Enabling Conditioned Based Maintenance
and
Improving Asset Health

Presented by **Chris Crosby (ccrosby@osisoft.com)**
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Presented at: OSIsoft India Regional Seminar

Agenda

- Conditioned Based Maintenance
- Asset Health
- Use Cases

India and America – Common Values, Shared Success
op ed last September, 2011, USINPAC Blog Network

"The remarkable deepening of US-India ties over the past decade is only a start, as the relationship has still not reached its full potential. If Indians and Indian-Americans continue to contribute their ideas, their energy and their commitment, I am sure that even more exciting days lie ahead."

Senator Richard Lugar, the Republican leader of the U.S. Senate Foreign Relations Committee

OSIsoft Receives E Award
May 17, 2012

U.S. Department of Commerce Secretary John Bryson at the White House in Washington, D.C. The "E" Awards are the highest recognition any U.S. entity may receive for making a significant contribution to the expansion of U.S. exports.

Europe represents a significant portion of the company's foreign market sales, and over the past few years the business has expanded significantly in other key markets such as Asia and Latin America.

Underlying Assumption

"*Household electricity consumption is widely viewed and accepted as providing substantial standard of living (quality of life) gains.* These gains come in many areas…refrigeration of food (health), lighting for reading (literacy), computers and internet access (education), productivity (income)…and suggest that observable household electricity consumption may provide useful insights into the nature of standard of living across countries and its changes over time."

by

Roselyne Joyeux and Ronald D. Ripple in *The Evaluation of Standard of Living and the Role of Household Electricity Consumption*

About OSIsoft and PI System

Corporate

- Founded 1980 by Dr. J. P. Kennedy, CEO
- Privately held
- Headquarters - San Leandro, CA
- Doing business in 110 countries
- 23 offices in 13 countries with corporate presence in 10 countries

Revenue

- 2011 Revenue $273MM; 2012 >820 employees

Installed Base

- 2,800+ Active Customers
- 10,000+ Active System licenses (excluding OEM)
- 32,000+ I/F licenses (connection, node, server, site)
- 250,000+ Clients Licenses (individual, concurrent, enterprises
- 250,000,000+ Data Streams

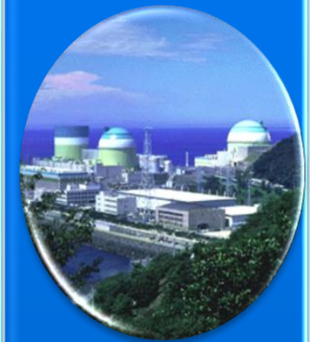
Managed PI (mPI)

- 612 Systems
- 803 PI Servers
- 77 Enterprise Agreement Customers
- Network Operation Center (NOC) PI Server has 1,206,080

OSIsoft Power & Utilities Industries

Power Gen Thermal

- Coal
- Gas
- Oil



Power Gen Nuclear

- Generation
- Fuel
- Regulators
- Services

Power Gen Renewables

- Wind
- Solar
- Hydro
- Marine
- Bio
- Geothermal

Water Wastewater

- Utilities
- Desalination
- Irrigation
- Industrial
- Metering
- Lifecycle

T&D - Smart Grid

- Grid Mgmt
- Phasor
- Substation
- Dist. Automation
- Dist. Generation
- Microgrids

AMI - Smart Grid

- Operational Data Manager
- Home Area Net
- Demand Response

Power & Utility Verticals

PI System -- Defacto Standard in Power and Utilities

OSIsoft Selected Power and Utilities Experience

- 55% of 475 GW average USA power generation is monitored by the PI System (coal, natural gas, renewables, hydro and nuclear)
- 85% of total 23 GW USA wind generation is monitored by the PI System
- 100% of the ISOs/RTOs in the USA use the PI System
- 17 of the top 20 wind generating producers in the world use the PI System
- Over 50% of the Concentrated Solar Plants (CSPs) in the world use the PI system
- Many of the largest solar companies in the world use the PI System (SunPower, EDF-EN, E.ON, Iberdrola, EGP, Abengoa Solar, Sempra)
- Many solar, wind, turbine and other major equipment power generation OEMs in the world use the PI System
- Over 100 water utilities in 17 countries use the PI System

