

SHUTDOWNS AND MANAGEMENT OF CHANGE

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In the process industry, various factors contribute to the maintenance and improvement of plant safety, while others convey risks that threaten it. The latter factors are often related to some sort of change and its management. The objective of change management has traditionally been to make sure that the post-change object is at least as safe as before. What is typically neglected in management of change systems is that safety must be ensured also while the change itself is executed, i.e. that the change-related work can be done safely. Much change-related work is carried out during plant shutdowns. This paper discusses management of change during shutdowns in the process industries based on experiences learnt during a recent Finnish study.

INTRODUCTION

At process plants, most alteration, inspection, repair, replacement, and minor maintenance work can be done while the plant is in operation. In spite of these activities, however, without scheduled maintenance outages equipment will eventually fail. An unscheduled outage is in most cases substantially more expensive than a scheduled one, and the cost is substantially higher again if the outage is due to a catastrophic failure. Therefore, in order to minimise costs, a plant needs to undergo scheduled process outages for major maintenance work and for possible modifications of the facility. Such an outage is referred to as a plant shutdown. Most major scheduled plant shutdowns are of high intensity involving sometimes hundreds of people.

PLANT TURNAROUNDS, SHUTDOWNS AND OUTAGES

Often the terms plant turnaround, plant shutdown and plant outage are used as synonyms. Here we have adopted the sometimes used alternative definitions for these terms. According to this approach a plant turnaround is the management process of a plant shutdown. Only the execution phase of a plant turnaround procedure is called a plant shutdown, which in turn is defined as a scheduled event wherein an entire process unit of an industrial plant is shut down for an extended period for revamp and/or maintenance. Plant outages, in turn, might be long or short, partial or complete, or for instance rolling, and they do not necessarily involve any substantial maintenance work.

A turnaround starts well before the plant is taken off-line and continues for some time after the scheduled major maintenance work has been completed. At major process plants the plant turnaround procedure is often a continuous process from one major scheduled maintenance shutdown to the next. Most organisations recognise that a turnaround is no longer a single occurrence that is simply part of the maintenance function. It is accepted that there is a need for multi-functional teams to be responsible for planning the shutdown.

A plant turnaround procedure has five fundamental phases: strategic planning, detailed planning, organising, execution, and closeout. The more complex plants a company operates, the more important it is that a plant turnaround management process document is in place as a fundamental building block for initiating and completing a plant turnaround. Being a standard operating procedure document, it provides consistency from one plant turnaround to the other. The framework this document defines is not restricted to major scheduled plant shutdowns. In an abbreviated form, it can also be used for any short, partial, or rolling scheduled plant outages.

It is the task of a senior management team to develop documents that are part of the company's management system. A plant turnaround management process document sets out the policies, procedures, and guidelines for developing and implementing an effective plant turnaround. The document is dynamic and should be reviewed at the end of each plant turnaround to ensure that it is consistent with the needs of the facility.

MANAGEMENT OF CHANGE PROCEDURE

Changes can be classified into permanent, temporary, and emergency changes. According to some definitions, an initiated change occurs, when someone – usually a manager or an engineer – decides that they would like to modify the operation so that conditions might move outside the current safe operating range. Any such change should be managed based on a management of change (MOC) process. The purpose of a MOC system is to verify that changes in facilities, documentation, personnel and operations are evaluated and managed to ensure that the safety, health and environmental risks arising from these changes are controlled.

The main – and in many cases, the only – objective of any change management in the Finnish process industries has been to make sure that the post-change object is at least as safe as it was before the change. This is in line with how prominent books on this topic, such as *Guidelines for the Management of Change for Process Safety* by the Center for Chemical Process Safety and Ian S. Sutton's *Management of Change* deal with this topic.

Invensys Operations Management's Ulric Roy noted in 2009 that companies must use MOC in each lifecycle phase of their equipment, application or facility. These phases include R&D, conceptual, design, detailed engineering design, procurement and construction, start-up (atypical operation), normal operation (typical operation), maintenance and turnaround, extended shutdown (atypical operation) and decommissioning (Roy 2009). Much change-related work is indeed carried out during plant shutdowns as a major scheduled shutdown is sometimes the only opportunity to make significant design changes in piping, equipment, buildings, and structures.

In its Safety Bulletin on management of change (CSB 2001) the U.S. Chemical Safety and Hazard Investigation Board states that, in addition to policies to manage deviations from normal operations, there is a need for chemical processing enterprises "to have MOC policies that include abnormal situations, changes to procedures, and deviations from standard operating conditions". Also, according to Hansen and Gammel (Hansen 2008), when implementing MOC, companies often overlook details. Factors that are often overlooked include those listed in Table 1.

