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Management of Change (MOC) Best Practices

EXECUTIVE SUMMARY

Since the OSHA Process Safety Management regulations were introduced in 1992, every plant owner with a covered process has had to implement a PSM program, including a Management of Change program.

A recent review, conducted by Gateway, has revealed that while plant owners are in compliance with their MOC programs, they are seeking ways to increase efficiency, drive down costs and continuously improve plant safety, environmental protection and reliability.

Over the last two years Dr. Hoff has been quantitatively analyzing MOC processes at over a dozen chemical and petrochemical facilities in the USA. Using well established simulation techniques, he's now capable of modeling any MOC process, running it thousands of times, and examining the resulting statistics to highlight bottlenecks, identify areas for improvement, and, most importantly, quantify the improvements that will result from changes in the process.

The approach is: quantify (based on existing data) -> simulate the existing process -> identify bottlenecks -> simulate alternatives -> and implement the optimum process.

Some of the key results of this work are presented in this whitepaper, "Management of Change: Best Practices".

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Since 1991, Gateway Group has been a consistent innovator in the design and implementation of electronic document management (EDM) and enterprise content management (ECM) solutions for chemical and pertrochem plant environments.

Dr. Rainer Hoff, the founder of Gateway Group is an industry leader in the application and implementation of EDM/ECM information systems in the chemical and petrochemical arena.

MOC Best Practices

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Introduction

The OSHA Process Safety Management regulations (29CFR1910.119) require that a management of change system must be in place for all PSM-covered processes, typically at chemical plants and petroleum refineries.

Figure 1. Basic MOC process.

Figure 1 shows the basic change control process, which yields different lifecycles depending on whether the change is permanent, temporary, full (Figure 2) or abbreviated. Figure 2 is a lifecycle diagram, which identifies the states that an MOC progresses through. There are many potential "loop backs" in a real MOC process which are not shown here.
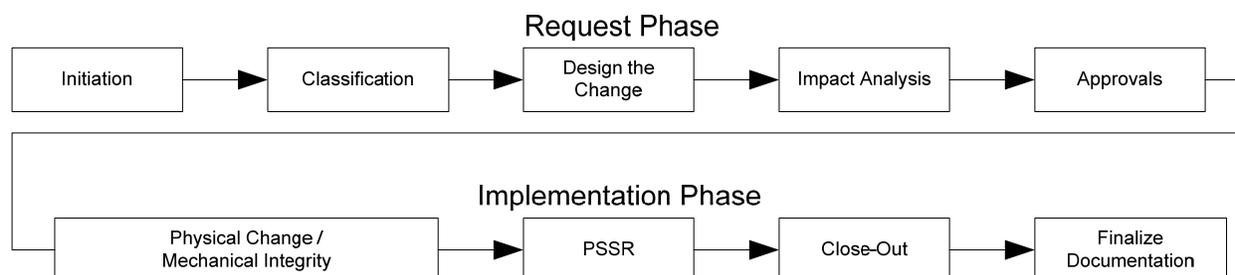

Figure 2. Lifecycle of a full MOC.

Every company implementing or upgrading the MOC process wishes to use the "best practice". However, due to the lack of any published analysis of best practices for MOC, it appears that most MOC implementations are simply refinements of past practice at the site.

This whitepaper introduces the author's research in the domain of establishing the best practice for MOC[1]. The author has condensed data collected at numerous sites and reviewed dozens of existing MOC practices. This information was used to build extremely detailed mathematical models, and hundreds of simulations were run to optimize MOC processes. The simulations use the Petri-Net technique, described in Appendix A, and demonstrate that computerized implementations of MOC, using enterprise content management and workflow software, are preferred for all but the smallest MOC implementations.

Electronic implementations of MOC require a number of support processes, described in the appendices.

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[1] The author is completing a text book, *MOC: Best Practices*, to be published in 2008.