OSIsoft Selected Nuclear Energy Experience

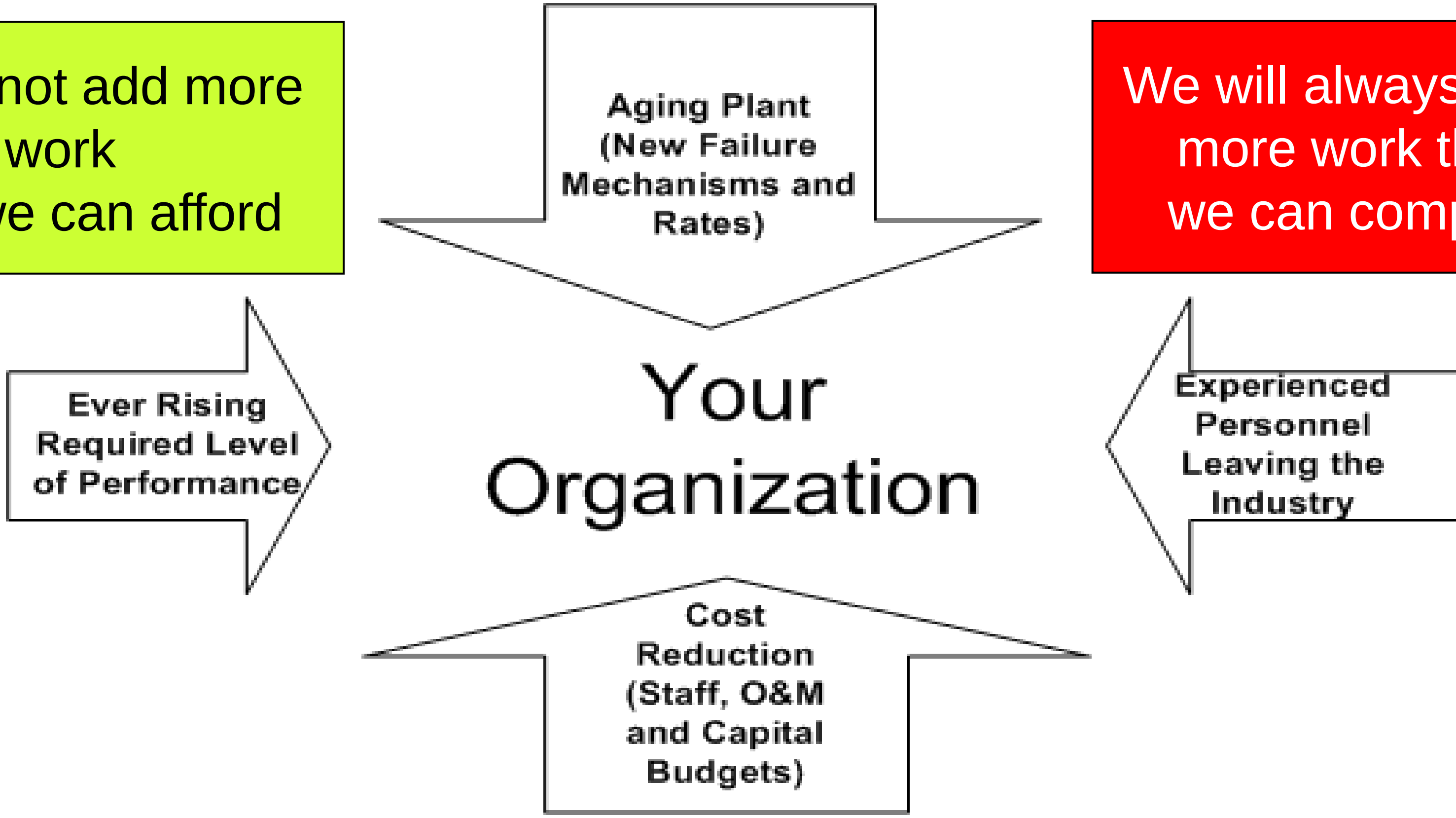
- 76% of operating nuclear power generators in the USA use the PI System (79 of 104), and growing
- 100% of operating nuclear power generators in Canada use the PI System (17 of 17)
- 100% of operating nuclear power generators in the United Kingdom use the PI System (18 of 18)
- 100% of operating nuclear power generators in Korea use the PI System (21 of 21)
- 66% of operating nuclear power generators in Chine use the PI System (10 of 15)
- 31% of under construction nuclear power generators in China have committed to use the PI System and others are considering (8 of 26)
- The PI System is widely used for emergency preparedness and response, including the US Nuclear Regulatory Commission
- Many nuclear mining, fuel conversion, fuel enrichment, fuel fabrication and waste processing companies use the PI System (over 20 companies)
- The PI System is already part of the standard design for KEPCOs advanced reactor
- The PI System is now being used as part of the testing phase for a US-based small, modular reactor and the intention is for it to become part of their standard design
- Nearly every leading advanced reactor OEMs (large and small, modular) is interested in making the PI System part of their standard design (or a standard option)

Conditioned Based Maintenance

These "Pressures" Appear to be Common

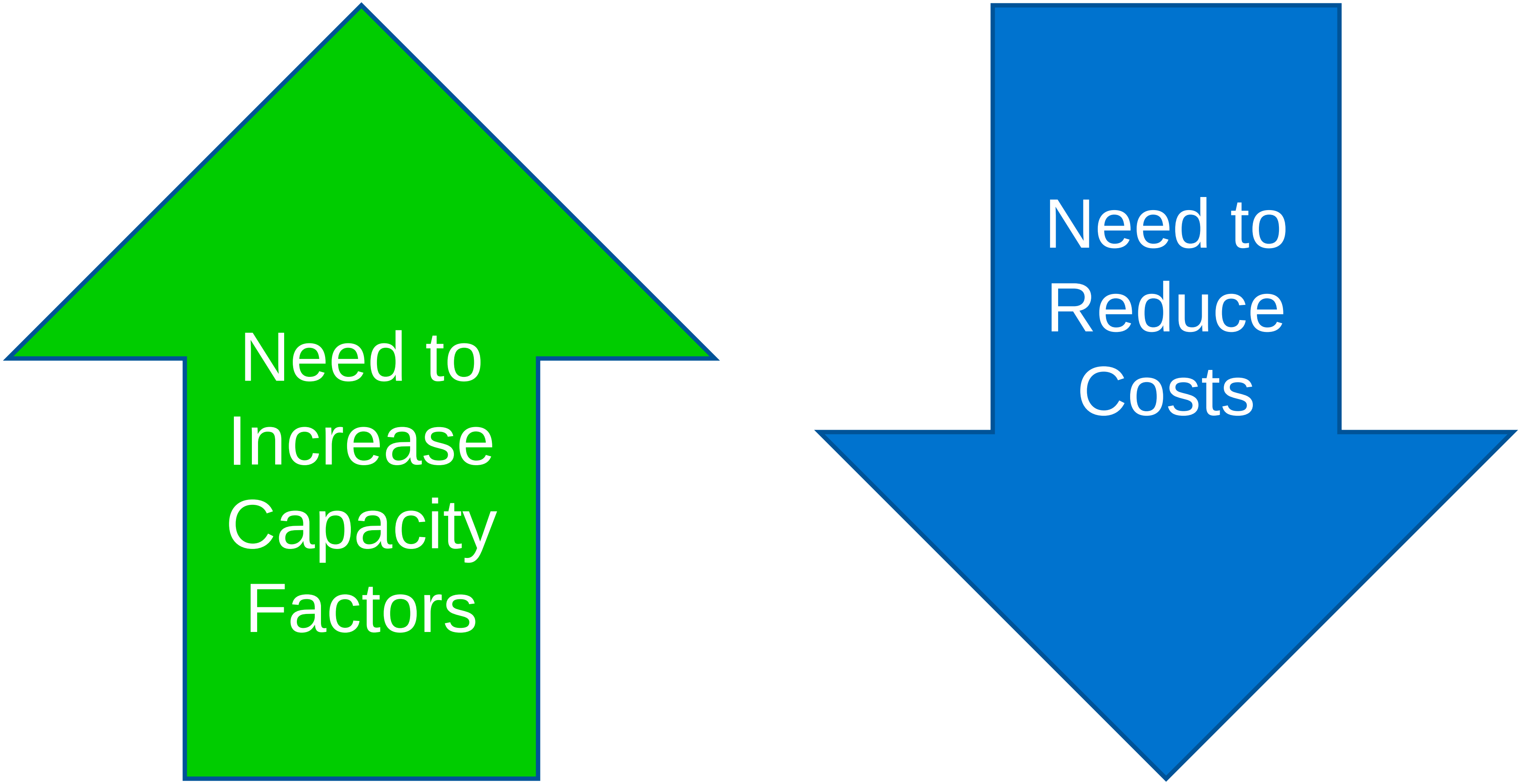
We cannot add more work
than we can afford

