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EFFECTIVE MAINTENANCE PM TASK SELECTION REQUIREMENTS

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ABSTRACT

Developing an effective scheduled maintenance program requires a profound awareness of risk tolerance, dominant failure modes, failure symptoms, diagnostic methods, and work practices. Effective PM task selection is hard work. Identifying applicable and effective tasks quickly and consistently for critical equipment is the first step towards reliable, cost-effective operations. Automating the PM task selection process by using relational database software removes developmental ambiguity, which speeds up analysis, but poses practical problems. Preventive maintenance (PM) work order development can be standardized and automated to achieve this objective.

Keywords: Preventive Maintenance, Reliability Centered Maintenance, Computer Software, and Scheduled Maintenance

INTRODUCTION

Equipment PM task selection in maintenance plan development has always been hard work. Critical equipment selection and failure analysis are demanding. Packaging resulting tasks for implementation involves process stakeholders and demands even more time. Task selection automation offers many subtle benefits. These include standardization, faster development, better consistency, and (most importantly) final tasks that more faithfully identify and address analyzed risk and probable failure with justification basis. This paper describes a streamlined Reliability Centered Maintenance (RCM)-based PM task selection process, and its associated RCM*trim*™ (*trim*) streamlined analysis software.

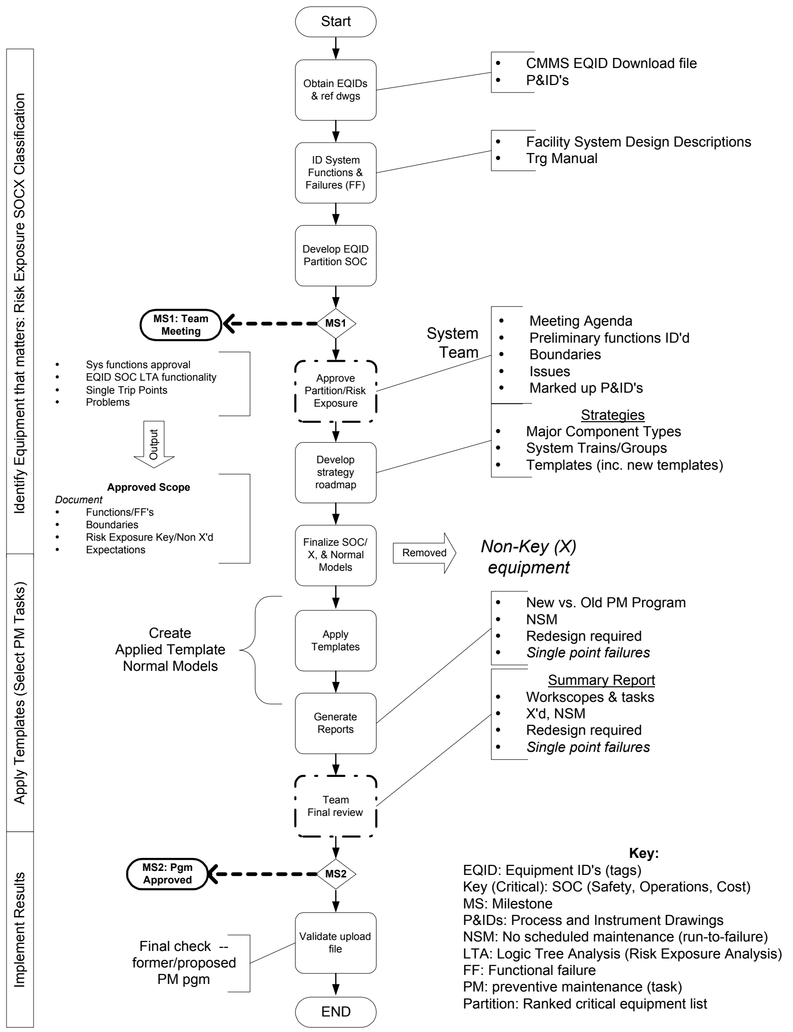
Customization and standardization complement each other in successful scheduled maintenance programs. Equipment integration during plant design creates the need for system analysis. Manufacturers can readily specify their equipment's maintenance, however, an overall plant PM program must consider local operations & work environment, as well as risk. Since Manufacturers never exactly know applied equipment operating conditions or failure risk, they recommend conservative programs directed towards their most critical application. Equipment management strategy runs the gamut from "run to failure" to intensive planned maintenance on similar installations. Context and risk acceptance are the only variables that explain the differences. Literal implementation of Manufacturer recommendations create unwieldy PM programs.

RELIABILITY-CENTERED MAINTENANCE (RCM)

In the mid-1970's RCM emerged as a proven aviation maintenance development process that had helped airlines improve operating reliability and reduce costs. RCM has not made a smooth transition to other industries, however. The reasons are the inherent complexity of other industrial environments, such as electric generation. Effective task selection requires statistics awareness, fundamental engineering knowledge, and plant operating experience. Senior maintenance workers become the planners and schedulers who select, package, and implement maintenance PM tasks. While their assignment facilitates maintenance implementation, it skirts inherently difficult task development and selection requirements.

Figure 1

System Review Steps



Traditionally, planners reviewed plant system equipment lists, pulled O&M manuals (opened to "Maintenance"), and selected manufacturer-recommended tasks. Practically, this led to unsustainable PM programs. Just as auto owners haven't literally implemented owner manual PM's, plants never exactly implemented vendor-recommended PM programs. Resources simply weren't available. Numerically, for one large centrifugal compressor, the manufacturer recommended over 120 separate tasks! Rationalized, these shrank to fewer than 20. Many could be performed quarterly. Daily monitoring was reduced to a fraction of the original time specified. Audits show low PM performance rates (e.g., under 10%) in fully developed programs. *Low completion rates are mature program characteristics*.

This is the traditional maintenance PM story, over and over. RCM can improve this situation greatly. What causes such huge discrepancies between intended and implemented PM program scopes? Most often the developers lack the technical skills and contextual knowledge to select "applicable and effective" PM tasks. Craft can readily identify failures, but effective PM task selection requires technical analysis. Engineers are needed to define dominant failure modes, specify objective failure limits, and plan tasks that mitigate dominant failures.

"Failure" means any event that prevents equipment from fulfilling a system's required functions. Preserving critical functions achieves operating objectives. Failures as slight as an alarm annunciator or indicator lamp out, or as major as a shed turbine blade result in functional failures. Some failures develop over long periods; others occur instantaneously.

RCM captures the design engineer's thoughts. A designer selects equipment to fulfill system design requirements, specifying exact equipment requirements, redundancy, instrumentation, diagnostic methods, maintenance, and calibration requirements. The reliability engineer must also select PM tasks based upon value and risk. This characteristic distinguishes RCM from other maintenance program development methods. That explains the difficulty encountered in trying to understand and apply RCM maintenance selection principles. It also explains why RCM can become time intensive.

