Risk-informed Equipment Reliability (ER) Risk Ranking

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CORE

Overview

Achieving equipment reliability (ER) requires identifying and managing risk. Risk-based processes that identify, select and control high-risk equipment failures bring focus to high-risk equipment maintenance. *Cost reductions and improved safety margins can result.*

Nuclear Industry ER Risk Classification

- Background
  - Good performance
  - NRC focus: risk informed
  - Though competitive, has high labor cost
- Nuclear
  - Equipment focus
  - AP-913 critical ER categories

Equipment Reliability Steps

- Select equipment
- Apply ER process
- Standardize methods
- Format analytical results for use
- Systematize methods

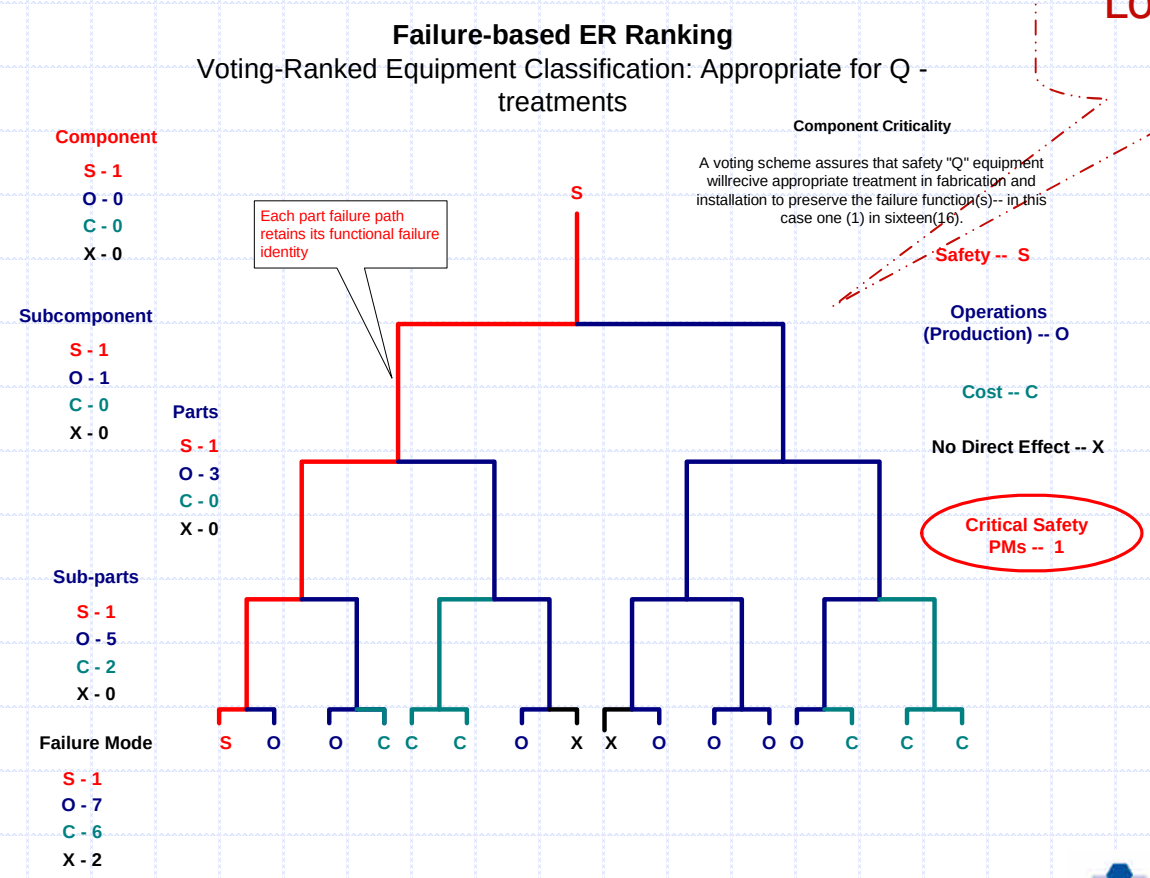
Risk Classification

- Based upon direct failure (SPV's)
- AP-913: eight categories
- Approximately three critical classifications
  - Safety (S)
  - Operations (O)
  - Cost (C)
- Noncritical (X): no foreseeable direct failure consequence

