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INTRODUCTION

Management of change (MOC) is a process for evaluating and controlling modifications to facility design, operation, organization, or activities – *prior to implementation* – to make certain that no new hazards are introduced and that the risk of existing hazards to employees, the public, or the environment is not unknowingly increased.

MOC is one of the most important elements of a process safety management (PSM) system. Changes occur when modifications are made to the operation or when replacement equipment does not meet the design specification of the equipment it is replacing. Other, more subtle changes can occur when new chemical suppliers are selected, National Fire Protection Association hazard classifications change, procedures are modified, or site staffing and/or company organization is revised. Such changes, if not carefully controlled, can increase the risk of process operation and result in incidents.

MOC has been called the minute-by-minute risk assessment control system in plants and companies. The significance of MOC – or the lack of it – was never more apparent than in the Flixborough accident, as shown in Figure 1.1.[1] This watershed event involved a temporary modification to piping between cyclohexane oxidation reactors. In an effort to maintain production, a temporary bypass line was installed when the fifth of a series of six reactors was removed at a facility in Flixborough, England, in March of 1974. The bypass failed while the plant was being restarted after unrelated repairs on June 1, 1974, releasing about 60,000 pounds of hot process material, composed mostly of cyclohexane. The resulting vapor cloud exploded, yielding an energy release equivalent to about 15 tons of TNT. The explosion completely destroyed the plant, and damaged nearby homes and businesses, killing 28 employees, and injuring 89 employees and neighbors.

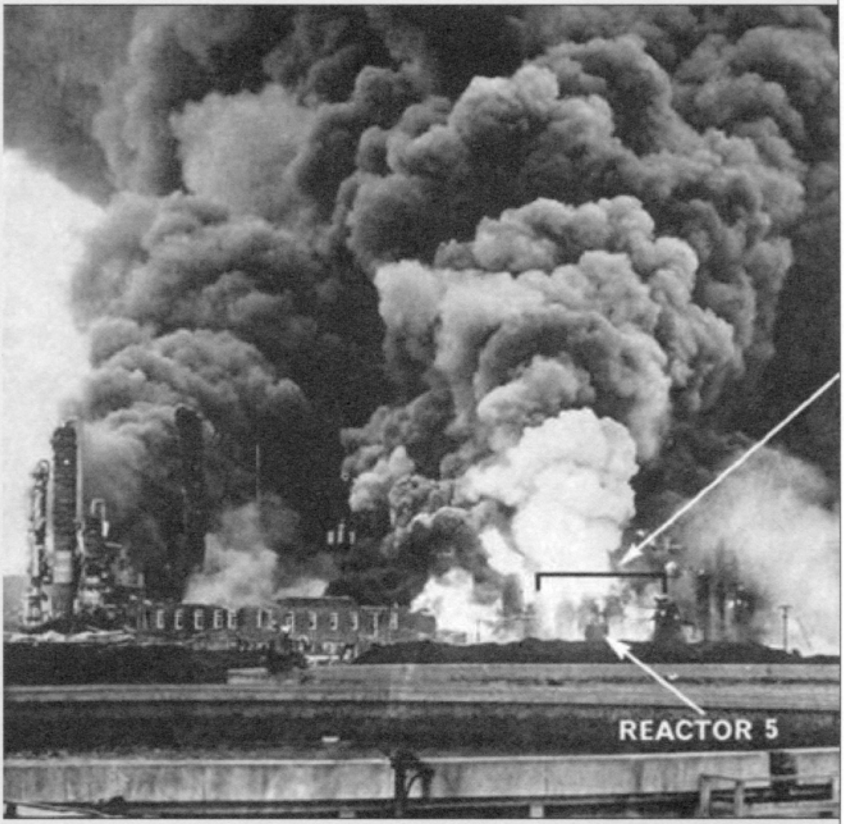

FIGURE 1.1 Flixborough Accident — Failure to Manage Change

No engineering support was available in the plant at the time of the accident. The temporary modification was constructed by people who did not know how to design large pipes equipped with bellows. As stated in the official report: "…they did not know that they did not know." An effective MOC system should have discovered the design flaw before the change was implemented, thus averting the disaster.