MAJOR STEPS

RCM maintenance program development involves three major steps: (1) selecting the components that matter, (2) selecting the PM tasks in risk context, and (3) packaging results for implementation. (Figure 1)

(1) SELECTING COMPONENTS THAT MATTER

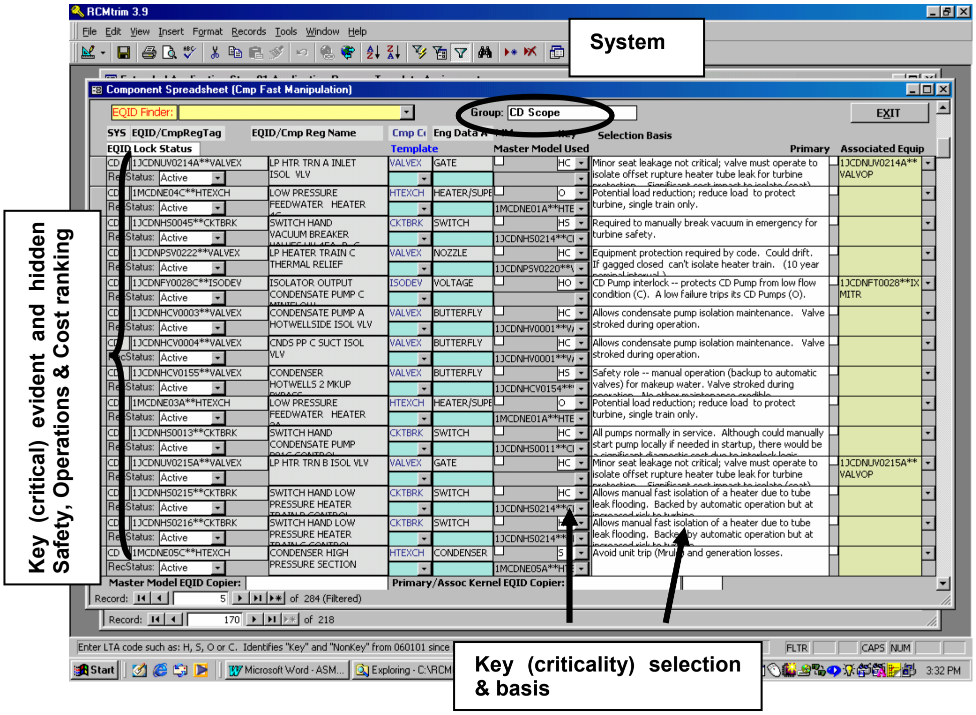
Components that matter have been called "significant", "important," "critical," "essential " and "key" by various program formulations. This equipment has the potential, through single failure, to compromise system operating goals. Though terms can vary, single failure qualification is important; equipment that can't compromise system functions in single failure drops to a lower status. It becomes "non-important," "non-critical" or "non-key," and is addressed by a program of no scheduled maintenance, e.g., run-to-failure. This equipment can be safely, cost-effectively maintained upon discovery of failure symptoms. Run-to-failure equipment makes up a large population of the equipment in any complex industrial facility, and supports a strategy of *no scheduled maintenance*. Engineers should use run-to-failure equipment to their advantage building a maintenance strategy. Taking advantage of inherent design characteristics, they reduce maintenance costs and improve reliability. This is the essence of RCM.

Single failure criteria leads to concise critical equipment lists. Excluding non-critical equipment from the analytical scheduled maintenance consideration focuses effort onto remaining critical equipment. Critical equipment is then assigned risk exposure classification of safety, operations or cost (SOC). These categories create a system risk profile (e.g., an equipment risk exposure list). This profile differentiates equipment that can benefit from scheduled maintenance from that which can't, ranking relative value. Developing this profile is valuable in its own right for evaluating failed equipment during plant operations. This profile complements the PM plan, providing a risk-monitoring guide for workers to prioritize failing equipment condition-directed maintenance. The profile follows the designer's logical thought process providing margin and spares, extracting plant design depth for maintenance task efficiency. Depth is an asset. Documenting design depth to manage risk exposure is an early step in efficient maintenance plan development. (Figure 2)

Effective maintenance programs dictate resource scheduling. By focusing on single failures, programs avoid the complexities and additional resources needed to address multiple-failure chains. In RCM-based maintenance programs, scheduled maintenance reduction accompanies an obligation to perform emerging condition-directed maintenance. Scheduled maintenance discovers needed maintenance real-time. Discovered, it must be performed or functional failures will eventually result. Plant PM implementation and condition-directed maintenance performance in RCM-based programs must be nearly 100%! Maintenance programs can fail by lack of implementation, resource allocation, or scheduling as much as fundamental strategy weakness. To reap efficient maintenance program design benefits, maintenance performance follow-through is necessary. In short, RCM is not a fickle-minded maintenance process. Follow-through is mandatory!

Critical equipment identification is based upon failure effects. Critical equipment failures that affect safety, operations, or cost operating goals are ranked mnemonically as "S," "O" and "C." This simple coding scheme reflects three criticality class's (excluding non-critical – "X") streamlining forms and reports. These categories differentiate qualitative effects based upon orders of magnitude. Safety losses are (at least) ten times as risky as operational ones; operational losses outweigh maintenance costs by another order. (These conclusions - cultural values aside - reflect many case studies reducing event consequences to costs!)

Figure 2: System Component Risk Exposure Classification: CD Condensate



Group: CD Scope

SYS	EQID/CmpRegTag	EQID Lock Status	EQID/Cmp Reg Name	Cmp C Template	Eng Data A	MM	Key	Master Model Used	Selection Basis	Primary	Associated Equip
CD	1JCDNUV0214A**VALVEX	RecStatus: Active	LP HTR TRN A INLET ISOL VLV	VALVEX	GATE	☐	HC		Minor seat leakage not critical; valve must operate to isolate offset rupture heater tube leak for turbine	☐	1JCDNUV0214A** VALVOP
CD	1MCDNE04C**HTEXCH	RecStatus: Active	LOW PRESSURE FEEDWATER HEATER	HTEXCH	HEATER/SUPE	☐	O	1MCDNE01A**HTE	Potential load reduction; reduce load to protect turbine, single train only.	☐	
CD	1JCDNHS0045**CKTBRK	RecStatus: Active	SWITCH HAND VACUUM BREAKER	CKTBRK	SWITCH	☐	HS	1JCDNHS0214**CI	Required to manually break vacuum in emergency for turbine safety.	☐	
CD	1JCDNPSV0222**VALVEX	RecStatus: Active	LP HEATER TRAIN C THERMAL RELIEF	VALVEX	NOZZLE	☐	HC	1JCDNPSV0220**	Equipment protection required by code. Could drift. If gagged closed can't isolate heater train. (10 year	☐	
CD	1JCDNFY0028C**ISODEV	RecStatus: Active	ISOLATOR OUTPUT CONDENSATE PUMP C	ISODEV	VOLTAGE	☐	HO		CD Pump interlock -- protects CD Pump from low flow condition (C). A low failure trips its CD Pumps (O).	☐	1JCDNFT0028**IX MITR
CD	1JCDNHCV0003**VALVEX	RecStatus: Active	CONDENSATE PUMP A HOTWELLSIDE ISOL VLV	VALVEX	BUTTERFLY	☐	HC	1JCDNHV0001**V	Allows condensate pump isolation maintenance. Valve stroked during operation.	☐	
CD	1JCDNHCV0004**VALVEX	RecStatus: Active	CNDS PP C SUCT ISOL VLV	VALVEX	BUTTERFLY	☐	HC	1JCDNHV0001**V	Allows condensate pump isolation maintenance. Valve stroked during operation.	☐	
CD	1JCDNHCV0155**VALVEX	RecStatus: Active	CONDENSER HOTWELLS 2 MKUP	VALVEX	BUTTERFLY	☐	HS	1JCDNHCV0154**	Safety role -- manual operation (backup to automatic valves) for makeup water. Valve stroked during	☐	
CD	1MCDNE03A**HTEXCH	RecStatus: Active	LOW PRESSURE FEEDWATER HEATER	HTEXCH	HEATER/SUPE	☐	O	1MCDNE01A**HTE	Potential load reduction; reduce load to protect turbine, single train only.	☐	
CD	1JCDNHS0013**CKTBRK	RecStatus: Active	SWITCH HAND CONDENSATE PUMP	CKTBRK	SWITCH	☐	HC	1JCDNHS0011**CI	All pumps normally in service. Although could manually start pump locally if needed in startup, there would be	☐	
CD	1JCDNUV0215A**VALVEX	RecStatus: Active	LP HTR TRN B ISOL VLV	VALVEX	GATE	☐	HC		Minor seat leakage not critical; valve must operate to isolate offset rupture heater tube leak for turbine	☐	1JCDNUV0215A** VALVOP
CD	1JCDNHS0215**CKTBRK	RecStatus: Active	SWITCH HAND LOW PRESSURE HEATER	CKTBRK	SWITCH	☐	HC	1JCDNHS0214**CI	Allows manual fast isolation of a heater due to tube leak flooding. Backed by automatic operation but at	☐	
CD	1JCDNHS0216**CKTBRK	RecStatus: Active	SWITCH HAND LOW PRESSURE HEATER	CKTBRK	SWITCH	☐	H	1JCDNHS0214**	Allows manual fast isolation of a heater due to tube leak flooding. Backed by automatic operation but at	☐	
CD	1MCDNE05C**HTEXCH	RecStatus: Active	CONDENSER HIGH PRESSURE SECTION	HTEXCH	CONDENSER	☐	S	1MCDNE05A**HT	Avoid unit trip (Mrul[illegible]) and generation losses.	☐	