Initiation

The first step in an MOC is to decide whether the proposed change satisfies the criteria for requiring an MOC. Some mechanism must be provided to ensure that change is addressed consistently. It's embarrassing, and potentially costly, to have a situation where an MOC had been used for a change in the past, and then not used for a similar change in the present. Regulatory agencies also have a reasonable expectation that information about what's occurred in a plant should be reasonably accessible to everyone in the plant. For instance, if Area 1 used an MOC for a certain change it's highly suspect when Area 2 doesn't use an MOC for the same change on similar equipment.

A computerized knowledge base, or even a centrally-administered list may be used to record analysis of potential changes that don't warrant an MOC. Obviously, the list of prior MOC's documents changes which do warrant an MOC.

If an MOC is needed, then the originator provides the following information, either on a paper form, or an electronic equivalent:

- His/her name
- MOC lifecycle: full or short; normal or emergency; temporary or permanent
- Relevant dates, including start date (and end date for a temporary change)
- List of affected equipment (see Appendix B)
- Technical basis for change: including what's to be changed, what's to be achieved by the change, why will the change achieve the intended goal, why is the change safe to make?
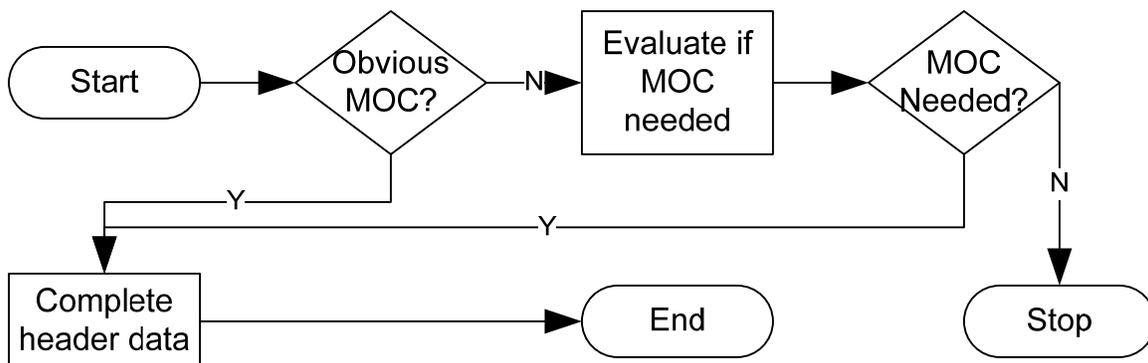

Figure 3. Change initiation.

The MOC process, whether paper or electronic, would then assign an MOC number and an origination date.

Classification

The number of potential changes at a chemical plant or refinery is astronomical. Somehow the universe of potential changes must be reduced to the scope of a single change. This is normally done through "classification". Classification occurs along 6 dimensions:

1. Change lifecycle: full vs short; temporary vs permanent; normal vs emergency.
2. Object of the change: change to the plant? documents? personnel?
3. Risk assessment: safety, health, environmental, etc.
4. Work scoping: what groups need to be involved? What documents need to be updated? etc.
5. Approver selection: who shall approve the change and its associated documents?
6. Size of project: $1 million projects are treated differently than $100 projects[2]

Items 1 and 2 establish the "lifecycle" or path that the MOC follows from start to finish. Item 3 requires detailed analysis. Items 4, 5, and possibly 6, are generally handled using an explicit set of "rules".
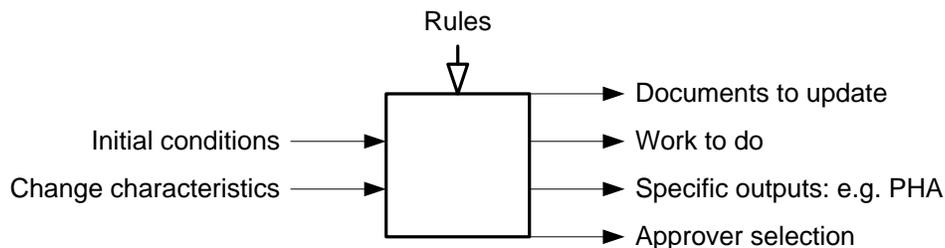

Figure 4. Rules are used to classify changes.