We will always have more work than
we can complete

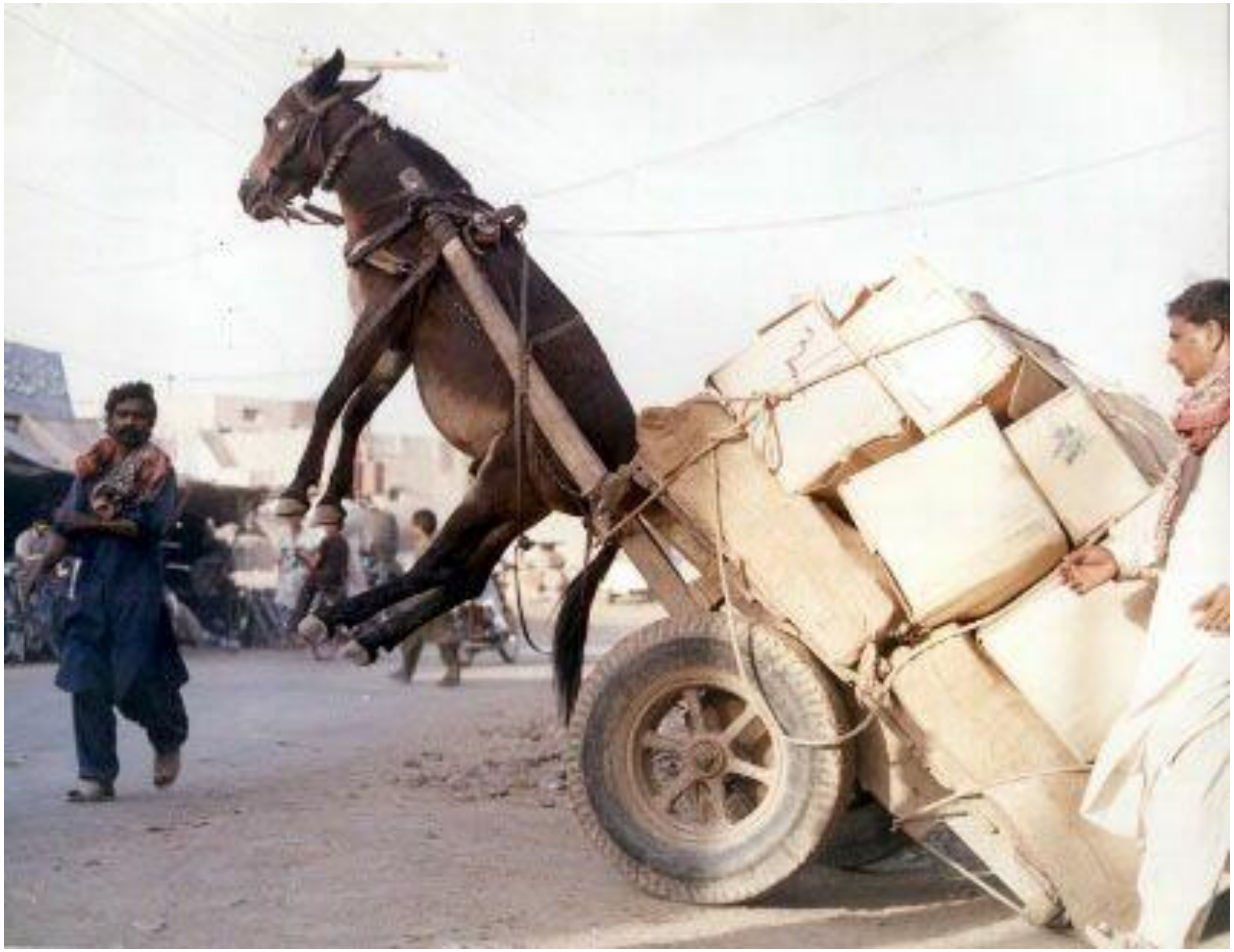


Asset owners and managers are being squeezed by aging assets, experienced personnel leaving the industry, and continuous pressures to reduce costs and improve performance.

