

PWR2005-50032

BASELINING STRATEGIES TO IMPROVE PM IMPLEMENTATION

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ABSTRACT

Content reviews optimize preventive maintenance (PM) strategy. However, reanalyzing strategy alone is pointless. Traditional PM optimization compares existing and revised PM's at the final step. Ignoring preexisting source PM programs removes analysis bias, but makes implementation more difficult; continuity is lost. Baseline existing programs provides an alternative. PM changes are smaller, easier to control, and process oriented. Ineffective PM tasks can be removed with minor impact. Shop-floor ownership simplifies changes and speeds implementation, lowering costs. New maintenance development techniques improve upon older PM development processes, substantially reducing costs. Significant benefits can result in complex industrial maintenance applications.

INTRODUCTION

Plants must generate financial returns. Cost reductions, capacity increases, and other quantified benefits justify reinvestment. Unimplemented, process improvements lose value. Techniques like Reliability Centered Maintenance (RCM), introduced into power generation in the 1980's, were ineffective partly based on lack of results. Plants approach new maintenance strategies with caution. New optimization methods evolved from old ideas, but improve value while reducing cost.

Reliability Centered Maintenance – ADA AO66 579 (Nowlan, S. & Heap, 1978) documented an early risk-based scheduled maintenance development process. Its successor "Airline Manufacturer Maintenance Program Development Document," MSG-3, (1993) continues to certify aircraft maintenance programs today. Airline maintenance cost declines with safety improvement over the past three decades testify to their success.

New processes simplify PM development, provide better results, lowering maintenance costs. Baseline industrial PM program content helps implement new scheduled maintenance processes. Baseline standardizes PM work, screens tasks, and establish a long-term, risk-based maintenance strategy reference. Plants not only move closer to the holy grail of living maintenance; they can measure progress. Software plays a role managing PM development costs in industrial environments, supporting these changes.

RISK CONTROL

Successful maintenance planning (1) identifies equipment failure modes that pose real risk, (2) identifies effective ways to manage those risks, and (3) implements selective PM tasks – quickly. Risk-based maintenance development strategies effectively:

- Partition equipment into failure risk classes for scheduled maintenance application
- Identify PM for scheduled maintenance tasks based upon failure functional consequences
- Organize and implement results in discrete, measurable packages as work orders

A hundred thousand or more components comprise an industrial facility, so plant operators must focus their maintenance efforts. Screening equipment that doesn't fail directly excludes the equipment that poses no acute failure consequences from scheduled maintenance programs. Surprisingly, much equipment falls into low risk categories. Critical equipment subassemblies have critical parts, which create failure risk. Classifying equipment failure risk for safety, production and cost functional effects differentiates failure consequences. Classification simplifies PM task selection, interval adjustment and work order development. Ranking equipment criticality requires familiarity with systems.

Analysts must know equipment functional contributions. Design basis reconstruction may be required. Although Architect-Engineer system design descriptions provide a well-defined starting point, effective scheduled maintenance, including rounds and operability tests evolve from clear functional requirements. Specific system requirements are not always clear – even in new plants.

Effective scheduled maintenance arises from known operating objectives. Formal analysis, repetitive performance and hard work incorporate maintenance changes into work order content in timely fashion. Computerized maintenance management system (CMMS) reentry, work re-planning, and work plan reorganization constrain this work. Experienced analysts develop maintenance strategy templates based upon specific equipment design knowledge, and application context to speed work. (See Figure 1: Component Template)