1.1 HISTORICAL PERSPECTIVE

Many companies have implemented MOC systems over the past 15 years. In 1989, the Center for Chemical Process Safety (CCPS) published its groundbreaking *Guidelines for Technical Management of Chemical Process Safety*, which included MOC as an element.[2] However, most of the initial chemical industry MOC implementation activity has been driven by two forces: (1) the Occupational Safety and Health Administration's (OSHA's) PSM standard and (2) quality initiatives.[3,4]

In 1993, the Chemical Manufacturers Association, now known as the American Chemistry Council (ACC), published the first comprehensive guidelines on MOC: *A Manager's Guide to Implementing and Improving Management of Change Systems.*[5] However, this treatise was not widely distributed. Since that time, many conference presentations have been given, journal papers written, and several additional texts completed on MOC; and yet the industry "thirst" for effective MOC practices remains.[6-7] More than ever before, companies recognize that insufficient control of changes plays a major role in accidents.

In addition, much has happened in the chemical industry since 1989 and a large amount of experience (good and bad) has been accumulated. Table 1.1 lists a number of events, happenings, trends, and experiences that CCPS considered as inputs to the development this book.

Given this industry experience, CCPS has developed these *MOC Guidelines* considering CCPS's new Risk Based Process Safety (RBPS) system approach (Chapter 2).[8] Table 1.2 lists the goals of these *MOC Guidelines* in serving identified industry needs.

As a result, companies can use these guidelines for any of the following activities:

- Implementing a company's first MOC system
- Diagnosing and correcting a defective MOC system
- Determining ways to continuously improve MOC effectiveness

1.2 MANAGEMENT OF CHANGE ELEMENT OVERVIEW

MOC reviews are performed at operating sites or in company corporate offices that are involved with capital project design and planning. MOC reviews focus on bona fide changes, not replacements-in-kind (RIKs). An employee first originates a change request. Then qualified personnel, normally independent of the MOC originator, review the request to identify any potentially adverse impacts. Based on this review, and after addressing any additional requirements, a responsible party either approves or rejects the change for execution. If the change is approved, it can be implemented. Before startup of the change, potentially affected personnel are either informed of the change or provided with more detailed training, if needed. Affected process safety information (PSI) is modified to reflect the change. Most of the time, these activities are completed prior to startup of the change.

TABLE 1.1. Things that Have Happened in MOC Since 1992

- More than 15 years of MOC experience, particularly with incidents for which failure of MOC was identified as a root cause
- Major increase in the use of electronic documentation of site information
- Emergence of MOC software applications
- Emergence of Web-based documentation sharing systems
- Company-wide MOC systems (involvement of non-local personnel in MOC reviews)
- Redistribution of PSM work to sites (lack of central monitoring of PSM/MOC)
- Downsizing and integration of MOC duties within production jobs
- Increased efforts to monitor MOC implementation via management reviews
- Organizational upheaval (divestitures, acquisitions lack of culture integration)
- Use of MOC in process areas not covered by regulatory standards
- Realization of the need for MOC for nontraditional types of changes
- PSM regulatory creep (broadening of the application for new change types and expanding the MOC work required)
- Expansion of the six-sigma approach and other productivity improvement initiatives, which has increased the workload associated with MOC systems involving subtle types of changes
- Accident investigations that have revealed the risk significance of previously under-considered sources of subtle change, such as organizational changes

TABLE 1.2. Goals of these *MOC Guidelines*

- Reduce the number of MOC related incidents and PSM audit findings
- Expand MOC into the process/project life cycle and nontraditional types of changes
- Tailor MOC systems to the facility size, perceived risk anticipated usage rate of the MOC system, and safety culture
- Monitor MOC performance at sites from afar, in real time, and cost effectively
- Quickly diagnose MOC problems without having to perform or wait for a PSM audit
- Make MOC systems more fault tolerant and resistant to circumvention or human error
- Monitor MOC performance and efficiency in a practical way
- Achieve better MOC results with fewer resources, if possible

The main product of an MOC system is a properly reviewed change request that is authorized, amended, or rejected. Ancillary products include modified PSI, change communication, and updated training records.