Within the European Union, *Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances* (the Seveso II Directive) requires that establishments, where dangerous substances are present in quantities equal to or in excess of quantities given in the Directive, must have a safety management system (SMS) in place. One of the required elements of a SMS is management of change. The Directive defines this as the "adoption and implementation of procedures for planning modifications to, or the design of new installations, processes or storage facilities". Correspondingly, the importance of MOC is also underlined by U.S. Occupational Safety and Health Association's *PSM standard 29 CRT 1910* and U.S. Environment Protection Agency's *Risk Management Program 40 CFR Part 68*. These standards regulate that all changes, except replacement-in-kind, are subject to the MOC procedure.

Few descriptions of companies' management of change procedures can be found on the Internet. We believe that one example published by the Irish Environmental Protection Agency (EPA 2006) is representative of a fairly standard MOC description as given in safety reports based on EU's Seveso II Directive: It is mainly dealing with the management of permanent technical changes.

Replacement-in-kind or routine job procedure updates do not normally require an MOC, but temporary changes are undoubtedly subject to MOC provisions according to both American and European legislation. The chemical companies concerned are required to establish ways to detect temporary changes as well as those that are permanent. We have found that MOC procedures – if they are at all considering temporary changes – are currently in a majority of cases used mainly to ensure that the equipment and procedures are returned to their original or designed conditions at the end of a temporary change.

What is typically neglected in these MOC procedures, however, is that safety must be ensured also while the change itself is executed, i.e. that the change-related work can be done safely. The question is: Why is this not covered by the MOC procedures? And subsequently: How is safety currently handled during the various phases of the turnaround process and during the execution phase in particular?

A FINNISH STUDY ON CHEMICAL SAFETY DURING PROCESS PLANT SHUTDOWNS

The starting point for the recent Finnish research project "Mitigation of hazards caused by process chemicals during shutdowns" (SEISOKKI) was that safety management systems should not only cover the normal operation period of the plant, but also special cases such as shutdown periods. From the chemical hazards perspective, shutdowns need to be addressed – in the vast majority of cases – because hazardous process chemicals are still present at the installation in storage tanks, warehouses, silos and pipelines, even when the production process is not running and some of the equipment have been emptied and cleaned.

The consequences of a chemical accident during a shutdown may be severe as the number of persons working at the plant during that time is typically quite high – some Finnish companies report that from 100 to 500 external maintenance workers may be at the plant during the busiest periods of a shutdown. The overall risk of a chemical accident during a shutdown might therefore be higher than expected at first glance (Malmén 2010).

Persons present at the plant during shutdowns might be affected by the process chemicals in various ways, and some examples are presented in Table 2. And naturally – although outside the scope of our study – the SMS should be adopted in order to also avoid non-chemical accidents and incidents.

Table 1. Some of the factors that are often overlooked in management of change systems (Hansen 2008)

Overlooked factor	Question to be resolved
Resolution of temporary changes	Do we want to extend the duration of the change, return the process to original condition or make the change permanent?
Managing emergency changes	How do we ensure that all requirements of normal changes are satisfied?
Tracking/closure of action items	How do we verify that action items have been completed and meet the intent of the recommendation?
Communication of the change	How do we achieve this and maintain adequate documentation?
Prestart-up safety review	How do we decide when one is needed?

Table 2. Examples of ways of exposure to process chemicals

Way of exposure	Comments
Inhalation of the chemical	e.g. gases such as CO, H_2S, SO_2, and various fumes and vapours. Also lack of oxygen, i.e. typically an excess of N_2 or CO_2.
Direct exposure through the skin	Caused by splashes, contaminated surfaces, etc.
Physical effects	e.g. burns due to chemical fires or hot substances, frostbite due to cold substances, injuries caused by pressure waves (as a consequence of explosions, failing containment or opening (safety) valves), impact by fragments caused by explosions, etc.
Radiation	Mainly from unprotected sensors that contain radioactive substances.

In 2008–09, the SEISOKKI project studied how the various safety management elements mentioned in the EU's Seveso II Directive were implemented in the safety management systems of six Finnish industrial installations, and in particular to what extent these procedures covered maintenance shutdowns. The six operating companies and one maintenance company taking part in the study were interviewed and safety management documents were reviewed by researchers from both VTT Technical Research Centre of Finland and the Emergency Services College. The reviewed documents included, for instance, hazard analysis requirements, management of change procedures, work permit routines, training schemes, and emergency plans.