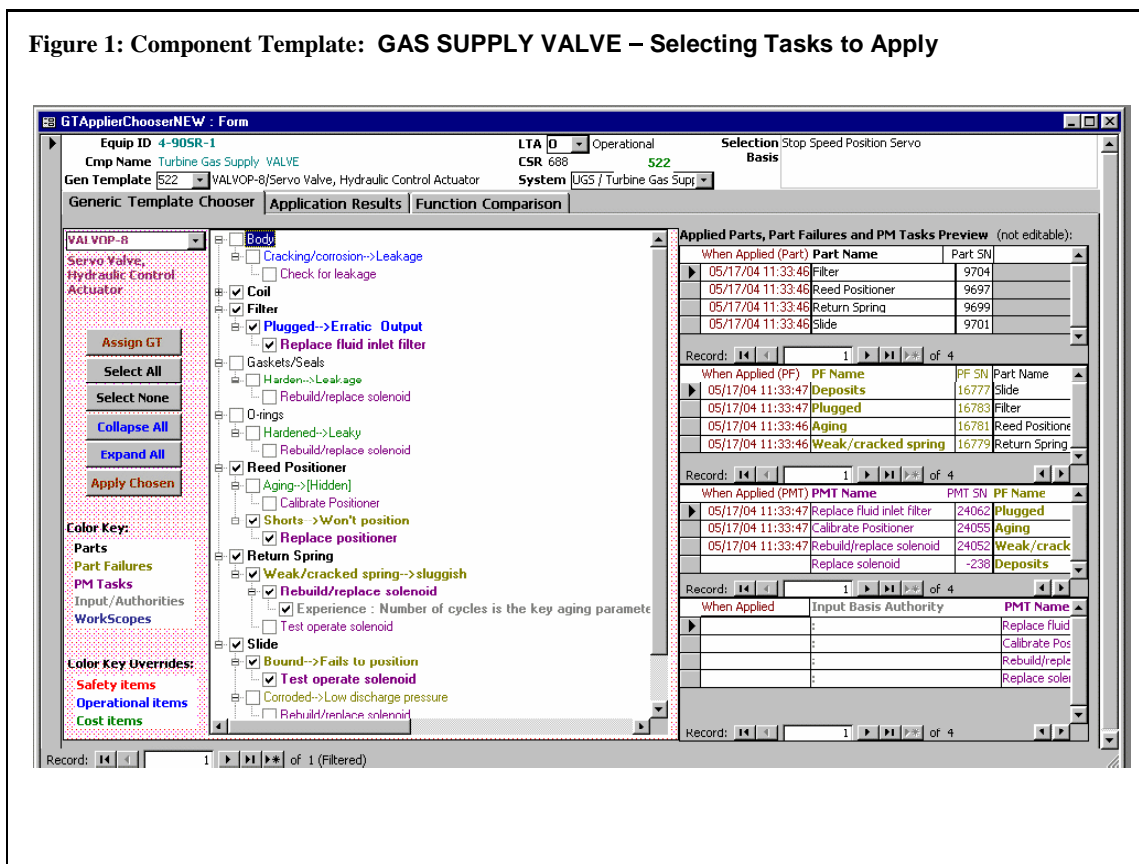
TRADITIONAL APPROACH

Originally, PM development started with vendor recommendations and plant experience. Today accepted industry standards like MSG-3 (Maintenance Program Development), SAE JA 1011 (RCM Processes) or AP-913 (Equipment Reliability) describe maintenance development processes. PM Optimization assembles recommendations, picking those relevant. Originally, someone developed the documented source recommendations in vendor/professional or code literature. Equipment suppliers, Architect Engineers, and

systems integrators published standards and industry experience providing the sources that a comprehensive literature search should identify. The scheduled maintenance plan's real objective is preventing functional failures, cost-effectively. Stated explicitly in 1950's maintenance theory, this maintenance objective seemed obvious – too obvious to state before that time. Complex maintenance requirements embodied in post-WWII era equipment created the need to exactly identify maintenance objectives. New systems were more complex, integrated, and more dependent on operators and other skilled workers for pre-operational tests and inspections. Because of complexity, many more things *could* be done, but not all were useful. Excessive maintenance actually reduced equipment reliability and raised cost.

Identifying the best, least-cost maintenance is a management objective. Different approaches reflect maintenance subject, culture and philosophy. Any maintenance plan development method should yield definitive, cost-effective PM processes. Historically, PM development preceded plant startup. However, plants have successfully started up without developed PM plans. Over the years development processes have evolved. Existing plant PM programs must be considered with any improvement initiative. With industrial facility lifetimes of forty or more years, many operating plants today started with older technologies and equipment, under then-current planning philosophies. The test of any new PM process is its ability to simplify operations while reducing cost.

Figure 1: Component Template: GAS SUPPLY VALVE – Selecting Tasks to Apply



PROCESS CHARACTERISTICS

What attributes separate risk-based from traditional maintenance development methods? Briefly, risk-based maintenance considers system functions, equipment failure functional risk, failure modes and effects analysis (FMEA), and PM technical validity (Figure 1, Component Template). "Failure" reflects context; exceeding functional specifications identifies "failed" equipment that needs maintenance. Default tasks provide PM strategies under all circumstances. Condition-monitoring substitutes for hard-time maintenance; maintenance based upon condition assessment reduces hard time tasks, extending performance intervals based upon experience. "Age exploration" describes this systematic step sequence.

Failure-risk classification considers safety, production, and cost consequences. Justifying PM tasks by failure consequences stratifies risks. Failure prevention to meet operating objectives ultimately justifies all maintenance. Engineering justification establishes tasks performed and their intervals, where scheduled maintenance is effective. Failure risk prioritizes work. In contrast with traditional PM development, risk-based PM processes specify exact choices. Seat-of-the-pants ad hoc selection diminishes.

Risk-based maintenance depends upon equipment context – system usage, stresses, installed redundancy, instrumentation, supported functions, likely failures and likely failure consequences. Defining part-failures explicitly for PM control removes traditional PM selection uncertainty. PM analysis focuses on addressing probable failures for real work tasks – "dominant failures." Traditional PM development diverges from certified standard ones today. (See Figure 2, Risk-based Task Selection Process) PM task selection consistently applied as specified should lead to the same results, repeatably. Historically, logic tree analysis (LTA) sets RCM-style scheduled maintenance task selection apart from earlier ad hoc PM selection methods. Formerly, anyone could select PM tasks; now qualification requires skilled, trained analysts. Reliability engineers must proficiently identify failure causes and select analytical, risk-based PM tasks. Of course, pre-developed analysis and other tools help.

Analysis should explicitly identify credible dominant failures. For ease, analysts should find one mitigating PM task – a very exacting requirement, addressing each failure. Selecting one task over others cost-effectively, using a specified selection process reduces variability and error. FFT vibration analysis may be preferred over lube oil analysis to identify bearing failure, for example. Context determines preference, departing from traditional PM development adhering to vendor prescription. Qualifying tasks by failure modes differentiates value-based scheduled maintenance. Critically reviewing ill-defined tasks develops their supporting basis, or eliminates the task. Basing PM tasks by risk makes

tasks actionable, developing value. Baselining develops acceptance criteria, reducing performer discretion. Documented low-value work may be comfortably dropped.

In large industrial facilities, PM work order models apply repetitively to different equipment application tags (serialized, code number identifiers) of common design. While large equipment overhauls encompass hundreds of tasks, even typical work orders contain several, each preventing one failure. Individual PM tasks should integrate easily into work orders to consolidate work administratively, allowing PM cost accounting evaluation. Task integration assures benefits trace PM value controlling failures to their sources – the equipment that directly supports production.