To understand rules, consider the following:

```
when
      P&ID is changed
then
      operations superintendent must approve the change
      area manager must approve the change
      design engineering manager must approve the change
      . . .
```

In a traditional hardcopy-based MOC system, these rules are usually implemented using a checklist.

In order to make the checklists practical, it's necessary to pose very broad questions: e.g. "is a P&ID changed?" But, who would be an approver on a P&ID change? Potentially, very many people. So, the fundamental problem here is that too many people are put on the approval list. People are asked to approve changes, which have little to do with their area of responsibility.

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[2] This is not a PSM requirement—this is a reflection of reality in today's business world

Classification II: Asset-Based Approaches

A better approach is to classify the change more accurately. The best practice is to classify change based on **assets**, not documents. After all, the change is actually made to the plant—document changes are a peripheral (although necessary) activity. For example, a more specific, asset-based rule is:

```
when
        design pressure in a pipe is increased
then
        operations superintendent must approve the change
        design engineering manager must approve the change
```

One can devise an entire set of very specific rules, which cover the majority of the known change cases in a plant. The outputs from processing the rules is a list of documents to be updated and a list of approvers for the change. This may result in 150 questions/rules, which would be time-consuming to answer for each change. A practical approach is to group the questions/rules into categories, and only the categories relevant to a specific change are reviewed. Change classification can be categorized as:

- Buildings, trailers, structures
- Control systems
- Electrical
- Environmental
- Industrial hygiene
- Operations issues
- Process characteristics
- Relief valves
- Rotating equipment
- Safety systems
- Special hazards
- Vessels and piping

Each category may have 5 – 15 more detailed questions.

Design the Change

During this phase of the MOC, new and updated documents are created, which specify the details of the proposed change. This quickly becomes complicated since an operating plant must maintain its current plant configuration, while new configurations are being proposed. The complexity arises from what to call the updated documents, and to whom they should be made available.

Let's review some basic concepts...Engineering drawings are used as the basis for these examples, although the concepts apply to all documents that are modified as part of a change.
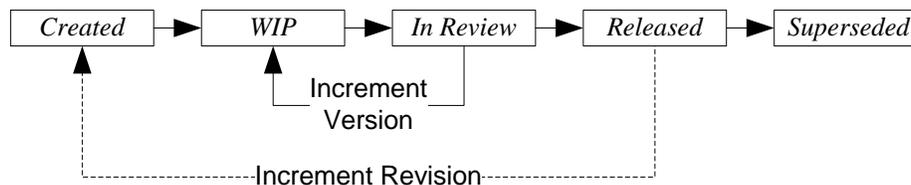

Figure 5. Typical drawing lifecycle.

The lifecycle of an engineering drawing is shown in Figure 5. Drawings are released as approved "revisions". Revisions are official corporate records, and cannot be changed—the only way to legally change a revision (e.g. Rev 0) is to create a new revision (e.g. Rev 1).

While the approval process is underway, many versions of the document may be created, updated and rejected, until a version is finally approved. This final version becomes the approved revision, as shown in the lower sequence of events in Figure 6.