Companies and sites usually have written MOC procedures that apply to all work that is not judged to be an RIK. The results of the review process are typically documented on an MOC review form. Backup information provided to aid the review or generated by the review is usually kept for several years as a foundation for updates and process hazard analysis (PHA) revalidations. This information also provides an auditable record of the MOC implementation process.

1.3 MOTIVATIONS FOR MOC

Companies that manufacture, handle, store, or use hazardous chemicals are committed to effective MOC for a variety of reasons. In addition to a desire to promote employee and public safety and to protect the environment, motivations for MOC include the intent to comply with (1) ACC's Responsible Care® initiative, (2) government regulations requiring MOC systems, and (3) quality/environmental initiatives such as International Organization for Standardization (ISO) 9000/14000.[3, 5, 9-12]

PSM practices and formal management systems have been in place in many companies for more than 20 years. PSM is widely credited for perceived reductions in major accident risk and improved chemical industry performance. Nevertheless, many companies continue to be challenged by resource pressures, inadequate management systems (as evidenced by chronic deficiencies found in MOC audit results), and stagnant process safety incident performance, particularly involving MOC systems.

1.3.1 Internal Motivations

Inappropriate changes can affect employee and/or public safety, damage the environment, or result in significant business interruptions. They can also reduce product quality or increase production costs. The desire to decrease the occurrence of change-induced incidents and reduce the cost of doing business motivates companies to create effective MOC systems that will enable them to remain competitive, grow, and prosper.

Experience has demonstrated that inadvertent, unintended, erroneous, or poorly performed changes – changes whose risk is not properly understood – can result in catastrophic fires, explosions, or toxic releases. The 1974 explosion at Flixborough, England, described at the beginning of this chapter, was fundamental to the development of formal safety management systems, both in Europe and the United States. Table 1.3 gives examples of changes that could increase risk.

MOC systems call for implementation of formal administrative procedures that require reviews and approvals of proposed changes within designated areas of a site. The objective of MOC is to prevent changes in process chemistry and technology, equipment operations, maintenance, and supporting functions from introducing unacceptable risks. Inadequate reviews of proposed changes can result in the potential for certain changes to violate the design basis of carefully engineered systems or to increase the risk of processes that have operated safely for years.

1.3.2 Industry Initiatives

Several industry organizations have recommended the development of MOC procedures through various guidelines (Table 1.4).

TABLE 1.3. Examples of Changes that Should Be Managed or Could Increase Risk

***Process equipment changes* such as materials of construction design parameters, and equipment configuration**
• Changing piping from carbon steel to stainless steel without considering the potential for pitting due to the presence of chlorides
• Replacing a reactor with one of equal volume but different length-to-diameter ratio without considering potential changes in vessel mixing and heat transfer characteristics
• Changing a vessel's service to a higher specific gravity material without considering the impact of the additional weight on the vessel support structure
• Changing a pump impeller to a larger diameter to increase capacity or head without considering the potential to (1) overpressure downstream equipment, (2) operate above PSV set pressures, or (3) cause pump cavitation because of suction side limitations
• Repairing a process leak via an engineered clamp without confirming that the pressure rating for the temporary repair is adequate for the service
• Replacing a metal wafered gasket with a Teflon gasket, which won't hold up to an external fire, on a temporary basis to make it through the weekend.
• Connecting the cooling system of a new reactor to an existing cooling tower, without assessing the impact of increased load on the tower
• Substituting plastic pipe for steel pipe without considering the potential for generating static electricity that could ignite flammable vapors or combustible dusts, or failure caused by lack of support, particularly at elevated temperatures
• Temporarily replacing a centrifugal pump with a positive displacement pump without considering the need for a reliable relief path in the downstream piping
***Process control changes* such as instrumentation, controls, interlocks, and computerized systems, including logic solvers and software**
• Raising the trip point on a safety-related high level alarm beyond the safe operating limit established by prior safety analyses
• Permanently converting a 1-out-of-3 voted safety sensing system to a 1-out-of-2 system because one of the sensors has failed, which ignores the hardware fault tolerance of the safety system
• Replacing a transmitter that produces an analog output with one that produces a digital output without considering the failure modes associated with the new transmitter and the potential effect on the reliability of the associated interlock circuit
• Adding a new alarm within the DCS without considering the incremental impact for creating a process alarm overload situation for operators
***Safety system changes* such as allowing process operation while certain safety systems are out of service**
• Adding an isolation valve beneath a pressure relief valve to make it easier to remove and test the relief valve without considering the management system required to be certain the valve is not inadvertently closed
• Replacing a building sprinkler system with a CO_2 system without considering the associated asphyxiation hazard
• Directing atmospheric relief valve discharges to an existing flare header without considering the impact on the flare header or the performance of other relief devices discharging into the header
• Replacing an explosion relief vent panel with a panel having a higher burst pressure to "prevent spurious openings"