These “Needs” Appear to be Common

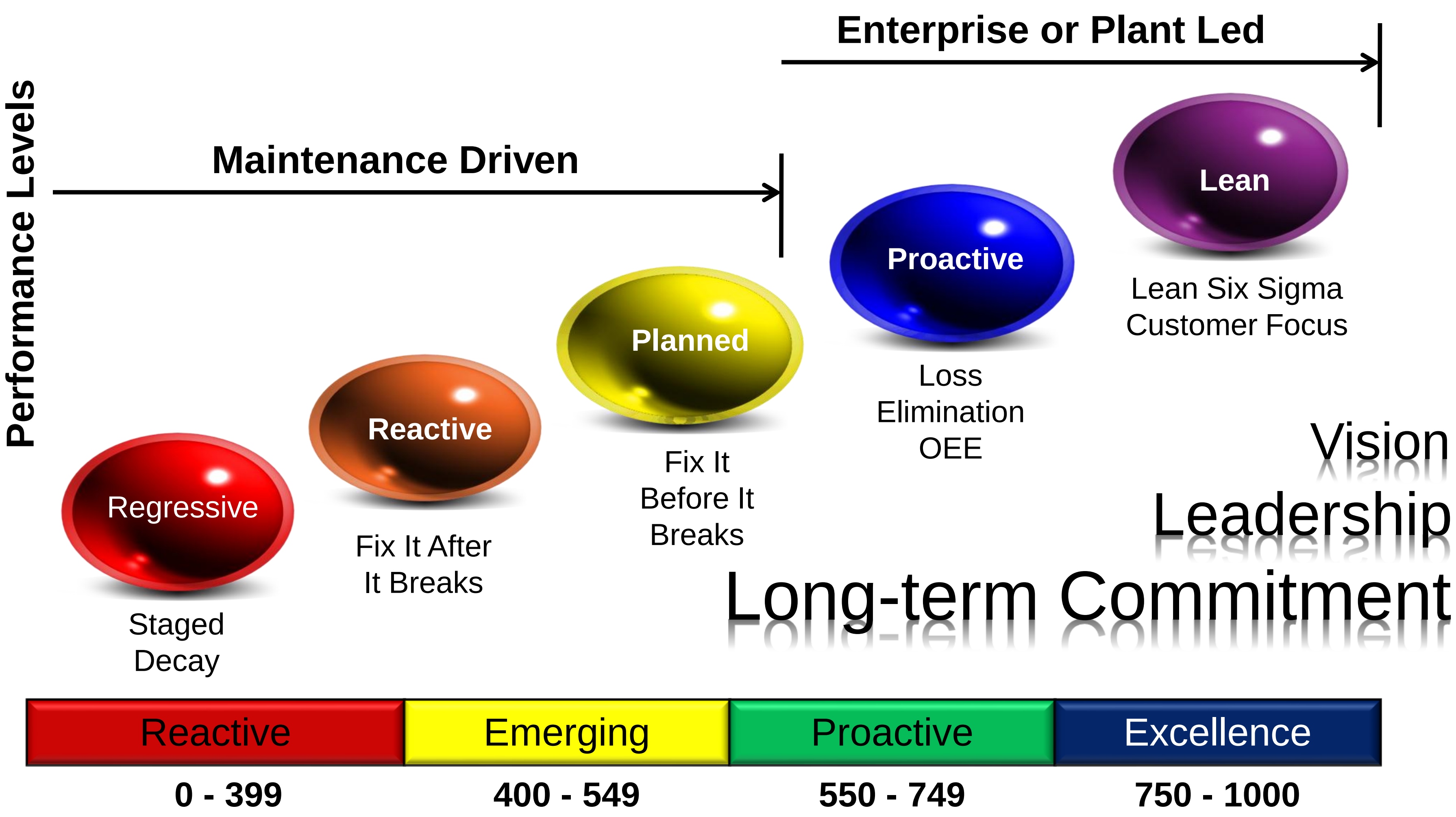


Getting Your Feet on the Ground!



Looking for long term solutions…not moving the load to the donkey!

The Reliability Excellence Journey



Some Definitions

- Risk-based Asset Management (RBAM) - risk-based asset management strategy couples risk management, standard work, and condition-based maintenance to properly apply resources based on process criticality
- Predictive Maintenance (PdM) – using a specific asset condition indicator to estimate when an asset failure might occur.
- Condition Monitoring – determining an asset's health (condition) based on one or more parameters. Usually visual indicators or notifications only.
- Condition-Based Maintenance (CBM) – performing maintenance activities based on the current or historical trend of an asset's condition.
- Reliability Centered Maintenance (RCM) – A set of techniques and practices used to ensure minimal asset maintenance involving operations, monitoring, inspection, etc.
- Preventive Maintenance (PM) – scheduled activity to remove an asset from service and perform needed maintenance. May be periodic (calendar) or condition based. Planned Maintenance is usually CBM and PM.
- Corrective Maintenance – maintenance performed in response to an incipient failure of an asset (reactive).
- Enterprise Asset Management (EAM) – context, description, classification and maintenance of a site, facility, unit or other physical asset (often part of ERP).

Risk-based Asset Management

Proactive Maintenance

- Screens and information with Maintenance in mind
- A focus on critical equipment, parameters for condition
  - Vibrations (rotating equipment, motors, pumps, turbine…)
  - Temperatures (bearings, oil, metal, motors…)
  - Amps
- Transform data and use in a new, valuable way
- Use out of the box, PI System functionality
  - Totalizers for run time counters, compare/balance usage, schedule maintenance, measure accumulative damage
  - Multi-state graphics
  - Notifications
- Increase speed and accuracy of decisions

Proactive Maintenance

- Is a strategy in which Corrective, Preventive, and Predictive processes complement one another
- Average industrial plant performs **more than 55% Reactive**
- Reactive is the highest cost!
- Top industrial plants perform **less than 10% Reactive**