Multiple, concurrent "modifications" may be made to a given drawing, as shown by "M0" and "M1" below. The modifications may be in the form of changed drawings or redlines on top of existing drawings. These modifications may never be acted upon, or they may be incorporated into an official revision at a later date. Since an MOC may be based on one of these modifications, the current state of the plant may be a combination of revisions and modifications. So the current state of the plant may progress from R0 to R1 to R1 + M1 to R2 to R2 + M0 to R3. Keeping this history straight is quite a challenge, and can be simplified by an enterprise content management system.
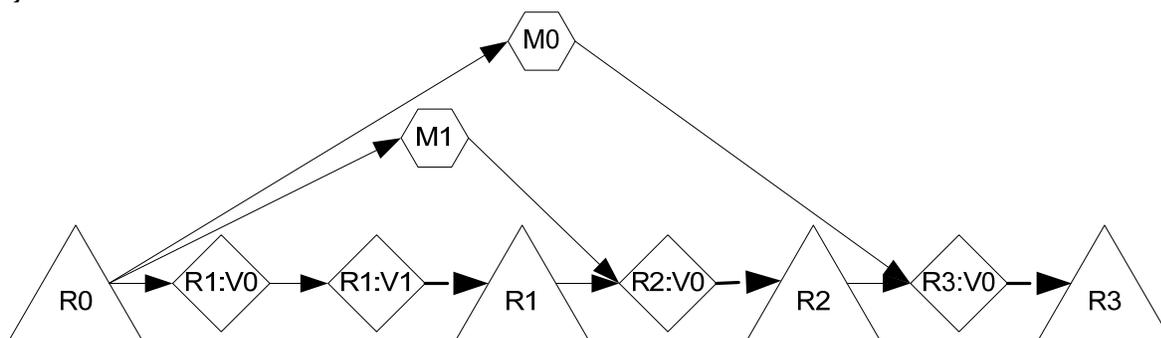

Figure 6. Revisions, versions, modifications.

Impact Analysis

The previous step, "Design Change", focused on documenting the details of a proposed change, largely from a physical perspective: what equipment and piping will change, what software will change, etc. Once this has been documented, it's possible to assess the impact of the change on people and the environment. These concerns are normally grouped as follows:

1. Safety concerns: safety equipment impacts, ladders, access to facilities,
2. Industrial hygiene concerns: sanitary sewers, lighting, noise, etc.
3. Environmental concerns: toxicity, potential for releases, etc.
4. Process safety concerns: assessed using a process hazards analysis

Items 1 and 2 can often be addressed with a checklist, but items 3 and 4 usually require a more detailed risk assessment. Typically a number of change characteristics are assessed and expressed as the probability and consequences of an undesired event (incident!). Figure 7 shows that different actions are required depending on the outcome of this analysis. For example, a change calling for "Action 1" may require a full HAZOP[3] and a full PSSR[4], while a change calling for "Action 5" may only require a brief PHA[5] and a short PSSR, however these are defined at the facility.

Consequences		Rare	Sometimes	Often
	Severe	Action 3	Action 2	Action 1
	Moderate	Action 4	Action 3	Action 2
	Minimal	Action 5	Action 4	Action 3
		Probability		

Figure 7. Risk assessment using probability-consequences diagram.

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[3] HAZOP: HAZard and Operability study
[4] PSSR: Pre-Startup Safety Review
[5] PHA: Process Hazards Analysis

Approvals

There are many "approval" steps during the typical MOC, and they mean different things. For example:

- An Area Manager may approve at the end of the Initiation phase. This approval means that the proposed change appears reasonable, and warrants further study.
- A PSM Coordinator may approve at the end of the Classification phase. This signifies that the Classification appears to have done correctly, and that the list of documents to update appears complete.
- A Design Engineering Manager may approve individual documents at the end of the Design the Change phase. This signifies that the individual documents appear correct and conform to company standards.