Master Model EQID Copier:
Primary/Assoc Kernel EQID Copier:
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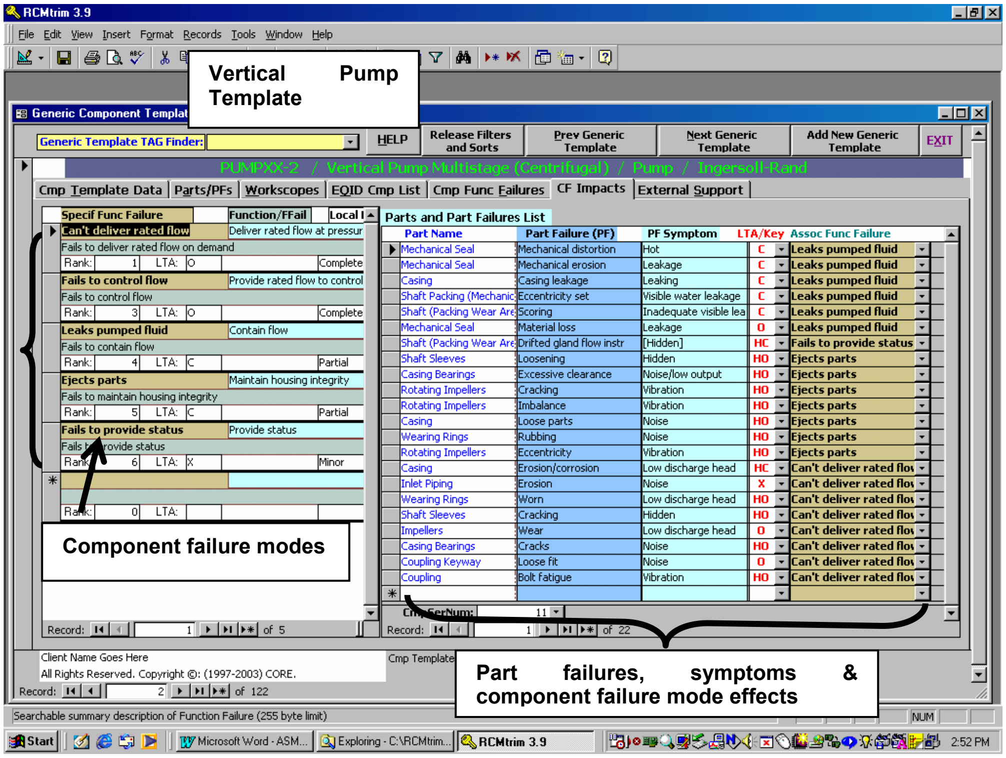
Record: 170 of 218
Enter LTA code such as: H, S, O or C. Identifies "Key" and "NonKey" from 060101 since

Sub-classification SOC categories depend on failure consequences. Discussing failure consequences in cross-discipline groups helps develop equipment risk profiles. Discussions capture risks and strategies that improve facility operations and maintenance understanding. Analysis participants reveal and gain fundamental operating risk awareness. Individuals with years of common operating experience still have different failure consequence insights and risk perceptions.

Plant owners -- engineers, workers, and operators should concur on risk exposure assessments. Theoretical operating risks are frozen by plant construction, providing an optimum design baseline. Architect-Engineer (AE) design descriptions document system functions that make design failures evident and easy to reconstruct. AE design also reveals intended installed-equipment functionality. Hidden maintenance costs from unfocused tasks compound over facility life. (Hidden maintenance costs are embedded in program assumptions.) Making RCM pay its way requires *realizing* improved operations. Keeping operational objectives at the forefront assures projects are completed on-time, with immediate payback.

Figure 3: Generic Template Part Failure Classification by Component Failure Modes



Vertical Pump Template

Generic Template TAG Finder:

PUMPXX-2 / Vertical Pump Multistage (Centrifugal) / Pump / Ingersoll-Rand

Specif Func Failure — Function/FFail — Local I

Can't deliver rated flow — Deliver rated flow at pressur
Fails to deliver rated flow on demand
Rank: 1 LTA: O Complete

Fails to control flow — Provide rated flow to control
Fails to control flow
Rank: 3 LTA: O Complete

Leaks pumped fluid — Contain flow
Fails to contain flow
Rank: 4 LTA: C Partial

Ejects parts — Maintain housing integrity
Fails to maintain housing integrity
Rank: 5 LTA: C Partial

Fails to provide status — Provide status
Fails to provide status
Rank: 6 LTA: X Minor

Rank: 0 LTA:

Record: 1 of 5

Component failure modes

Parts and Part Failures List

Part Name	Part Failure (PF)	PF Symptom	LTA/Key	Assoc Func Failure
Mechanical Seal	Mechanical distortion	Hot	C	Leaks pumped fluid
Mechanical Seal	Mechanical erosion	Leakage	C	Leaks pumped fluid
Casing	Casing leakage	Leaking	C	Leaks pumped fluid
Shaft Packing (Mechanic	Eccentricity set	Visible water leakage	C	Leaks pumped fluid
Shaft (Packing Wear Are	Scoring	Inadequate visible lea	C	Leaks pumped fluid
Mechanical Seal	Material loss	Leakage	O	Leaks pumped fluid
Shaft (Packing Wear Are	Drifted gland flow instr	[Hidden]	HC	Fails to provide status
Shaft Sleeves	Loosening	Hidden	HO	Ejects parts
Casing Bearings	Excessive clearance	Noise/low output	HO	Ejects parts
Rotating Impellers	Cracking	Vibration	HO	Ejects parts
Rotating Impellers	Imbalance	Vibration	HO	Ejects parts
Casing	Loose parts	Noise	HO	Ejects parts
Wearing Rings	Rubbing	Noise	HO	Ejects parts
Rotating Impellers	Eccentricity	Vibration	HO	Ejects parts
Casing	Erosion/corrosion	Low discharge head	HC	Can't deliver rated flo
Inlet Piping	Erosion	Noise	X	Can't deliver rated flo
Wearing Rings	Worn	Low discharge head	HO	Can't deliver rated flo
Shaft Sleeves	Cracking	Hidden	HO	Can't deliver rated flo
Impellers	Wear	Low discharge head	O	Can't deliver rated flo
Casing Bearings	Cracks	Noise	HO	Can't deliver rated flo
Coupling Keyway	Loose fit	Noise	O	Can't deliver rated flo
Coupling	Bolt fatigue	Vibration	HO	Can't deliver rated flo

CmpSerNum: 11
Record: 1 of 22

Part failures, symptoms & component failure mode effects

Client Name Goes Here
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Cmp Template
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Searchable summary description of Function Failure (255 byte limit)

Thumbrules emerge as the process of design guideline and other paradigms rediscovery unfolds. Manual valves, for example, usually support maintenance. Manual valve failure consequences are typically cost-based. Manual valves for maintenance can be treated as "run-to-failure." (Operationally critical valve applications typically have automatic operators.) This rule numerically reduces coded components for analysis review by over 25%. (Or, for a typical list of 40,000 installed components, analysis declines by 10,000 items!)

All rules have exceptions. One manual valve, for example, may be necessary under special operating conditions to realign an equipment train. That valve could be critical! RCM thumbrules improve with each new system analysis, case-by-case, superseding existing ad hoc PM task selection. Unique design insights are revealed, with more reliability benefit.