The researchers also made observations during the planning phase of the turnarounds and during the actual annual maintenance shutdowns.

The study revealed some shortcomings in the companies' safety management procedures in relation to process chemicals (Malmén 2008 & 2009a). It showed, for instance, that MOC procedures in the companies taking part in the study typically covered only part of the range of possible changes. Typically, the MOC focused only on hardware changes, while organisational changes were completely overlooked. Temporary changes were also neglected in most cases and none of the MOC documents studied specifically mentioned shutdowns. Neither were they written in such a way that the instructions could easily be applied during the turnaround management process.

Indeed, according to our study of the Finnish process industry, shutdowns are generally not seen as being change situations at all. Consequently, safety during shutdowns is normally not considered from a MOC perspective. This is true despite the fact that a shutdown in itself clearly constitutes a change in the operation of the process facility: the normal operation stops.

The question raised by the researchers was: Can companies be sure that they stay within "the current safe operating range" during a maintenance shutdown and therefore do not need to consider MOC? We found no proof that such certainty exists, and a shutdown should therefore be regarded as a temporary change. To further substantiate our conclusions, a survey of two Finnish accident databases held by the Safety Technology Authority (TUKES) and the Federation of Accident Insurance Institutions (FAII) was undertaken. The survey revealed that during the last 25 years some 80 reported accidents caused by process chemicals had occurred during a shutdown, or at the start-up after the shutdown (when external personnel was still present at the site). Other types of accidents were outside the scope of our study.

During the SEISOKKI project, several tools were developed to help Finnish companies mitigate chemical hazards during shutdowns at process plants, but practical guidance on MOC suited for the turnaround process remains to be developed. Neither did a literature survey conducted by VTT reveal any guidance on how MOC should be adopted to shutdowns. Our conclusions are in line with the Center for Chemical Process Safety in the USA, which at the time of our study declared: "Experience has shown that management of change is one of the more difficult process safety management elements to implement – and to get and keep right!".

MANAGEMENT OF CHANGE AND SHUTDOWNS

One can argue as to whether a shutdown is a temporary change situation, or not. Eastman and Sawers (Eastman 1998) listed examples of temporary changes that require MOC. Table 3 presents some of the points on their list that seem to be specifically relevant for turnarounds.

Based on the list presented in Table 3, our conclusion is that shutdowns must certainly be covered by a MOC system as there are several technical aspects of a turnaround, which according to Eastman and Sawers should be categorised as temporary changes requiring an MOC. In addition to many technical changes, also a variety of temporary organisational changes associated with a turnaround need to be addressed.

According to our study, for most turnarounds there are typically three fairly autonomous teams planning the shutdown (Table 4). What is not always recognised is that working as separate teams raises it own challenges. It may be that the self-directed teams proceed in self-directed directions, which can be in conflict with corporate or plant MOC and other requirements. The teams require coordination, leadership, and guidance.

Also the organisation carrying out a shutdown is typically significantly different from the organisation during

Table 3. Examples of temporary changes requiring an MOC (Eastman 1998)

Temporary changes relevant for plant turnarounds
Replacement equipment, machinery and piping that differ from the original design specifications.
Addition or removal of process equipment or piping.
Changes in physical layout that may affect employee escape paths.
Temporary electrical equipment or connections.
Removal or decommissioning of equipment, alarms and safety systems.
New projects that involve tie-ins of equipment modifications of units already operating.
Equipment changes including the installation of new equipment and modifications of equipment already in use.
An alternative supply of process materials, catalysts or reactants, possibly through temporary drums or tanks in the plant.
Major equipment replacement by a manufacturer that did not make the original equipment.
Temporary piping connections or hoses.
Change in process control or conditions including changing control ranges of temperature and pressure instruments to exceed defined standard operating limits.
Change in electrical service.
Adding or removing insulation on a major scale.
Installation of, or changes in, structural members supporting covered processes.
Changing or bypassing ("jumping") alarms, permissive switches or trips.

normal plant operation and, for the most part, the tasks of the plant's own personnel are different to their routine production tasks.

One must also keep in mind that there are two recent trends that might increase the risk for failure:

- The time between shutdowns is increasing. For instance, shutdowns, which in the Finnish process industry used to take place twice a year (during the Christmas and Midsummer holidays), are now scheduled at 12 to 18 months' intervals. Subsequently, the staff are not confronted with turnarounds as often as in the past.
- Maintenance departments have been outsourced and the shutdown involves more companies (domestic and international) than ever before. The adopted safety culture might differ from company to company, which increases the difficulty of safely managing the shutdown.