But, the most significant approval occurs during the Approvals phase. These approvals signify that the change to the plant is accepted by the (usually many) signatories and is ready to be made.
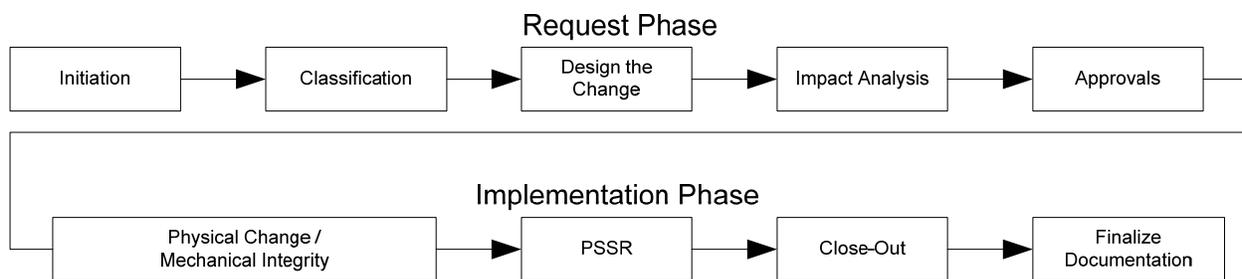
Request Phase

| Initiation | → | Classification | → | Design the Change | → | Impact Analysis | → | Approvals |

Implementation Phase

| Physical Change / Mechanical Integrity | → | PSSR | → | Close-Out | → | Finalize Documentation |

Figure 8. Lifecycle of a full MOC.

Electronic approvals is one area where an electronic MOC system can provide great benefits, specifically by:

- Shortening the cycle times to get all the approvals: days or weeks can be reduced to hours or minutes.
- Reducing the effort needed to obtain all the approvals: no person needs to abandon his job in order to drive from building to building to get the necessary approvals.
- Ensuring that the set of approvals, for a given MOC, is consistent with similar MOC's done in the past.
- Elimination of waste: In a paper-based system, often people are on the approval list simply because they need to be notified of a change. An electronic system can transmit a change notification, without putting this on the critical path for approval.

Physical Change/Mechanical Integrity

Once approvals are complete, the change is scheduled for implementation in the plant. There are many "best practices" associated with how work is done in a plant, but none of them are MOC-specific.

As various portions of the plant change are completed, they are usually inspected (i.e. mechanical integrity is checked) right away. So there is a great deal of overlap between making the change and checking mechanical integrity.

Mechanical integrity is quite document-intensive, since documents are the only long-term evidence that inspection has been conducted.

The previous sections have promoted the benefits of an electronic MOC system. The electronic MOC process works because each participant is presumed to be a computer user, and be at his/her workstation when the task needs to be done. Inspection is different, since it almost always occurs at a worksite in the plant, rather than at a location where computers are located. So, a best practice may be to fully automate the data collection aspects of inspection, including the use of handheld computers and data collection units, which are programmed with the full suite of inspection "forms" that apply to the site. This high level of automation may be out of the reach of most companies in the short term, so alternate approaches would be the best practice in the interim. An approach using hybrid documents is described in Appendix D, which is a pragmatic solution for those with an electronic enterprise content management system.

Regardless of whether mechanical integrity is highly automated (using handheld computers), partially automated (using hybrid documents), or entirely manual, there is always a need for the responsible party to certify that mechanical integrity is finished. Automation can dramatically reduced the time and effort associated with managing the paperwork for mechanical integrity, but an automated system should not initially make a decision that a sufficient number of inspections have been done—that's still in the domain of humans.

Pre-Startup Safety Review

The scope of the pre-startup safety review, "PSSR", depends on the requirements of the change—it is often determined during the Classification phase, described previously. The details of the pre-startup safety review differ from site-to-site and from case-to-case. However, PSSR does share the characteristic with mechanical integrity that PSSR's are generally done in the plant, and not at a computer. As a result:
1. The automated or hybrid techniques would provide a benefit to the process, and,
2. A person still needs to sign off that the PSSR is adequate and complete.

Once the PSSR has been signed off, the unit is ready to be restarted.

Close-out

Once the PSSR has been signed off, the MOC can be closed out. The items completed, documents updated and approvals acquired during the life of the MOC ought to be sufficient for regulatory compliance purposes, therefore the close-out effort is theoretically nil.