(2) SELECTING PM TASKS

Components determine the next analysis level – identifying dominant failure modes. Vendor O&M manuals document dominant failure modes implicitly with recommended PM tasks. Venders must infer failures that could become dominant in their equipment. They can't actually learn a facility's operations. Vender-recommended PM applied indiscriminately produces lengthy, enumerative task lists – many of which have little direct applicability. At complex plants, common equipment presents low risk based on design redundancy, low utilization, and absence of dominant failures over economic life. Eliminating low risk equipment from scheduled maintenance consideration early in strategy development, before detailed failure modes and effects analysis (FMEA), streamlines analysis.

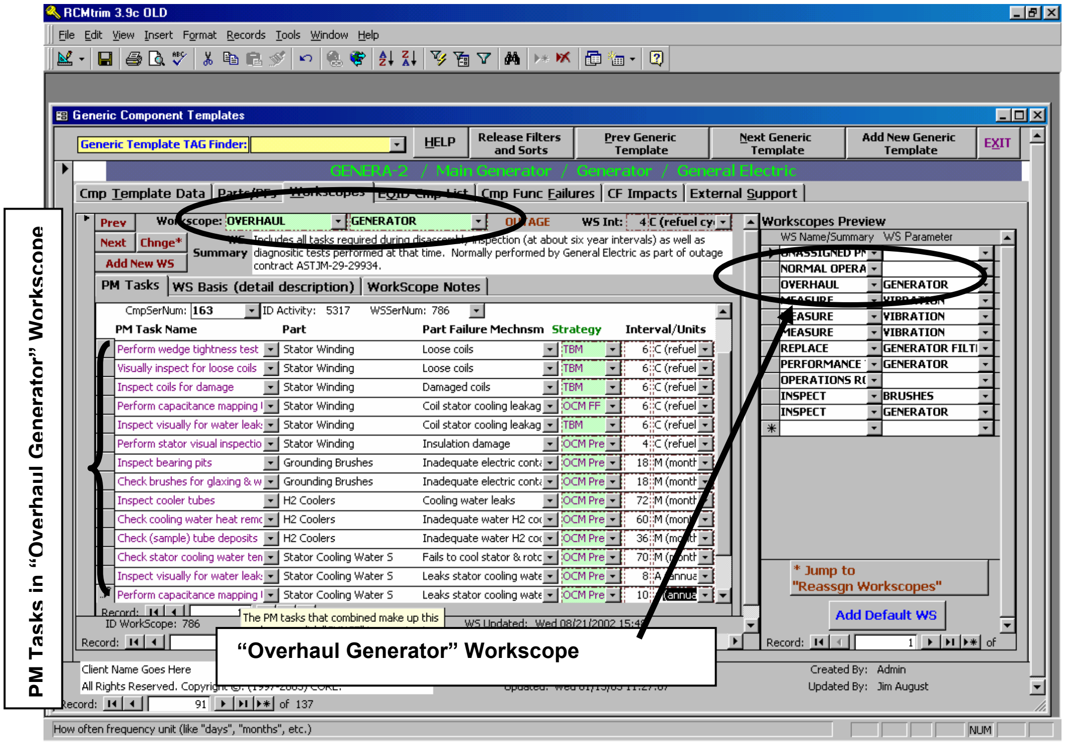
Classifying part failures by failure modes speeds failure analysis and simplifies risk assessment. For example, a pump may "fail to start," "fail to deliver flow at pressure," or "leak." Several part failures can lead to the same pump failure mode. Consider "fails to deliver flow at pressure." For a centrifugal pump, this mode could arise from worn seals, impeller erosion, volute erosion, a single-phased motor or other causes. A loose bearing guide, however, won't cause "fails to deliver flow at pressure." Many part failures are inconsequential. Consolidating part failures into component failure modes simplifies system effects analysis performed later. FMEA identifies failure modes that can cause system failures. This is a direct FMEA benefit. (Figure 3)

(3) WORKSCOPES: PACKAGING RESULTS TO IMPLEMENT

A workscope assembles PM tasks for concurrent performance. Organizing tasks into workscopes eases implementation. Tasks consolidated into workscopes for work orders present fewer demands on the station's work-order system. (Figure 4) Many plants assign senior personnel familiar with work practices to assign or "block" PM tasks into organized, implementable workscope packages.

In software, grouping of tasks into workscopes must be an easy process. Subroutines must allow efficient blocking and re-blocking supporting workscope development. For an auto, this would be like shifting "Check brake pads" from the "12,000 mile" to "24,000 mile" check. As craft worker and workgroup participation increases, the need to reorganize work flexibly becomes compelling. Point and click techniques to reassign workscope tasks were developed in RCM*trim*™ automating workscope editing.

Figure 4: PM Tasks Grouping into Workscopes



Workscope: OVERHAUL GENERATOR OUTAGE WS Int: 4 C (refuel cy

WS Summary: Includes all tasks required during disassembly inspection (at about six year intervals) as well as diagnositic tests performed at that time. Normally performed by General Electric as part of outage contract ASTJM-29-29934.

CmpSerNum: 163 ID Activity: 5317 WSSerNum: 786

PM Task Name	Part	Part Failure Mechnsm	Strategy	Interval/Units
Perform wedge tightness test	Stator Winding	Loose coils	TBM	6 C (refuel
Visually inspect for loose coils	Stator Winding	Loose coils	TBM	6 C (refuel
Inspect coils for damage	Stator Winding	Damaged coils	TBM	6 C (refuel
Perform capacitance mapping (	Stator Winding	Coil stator cooling leakag	OCM FF	6 C (refuel
Inspect visually for water leak	Stator Winding	Coil stator cooling leakag	TBM	6 C (refuel
Perform stator visual inspectio	Stator Winding	Insulation damage	OCM Pre	4 C (refuel
Inspect bearing pits	Grounding Brushes	Inadequate electric conta	OCM Pre	18 M (month
Check brushes for glaxing & w	Grounding Brushes	Inadequate electric conta	OCM Pre	18 M (month
Inspect cooler tubes	H2 Coolers	Cooling water leaks	OCM Pre	72 M (month
Check cooling water heat remo	H2 Coolers	Inadequate water H2 coo	OCM Pre	60 M (month
Check (sample) tube deposits	H2 Coolers	Inadequate water H2 coo	OCM Pre	36 M (month
Check stator cooling water ten	Stator Cooling Water S	Fails to cool stator & roto	OCM Pre	70 M (month
Inspect visually for water leak	Stator Cooling Water S	Leaks stator cooling wate	OCM Pre	8 A (annua
Perform capacitance mapping (	Stator Cooling Water S	Leaks stator cooling wate	OCM Pre	10 A (annua

The PM tasks that combined make up this

ID WorkScope: 786 WS Updated: Wed 08/21/2002 15:4

WS Name/Summary	WS Parameter
UNASSIGNED PM	
NORMAL OPERA	
OVERHAUL	GENERATOR
MEASURE	VIBRATION
MEASURE	VIBRATION
MEASURE	VIBRATION
REPLACE	GENERATOR FILT
PERFORMANCE	GENERATOR
OPERATIONS R	
INSPECT	BRUSHES
INSPECT	GENERATOR

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Updated By: Jim August
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How often frequency unit (like "days", "months", etc.)