An industry "best practice" target goal maintenance mix

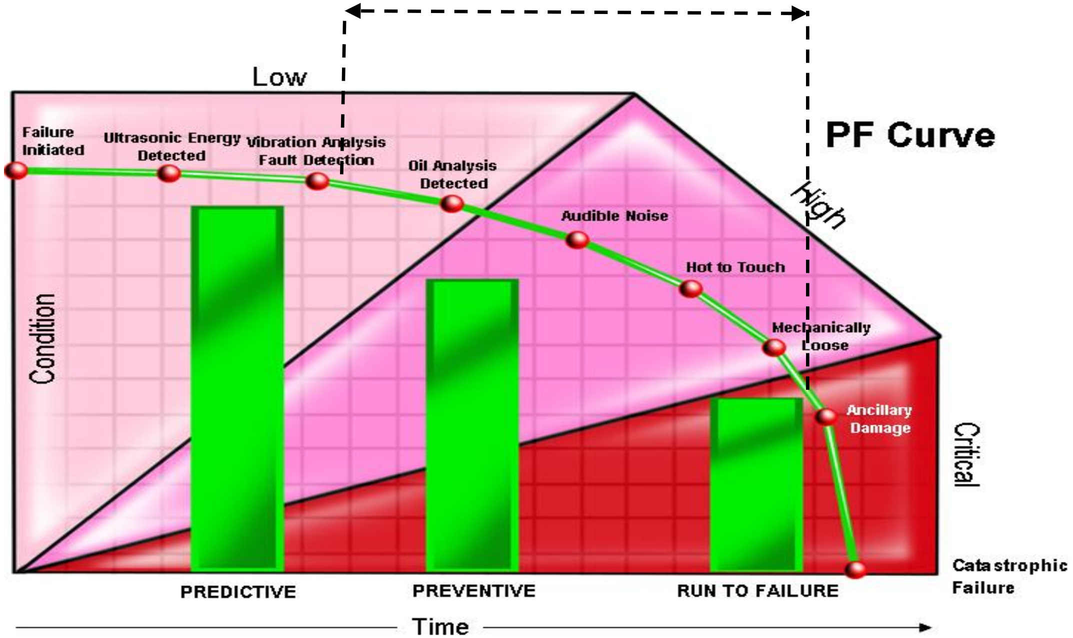
Reactive 10%	Preventive 35%	Predictive 55%
↓	↓	↓
Minimize emergent work	Optimize current PM Practices	Expand existing PdM Applications

In support of this strategy, enhance & expand the effective use of data and analytical systems

Proactive Maintenance P-F Curve

P-F curve shows the behavior of equipment as it approaches failure

- “P” represents the first possible point degradation can be detected
- “F” represents the point of equipment or system failure
- The time between is your “opportunity” to avoid unplanned events



P-F Interval
P-F

Time frame to rectify impending equipment failure: Planning, Scheduling, Execution Window

Earliest detection provides the greatest opportunity time

CBM Driving Factors

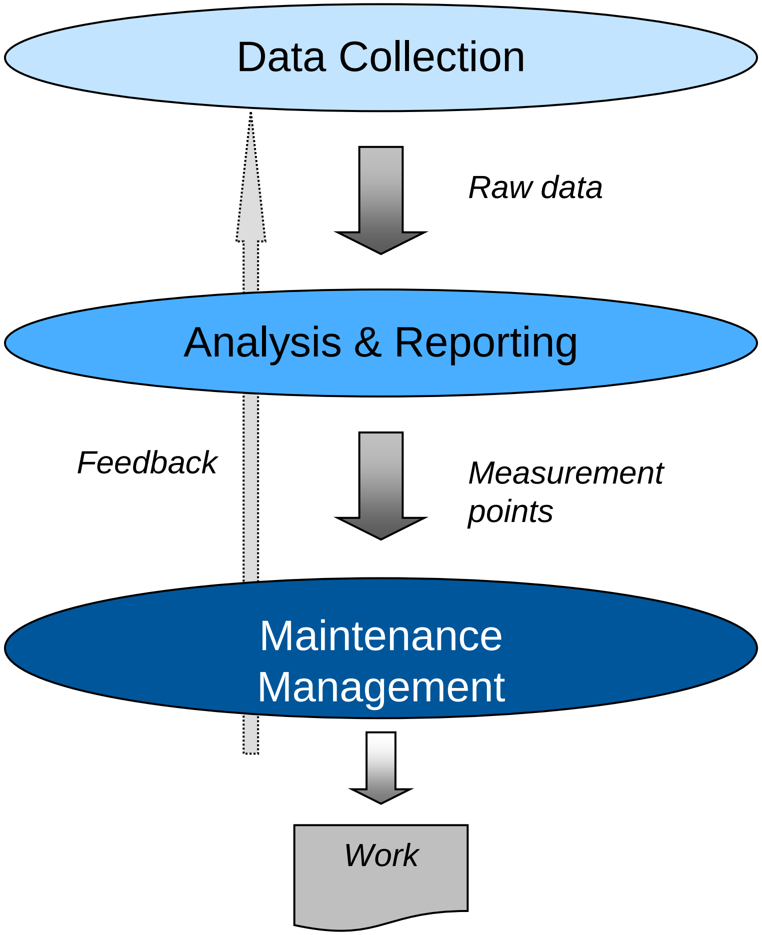
- Continued expectations of improvements in reliability and availability
- Lack of comprehensive asset maintenance strategy – most if not all PM work calendar-based (overly conservative)
- Aging asset profiles – asset life extensions
- No link between asset performance/health and maintenance decisions
- Complexities in data systems implemented as point solutions
- Continual staff reductions
- Aging workforce

CBM Expected Benefits

- More targeted capital expenditures with eventual overall reductions
- As incipient failures are reduced, corrective maintenance costs go down and more maintenance is moved to 'planned'
- With a move to condition-based maintenance, calendar-based preventive maintenance is reduced
- Automation of condition-based notifications (emails, pages, maintenance notifications, etc.)
- Codification of organizational intelligence into condition-based algorithms
- Prioritization of maintenance, shorter downtimes, do the right work at the right time
- Improved visualization of asset health status
- Improved decision making capabilities