STRUCTURED PM DEVELOPMENT BENEFITS

"When there is an existing program, it is tempting to modify [the existing program] by piecemeal decision logic. This perpetuates tasks that are not really justified. Moreover, this approach will overlook the need for new tasks. The best procedure puts the old program aside" –S. Nowlan and H. Heap, ADA AO66 579

ADA AO66 579 ("RCM") documented maintenance developments, opinions, and methods from the 1960's. MSG-3 specifies how to develop scheduled maintenance programs. Based upon commercial maintenance experience, ADA AO66 579, states that economic benefits result from:

1. Eliminating inapplicable tasks
2. Converting hard time tasks
3. Increasing task intervals
4. Reducing unnecessary tasks
5. Reducing overlap
6. Reducing PM program components
7. Improving new equipment design
8. Avoiding unnecessary work risk

New technologies substitute diagnostics (examples of 1 or 3 above). New designs improve maintainability by non-maintenance techniques like parts and material substitution, or failure mode elimination altogether by redesign. Sintered graphite bearings demonstrate design evolution removing a failure mode for exterior bearing applications.

RISK BASIS

Risk-based maintenance challenges regulated industry. Analysis requires industry skill and awareness. From plant design, analysts must identify system operational and maintainability risks. Specifying failures, they may identify design changes that are necessary; some could remove "hidden failures" with instrumentation, for example. Condition monitoring, testing, and failure-finding tasks reduce hard-time maintenance lowering cost.

Ignoring previous PM program content (per Nowlan and Heap) creates a practical dilemma. Building maintenance on a factual basis requires specific analytical skills. Schedulers, planners or shop lead personnel lacking these skills could be excluded from previous work efforts. Developing new plant technical programs from fundamental maintenance requirements contrasts sharply with survey-oriented development processes.

Accurate technical results should be implemented at the lowest possible cost. Theory omits:

- Source plan validity
- Program ownership
- Implementation costs
- Baseline comparison cost
- Final work integration costs
- Industrial risk rank comparison

Work organizations are cultures. Changing maintenance or its development methods requires organizational change. Though useful to manage conflict, trusting legacy owners for final changed work order implementation risks completion altogether.

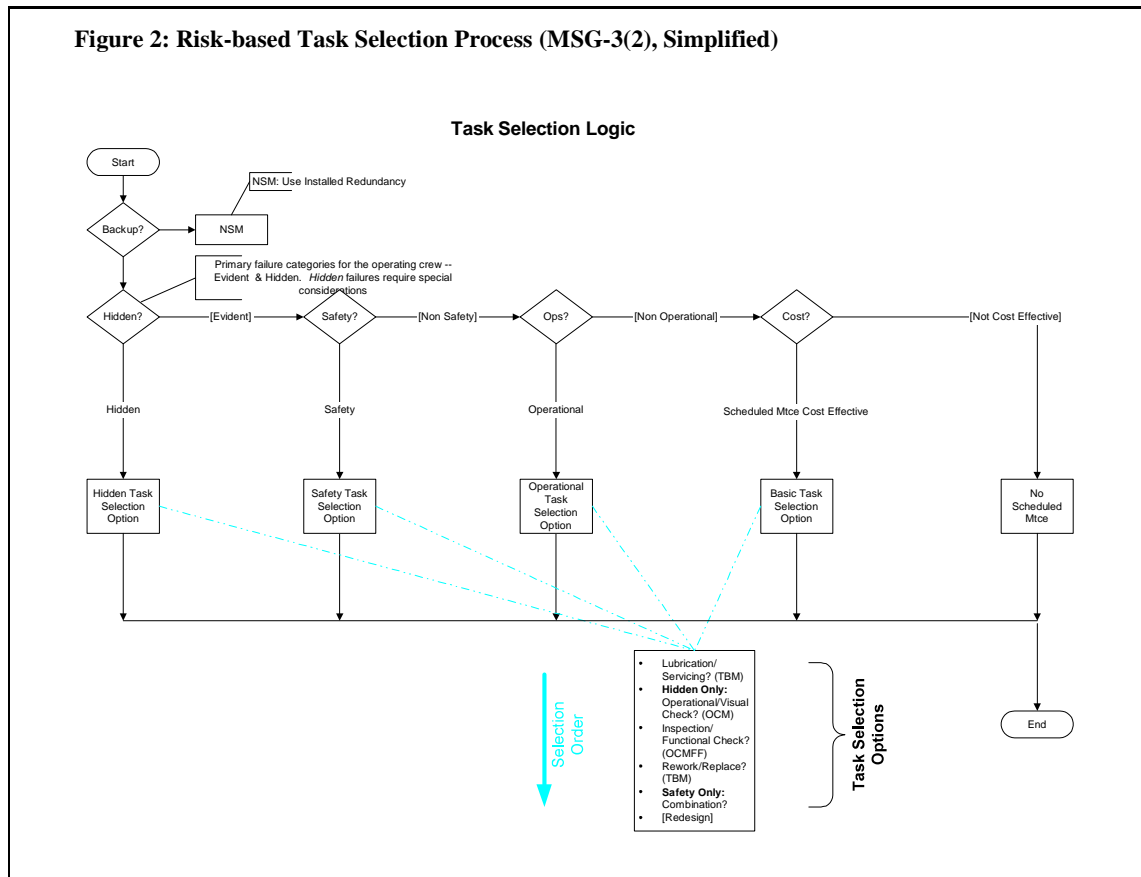
MAINTENANCE CHANGES

Reliability-centered maintenance changed aviation with

MSG-1. JA1011-style front-to-back PM development has influenced new construction programs as well. Re-developing PM imposes tough change requirements. Nuclear RCM studies in the 1980's generated thousands of analysis pages, per system! One comprehensive plant study (80 systems) encompassed forty file boxes with one hundred-thousand pages of hard-copy analysis in final form! Sheer work volume made results easy to ignore.