FAILURE MODE ASSESSMENT

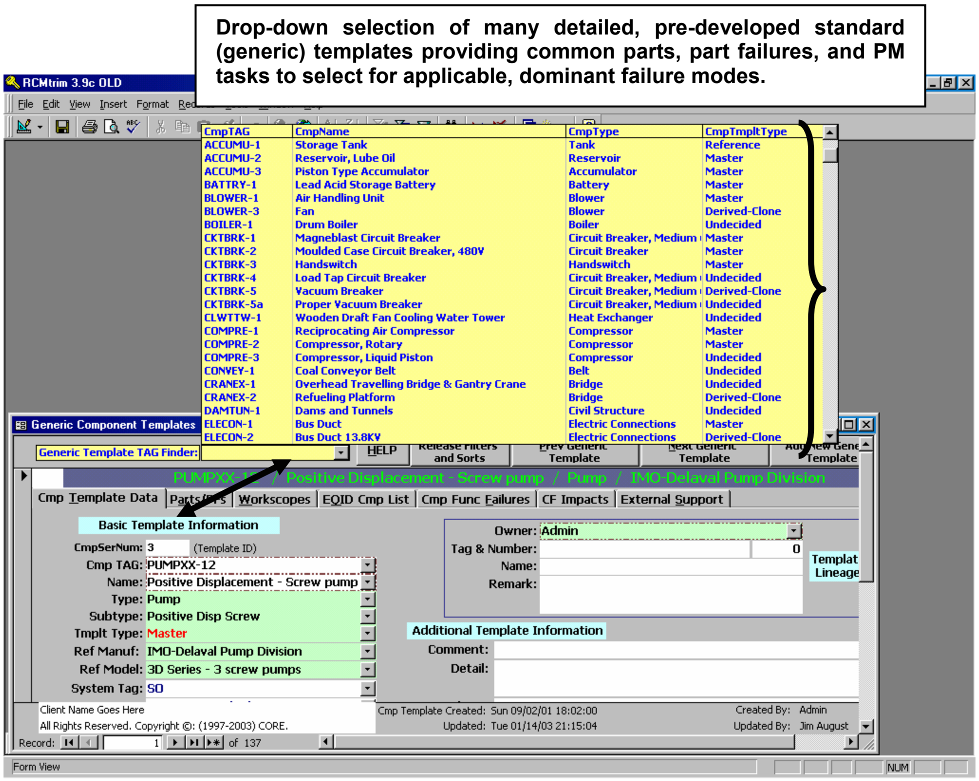
Equipment degrades over time by aging as well as random deterioration. Perfect aging is predictable. Random deterioration requires a probabilistic assessment. Real-world behavior falls between aging and random extremes. Developing effective PM requires identifying tasks that address dominant equipment failure modes. The reliability engineer must identify component failure modes, parts causing failure modes, part failure mechanism's aging behavior *and only then* -- applicable tasks. (Figure 4) Applicable tasks must cost-effectively address failure. Failures, to be suitable for preventive maintenance, must be reasonably likely, addressable by maintenance, and exhibit symptoms discernible with commercial technology. Theoretical failure modes simply confuse PM performers. In fact, PM addressing failures that don't occur in practice, PM tasks that are ineffective, or rely on commercially unavailable technology have no practical utility in industrial maintenance plans.

FMEA identifies failure consequences. Failure consequences determine system effects. System failure effects are more easily discerned displaying component failure modes with the system's functional requirements. Displays that present component failure modes with system effects assist selecting critical failure modes. (Figure 6)

PM tasks must address engineering failure mechanisms – e.g., part failure causes. These are failure processes like stress corrosion cracking, fatigue, or material erosion. Preventing crack failures requires reworking cracks when a crack failure mechanism like fatigue is present, as an example. Eliminating a failure mode is usually beyond the scope of maintenance. Programs need not identify root causes (although that may help), nor need be perfect. Often failure modes can be managed without resolving root cause. Eliminating equipment failure modes through redesign with root cause analysis is ideal, but cost prohibitive for most non-risky cost or operationally based failures. Only very expensive failures, or those based upon safety, warrant redesign.

Failure mode definition and development takes time. Studying many equipment types and failures over years of plant support, the authors' conclude that most industrial failure mechanisms are well-known. The challenge is recognizing and selecting *applicable* failure mechanism PM tasks quickly on installed plant equipment! Standard templates (Figure 5) help, addressing common components and their parts, based upon known failure mechanisms. Selecting failure modes, critical parts, failure causes, and PM tasks in "pick list" format based upon underlying engineering fundamentals simplifies analysis. Automating rote analysis makes large plant RCM-based PM development not only feasible, but also rewarding!

Figure 5: Standard Templates (Selection Drop-Down)



Drop-down selection of many detailed, pre-developed standard (generic) templates providing common parts, part failures, and PM tasks to select for applicable, dominant failure modes.

CmpTAG	CmpName	CmpType	CmpTmpltType
ACCUMU-1	Storage Tank	Tank	Reference
ACCUMU-2	Reservoir, Lube Oil	Reservoir	Master
ACCUMU-3	Piston Type Accumulator	Accumulator	Master
BATTRY-1	Lead Acid Storage Battery	Battery	Master
BLOWER-1	Air Handling Unit	Blower	Master
BLOWER-3	Fan	Blower	Derived-Clone
BOILER-1	Drum Boiler	Boiler	Undecided
CKTBRK-1	Magneblast Circuit Breaker	Circuit Breaker, Medium	Master
CKTBRK-2	Moulded Case Circuit Breaker, 480V	Circuit Breaker	Master
CKTBRK-3	Handswitch	Handswitch	Master
CKTBRK-4	Load Tap Circuit Breaker	Circuit Breaker, Medium	Undecided
CKTBRK-5	Vacuum Breaker	Circuit Breaker, Medium	Derived-Clone
CKTBRK-5a	Proper Vacuum Breaker	Circuit Breaker, Medium	Undecided
CLWTTW-1	Wooden Draft Fan Cooling Water Tower	Heat Exchanger	Undecided
COMPRE-1	Reciprocating Air Compressor	Compressor	Master
COMPRE-2	Compressor, Rotary	Compressor	Master
COMPRE-3	Compressor, Liquid Piston	Compressor	Undecided
CONVEY-1	Coal Conveyor Belt	Belt	Undecided
CRANEX-1	Overhead Travelling Bridge & Gantry Crane	Bridge	Undecided
CRANEX-2	Refueling Platform	Bridge	Derived-Clone
DAMTUN-1	Dams and Tunnels	Civil Structure	Undecided
ELECON-1	Bus Duct	Electric Connections	Master
ELECON-2	Bus Duct 13.8KV	Electric Connections	Derived-Clone

PUMPXX-12 / Positive Displacement - Screw pump / Pump / IMO-Delaval Pump Division

Basic Template Information

CmpSerNum: 3 (Template ID)
Cmp TAG: PUMPXX-12
Name: Positive Displacement - Screw pump
Type: Pump
Subtype: Positive Disp Screw
Tmplt Type: Master
Ref Manuf: IMO-Delaval Pump Division
Ref Model: 3D Series - 3 screw pumps
System Tag: SO

Owner: Admin
Tag & Number: 0
Name:
Remark:

Additional Template Information

Comment:
Detail:

Client Name Goes Here
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Cmp Template Created: Sun 09/02/01 18:02:00
Updated: Tue 01/14/03 21:15:04
Created By: Admin
Updated By: Jim August

Record: 1 of 137

DIAGNOSTIC SELECTION

Once a failure mechanism is known, selecting a PM technology is easy – if one exists. Wall thinning warrants ultrasonic NDE wall thickness measurement. Pitting can be identified with eddy current testing. Standardized part-focused PM tasks for common dominant failures should be provided. Efficient template development identifies dominant failure modes. Providing generic template models simplifies applied template development, reducing it to choosing parts, failures, and preventive tasks from a pick-list of generic template options. (Figure 6)

Failure symptoms determine on-line condition assessment options. Instrumentation must identify incipient failure. Selecting instrument diagnostics requires an equipment expert and an instrumentation specialist. Suppliers provide fault-identifying instruments, ideally discriminated from "status only" ones. (The latter are run-to-failure.) Critical fault identifying instruments reveal hidden failures, and their risk exposure classification corresponds to the risk associated with the failure they reveal. As failure modes, causes, and operating symptom understanding grows, designers apply more instrumentation and inspection access points to equipment design. Industries that have grown RCM-compliant involve designers early to resolve equipment problems. Design improvements that result simplify maintenance and diagnostics.

In contrast, Generation RCM is still relatively new. Design features supporting RCM-based maintenance are new. Techniques like generator partial discharge monitoring may be added as retrofits to existing generators based on value, but life cycle costs of these features are lowest when they are incorporated with new equipment.