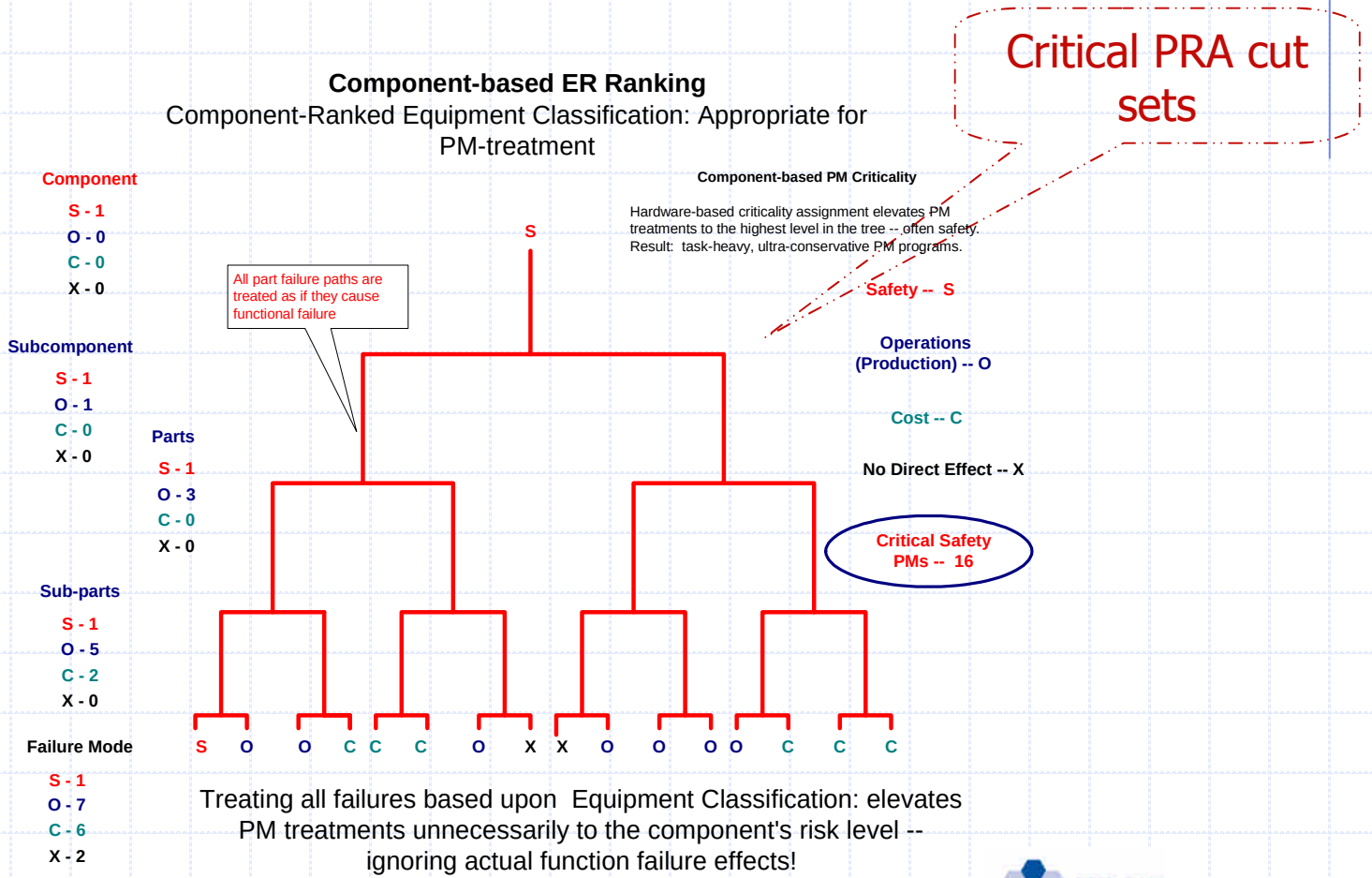
Failure context

- Loss of functions
- Systems
- Direct failure consequences

Failure-based ER focus



Equipment-based ER focus



Contrasts

(1) Upward vs. downward

(2) Event vs. hardware

(3) Function vs. form

(4) Internal viewpoint vs. external

Classification Method Comparison

Equipment Based

(1) Hardware focused
- Equipment classification drives program

(2) Failure chain equivalence
- Equal
- Template source

(3) Scheduled tasks – PM
- Weighted equal
- Redesign (rarely)

(4) General
- Expertise less important – common templates
- More work volume

Failure-based

(1) Function-loss risk focused

(2) Consequence based (e.g., risk-based)
- Dominant/high-risk failures stand out

(3) Discriminates and prioritizes failures by consequence
- Focused on scheduled maintenance results

(4) Contextual (Takes more technical expertise)
- Focuses work
- Assesses context

Risk-Based ER Focus Benefits

(1) Develops risk/reliability understanding

(2) Provides more exact work basis

(3) Simple checks & tests increase

(4) Total PM workhours drop

- Eliminate non-critical failure PMs
- Extend critical PM to justifiable, appropriate intervals
- Convert time-based to condition-directed tasks