Safety justifies maintenance that would otherwise be prohibitively expensive. Maintenance addresses different equipment failure risks however, and most don't directly affect safety. Engineered maintenance programs should not only justify work, but clarify work basis. Continuously reviewing existing work orders, validating PM tasks, refreshes program content. Appropriate safety consideration, when few failures pose direct safety threat, challenges all scheduled maintenance development processes.

Planners build worksopes comprising work order tasks, planning work, estimating requirements, arranging support, and coordinating workers. Maintenance requires planning support. Support infrastructure development increases process improvement cost. Early PM optimization used documents, spreadsheets and first-generation software. Contemporary CMMS systems of that era lacked relational design – or even master equipment lists! Software still limits PM optimization, but technology has improved. Relational software, PC networks, database servers, custom user interfaces, and other



automation minimize rote information manipulation. More effort can focus on PM failure analysis.

INHERENT DIFFICULTIES

Failure analysis identifies failing equipment parts, cause(s), and probable effects. Loading CMMS end products – finished PM model work orders task lists, requires a second effort. Tools should transfer finished model work orders content into CMMS material, efficiently. Reliability processes, databases, and other tools help automate this effort. Streamlined processes identifying critical equipment PM content to eliminate non-critical equipment with no direct failure consequences, document selection. Validating PM content screens ineffective tasks. (See Figure 3, Upload Process Summary Display)

If many legacy PM tasks are effective, pre-existing analysis re-use would speed work. Screening could exclude non-critical equipment, ineffective tasks or even extend remaining equipment task intervals, appropriately. Rigorously challenging pre-existing PM tasks consolidates legacy content. Conversely, “grandfathering” retains low-value work; pre-developed, industry-based PM templates help counter work perpetuation bias. Documenting how PM tasks address equipment failure risk develops the PM basis. Recognizing credible dominant failures comes largely with experience. Standard equipment templates incorporate organizational/industry experience, focusing design failure

analysis.

WHY BASELINE?

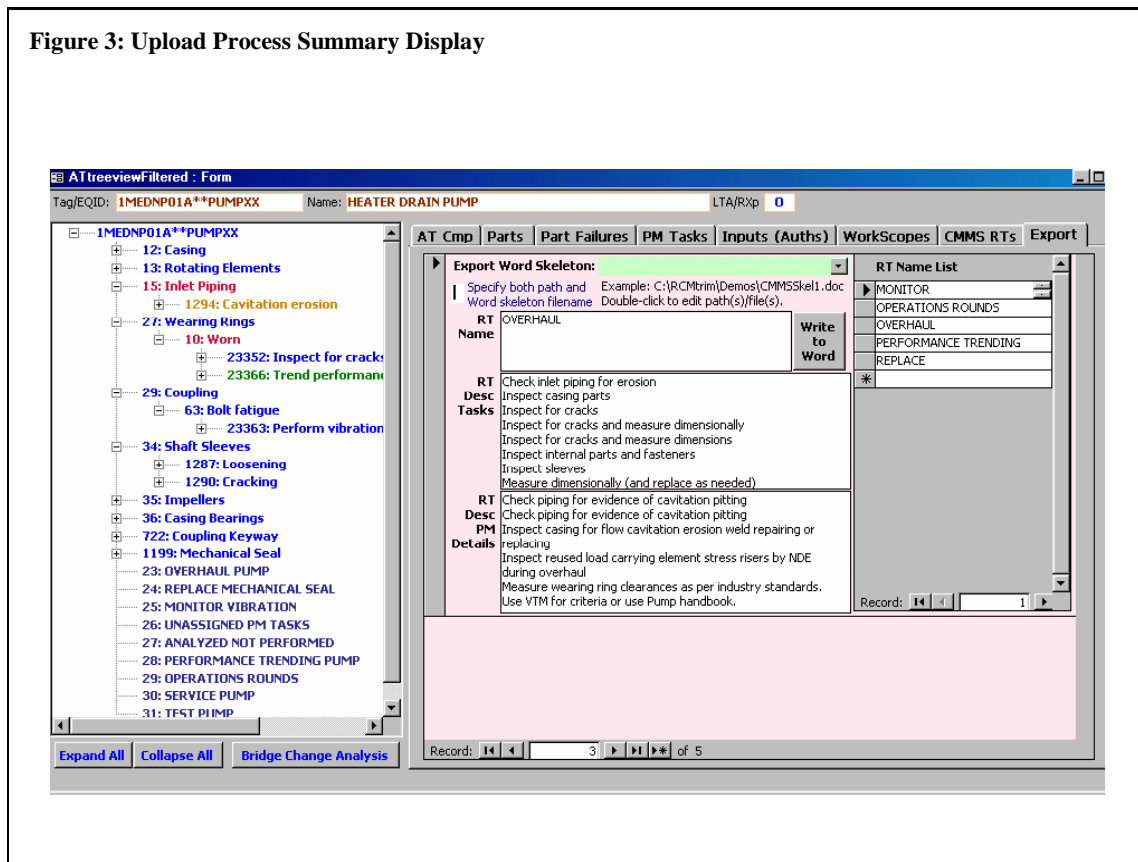
CONTENT VALIDATION

Overly-aggressive industrial PM programs choke on scope. Plant equipment numbers assure that more equipment is always available to maintain than resources will ever be available to do so. Maintenance requires focus to be effective. Baseline scrutinizes every PM task – analogous to zero-based budgeting. Without a clear, rigorous failure-prevention basis, PM tasks should be discarded for the program’s common well-being, if not cost alone. Validating PMs removes ineffective tasks, reducing overall work volume. Baseline simplifies existing PM content use. Standard template plans reduce PM model work orders numerically. Fewer model work orders yield simpler maintenance plans.