APPLIED TEMPLATE

The applied template completes failure management transition from theory to practice. An applied template represents real installed plant equipment. Streamlining template application reduces to (1) defining installed system functions, (2) identifying equipment providing functionality, and (3) applying service and environmental factors on standard (generic) templates by selecting dominant failures and associated PM tasks. The result is an applied template. Applied templates are based upon equipment operating cycles, environment, and other contextual factors. Applied templates provide traceability, enable re-analysis, and provide the foundation for template-based RCM. Applied templates capture actual installed equipment dominant failure mechanisms from standard part-failure-task lists, automating PM task selection.

An applied template complements its generic counterpart. The generic template (similar to manufacturer's O&M manual) provides *potential* part failures with representative PM tasks. This prompts the developer to consider failure effects. Generic template parts, failures and PM tasks can then be selected based upon failure mechanisms observed, expected and foreseen in light of contextual risk. (Figure 6) Risk is probability times consequence. Risk determines the value represented by managing any specific failure consequences. For example, a single jet engine plane presents a different risk profile than a multiple engine one with the identical engine installed twice. PM tasks are likewise selected and performed based upon risk. Engine loss in the first context is critical; the second is not.

RESULTS

Engineers using the RCM*trim*™ streamlined approach developed a PM program applying templates for a three unit nuclear generating plant on 22 "risk significant" systems, including condensate, feedwater, extraction steam, main steam, turbine and turbine hydraulic control. Objectives included developing a reliability-based process, identifying single failure risks (recommending redesign where appropriate) and simplifying PM basis maintenance, while improving plant reliability. (The PM "basis" is the documented justification for performing PM.)

Station personnel performed work with contract support. System size varied numerically from feedwater (several hundred equipment tags) to 480V non-Q electrical (several thousand tags). The process simplified traditional RCM using a risk exposure profile, generic, and applied templates. P&ID drawing markups expedited critical equipment selection. (Figure 7)

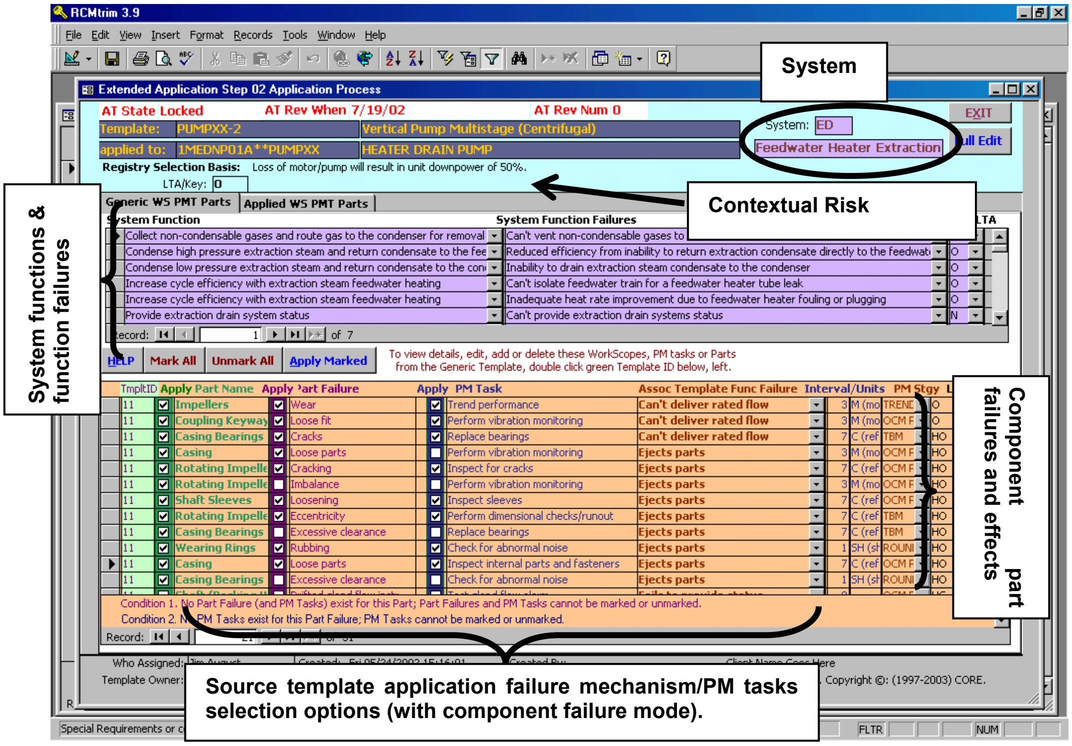
During work, engineers redefined original system boundary interfaces. Circuit breakers were reanalyzed with driven loads. Risk-based system boundaries simplified AE craft-based ones (in the original CMMS). On average, 60% of reviewed equipment became non-critical.

Risk definition evolved during the project. These and other process changes demanded database flexibility. Compared to earlier MS Excel spreadsheet-based RCM projects, requirements reanalysis work went easily. Software database availability on a local area network improved report distribution and review eliminating hardcopy transmittal need.

Project reliability engineers found learning and using a relational database challenging. (MS Access and Excel provided database platforms.) Familiarity with Excel prompted spreadsheet format development early in the project. Two reliability technicians assisted four engineers with data entry, template development and reports. The reliability technicians also coordinated support for other workgroups, especially system teams and work planners. Technicians quickly became highly knowledgeable with software risk assessment and template application principles. Intense immersion in the processes and software supporting all other participants helped develop their expertise. With their help, assigned engineers, the reliability team, and system teams developed preliminary system risk exposure profiles. System teams approved each final completed risk exposure profile. Reliability engineers then developed any needed generic templates. Once developed, they applied the generic templates creating applied templates by selecting the applicable failure modes and customizing task intervals based on failure experience.

Spreadsheets were popular and problematic. Popularity stemmed from flexibility. Exporting source records, developing data, and re-importing results to the main database could be burdensome. Excel spreadsheets could manually sort data but required additional preparation time. Users could manipulate spreadsheet formats, freelancing until data had to be (re) imported to the database. Then records were either reconciled or lost. Manual data effort grew over time with external data developer work in Excel and Access. Inefficient work processes froze. The practical solution was reducing the need for external work by improving database utility. A general strategy evolved to perform as much data entry as possible directly in the database. Eventually an external work moratorium was imposed.

Figure 6: Applied Template Part-Part Failure-PM Task Selection Boxes



AT State Locked AT Rev When 7/19/02 AT Rev Num 0

Template: PUMPXX-2 Vertical Pump Multistage (Centrifugal)

applied to: 1MEDNP01A**PUMPXX HEATER DRAIN PUMP

System: ED Feedwater Heater Extraction

Registry Selection Basis: Loss of motor/pump will result in unit downpower of 50%.

LTA/Key: 0

System Function	System Function Failures	LTA
Collect non-condensable gases and route gas to the condenser for removal	Can't vent non-condensable gases to	
Condense high pressure extraction steam and return condensate to the fee	Reduced efficiency from inability to return extraction condensate directly to the feedwat	O
Condense low pressure extraction steam and return condensate to the con	Inability to drain extraction steam condensate to the condenser	O
Increase cycle efficiency with extraction steam feedwater heating	Can't isolate feedwater train for a feedwater heater tube leak	O
Increase cycle efficiency with extraction steam feedwater heating	Inadequate heat rate improvement due to feedwater heater fouling or plugging	O
Provide extraction drain system status	Can't provide extraction drain systems status	N

Record: 1 of 7

To view details, edit, add or delete these WorkScopes, PM tasks or Parts from the Generic Template, double click green Template ID below, left.