Reduce costs, while improving reliability

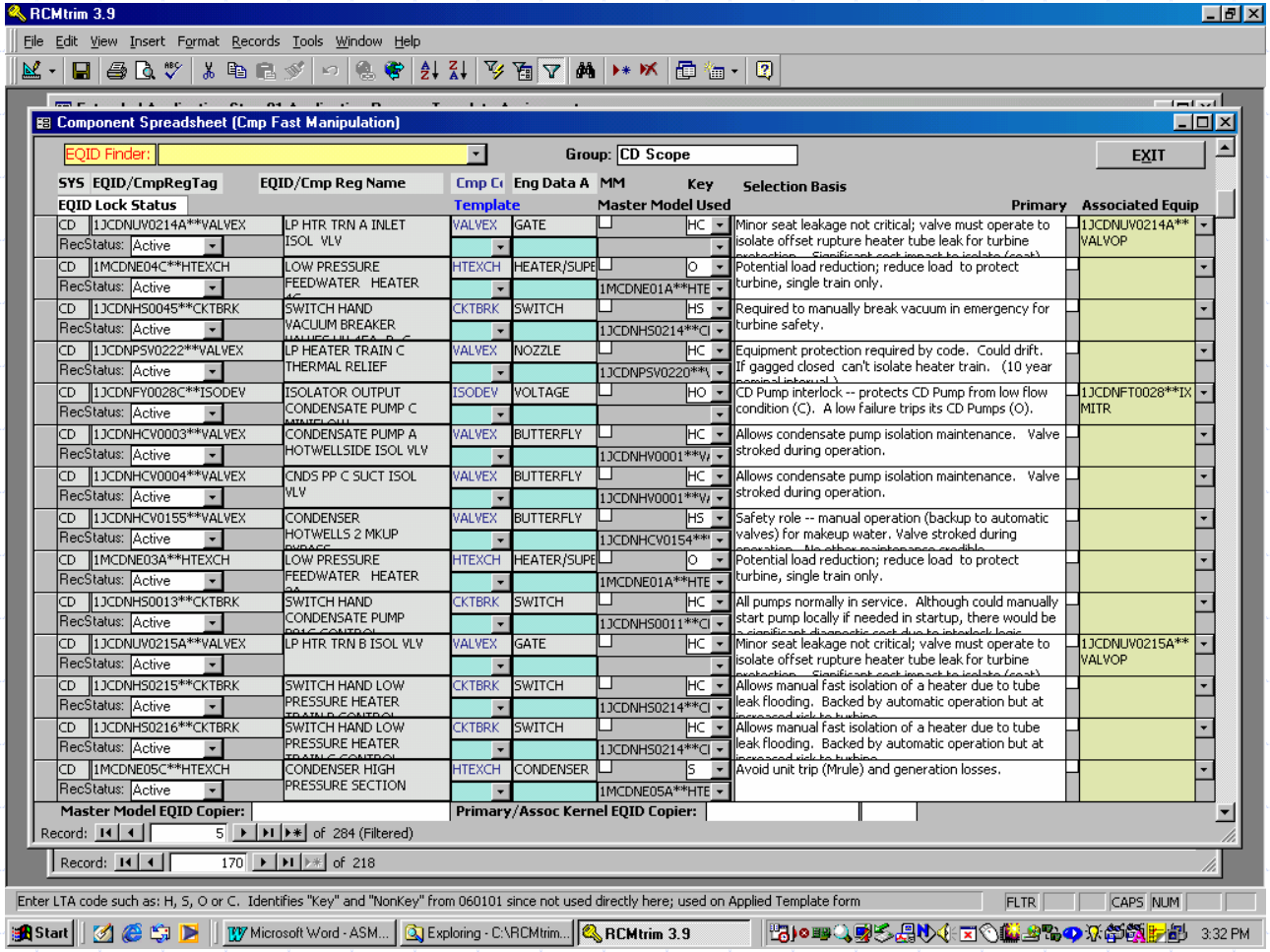
Management Support Required

- Executive Sponsorship
- Maintenance planner involvement
- Aggressive "can do" mentality
  - Avoid compromising fundamentals
  - Retain cost focus
  - Avoiding bogging on details
  - Implement results
- Organizational Change Support
  - "Uncompartmentalizing" maintenance
  - Applying results
  - Example: Maintenance performing recommended-delete non-critical PMs
- Teamwork
  - Build joint engineering/maintenance/operations teams

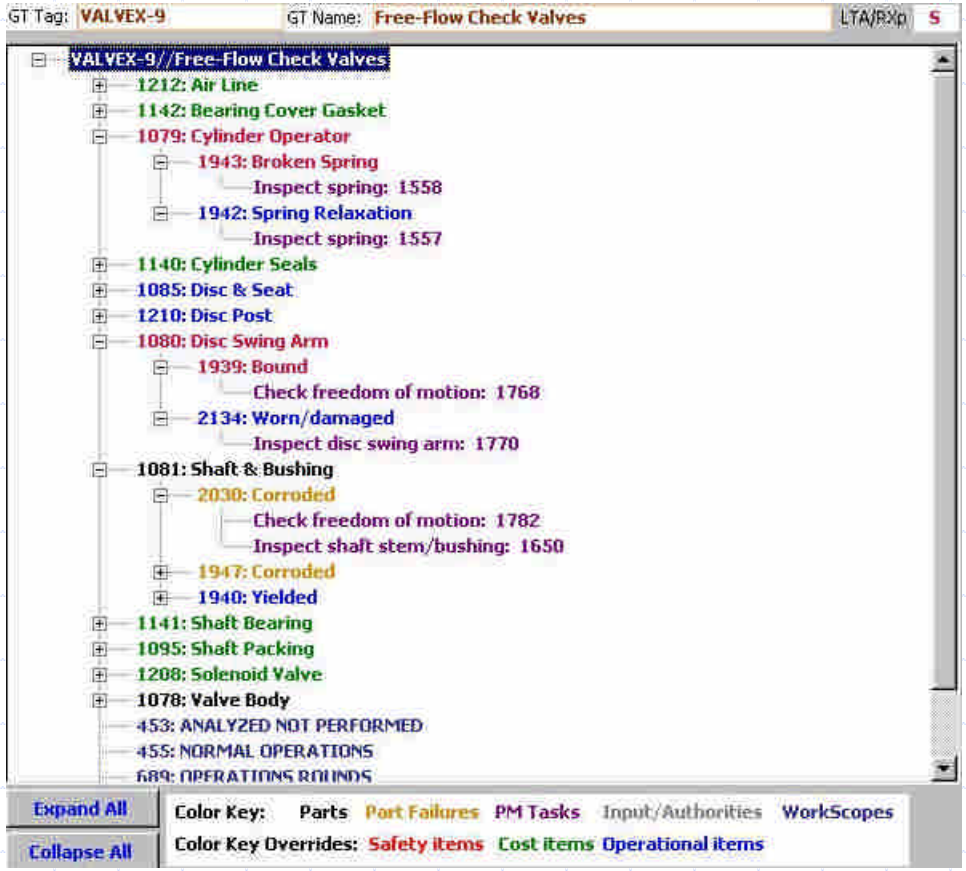
Strategy

- For credible equipment failure
  - Interrupt next fault node
  - Use redundancies, margins & instrument/alarms
- Options
  - Simple checks/inspections
  - Discovery tests unveiling hidden failures
  - Condition assessment (predictive/diagnostic)
  - Replacement/rework (including overhaul)
  - Combination
  - [Redesign]