CBM Fundamentals

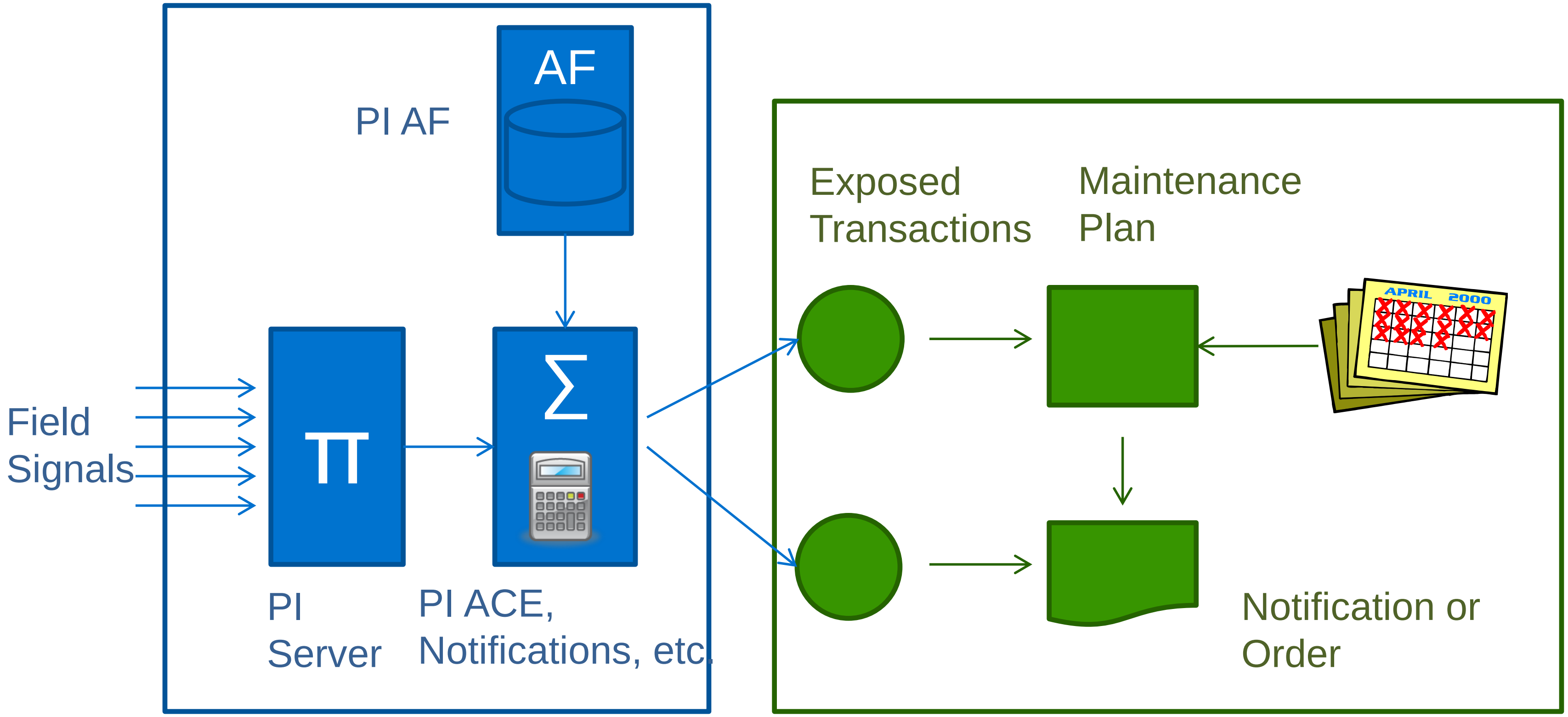
- Data Collection and Consolidation (Data)
  - Diagnostic and Inspection Data
  - Time-series Data
  - Relational Data
- Asset Analysis and Reporting (Information)
  - Condition & Criticality Assessment
  - Equipment Ranking
  - Work Prioritization
- Maintenance Management (Knowledge)
  - Meters
  - Work Order Generation
  - Maintenance Planning
  - Decision Support



Condition Monitoring

- CBM requires condition monitoring
- Condition monitoring is more than simple alarms (already done by Operations) or simple tests (usually immediately alert maintenance personnel already)
- Condition monitoring illuminates:
  - Slow moving variables (changes over many samples)
  - Multi-factor combination **CA = F1(M1) + F2(M2) + F3(M3) + …**
- Condition monitoring should consider performance and process data
- Condition monitoring assigns a score (e.g. 0-10, Red, Yellow, Green), detects a condition, updates a meter, etc.

CBM Integration Scenario



- PI Collects raw signal values and conditions these values via calcuations and determines when to initiaite transaction to EAM
- PI invokes transactions to either update measurement points (meters) or generate a notification/order, dependent on condition rules
- If meter updates, then EAM compares maintenance plan logic to current state to deteremine if notification/order should be generated.