OWNERSHIP

Constructing a new facility, Architect-Engineers provide P&ID drawings, purchase order (PO) specifications, and vendor O&M manual references; using these plant staffs build maintenance plans. Scheduled maintenance reflects warranty, compliance, asset management and due-diligence strategies, e.g., owner operating philosophy and culture. Planners, schedulers and supervisors provide routine PM support own

Figure 3: Upload Process Summary Display



programs. Baseline rebuilds maintenance program ownership among stakeholders, as done at startup.

MEASUREMENT

PM changes justify PM reanalysis. In traditional PM optimization, pre/post analysis statistical comparisons finish work. Implementation realizes PM benefits. Tracking PM changes to implementation assures benefits get realized. Consequently, users often track changes to implementation.

Different change types offer different value. Statistically key performance indicators (KPI) break PM changes down by type supporting performance measurement and cost accounting. Summarizing PM changes by add, delete, modify, extend, or no change ("ADMEN") yields five change outcomes. *Delete* and *extend* reduce maintenance workload, *modify* substitutes new technology, materials, or regroups tasks leaving basic failure prevention relationship unchanged. *Modify* outcomes reduce workload, overall. *Modify* can supersede older technology with more effective new ones, for example, a common trend. Over the past two decades, vibration analyzer development enabled more effective vibration analysis. *Condition monitoring* replaces *hard-time* with *condition-directed* tasks, another desirable outcome. Changing hard-time *replace filter* substituting condition monitoring *check filter DP* reduces maintenance work. As plants substitute condition-directed maintenance for historical hard-time tasks, KPI's will measure this trend.

IMPLEMENTATION ALIGNMENT

CMMS systems manage PM models and schedule work orders. Completing reanalysis, changes must enter the scheduled maintenance work order models. Manually incorporating model work orders changes requires as much effort as initial development. Results reentry (re-keying), batch CMMS upload, or other finishing steps should be considered as alternatives in early PM project completion planning. Windows™ cut and paste techniques can transfer results from one application to another. Manually re-entering PM model changes is another option. Some work order changes are difficult to plan, requiring new procedures, changed warehouse parts stocking or other work plan changes. Re-planning needs consideration. PM change implementation through application software "middleware" requires software experts to develop the applications that move finished results into the CMMS. Software support, special arrangements and budgets may be needed. Aligning pre-existing model work order PM changes simplifies implementation. This reduces completion validation effort, speeds implementation, lowering cost. Simplified implementation makes a compelling PM baselining argument. Final results upload easier. Tracking work is simpler, pre-aligned for implementation.

CONTINUOUS IMPROVEMENT PREPARATION

Static maintenance programs eschew new technology, methods or learning. In contrast, continuous improvement requires dynamic processes to update CMMS PM models. Large PM projects disrupt routine improvement processes.

Adjusting instrument calibration intervals has been the industry norm for years. Other service, replacement and equipment inspection interval *age exploration* have not achieved such widespread acceptance. *Age exploration*-based task changes require workers' hands-on knowledge and intuitive thoughts regarding equipment application capability and failure. How much service will equipment really tolerate while still maintaining functional requirements? Programs incorporating craft worker insights develop rapidly, controlling costs. Dynamic task adjustment – *age exploration*, requires critical performance interval and task content review, task by task. Differentiating PM work orders into workscope tasks clearly discriminates technical content for review.

SUMMARY

An extensive, preexisting implemented PM program provides the best reason to baseline. Naturally establishing a reference point prior to starting work justifies baseline effort. A significant benefit is the PM owner support for future PM program changes.

BASELINE PROCESS

Baselining PM content should:

- Consolidate and standardize
- Develop an equipment risk map
- Develop applicable templates
- Define PM model work scopes
- Align templates & PM models
- Develop the PM Engineering Basis

Measurement requires a reference state to quantify changes and benefits. Software, hardware, training, and other one-time efforts prepare for implementing changes, defining scope to standardize PM plans. Typical maintenance reviews reduce scheduled maintenance costs by 15%. Baselining should standardize, integrating similar equipment requirements. (Template libraries help standardize component plans.)

Key performance indicators (KPI) track important improvement measures, assessing results at system, component, and ad hoc grouping levels. Databases support data metrics. Baselining the MEL PM models and risk basis benchmarks maintenance programs. Measurement should consider equipment unavailability, reliability and maintenance costs, as well as safety. Methods should streamline processes, incorporate operating experience, and reduce analytical processing time.

BASELINE STEPS

Baselining establishes (1) critical equipment, and (2) PM content by equipment type. The first differentiates critical from non-critical equipment; the second establishes scheduled maintenance work order content for critical equipment.

(1) MASTER EQUIPMENT LIST (MEL) EQUIPMENT SCOPE

Component type classification allows developing common templates, like “motor operated valve” or “surface condensing heat exchanger,” and assigns critical MEL equipment to a template by unique component tag number identifier. Typically about 50 component types cover most plant equipment. Details differentiate template requirements. Diaphragm and cylinder air-operated valve operators are similar. Common valve setup, calibration, inspection, and testing activities apply broadly to either component type. Specific application differences depend on service and wear unique to each installation configuration (material and parts), service and stresses. Maintenance can maintain more unique templates, applied completely, or develop one comprehensive template, customized upon application. Achieving final specifications leaves the PM developer a choice – one template, custom applied, or multiple templates, wholly applied. Either approach gets to the same end result, different ways. Selection is a matter of preference and simplicity. (See Figure, 4 Equipment Risk Map)