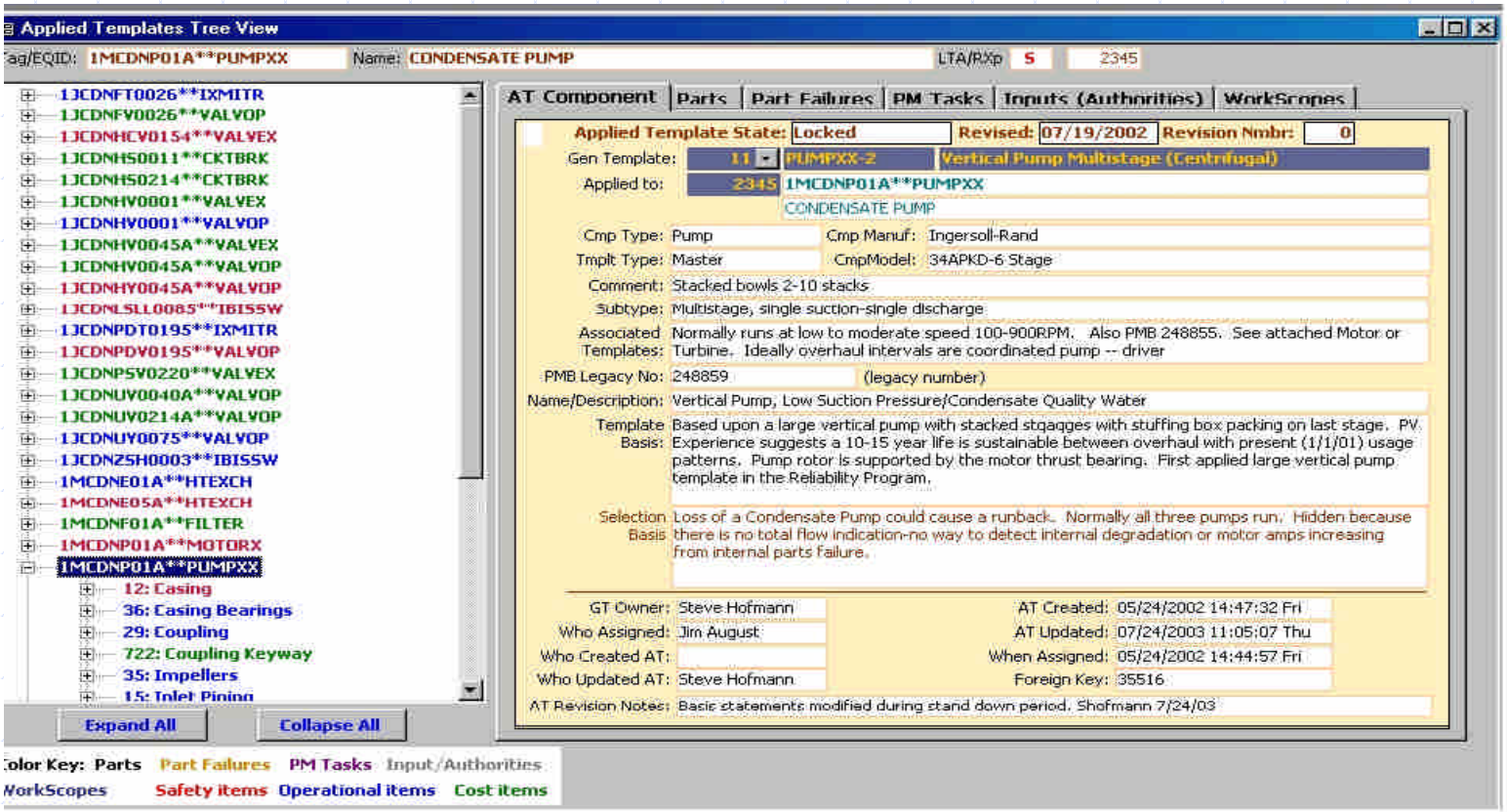
Condensate System Risk Map



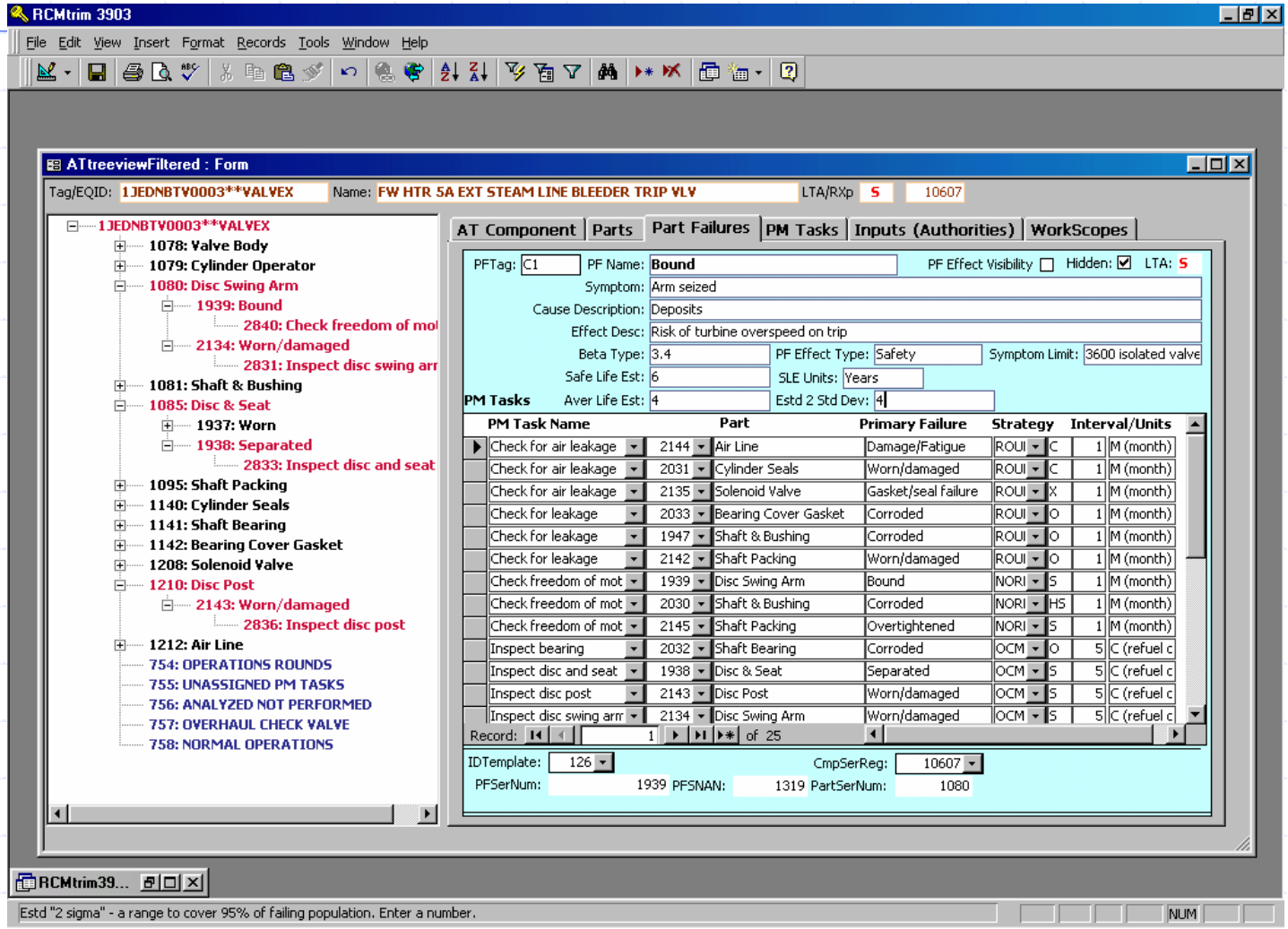
Template


GT Tag: VALVEX-9
GT Name: Free-Flow Check Valves
LTA/RXp
S
VALVEX-9//Free-Flow Check Valves
1212: Air Line
1142: Bearing Cover Gasket
1079: Cylinder Operator
1943: Broken Spring
Inspect spring: 1558
1942: Spring Relaxation
Inspect spring: 1557
1140: Cylinder Seals
1085: Disc & Seat
1210: Disc Post
1080: Disc Swing Arm
1939: Bound
Check freedom of motion: 1768
2134: Worn/damaged
Inspect disc swing arm: 1770
1081: Shaft & Bushing
2030: Corroded
Check freedom of motion: 1782
Inspect shaft stem/bushing: 1650
1947: Corroded
1940: Yielded
1141: Shaft Bearing
1095: Shaft Packing
1208: Solenoid Valve
1078: Valve Body
453: ANALYZED NOT PERFORMED
455: NORMAL OPERATIONS
689: OPERATIONS ROUNDS
Expand All
Collapse All
Color Key: Parts Part Failures PM Tasks Input/Authorities WorkScopes
Color Key Overrides: Safety items Cost items Operational items