TmpltID	Apply	Part Name	Apply	Part Failure	Apply	PM Task	Assoc Template Func Failure	Interval/Units		PM Stgy	L
11	☑	Impellers	☑	Wear	☑	Trend performance	Can't deliver rated flow	3	M (mo	TREND	O
11	☑	Coupling Keyway	☑	Loose fit	☑	Perform vibration monitoring	Can't deliver rated flow	3	M (mo	OCM F	O
11	☑	Casing Bearings	☑	Cracks	☑	Replace bearings	Can't deliver rated flow	7	C (ref	TBM	HO
11	☑	Casing	☑	Loose parts	☐	Perform vibration monitoring	Ejects parts	3	M (mo	OCM F	HO
11	☑	Rotating Impelle	☑	Cracking	☑	Inspect for cracks	Ejects parts	7	C (ref	OCM F	HO
11	☑	Rotating Impelle	☐	Imbalance	☐	Perform vibration monitoring	Ejects parts	3	M (mo	OCM F	HO
11	☑	Shaft Sleeves	☑	Loosening	☑	Inspect sleeves	Ejects parts	7	C (ref	OCM F	HO
11	☑	Rotating Impelle	☑	Eccentricity	☑	Perform dimensional checks/runout	Ejects parts	7	C (ref	TBM	HO
11	☑	Casing Bearings	☐	Excessive clearance	☐	Replace bearings	Ejects parts	7	C (ref	TBM	HO
11	☑	Wearing Rings	☑	Rubbing	☑	Check for abnormal noise	Ejects parts	1	SH (sh	ROUNI	HO
11	☑	Casing	☑	Loose parts	☑	Inspect internal parts and fasteners	Ejects parts	7	C (ref	OCM F	HO
11	☑	Casing Bearings	☐	Excessive clearance	☐	Check for abnormal noise	Ejects parts	1	SH (sh	ROUNI	HO

Condition 1. No Part Failure (and PM Tasks) exist for this Part; Part Failures and PM Tasks cannot be marked or unmarked.

Condition 2. N PM Tasks exist for this Part Failure; PM Tasks cannot be marked or unmarked.

Who Assigned: Jim August

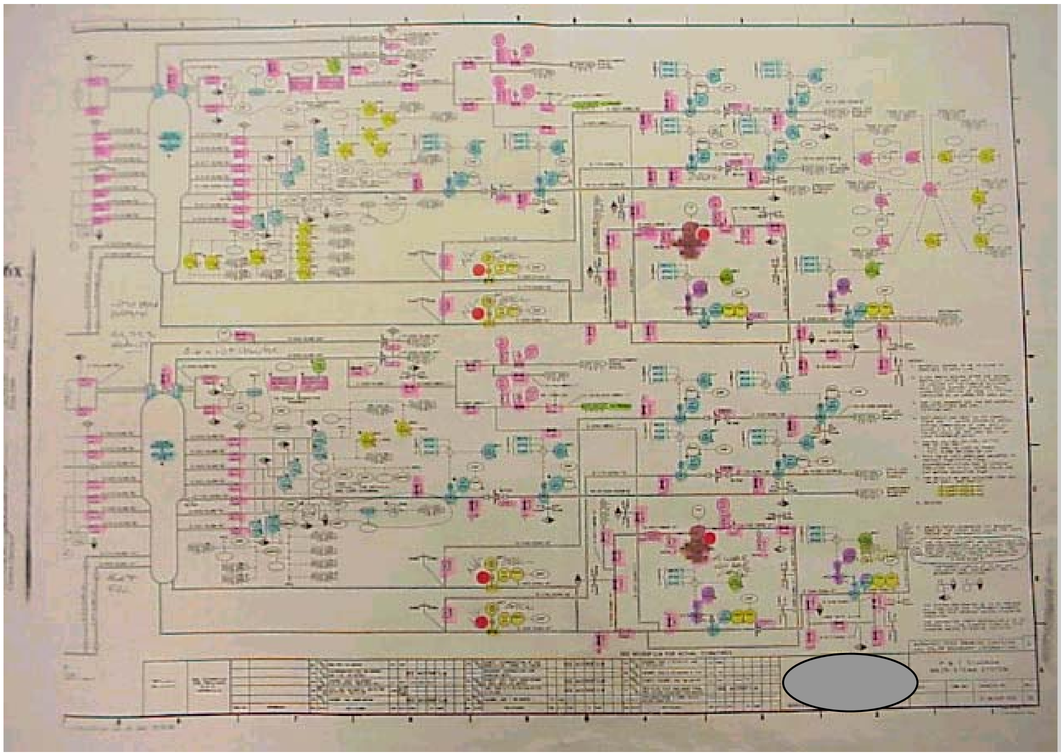
Template Owner:

Copyright ©: (1997-2003) CORE.

Special Requirements or c

PM task selection required equipment research and knowledge. Information was developed by interview, operating logs review, work orders history reviews, operational events, and other performance history reviews. Engineers (1) developed generic templates and (2) applied generic templates creating custom applied templates. Their strategies diverged. Generic template application could be summarized by several styles. At one extreme, a new generic template was created for each new component. The other extreme covered all components with one *very* general generic template. RCM*trim*™ database software accommodated either style. Balancing detailed, customized templates (at the cost of generality) against many specific applications of very general generic templates (with extensive customization at application) was tedious. A custom generic template could be applied with less effort, but had less overall utility. A more generic template required more customization during application. Subroutines

Figure 7: P&ID Drawing System Criticality Analysis by SOC Marked Up



were developed to speed template customization at generic and applied levels. (Figure 8)

Most engineering time was spent performing system analysis. For each system, a lead reliability engineer learned the system. Familiarized with the functions, equipment, flowpaths, and history they developed a draft system risk exposure equipment list. The approved risk exposure list allowed template application. Template application began with a source generic template. A new equipment encounter might require a new generic template to initiate the template application process. When this occurred, one had to be developed. Subroutines extending existing templates to new designs sped new template development. An existing “diaphragm operator” template could be copied and edited to create a “cylinder operator” in lieu of building the cylinder operator template entirely from scratch.

Production required overcoming two limiting factors. First, engineers lacked practical RCM experience. They found it hard to focus on critical equipment applying templates. Like manufacturers, there was the temptation to address all failure possibilities with PM tasks, whether or not analysis indicated a task was required based on dominant failure modes. Second, database utilities to simplify work, support analysis, and speed RCM processes had to be improved. Template dominant failure modes needed consideration in terms of system functions and functional failures selecting tasks to apply. Template application engineers and analysts needed help to select dominant failure mode parts quickly, streamlining template application. Many software displays (as MS Access “forms”) were built and modified, expediting selection results.

Preliminary analysis, the assignment of equipment component risk exposure, required about half of the total effort. Development and tuning applied templates into final equipment scheduled maintenance plans reflected the balance. Template application included system failure review details, which varied depending on system, failure and detail level sought. Process changes, group discussion, comments and rework diminished steadily throughout the project. Several rework stand-down periods incorporated lessons learned, improving the core process while standardizing results.

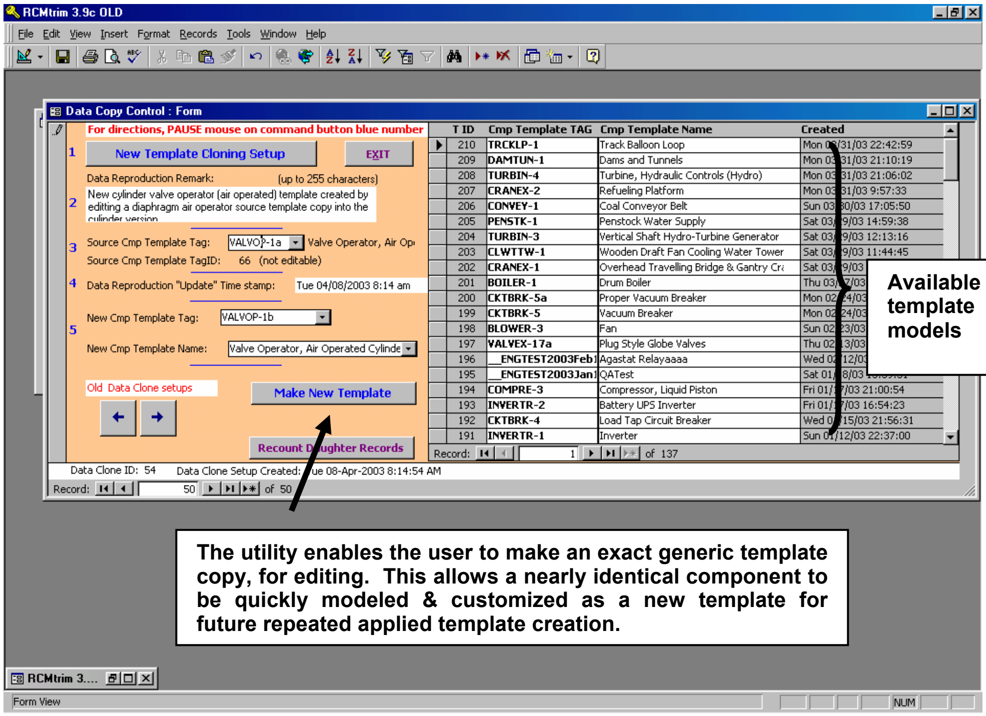
During the course of work, turbine trip challenges fell, reflecting increased awareness. Unit trip experience approached “breaker-to-breaker” perfect performance. Actual measured reliability steadily improved even before final RCM PM task workscopes implementation. A fair question asks, “how could RCM analysis have *caused* plant operations benefit, then?” The answer, we believe, is that it didn’t, *directly*. During the analysis period, however, operating and maintenance staff reliability awareness, methods, strategies, and concepts improved across the board as a result of participating in the project. These new skills in plant daily use yielded the preliminary gains. It’s anticipated that the continued automation of the PM task selection process will further improve plant performance with basis and cost efficiencies.