As a practical matter, most companies accomplish more with their MOC process than merely regulatory compliance. So close-out typically involves a number of activities:
- The MOC file is reviewed for completeness,
- MOC metrics are gathered, for future analysis,
- Quality audits may be performed on some percentage of MOC's to verify they are implemented as planned.

Finalize Documentation

During the Design the Change phase, documentation is updated. The nature of the documentation is such that it contains sufficient detail to allow a process hazards analysis to be conducted. Also, there must not be any confusion about the current state of the plant and the proposed change.

It's entirely possible that the form of the documentation, produced during Design the Change, is in it's final format: drawings are updated in CAD, documents are updated in a word processor, etc. However, there's no regulatory requirement that a document look "nice", so, as often as not, drawings and documents are simply marked up during the Design the Change phase. Ultimately, these documents need to be rendered into their final form; that's the intent of this "Finalize Documentation" phase.

There's some debate whether the documentation needs to be finalized before Close-Out of the MOC. Since there's no regulatory requirement for this, the author's position is that Finalize Documentation can occur after Close-out, as long as the list of documents to update is known at Close-out.

Finalize Documentation is just a special case of closing all the open action items at the end of an MOC. The quintessential example is painting. Since most painting is for cosmetic reasons, there's no regulatory requirement to complete painting before an MOC is closed. However, it's necessary to track these action items, in order to ensure it's done at "some time" in the future.

Appendix A.   Petri-Net Primer

A Petri-net is a modeling technique for dynamic systems, originally published by Card-Adam Petri in his Ph.D. dissertation. Petri-nets are particularly good for representing business processes and workflows, since they allow very large, complex and therefore accurate representations to be created of "real" processes.

As shown in Figure 9, a Petri-net has 4 basic elements:
- Transitions: this is where "work" occurs,
- Places: which provide connectivity of the model and establish the routes or paths that the work takes,
- Tokens: shown by the shaded circles, represent the "jobs"; in this case, each MOC is represented by a token.
- Arcs: directed line segments which connect the Places and Transitions

The topology of the net can be as complex as desired with "AND"-branching, "OR"-branching, as well as more complex rule application.
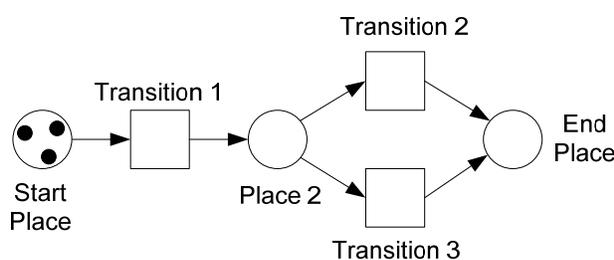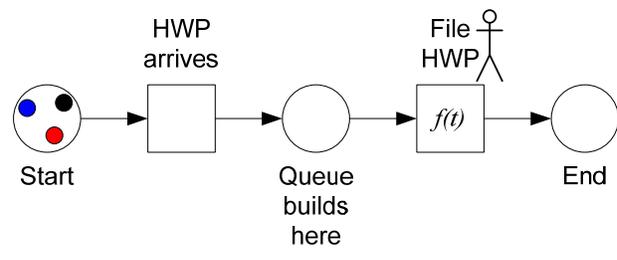

Figure 9. A simple Petri-net.   Figure 10. Filing hot-work permits.

Jobs may arrive randomly, such as the hot-work permits in Figure 10. So the tokens, which represent the jobs, appear in the start place according to some statistical distribution.

When a transition "fires", a token is removed from one (or more) input place(s) and a token is placed in one output place. This represented a certain task being accomplished and the job moving forward in its lifecycle.

Work is performed at the transitions by resources (e.g. drafter, area manager). The time required for a person to begin to work on the tasks (i.e. the wait time), can be represented as a fixed amount, or a probability distribution. For instance, the area manager will sign a document in about 4 hours (average) with a standard deviation of 2 hours. Also, the task duration can be represented by a probability distribution: e.g. a drafter takes 8 hrs to update a drawing (std. dev. = 2hr).