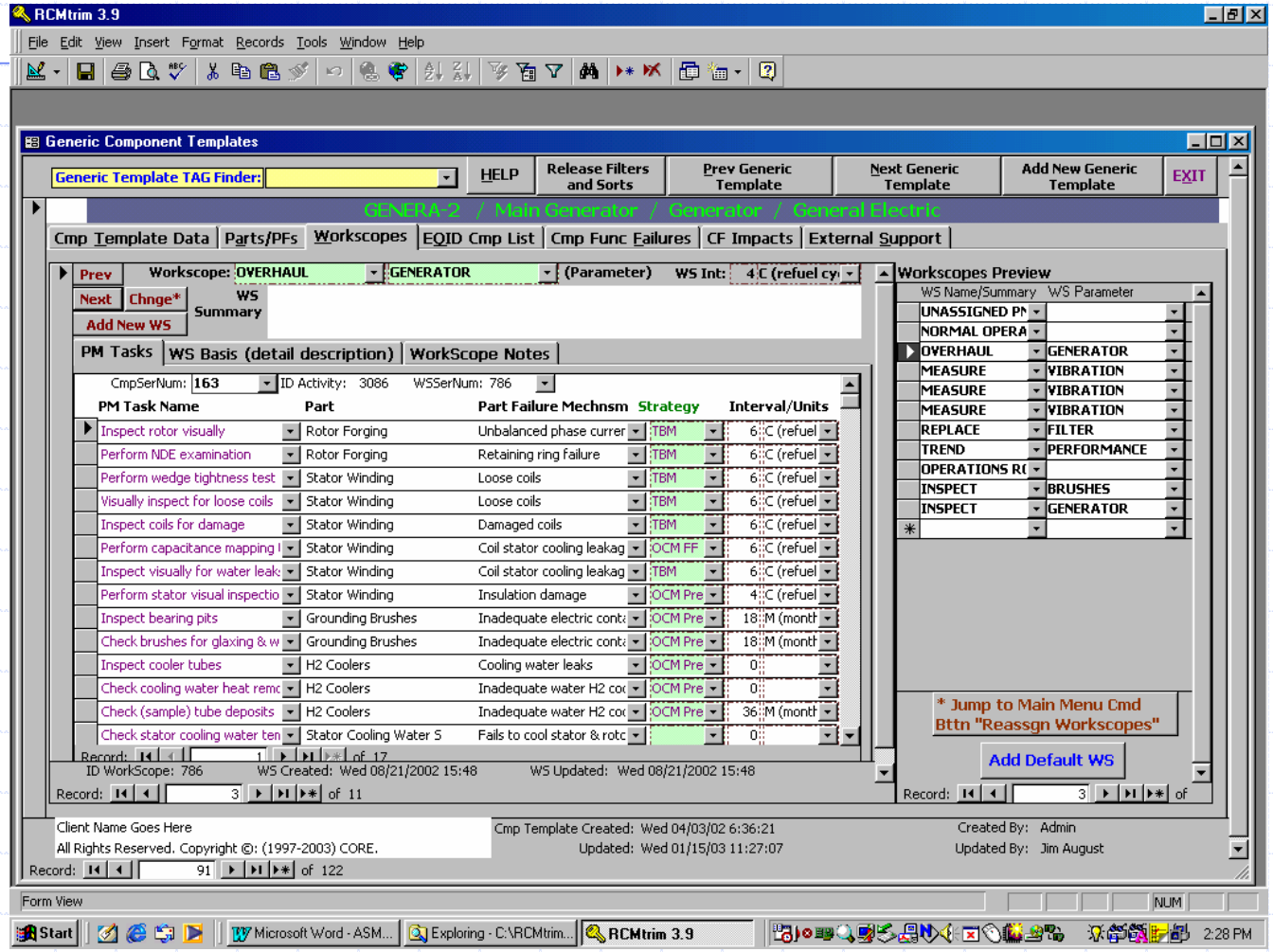
Partition


Applied Templates Tree View
Tag/EQID: 1MCDNP01A**PUMPXX
Name: CONDENSATE PUMP
LTA/PXp S 2345
1JCDNFT0026**IXMITR
1JCDNFV0026**VALVOP
1JCDNHCV0154**VALVEX
1JCDNHS0011**CKTBRK
1JCDNHS0214**CKTBRK
1JCDNHV0001**VALVEX
1JCDNHV0001**VALVOP
1JCDNHV0045A**VALVEX
1JCDNHV0045A**VALVOP
1JCDNHY0045A**VALVOP
1JCDNLSLL0085**IBISSW
1JCDNPDT0195**IXMITR
1JCDNPDV0195**VALVOP
1JCDNPSV0220**VALVEX
1JCDNUV0040A**VALVOP
1JCDNUV0214A**VALVOP
1JCDNUY0075**VALVOP
1JCDNZSH0003**IBISSW
1MCDNE01A**HTEXCH
1MCDNE05A**HTEXCH
1MCDNF01A**FILTER
1MCDNP01A**MOTORX
1MCDNP01A**PUMPXX
12: Casing
36: Casing Bearings
29: Coupling
722: Coupling Keyway
35: Impellers
15: Inlet Piping
Expand All
Collapse All
AT Component
Parts
Part Failures
PM Tasks
Inputs (Authorities)
WorkScopes
Applied Template State: Locked
Revised: 07/19/2002
Revision Nmbr: 0
Gen Template: 11 PUMPXX-2 Vertical Pump Multistage (Centrifugal)
Applied to: 2345 1MCDNP01A**PUMPXX
CONDENSATE PUMP
Cmp Type: Pump
Cmp Manuf: Ingersoll-Rand
Tmplt Type: Master
CmpModel: 34APKD-6 Stage
Comment: Stacked bowls 2-10 stacks
Subtype: Multistage, single suction-single discharge
Associated Templates: Normally runs at low to moderate speed 100-900RPM. Also PMB 248855. See attached Motor or Turbine. Ideally overhaul intervals are coordinated pump -- driver
PMB Legacy No: 248859 (legacy number)
Name/Description: Vertical Pump, Low Suction Pressure/Condensate Quality Water
Template Basis: Based upon a large vertical pump with stacked stgaqges with stuffing box packing on last stage. PV. Experience suggests a 10-15 year life is sustainable between overhaul with present (1/1/01) usage patterns. Pump rotor is supported by the motor thrust bearing. First applied large vertical pump template in the Reliability Program.
Selection Basis: Loss of a Condensate Pump could cause a runback. Normally all three pumps run. Hidden because there is no total flow indication-no way to detect internal degradation or motor amps increasing from internal parts failure.
GT Owner: Steve Hofmann
Who Assigned: Jim August
Who Created AT:
Who Updated AT: Steve Hofmann
AT Created: 05/24/2002 14:47:32 Fri
AT Updated: 07/24/2003 11:05:07 Thu
When Assigned: 05/24/2002 14:44:57 Fri
Foreign Key: 35516
AT Revision Notes: Basic statements modified during stand down period. Shofmann 7/24/03
Color Key: Parts Part Failures PM Tasks Input/Authorities
WorkScopes Safety items Operational items Cost items

Applied Template Structure: Fault Nodes



Deliverable: Generator Overhaul WO Tasks



Challenges

- Redundancy
  - Handling indirect failure risk with defense-in-depth
- Direct risk focus (e.g., SPV's)
  - Maintaining direct failure threat risk focus
  - (Ultimately didn't)
    - Treated redundancy levels as if they didn't exist, classifying
- Simplicity
  - Defining simple risk classification standards: SOCX
  - Safety
  - Operations
  - Cost

Results

- Quick hits
  - Quick assessments of likely hitters (expansion joints…)
- Non Critical PM WO identification
  - Cancellation of many lesser component RT's
  - Status instrument calibrations
  - Recognition of tasks better address at point of discovery
- Numbers
  - 65,000 EQID's
  - 15,000 critical: approximately 30/20/50 (%-age, SOC)
  - 450 Master/Normal Model EQIDS with Templates Applied
  - 60 Templates

Results

- Culture
  - Engineering role acceptance
  - Risk based methods
  - Streamlining