CONCLUSIONS

RCM is an effective process to develop generating plant PM, improving reliability with limited resources. Maintaining a simple process, avoiding extraneous details, controlling rework and limiting reviews are necessary to achieve immediate RCM benefits. Software like *trim*™ is essential to streamlined RCM application. Streamlined, the RCM process becomes accessible and useful to many more users. Benefits occur in part from general site reliability awareness, in addition to direct PM improvements.

Cost effective RCM is streamlined. Automated processes help achieve streamlined RCM. Station engineers learn RCM through analysis. As they do, user and reviewer productivity and consistency improve. Typical engineers have difficulty manipulating RCM database software. This reflects computer database literacy in an aging workforce. The full spectrum of RCM principles available must be learned through experience and performing analysis. Effective software enables inexperienced RCM analysts and engineers to perform necessary RCM steps, without burdening the process artificially in ways that impede expert use. RCM*trim*™ software familiarity improved with training and repetition during this project. Technicians were effective developing failure statistics, but failure mode definition and interpretation required engineering. The learning period for RCM project performance was intense. Most participants were "forty-ish", and required special training. Those who had prior MS Access™ and network experience before the project -- the technicians -- were confident with the software tools available and became productive users quickly.

Figure 8: Generic Template Copy (Cloning) Subroutine



For directions, PAUSE mouse on command button blue number

1 New Template Cloning Setup

Data Reproduction Remark: (up to 255 characters)

2 New cylinder valve operator (air operated) template created by editting a diaphragm air operator source template copy into the cylinder version

3 Source Cmp Template Tag: VALVOP-1a Valve Operator, Air Op

Source Cmp Template TagID: 66 (not editable)

4 Data Reproduction "Update" Time stamp: Tue 04/08/2003 8:14 am

5 New Cmp Template Tag: VALVOP-1b

New Cmp Template Name: Valve Operator, Air Operated Cylinde

Old Data Clone setups

Data Clone ID: 54 Data Clone Setup Created: ue 08-Apr-2003 8:14:54 AM

Record: 50 of 50

T ID	Cmp Template TAG	Cmp Template Name	Created
210	TRCKLP-1	Track Balloon Loop	Mon 0 /31/03 22:42:59
209	DAMTUN-1	Dams and Tunnels	Mon 03 31/03 21:10:19
208	TURBIN-4	Turbine, Hydraulic Controls (Hydro)	Mon 03 31/03 21:06:02
207	CRANEX-2	Refueling Platform	Mon 03 31/03 9:57:33
206	CONVEY-1	Coal Conveyor Belt	Sun 03 30/03 17:05:50
205	PENSTK-1	Penstock Water Supply	Sat 03/ 9/03 14:59:38
204	TURBIN-3	Vertical Shaft Hydro-Turbine Generator	Sat 03/ 9/03 12:13:16
203	CLWTTW-1	Wooden Draft Fan Cooling Water Tower	Sat 03/ 9/03 11:44:45
202	CRANEX-1	Overhead Travelling Bridge & Gantry Cra	Sat 03/ 9/03
201	BOILER-1	Drum Boiler	Thu 03/ 7/03
200	CKTBRK-5a	Proper Vacuum Breaker	Mon 02 24/03
199	CKTBRK-5	Vacuum Breaker	Mon 02 24/03
198	BLOWER-3	Fan	Sun 02 23/03
197	VALVEX-17a	Plug Style Globe Valves	Thu 02 13/03
196	__ENGTEST2003Feb1	Agastat Relayaaaa	Wed 02 12/03
195	__ENGTEST2003Jan1	QATest	Sat 01/ 8/03
194	COMPRE-3	Compressor, Liquid Piston	Fri 01/ 7/03 21:00:54
193	INVERTR-2	Battery UPS Inverter	Fri 01/ 7/03 16:54:23
192	CKTBRK-4	Load Tap Circuit Breaker	Wed 0 /15/03 21:56:31
191	INVERTR-1	Inverter	Sun 01/12/03 22:37:00

Record: 1 of 137

Available template models

The utility enables the user to make an exact generic template copy, for editing. This allows a nearly identical component to be quickly modeled & customized as a new template for future repeated applied template creation.

Work methods ideally freeze before a project starts. If methods change, rework will be needed. In this case, learning justified rework, was a project objective, and process evolution was assumed. Growing pains to keep software and processes matched were evident as work ebbed and flowed.

Engineers and analysts became effective discriminating failure modes and consequences. They debated failure classifications, occasionally with intensity. Capturing operational details in the basis lead to widespread recognition of *hidden failures* -- a significant project reliability benefit. Reliability discussion intensification over the project reflected reliability awareness and skill improvement.

Upon completing analysis, electronically uploading analytical results to the CMMS had been a goal. Organizational barriers precluded this during the project. Different workers, process ownership and technology challenges led to impasse. These still await resolution. Importing revised PM workscopes into the CMMS was demonstrated, with potential for closing the loop (in the future) providing the living maintenance program concept.

Plant design awareness is cultural. Few individuals know designs completely. Organizations share collective design awareness. Reliability awareness at the individual level must improve to successfully improve plant reliability. Specific tools – like RCM, provide the means to achieve that end.

NOMENCLATURE

Reliability Centered Maintenance (RCM), Scheduled Maintenance, Preventive Maintenance (PM), Corrective Maintenance, Critical (important, essential, significant, key), Run-to-failure, Condition-directed, On-condition, Coded (tagged), Work Order, Workscopes, Basis, Equipment Partition, Nuclear Steam Supply Systems (NSSS), Functions, Failure, Failure modes and effects analysis (FMEA), Failure mechanisms, Failure Mode, Dominant Failure Mode, Operational (Production), Root Cause, Architect Engineer (AE), Applicable (task), Effective (task), Equipment (Components), Safety Operational Cost (SOC), Task (PM task), Computerized Maintenance Management System (CMMS), Blocking (Workscopes), Hidden maintenance, Template, Applied Template, Database, View (Form).

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James Clerk Maxwell, the great Nineteenth century physicist, modestly said that he achieved great things because he stood on the shoulders of giants – alluding to Isaac Newton, Leibnitz and other early mathematicians & physicists. Previous power plant RCM program & software development efforts provided this one's foundation. Names are hard to recite, but those lessons influenced this effort. We would like to acknowledge previous efforts at Cooper NGS (NPPD), Pawnee & Arapahoe Generating Stations (Xcel Energy), Colstrip SES (PPL Montana), Carmen-Smith HGS (EWEB), and Susquehanna NGS (PPL) for their generous efforts supporting the development of applied RCM technology.

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