A meaningful simulation of a real MOC process requires a model with over 600 places and over 400 transitions. The simulation must be run thousands of times, in order to gather the statistical data needed to form conclusions and prove what might be the best practice.

Appendix B.   Supporting Function: Plant Structure Representation

A process plant is one which processes chemicals of various kinds. An individual process occurs in a process unit, or "unit" for short. A unit is the basic building block of a refinery or chemical plant.

A typical plant has between 10 and 100 units. A given unit is generally too small to warrant its own control room, maintenance organization and management structure. So units are aggregated into Areas and other groups largely for administrative purposes. Figure 11 illustrates various aggregation schemes, used at different sites.
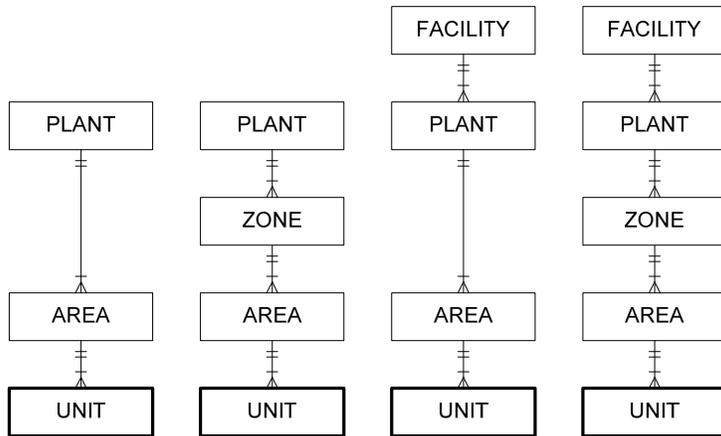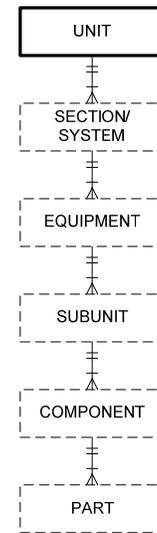

| Figure 11. Unit aggregation. | Figure 12. Unit decomposition. |

A unit is composed of "equipment": pumps, valves, piping, wiring, etc. Each of these can be broken down into nuts, bolts, screws, connectors, flanges, etc. Analogous to the notion that units are aggregated for administrative purposes, units are also decomposed for maintenance purposes. Unfortunately the decomposition mechanisms and the associated terminology are not standardized throughout the industry. The open standard that comes closest to addressing this issue is *ISO 14224*[6]; there are several proprietary approaches as well. Main criticism of unit decomposition "taxonomies" is that, since they are very detailed, they tend to be burdensome for many business applications. So a practical approach to unit decomposition is to just use the levels in Figure 12 that are actually needed for the job; that's why all the levels have been indicated as optional in Figure 12, since they may not be needed for all applications.

Why is this so important?

Almost all MOC's affect the plant structure in some way. In order to manage MOC's by area, unit, etc., it's necessary to attach area or unit information to an MOC through the use of a link to an area or unit object Allowing textual representation is just too imprecise: e.g. if "unit 100", "U100", "Cat cracker 2", "No 2 cat cracker" all refer to the same thing, reporting becomes difficult.

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[6] *ISO/CD 14224 Rev 1, Petroleum, petrochemical and natural gas industries—Collection and exchange of reliability and maintenance data for equipment,* Internal Standard Organization, Geneva, 2003.

Appendix C.   Supporting Function: Issue Management

An issue is a simple indication that something needs to be done. Issues are distinct from other work processes (e.g. MOC, Incident Reporting) in that issues are inherently *ad hoc.* If the work of an issue were predictable, it would already be part of a routine business process. Since issues aren't predictable, they are *ad hoc*. Issues are known by other names as well: "action items" is a common term for issues; "punch list items" is another term often associated with the physical inspection of a facility.