Fundamental Lessons

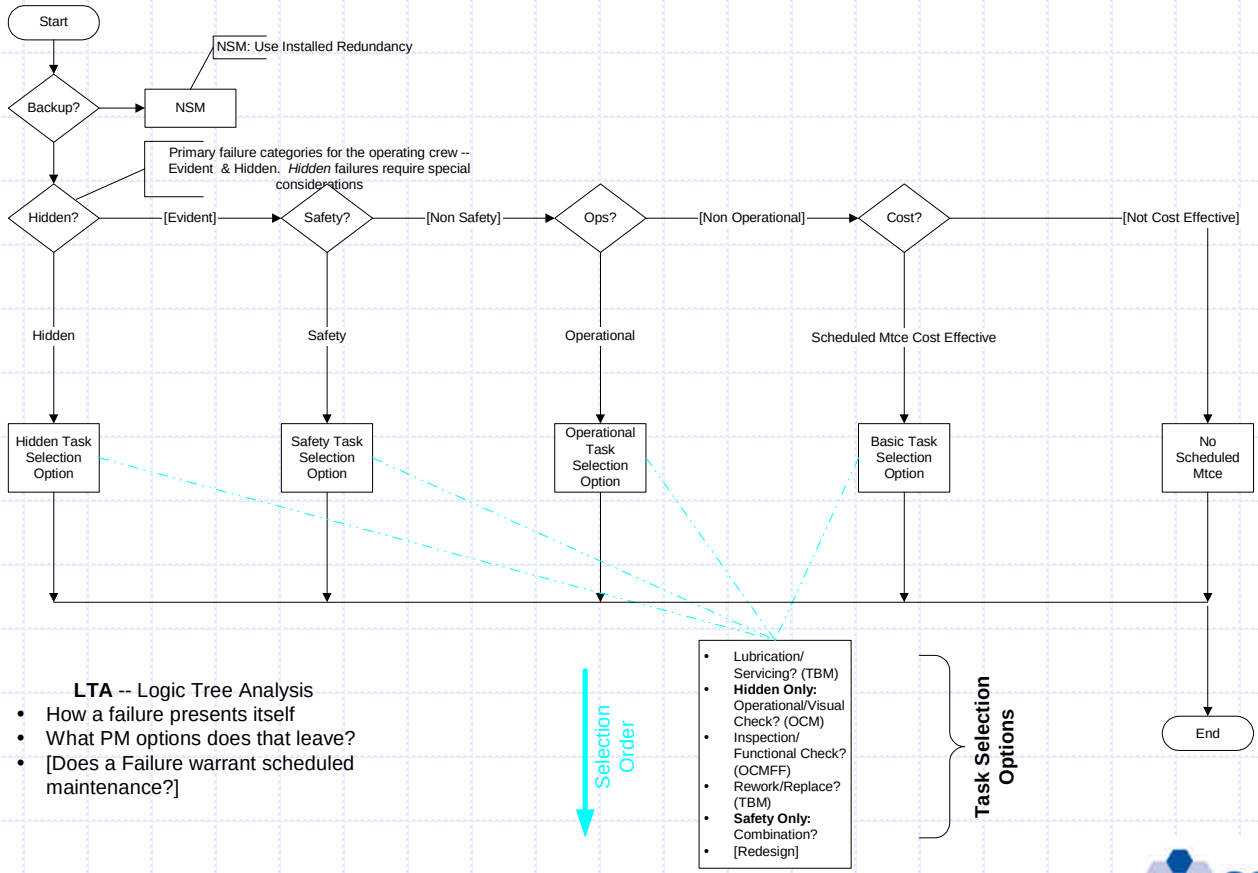
- Process speed
  - Output lagged expectations
  - Details hindered analysis production
  - Complex, non-standard risk classifications slowed development
- Conservatisms
  - Safety-classed equipment maintenance rule interpretation
    - Possible vs. certain failure cause interpretation
    - Multiple PM tasks addressing WO's (non-safety failure risk)
- Difficulty
  - Developing failure data
  - Finding sound PM intervals
  - Reducing scope (once complete)

Conclusions

- Risk-based PM development
  - Reduces cost
  - Improves reliability
- Cost-competitive with other ER development
  - Same costs for similar project scope as PMO
  - Long-term cost-savings much greater
  - Reduce costs by reducing over-prescribed work
- *Substantially* exceeds AP-913 requirements
  - Supports risk-based operations
  - Improves all ER risk management
- ***Though harder to learn and apply, risk-based method benefits offered are worth it!***

(Supporting Material)

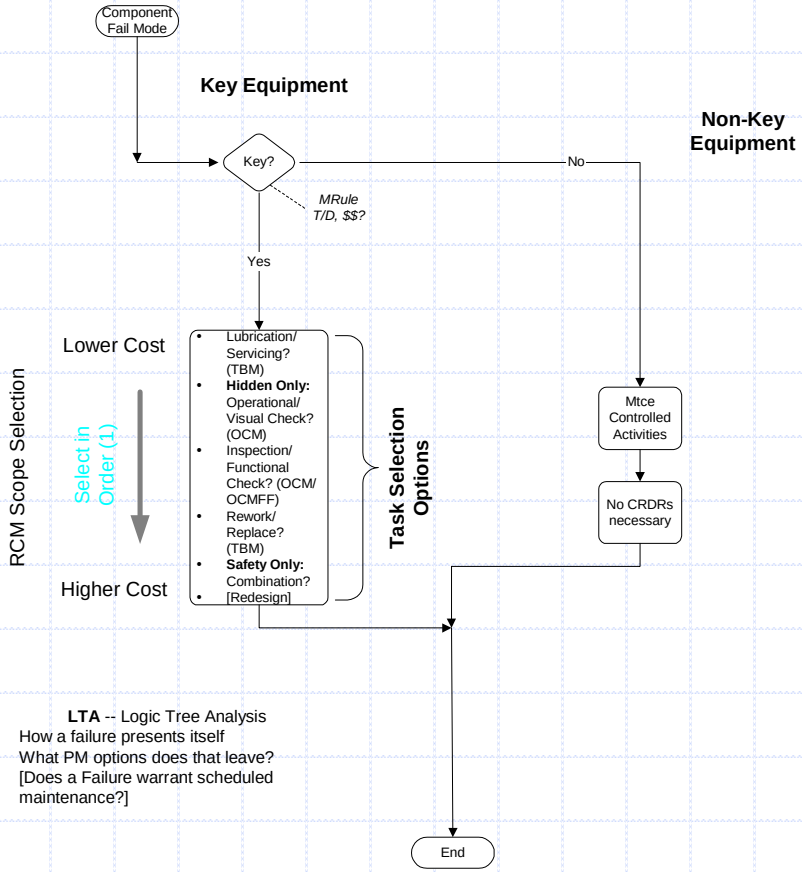
Component Failure Risk Classification



LTA -- Logic Tree Analysis

- How a failure presents itself
- What PM options does that leave?
- [Does a Failure warrant scheduled maintenance?]