TABLE 1.3. Examples of Changes that Should Be Managed or Could Increase Risk (cont'd)

***Site infrastructure changes,* such as fire protection, permanent and temporary buildings, roads, and service systems**

- Increasing the occupancy of the control room building without considering the increased risk of building occupancy
- Increasing the size of the chemicals warehouse without considering the impact requirements for sprinkler protection may have on the flow/pressure capability of the firewater supply
- Relocating a unit's control room to a remote location to reduce operator exposure to unit hazards, without considering the impact of decreased operator presence in the process area
- Temporarily closing a major site road because of interferences from a construction project or a maintenance turnaround without considering the impact on the accessibility of emergency response vehicles to certain portions of the facility
- Disbanding facility emergency response capabilities in lieu of support from municipal emergency response agencies without considering the response time and capabilities of such groups

***Operations and technology changes* such as process conditions, process flow paths, raw materials and product specifications, introduction of new chemicals on site, and changes in packaging**

- Increasing process throughput beyond the currently established unit nameplate capacity without considering the potential impact on relief system capacity requirements
- Temporarily bypassing a heat exchanger without considering low temperature embrittlement of downstream equipment
- Temporarily receiving a highly toxic material via tank truck instead of railcars without considering that more frequent connections and disconnections of unloading lines could increase the likelihood of process material releases
- Using a more reactive catalyst type than that recommended by the vendor without considering that the higher reaction rate may exceed the cooling capacity of the reactor, potentially leading to runaway reaction

***Changes in inspection, testing, and preventive maintenance, or repair requirements,* such as lengthening an inspection interval or changing the lubricant type used in a compressor**

- Postponing a unit turnaround beyond the design run time limit, resulting in exceeding the maximum allowable intervals for certain equipment tests and inspections
- Increasing maintenance intervals based on resource constraints without considering past operating experience
- Reassigning certain maintenance tasks from maintenance personnel to operators without providing the operators with appropriate procedures, tools, and training for their new responsibilities
- Changing the inspection method for unit piping thickness from ultrasonic to X-ray without considering the hazards associated with more frequent use of ionizing radiation in the unit

TABLE 1.3. Examples of Changes that Should Be Managed or Could Increase Risk (cont'd)

***Changes in procedures,* such as standard operating procedures, safe work practices, emergency procedures, administrative procedures, and maintenance and inspection procedures**
• Modifying operating procedures to reduce or eliminate operator rounds in an area without considering the benefits of operator presence, such as leak detection
• Changing previously established safety, quality, or operating limits in the operating procedure
• Moving from a hard-copy based operating procedure system to one where personnel access all procedures through the site intranet
• Abandoning the OEM manuals in lieu of site-generated maintenance procedures
***Organizational and staffing changes* such as reducing the number of operators on a shift, changing the maintenance contractor for the site, or changing from 5-day operation to 7-day operation**
• Relocating the site technical group to a remote central corporate location without considering the impact on their ability to provide support to the facility
• Changing from an 8-hour shift schedule to a 12-hour shift schedule without evaluating the potential effect of greater fatigue associated with longer shifts
• Replacing an operations unit manager without considering the training needs for the new unit manager
• Deciding not to replace a retiring corporate loss prevention expert who previously reviewed all relief system designs, or replacing the expert with an inexperienced engineer
• Realigning the corporate PSM auditing function, placing primary auditing responsibility at the site level, without considering the possible reduced expertise or independence of local auditors
***Policy changes,* such as changing the amount of overtime permitted**
• Liberalizing the limits on the amount of overtime that an individual can work each month without considering the possibility of worker fatigue, or reducing the amount of overtime without considering the impact on staffing emergency response teams
• Revising the facial hair policy to allow facial hair for some classes of employees who are perceived to have a reduced need to wear respiratory protection
• Adopting a new paperless document policy intended to manage all site documentation electronically, including review/authorization, access, and retention of PSM-related information on PHAs, procedures, MOCs, PSSRs, and training records
• Implementing a new corporate policy for selecting external equipment manufacturers/ vendors and services that calls for a reverse auction and low-cost bidding process without consideration of the impact of non-standard equipment or less reliable equipment
• Changing the timing and means for shift change and turnover of operating control