The external workforce needed might be available only for a certain period of time, within which all the required maintenance work must be completed. Due to the typically high tempo of a shutdown, there is a higher risk that some changes will go unnoticed and that MOC instructions – if there are any – will be neglected. Also, the possibility of several changes, which on their own would be considered innocuous, occurring simultaneously, may together pose a danger to shutdown workers.

In addition, the plant might experience changes due to external factors. For example, the facility normally supplying heat or cooling water might also not be operational.

Table 5 gives a brief summary of changes that are typical for shutdowns.

So, based on the results of our case-study, how is safety during a shutdown currently assured in the Finnish process industry if not through a MOC procedure?

Our study revealed that currently the safety during shutdowns is neither due to the company's management of change procedures nor the plant turnaround management process, but is heavily reliant on the experienced individuals in charge of the shutdown at the plant's various departments. So far this way of organising shutdowns has worked fairly well in the Finnish process industries, although, as mentioned above, some accidents have occurred.

Table 4. Teams involved in the planning of shutdowns and their roles during the turnaround process

Team	Role during the turnaround
Team of plant operators	This team plans the tasks that the plant operators will handle themselves during the shutdown. Some of these tasks are purely operational while others are managerial (such as releasing work permits), and many may be a combination of these.
The team of maintenance staff*	This team plans the majority of maintenance work to be accomplished during the shutdown. Representatives of the plant operators are normally a part of this team.
The engineering team for plant modifications**	This team plans the more significant modifications to the plant, part of which has to be carried out when the plant is off-line, i.e. during the shutdown.

* The majority of the maintenance staff nowadays tends to be employed by a company that provides maintenance services.
** Often referred to as the "Project team".

Table 5. Changes typical for plant shutdowns

Change
The processes at the facility are not running normally.
The facility's own staff are carrying out tasks which they seldom confront.
There are a high number of external personnel at the site.
Temporary changes might be made to safety and security arrangements of, for example, the automation system, smoke detectors, cooling water, etc. – or these might be disconnected altogether.

CONCLUSIONS

It takes a combination of people, culture and technology to comprise a good management of change system. To our knowledge, no published MOC procedures tailored for plant turnarounds exist, even though a plant shutdown is typically characterised by a variety of changes: technical and organisational, temporary and emergency changes. Some companies treat only high-cost changes as worthy of MOC, while others subject every maintenance work order to MOC safety reviews. And neither of these extremes is desirable. Some companies have encountered difficulties when no written operating procedures are available for certain temporary operating situations – particularly those rarely used that require operation with some process units that are off-line or operating at reduced capacity.

The Finnish SEISOKKI research project developed several tools to be used in order to minimise the risk of chemical accidents during a plant shutdown. The tools are published in Finnish and include the following (Malmén 2009c):

- A Guidebook describing the topic from various perspectives,
- An Auditing Method, by which various management issues related to chemical safety can be addressed by key persons at the plant,
- A Hazard Analysis Method, which is developed especially for the purpose of identifying hazards associated with process chemicals during shutdowns (Malmén 2009b),
- A set of Safety Checklists for quick reference during the shutdown, and
- A set of Work Permits.

These tools might be building blocks on top of which a MOC system could be built. In addition, the following recommendations can be given based on observations made during the Finnish project:

- If two or more self-directed teams are responsible for the planning of a shutdown, proper coordination, leadership, and guidance is needed.
- Risk analyses related to the shutdowns must not focus only on the safe execution of individual tasks carried out by external contractors. The tasks of the own personnel and the overall planning of the shutdown should be equally included.
- EHS and emergency response personnel should take a more active part in the planning process. For instance, plans should be made so that emergency and escape routes are available at any time.
- It is not enough to train external contractors prior to the shutdown, the own personnel must also be trained, as their duties during the shutdown differs radically from their normal ones. The training given to both groups of people should be recorded in a training register.
- Special attention should be given to the avoidance of false fire or gas alarms during the shutdown – and all alarms must be reacted to according to the emergency plan also during a shutdown.
- If safety related equipment such as alarms, ventilation, water, inert gas, safety valves, electrical systems, process computers, etc. need to be turned off, alternative solutions to ensure safety must be applied.
- Control rooms should not be left empty during the shutdown, if this means that alarms coming only to the control room will go unnoticed.

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