Asset Health

Asset Health – The Big Opportunity

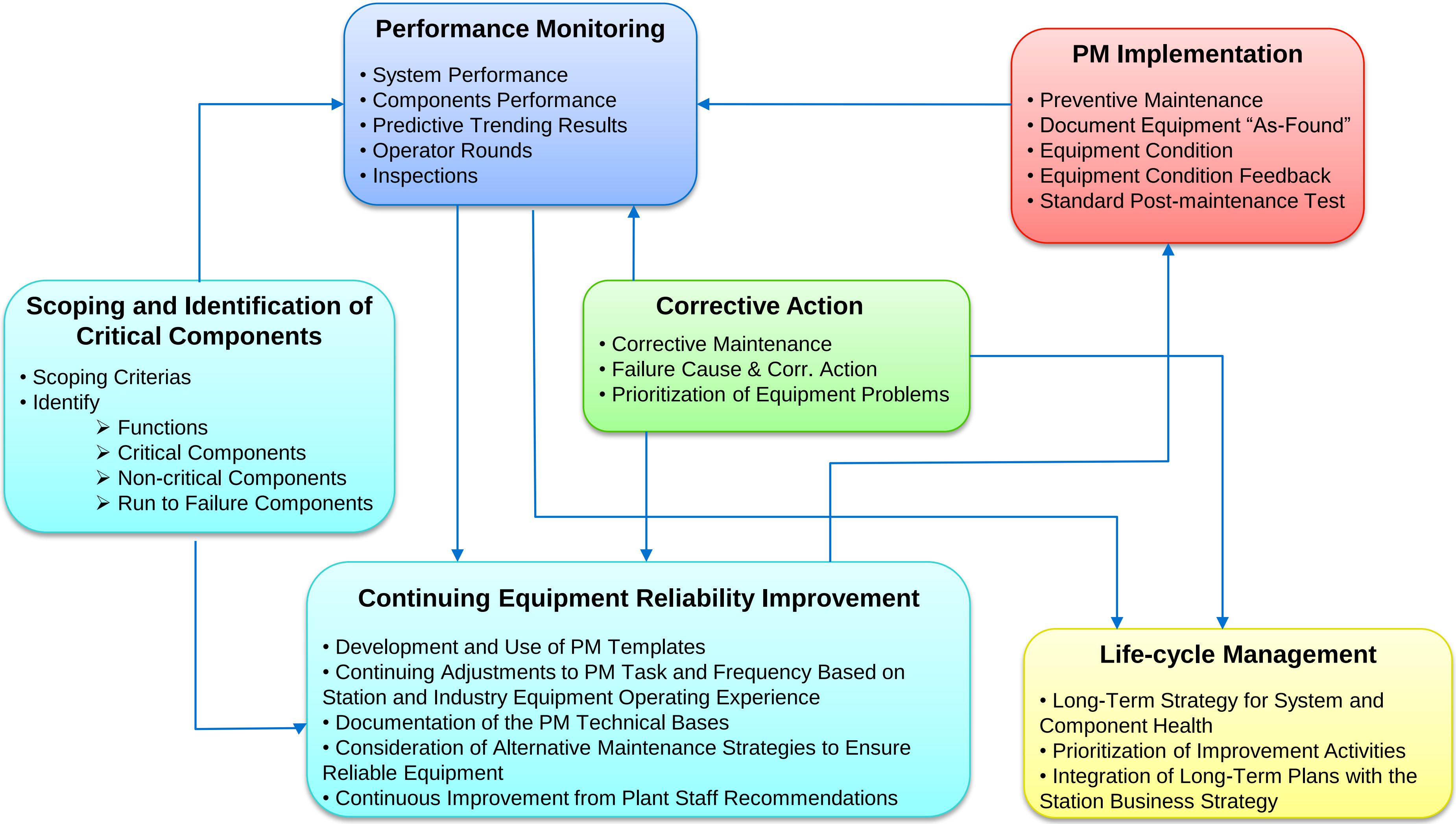
Nuclear Specific Driver - Equipment/Asset Reliability…

– *Cornerstone* of Operational and Reliability Excellence in NPPs
– Critical for NPP Life Extension and *License Renewal*
– Heavily *regulated* by international standards (10CFR50.65)
– INPO AP-913 (Equipment Reliability Process Description) *endorses* 10CFR50.65
– *Requires real-time data* = REAL-TIME INFRASTRUCTURE (as many other Operational and Reliability Excellence applications do)

Nuclear Specific Driver - Equipment/Asset Reliability…

– Other guides include:
  - NEI “Standard Nuclear Performance Model”
  - INPO AP-928 “Work Control Process Description”
  - INPO 01-004 “Achieving High Equipment Reliability – A Leadership Perspective”