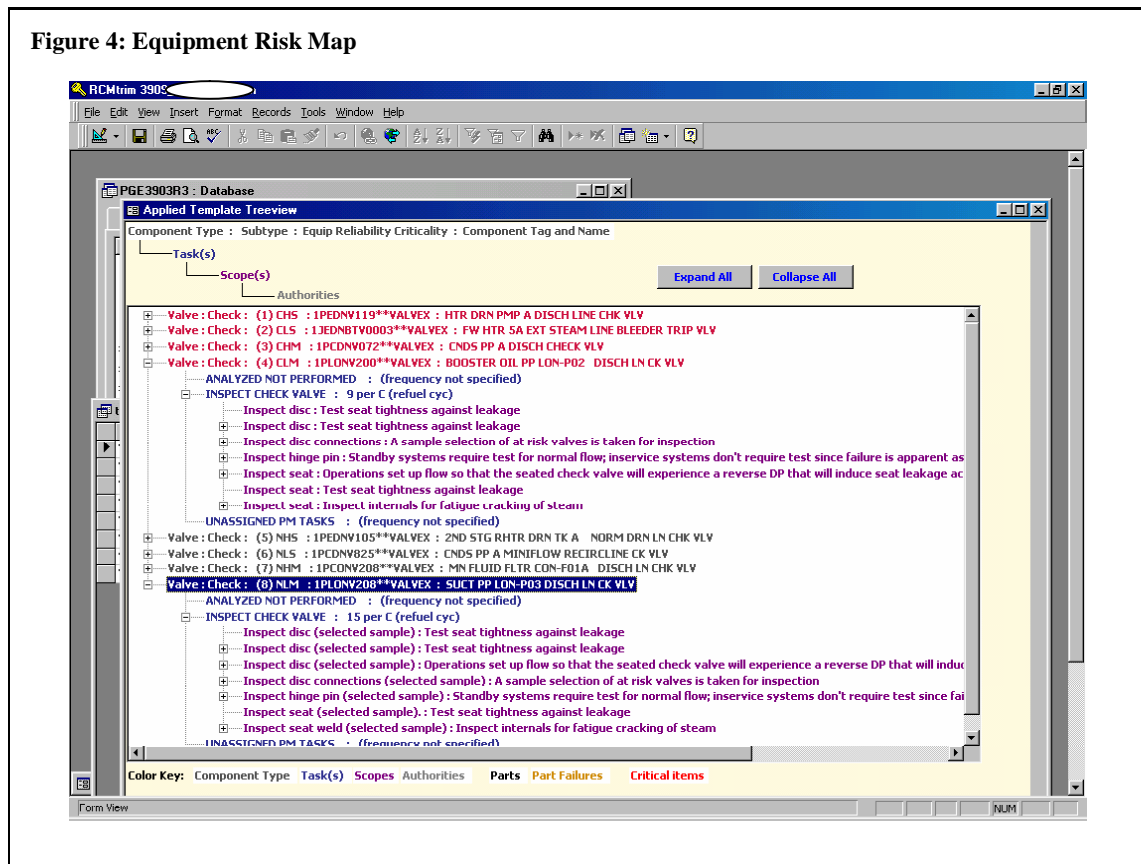
(2) EQUIPMENT PM CONTENT

The CMMS provides MEL-based PM lists. Optimization finishes PM scope to implement. Organizing PM work order models by equipment component type standardizes component template development. Standardized templates, developed by component type, context (duty, environment and risk) quickly baseline PM content. Supported functions, special programs, and ancillary requirements, customize final component templates.

Reverse-engineered from PM Models, taken from standard libraries, or developed from O&M manuals – templates must consolidate. Engineering guides PM task selection where multiple similar task descriptions exist. PM task-failure relationship – one failure mode per PM task – assures template tasks address failures, efficiently. Rigorous adherence to specifications creates efficient templates; efficient PM programs result. A check valve template merging thirty check valve PM model tasks into five unique composite template tasks removes duplicate content. Templates then reapply tasks uniformly by component model group. With standardized content, fewer unique work order models result.

Defining parts and failures addressed by each PM task develops PM scope. Component functions, task importance, and organization into workscopes create a template structure for implementation. Work order task content is never complete in a living program. Software templates can build PM task content relationally, making template construction and revision easier, simplifying application and use. Structure organizes subject matter expert opinions, encouraging documenting exceptions, case-by-case, customizing applied templates. Although a component template is a composite, differentiating parts, failures, PM tasks and work scopes enables application customization. (See Figures 1 & 3) As developed, templates provide structure upon which details can be added, selectively. Applied templates provide subsequent reapplication sources for plant equipment tags based upon common component type.

Figure 4: Equipment Risk Map



Cut/paste, clone and automatic copy subroutines scratch-build new templates from those already available. Standard industrial facility templates provide baseline libraries. Although new plants typically need a few new templates, rarely are these more than a few. Existing PM model prototyping provides a facility's template foundation. These define standardized, facility scheduled maintenance from that time forward.

SCOPE DEFINED

Technically performing specified work order content meets completion requirements. Completion to specified PM requirements assures reliability objectives. Incomplete work completion requires evaluation. Is equipment operable? What risk has been incurred from incomplete steps? Is that acceptable? Where programs accept incomplete work and failures don't result, scheduled maintenance lacks grounded, failure-based PM task correspondence. Traditional PM programs exhibit inexact work-failure linkage, characterizing ill-defined scheduled maintenance.

With engineered PM plans, incomplete work orders either mean original task assessment was too conservative, and PM interval should be extended, or equipment will need servicing before the next scheduled period. (In the latter case, equipment will fail during the potential failure/failure (P/F) interval, before the next service period.) Rescheduling PM work requires unscheduled outage(s), a production loss/cost increase. Obviously, where new production outages must be scheduled, severe economic penalty results. Outage penalties, however severe, are the least concerns, however; control of safety failure risk is paramount. Safety provides another compelling reason to identify explicit task risks; people comply with maintenance when they view its safety implications clearly. In a template, scope defines performance expectation; failure to complete scope should reflect unacceptable equipment failure risk.

