Error

In many instances, operator error is cited as the reason for an accident. Operator error may be the result of inadequate training or supervision, but the control system design may be a contributing factor. The design needs to be friendly, easy to operate, not overly complicated, and without too many alarms or interlocks (overalarming and interlocking are common maladies of control system design). The process information needs to be presented in an easy-to-understand and usable manner. Controls need to be designed to account for equipment and control system failures and operator error.

Inadequate Maintenance

Inadequate maintenance has also been cited as a contributing factor to accidents. Some maintenance problems may be attributable to poor design and installation. The equipment may be inaccessible or may not have adequate working space. [These deficiencies are violations of the OSHA regulations and the *National Electrical Code* (*NEC*).] (*National Electrical Code*® and *NEC*® are registered trademarks of the National Fire Protection Association, Inc., Quincy, MA 02269.) The equipment may be difficult to calibrate or test; the proper test or calibration equipment may not have been provided; or the vendor data may be nonexistent, in error, or too complicated.

There are undoubtedly other reasons or contributing factors as to why accidents occur, but regardless of the factors, they could have been controlled.

SAFETY PHILOSOPHY AND PRINCIPLES

The following excerpt is from the Bureau of Naval Personnel Rate Training Manual, *Basic Electricity:*

> In the performance of his normal duties, the technician is exposed to many potentially dangerous conditions and situations. No training manual, no set of rules or regulations, no listing of hazards can make working conditions completely safe. However, it is possible for the technician to complete a full career without serious accident or injury. Attainment of this goal requires that he be aware of the main sources of danger, and that he remain constantly alert to those dangers. He must take the proper precautions and practice the basic rules of safety. He must be safety conscious at all times, and this safety consciousness must become second nature to him.

The same statement is true for those who work in chemical processes. There are people who have worked more than 40 years in chemical facilities without being involved in an accident or sustaining any injury at work.

Explosions, fires, spills, releases, injuries, and fatalities can all be prevented. A statement from the cover of the Chemical Safety Data Sheets published by the Manufacturing Chemists Association (now the Chemical Manufactures Association) indicates that chemicals in any form can be handled, stored, or processed if the physical, chemical, and hazardous properties are fully understood and the necessary precautions, including the use of protective equipment and proper safeguards are followed.

Webster's definition of an accident includes the phrases "an event occurring by chance or from unknown causes" and "any unfortunate event resulting from carelessness, unawareness, ignorance, or unavoidable causes." The second statement describes the type of situation with which we are concerned, except we should question "unavoidable causes." Nearly all accidents are avoidable. Some accident reports seem to indicate that the cause of the accident was mysterious forces, unforeseen conditions, or an act of God.

My experience with accident investigation indicates that this is not true. In most cases, established codes and practices, standards, and sound engineering principles have been violated. In a court case involving lightning damage to a structure, an attorney argued that lightning has for some time been considered "an unforeseeable intervening force," but it is a "reasonably foreseeable danger" for which there are inexpensive simple protection systems. (Lightning protection systems were proposed by Ben Franklin.)

The same is true for electrical and process control safety in chemical processes. The engineering technology to protect against hazards is known; however, it is not always simple or inexpensive.

The steps in achieving safety are as follows:

1. Know the nature and characteristics of the hazard involved.
2. Convert this knowledge to usable, understandable, practical information. This information includes reference documentation, standards and practices, technical studies and papers, and training and inspection material.
3. Provide training—especially at the operating and maintenance level.
4. Conduct inspections, audits, and investigations to provide feedback to the organization.
5. Update and upgrade the process as technology, people, and the environment change.

Electrical and control system safety requires interaction and coordination with many other systems, disciplines, and groups of people. Structural, mechanical, and process design, plant operations, plant maintenance, construction, and purchasing are all part of the process, as are staff safety and research. Safety involves a systems approach. Failure to recognize this requirement can only lead to less than desirable results.

ELECTRICAL AND CONTROL SYSTEM SAFETY INCIDENTS

The following is a list of some safety incidents that have occurred, some a number of times, and can be expected to happen again:

1. Lightning that struck caused an explosion in a flammable liquid storage tank.
2. Static discharge exploded vapor in a duct system.

3. A building exploded as a result of interlock bypass and runaway reaction.
4. Programmable Logic Controller (PLC) and Unit Operations Controller locked up during an electrical storm.
5. Thermowell failure caused toxic and flammable gas to enter a control room.

ACRONYMS AND ABBREVIATIONS

The following acronyms and abbreviations are used throughout this text.

AIChE	American Institute of Chemical Engineers
AIT	Autogenous ignition temperature
ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing Materials
AWG	American wire gauge
CEC	*Canadian Electrical Code*
CENELEC	European Electrotechnical Committee for Standardization
CRT	Cathode ray tube
CMA	Chemical Manufacturers Association
CSA	Canadian Standards Association
CT	Current transformer
DCS	Distributed Control Systems
DIP	Dust-ignition-proof
d/p	Differential pressure
EMI	Electromagnetic interference
EP	Explosionproof (enclosure)
EPA	Environmental Protection Agency
FM	Factory Mutual Research Corporation
FP	Flash point
GFCI	Ground Fault Circuit Interrupter
HP	Horsepower
HS	Hermetically sealed (contact)
I	Amperes
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IES	Illuminating Engineering Society
I/O	Input/Output
IS	Instrinsic safety
ISA	Instrument Society of America