TABLE 1.3. Examples of Changes that Should Be Managed or Could Increase Risk (cont'd)

***Other PSM system element changes*, such as modifying the MOC procedure to include a provision for emergency change requests**

- Reclassifying an area that currently requires a hot work permit as a designated area
- Revising the qualifications required for incident investigation leaders
- Eliminating a step in the approval of safe work permits that currently requires sign-off by the control room lead operator
- Modifying the way in which temporary trailer occupancy is controlled

***Other changes* including anything that "feels" like a change but does not fit in a change-type category that has been established for your facility; this "other type" should be in every MOC system**

- Adopting a new RAGAGEP on site, such as ISA 84.0104 standards for safety interlock life-cycle management
- Relocating a laboratory within an existing building
- Adding/deleting emergency response rolling stock (ambulances, etc.)
- Local municipalities/governments consolidating police, emergency medical service, and fire emergency response capabilities into one central location with enhanced communication and response technologies
- Changing the policy of using bicycles for onsite transportation

TABLE 1.4. Industry Initiatives to Implement MOC

- American Chemistry Council Responsible Care Management System® [9]
- American Institute of Chemical Engineers *Guidelines for Risk Based Process Safety* [8]
- American Petroleum Institute *Guidelines for Management of Process Hazards Recommended Practice 750* [13]
- Canadian Chemical Producers Association Responsible Care Program, *Manufacturing Code of Practices*
- GE Corporation, Six Sigma – The Road to Customer Impact

1.3.3 Regulatory Influences

Various U.S. and international government regulations require that changes to processes be reviewed. For example, the U.S. Congress has mandated that both OSHA and the Environmental Protection Agency (EPA) implement regulations that address accidents involving hazardous chemicals.[3,10] The regulations issued by both of these agencies include MOC requirements. In February 1992, OSHA adopted a regulation, *Process Safety Management of Highly Hazardous Chemicals* (29 CFR 1910.119), which requires MOC as a key element of a complete PSM program. Specifically, the OSHA PSM regulation [paragraph (l)] includes the following requirements:

- Develop written procedures for managing change
- Address the technical basis for each change
- Evaluate potential safety and health impacts for each change
- Define requirements for authorizing changes to be made
- Appropriately inform and train affected employees and contractors before changes occur

In addition, OSHA requires that MOC systems specify the appropriate time period for the change (e.g., a change that is permitted for only 1 week) and that PSI, procedures, and practices be updated, as necessary, when changes occur.

In June 1996, EPA finalized its risk management program (RMP) rule. The accident prevention program component of the RMP rule requires companies to develop MOC procedures.[10] These requirements are nearly identical to OSHA's MOC provisions, but they expand the evaluation to consider the potential offsite impacts of changes.

In addition to these federal regulations, various state process safety-related regulations specify MOC requirements. Companies should also consider these state regulations as they develop their corporate and local MOC programs.

Internationally, numerous legislations, regulations, and guidance documents require companies to address MOC (e.g., the EC Directive on Seveso, the UK COMAH regulations, OECD *Guiding Principles for Chemical Accident Prevention, Preparedness, and Response*).[14-16]

1.3.4 Quality Initiatives

ISO has established rigorous quality standards (i.e., the ISO 9000 series) that include MOC concepts for companies desiring to do business in the international marketplace. Specifically, ISO 9004, *Quality Management and Quality System Elements – Guidelines,* requires the documentation and authorization of all process changes. In addition, changes to work instructions, specifications, and drawings are to be controlled. Some purchasers of products have requested final approval of any MOCs related to that product to ensure that product quality is not compromised. ISO has also promulgated ISO 14000 on *Environmental Management Systems,* which also requires that changes be managed.