TASK BREAKDOWN RISK DIFFERENTIATION

Templates differentiate component parts, part-failures, and PM failure-control tasks. Reintegrated into work orders, PM tasks must be actionable. Task lists provide scheduled maintenance work order scope. Work order scope is simply a work completion checklist. Completed work orders allow PM task rescheduling by work order model for next performance.

Grace periods extend allowable work completion period. PMs scheduled considering grace periods must be shorter than their P/F interval. Arbitrarily extending performance intervals with a grace period otherwise exceeds average failure interval (mean-time-between-failure – MTBF), assuring failure. The

recourse for life-limited equipment requires exceptionally conservative scheduling or no grace periods altogether. Grace period programs *must* conservatively schedule PM intervals – raising cost. Aggressive PM programs have no grace periods and virtually 100% PM work completion. These characterize MSG-3/JA-1011-based maintenance programs. While they strike many maintenance managers as demanding, their utter simplicity and forced discipline reduce maintenance costs and ultimately – failure risk.

COMPONENT TYPE STANDARD TEMPLATE INTEGRATION

Templates constructed by equipment types integrate best practices. Applying task content requires considering the equipment characteristics including application risk, duty and environment. Manufacturer, model, ASME piping category, and other engineering attributes uniquely identify templates.

Essentially identical equipment template applications can use a "normal model." Equivalent equipment references the normal model. Applied templates functionally define the equipment. Reusing one application model – the normal model, standardizes equipment programs. Normal model reference groups extend standardization, reducing unique templates required in plant applications, using design symmetry. This reduces PM models, standardizing work orders.

TASK SPECIFICATION

Of necessity, PMs must control failure. Tasks should therefore clearly mitigate failure. Performance workhours and cost combined with avoided failure benefits jointly define each task's value. Task/failure correspondence, one-to-one, justifies work. Failure/task relationship can be reviewed with individual details updated by new experience, as required. In operating plants, failures emerge daily in completed work orders and industry events. Experience requires PM revision with new information, easily administering changes.

Workscopes accumulate task costs. Workscopes block tasks for implementation. Workscopes assemble discrete tasks' under major activity like "Overhaul," for organizational simplicity. Simplifying content, workscopes integrate. Workscopes also retain tasks' individuality differentiated by failure, weighing each on merit. Practically, workscopes simplify implementation. Tasks should be independent of workscope, applied to plant installed equipment to address failure. Software facilitates maintaining task identity while simplifying movement for workscope reassignment. (See Figure 5, Workscope)

SOFTWARE PROCESSES

Pencil and paper, electronic document, files, spreadsheets, or database software can develop PM programs. The right tools simplify the job transparently to the user. Software reduces completion effort. Tracking process plant equipment (~10,000 to 100,000 tags per unit) part/failure/PM task combinations *manually* is virtually impossible. Two-dimensional spreadsheets provide partial relief, but with thousands of null/repetitive spreadsheet row entries, lack simple data form. Relational databases independently define multiple relationships. Maximizing relationship efficiency, minimizing database size, normal data form maximizes information value.

Templates control applied equipment PM content. Controlling format, templates compare and contrast similar information. Standard format allows technical comparison on multiple levels. Standard templates generalize component designs; application templates customize these to plant design context. Separation of templates (into standard and application) facilitates PM tasks reevaluation based upon design, application, usage and other similarity. Many levels – parts, failures, and PM basis inputs – can be queried to sort information.

Software automates tedious analysis that should be quick, easy, consistent and correct. Template application work order processes simplify and automate implementation. Without templates, slightly different spreadsheets or documents frustrate

information use. Relational databases ultimately simplify information structure, automating CMMS table loading. As project completion clean-up, analysis reentry can be tedious. Software simplifies or entirely eliminates reentry, tracing completion details concurrently on many levels to their sources.

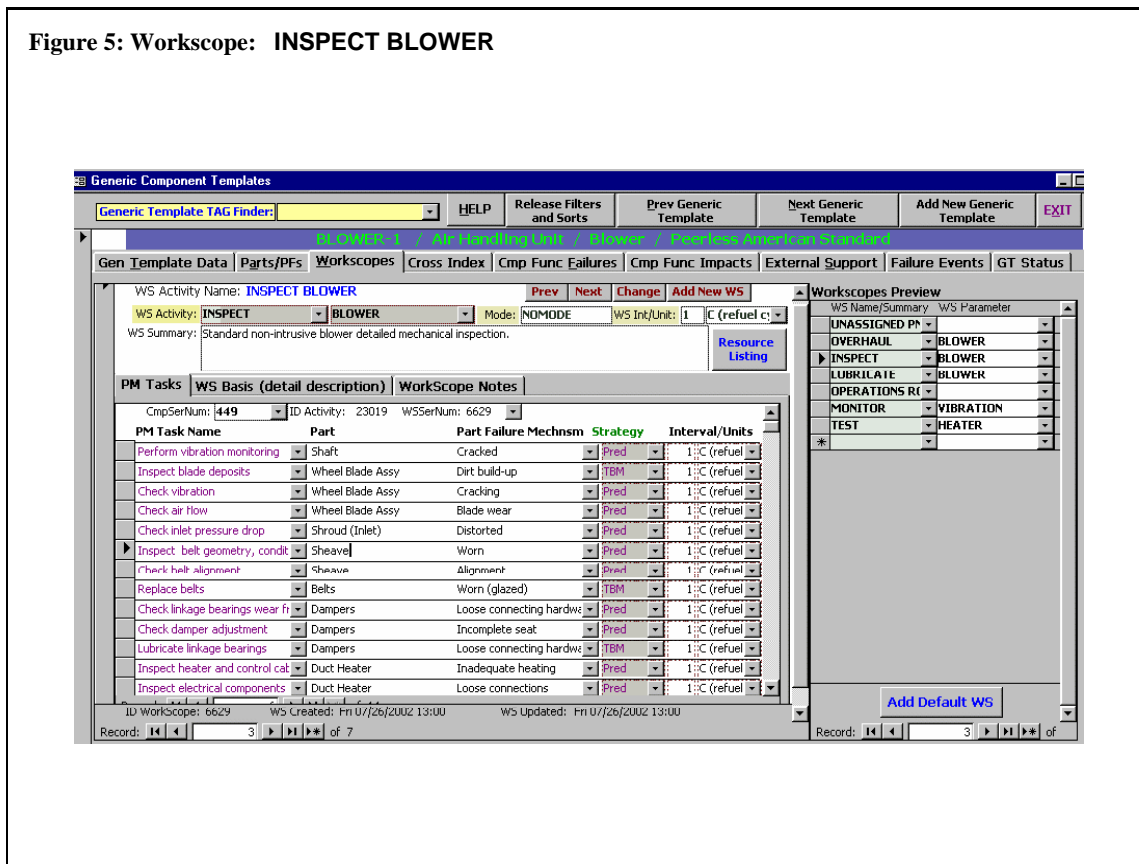
Controlling variability maintains industrial PM programs. In technical work, controlling work, its evolution and engineering data format challenges everyone. Many vintage 1990's era spreadsheet analyses were unusable upon completion. End users could not extract, review and revise plans upon discovering they needed change revision.