Issues do not exist in isolation—they are very closely associated with various kinds of events, as shown in Figure 13:
- originating events
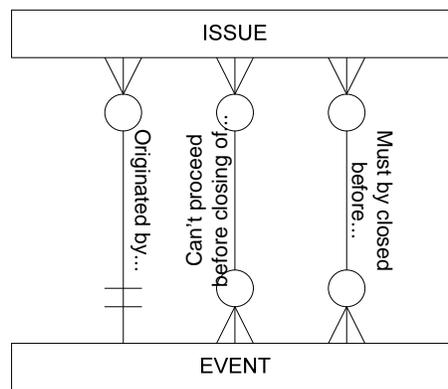- dependent events
- event deadlines

Figure 13. Issues and associated events.

Originating events serve as the catalyst for the issue to come into existence. For example, during a mechanical integrity inspection (the event), an inspector discovers that a connector is broken on the control cable for a motor (the issue).

Dependent events cannot be completed until the related issue is closed. For example, the unit cannot be restarted (event) until the control cable connector is replaced (issue, identified previously).

An "event deadline" is a future event, which establishes the timing for when the issue can be closed out. Turnarounds are common examples of this in the process industry: issues accumulate and are addressed during the next turnaround, which may be months or years in the future.

Issue management must be provided in an MOC environment, otherwise EVERYTHING would have to be closed out during the MOC, regardless of whether it had a safety impact—which would be clearly inefficient.

Appendix D.   Supporting Function: Hybrid Documents

One problem has frustrated attempts to automate the MOC process: the question of what to do with hardcopy documents generated in the plant? The first half of an MOC's lifecycle can be done entirely electronically, because the participants would reasonably be sitting at a computer when they doing this work. However, mechanical integrity inspections and pre-startup safety reviews typically involve checklists and other data collection forms which must be completed in the plant, at the equipment, and away from desktop computers. There are 3 feasible solutions to this problem:

- The manual indexing approach
- The auto-indexing approach
- The hand-held computer approach

The manual indexing approach proceeds as follows (using the PSSR form as an example)... The PSSR form is preprinted, and used whenever a PSSR is conducted. The PSSR form is completed by hand, in the plant, when the PSSR is performed. The completed form is transmitted to someone who scans it in. The form is then indexed manually, by logging on to an electronic system, identifying the MOC number to which this applies (or other event, since not all PSSR's are MOC-related), and then uploading the PSSR form. This approach is workable, but time-consuming and error-prone (what if the wrong MOC number is entered? What if the wrong scanned image is uploaded? Etc.)

The auto-indexing approach proceeds as follows...The PSSR form is not a preprinted form, rather it's generated when the PSSR is to be done. This form has bar codes identifying what the form is (i.e. PSSR form), and which MOC it applies to. The form is completed in the plant as before. At the end of the work period, this form is but in a batch with all the other forms and scanned as a batch. A program reviews the scanned images, reads the barcode, and indexes the scanned image in the correct MOC folder. This approach is less time-consuming, uses fewer resources than the manual indexing approach, and is much less error-prone.

The hand-held computer approach proceeds as follows...The PSSR form, with identifying data (e.g. MOC number, Unit ID, etc.) is downloaded to a handheld computer. The PSSR is conducted and the inspector enters the results directly into the PSSR form on the hand-held computer. When the PSSR is done, the data is uploaded to the electronic MOC system. This is certainly the most reliable, but the start-up costs are high: each form needs to be reauthored for the hand-held PC environment, and hand-held PC's have to be readily available for the persons doing the in-plant work.

While the third solution would be the "best", if the up-front work is done, the up-front work is a large hurdle at this time. So the auto-indexing approach appears to be the best practice at this time.