1.4 COMMITMENT REQUIRED FOR EFFECTIVE MOC SYSTEMS

Even though the concept and benefits of managing change are not new, the maturation of MOC programs within industry has been slow, and many companies still struggle with implementing effective MOC systems. This is partly due to the significant levels of resources and management commitment that are required to implement and improve such programs. MOC may represent the biggest challenge to culture change that a company faces. For example, seasoned engineers may feel as though an MOC process "second-guesses" their judgment, or operating managers may dislike having to "get permission" from others to make a change, even though they are the "experts."

Many companies have installed protocols for addressing changes without regulatory impetus because such controls represent sound business practices for achieving safety, quality, and environmental objectives. However, many of these protocols may not fully address the scope and depth that external guidelines and regulations now demand. That is, the MOC systems at many companies may lack the formal structure to help ensure that:

- Designs of site processes are well understood and documentation is up to date
- Proposed modifications are routinely evaluated for potential safety and health impacts before being implemented
- The level of detail for each review is appropriate for the potential hazard it poses
- The appropriate level of company management authorizes the changes
- Related activities required to safely implement the changes (e.g., training) are conducted
- Training of personnel on the changes is effective
- Records are maintained to document the changes

Developing an effective MOC system may require evolution in a company's culture; it also demands significant commitment from line management, departmental support organizations, and employees. Strong management commitment should include allocation of adequate resources for managing change and the willingness to modify existing management systems when necessary to accommodate MOC requirements. Only when management commitment is visibly demonstrated is it possible to obtain the widespread involvement and support essential to implementing an MOC system. In addition, to obtain the employee commitment necessary to make widespread employee involvement effective, management should provide effective orientation and training for all personnel (including contract personnel) involved in activities that can result from or be affected by changes.

1.5 ORGANIZATION AND USE OF THESE GUIDELINES

These *MOC Guidelines* are meant to be evaluated by companies who may elect to implement some aspects of these practices based on a thoughtful consideration of risk-based design and implementation criteria. Not all companies – even those with facilities in nearly similar circumstances – may elect to adopt and implement the MOC activities in the same way. Company-specific and local circumstances may give rise to very different applications of MOC activities based on the perceived needs, resource requirements, and existing safety culture of the facility.

These *MOC Guidelines* are not meant to represent the sole path for compliance with process safety regulations, nor is this book meant to establish new performance-based requirements for process safety. Nonetheless, in some sense, these *MOC Guidelines* do establish new risk-based expectations for PSM and MOC.

Companies can use the information provided in this book to help implement new MOC systems, repair defective systems, or improve mature systems using a life-cycle approach, including the following tasks:

- Design the MOC system
- Develop a written description of the system based on the design requirements
- Install the system
- Operate the MOC system over the life of the site
- Maintain the system and modify it as appropriate using information from audits and management reviews and through continuous improvement activities

This book devotes chapters and appendices (as appropriate) to each of these activities. Personnel creating a new MOC system or repairing/improving an existing one can consider the features described for each activity. Several appendices include additional information useful to those personnel.

Table 1.5 provides a list of perceived user needs and instructions on how to use this book to best meet those needs.

TABLE 1.5. Using ***Guidelines for Management of Change for Process Safety***

User Need Description	Sections to Review to Meet Needs
Want to know the basics	1, 2
Just getting started	1, 2, 3, 6, Appendices A, B and C
MOC system may be broken	1, 2, 3, 4, 5, 6, Appendices C, G, and H
Established system trying to get better	1, 2, 6, Appendices F and G
Understand MOC regulatory requirements	1, 4.5.4
Use MOC during process design	1, 2, 3, 4
Develop a corporate MOC policy	1, 2, 3
Develop an MOC awareness presentation	1, 2, 3, Appendix A
Improve audit protocol for MOC	1, 2, 3, 4, 5, Appendix E
Go from a paper system to an electronic MOC system	1, 2, 3, 4, Appendix D

Although managers and engineers can use these guidelines to implement, correct, and improve MOC systems at their sites, they can also be used by corporate personnel responsible for establishing company-wide standards or guidelines for MOC systems. In either case, the MOC implementation process described in this book allows company management to implement an MOC system that has a level of detail commensurate with the hazards associated with the facility and that is appropriate and workable for the site.