FUTURE MAINTENANCE

Maintaining PM work basis maintains work performance justification, facilitating review and rework of reliability strategy. Strategy redevelopment occurs naturally in an evolving program. Operating experience, internal failure trends, and accident analysis require reworking scheduled maintenance plans. Simple PM maintenance methods support an evolving program.

The CMMS schedules PM with model work orders. PM changes must update CMMS scheduled maintenance. Systems that effectively upload results support living maintenance programs. Software provides options for batch data upload, copy/paste manual reentry, and auditability. (Figure 3, Upload Process)

Figure 5: Workscope: INSPECT BLOWER



LIVING MAINTENANCE PROGRAM

In maintenance, all work should add value, and all changes should improve work value. Numerically, a few failure control efforts provide the most value. Measuring costs and benefits ultimately provides the economic basis for risk-based maintenance. Measuring change value against a reference point anchors improvement efforts. All changes should clearly address failure controls, and show clear cost benefit. The most significant tasks should be easily distinguished based upon their value.

BENEFITS

Aggressively improving maintenance yields results. However, some equipment cannot benefit from scheduled maintenance. Time-based maintenance on manual valves (which leak randomly), status-only instruments (used for secondary and validation purposes), or electronics (that fail randomly) exemplify maintenance not to do. Plants benefit dropping ineffective PM. However, plants lack processes to systematically identify and remove ineffective work.

PM tasks performed ultra-conservatively reflect outside vendor guidance. Vendors aren't malicious; they just can't accept risk outside their control. Extending normal prescribed maintenance intervals, substantial workhours reductions occur. *Overhaul* heavy equipment time-based tasks carry many burdened labor hours. Timid interval extension displays lack of tools, skill or confidence. Modern reliability techniques can extend intervals based upon sound, uniform engineering justifications, augmented with regulatory code inputs providing a high degree of safety and performance assurance.

Work orders support cost accounting, quantifying results. Historically, cost-accounting was impossible; today it is easy. Work order task-level actionability complements cost-accounting. No benefit accrues knowing a task effectively manages failure, if there's no way to assure it gets performed. Plants seeking effective, analyzed maintenance task implementation must control content, implement changes exactly, and assure virtually complete planned task performance.

CONCLUSIONS

Performing a well-designed scheduled maintenance plan assures industrial plant reliability. The scheduled maintenance program initiates most maintenance, including corrective maintenance. Achieving equipment reliability requires consistent maintenance performance. Consistent processes to make program changes build confidence. Baselineing supports maintenance improvement in multiple areas. Simplifying process tools make improvements feasible in multiple ways, providing keys for equipment reliability success.

ACKNOWLEDGMENTS

The authors would like to acknowledge the members of the EPRI Maintenance Rule Users Group, Brian Ramey and Steve

Coppock of Arizona Public Service, Marty Block of Xcel Energy, Fort St. Vrain Station, and Frank Novachek of Xcel Energy for their contributions.

TERMS

Activity
Age exploration
Application
Applied template (application template)
Computerized Maintenance Management System (CMMS)
Condition-directed (condition-based)
Data normal form (relational data normal form)
Dominant failure (DF)
Failure finding (FF)
Grace period
Hard time (Time based)
Hidden failure (HF)
Key Performance Indicators (KPI)
Labor hour burden
Life-limit
Mean-time-between-failures (MTBF)
Middleware software (interface software)
Model (PM model)
Normal Model (Master Model)
Models (PM Models, CMMS Models)
Normal data form
Normal Form
Normal model (applied template normal model)
PM work order model
Potential Failure/Failure (PF/F) Interval
Potential Failure-to-Failure (PF/F or P/F) Interval
Preventive Maintenance (PM)
Primary/Secondary Components
Probable Failure
Purchase Order (PO)
Reference Normal Model User
Reliability Centered Maintenance (RCM)
Repetitive task (RT), routine task
Safe Life Limit (SLL)
Scope (work order scope)
Seven-step RCM
Subtype (Component subtype)
Task Accounting
Task; Task block
Template (standard template)
Traditional PM
Traditional RCM
Type (Component type)
Work Order (WO)
Workscope

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