Critical Equipment Task Selection



LTA -- Logic Tree Analysis

- How a failure presents itself
- What PM options does that leave?
- [Does a Failure warrant scheduled maintenance?]

Effort Breakdown

(1) Classify equipment (risk)	50%
(2) Develop equipment list partition	15%
(3) Apply templates	30%
(4) Generate reports	5%
(5) Interpret results	10%
	100%

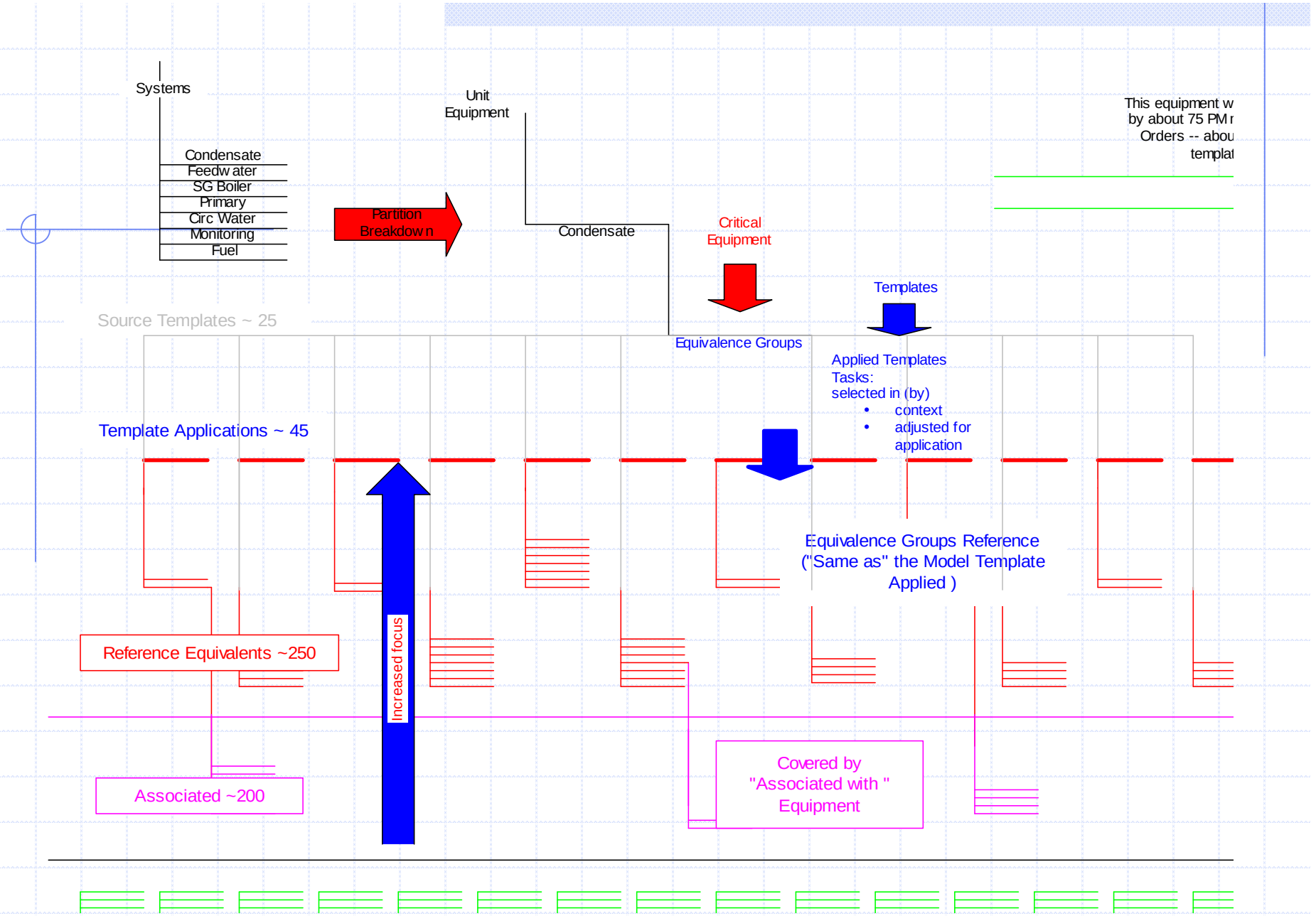
Classifying risk context allows subsequent template application and development as an "applied template"

Cost

- Analysis drives ER program development cost
- "System study" engineering analysis contributes significantly (~50% total time)
  - Reduced using pre-developed standard rules
  - Most significant project cost risk factor
- 'Learning' pronounced
  - Especially early systems
  - Maintaining learning rate requires avoiding rework and 'reprogramming'

ER Process

- Select functional requirements
- Partition equipment
  - Develop symmetries; establish components/scope (critical/non-critical)
- Rank equipment (excluding low-risk equipment)
  - Based upon credible failures
  - Exploits design symmetries
- Develop normal cases
  as reusable models
- Apply templates
  - Consider risk
  - Use operating context
  - Customize application based on context


Systems
Condensate
Feedw ater
SG Boiler
Primary
Circ Water
Monitoring
Fuel
Partition Breakdow n
Unit Equipment
Condensate
Critical Equipment
Templates
This equipment w
by about 75 PM r
Orders -- abou
templat
Source Templates ~ 25
Equivalence Groups
Applied Templates
Tasks:
selected in (by)
• context
• adjusted for application
Template Applications ~ 45
Equivalence Groups Reference
("Same as" the Model Template Applied)
Reference Equivalents ~250
Increased focus
Associated ~200
Covered by "Associated with " Equipment