INPO AP-913 Business Process

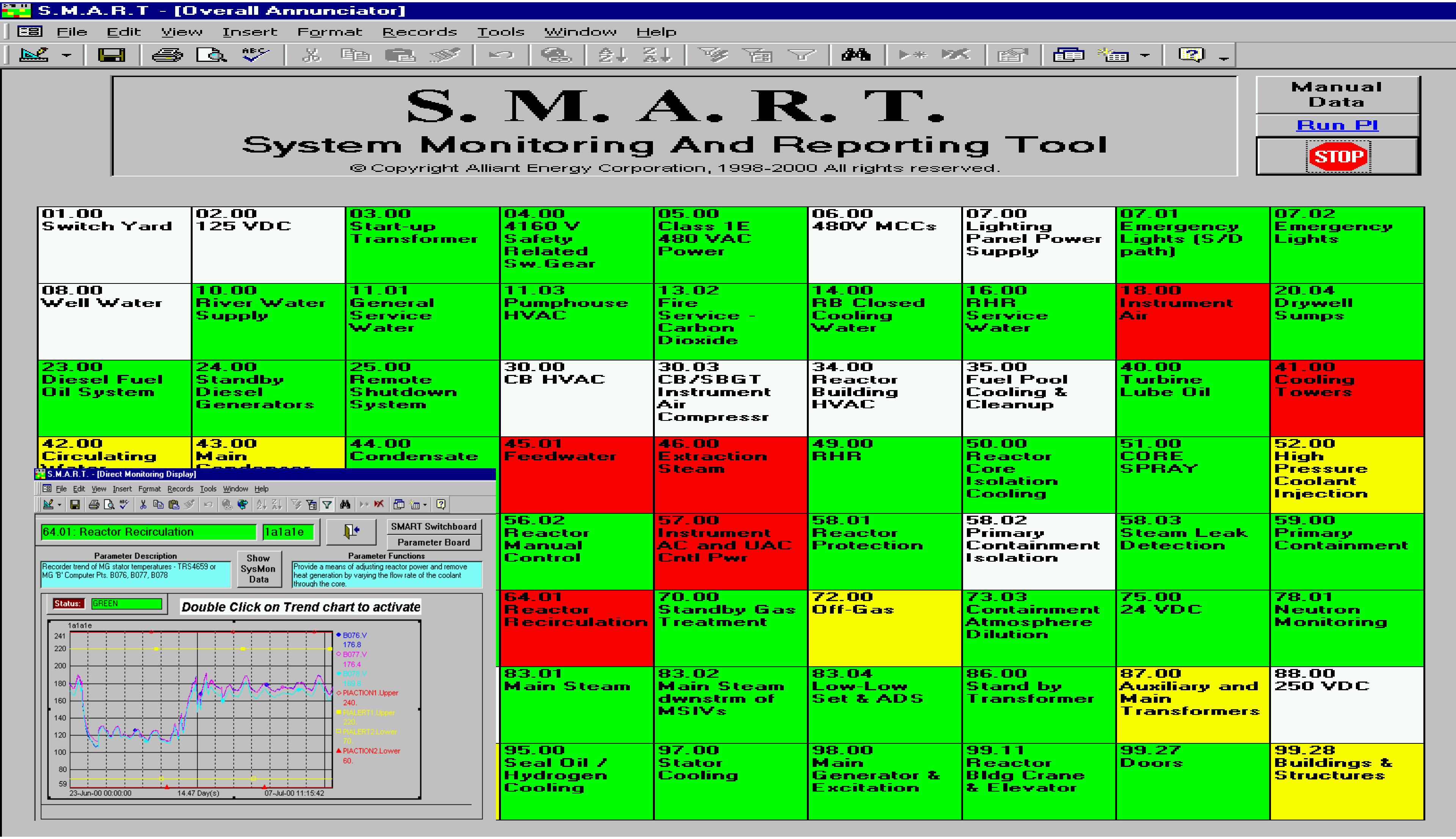


Specific Asset Health-related Uses for PI System Information in Power Generation

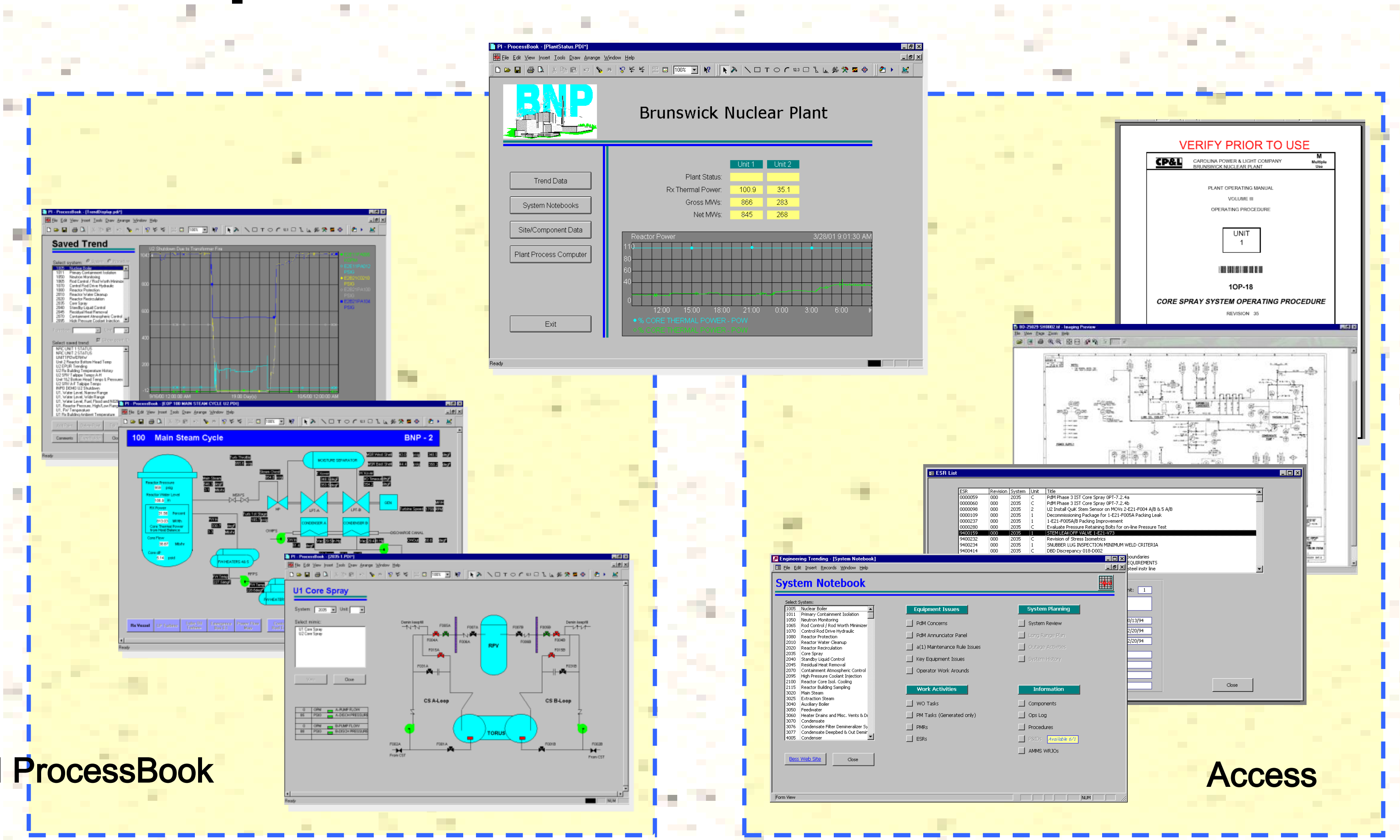
- Operations (Extend DCS Beyond the Control Room)
  - Controllable Losses – Start Up/Shut Down
- Proactive/Condition-based Maintenance
- Root Cause Analysis (RCA)
- Outage Planning (Spend $ on the Right Things)
- Vendor Performance (Pre and Post Work Review)
- Equipment/Manufacture Performance
- Plant and System Performance/Efficiency
  - Production vs. Schedule - Heat Rate/Condenser
- Environmental (Compliance, Emissions, Limits, Reporting)
- Water Chemistry
- Fleet/Enterprise View of Core Metrics and KPIs

Single version of the truth

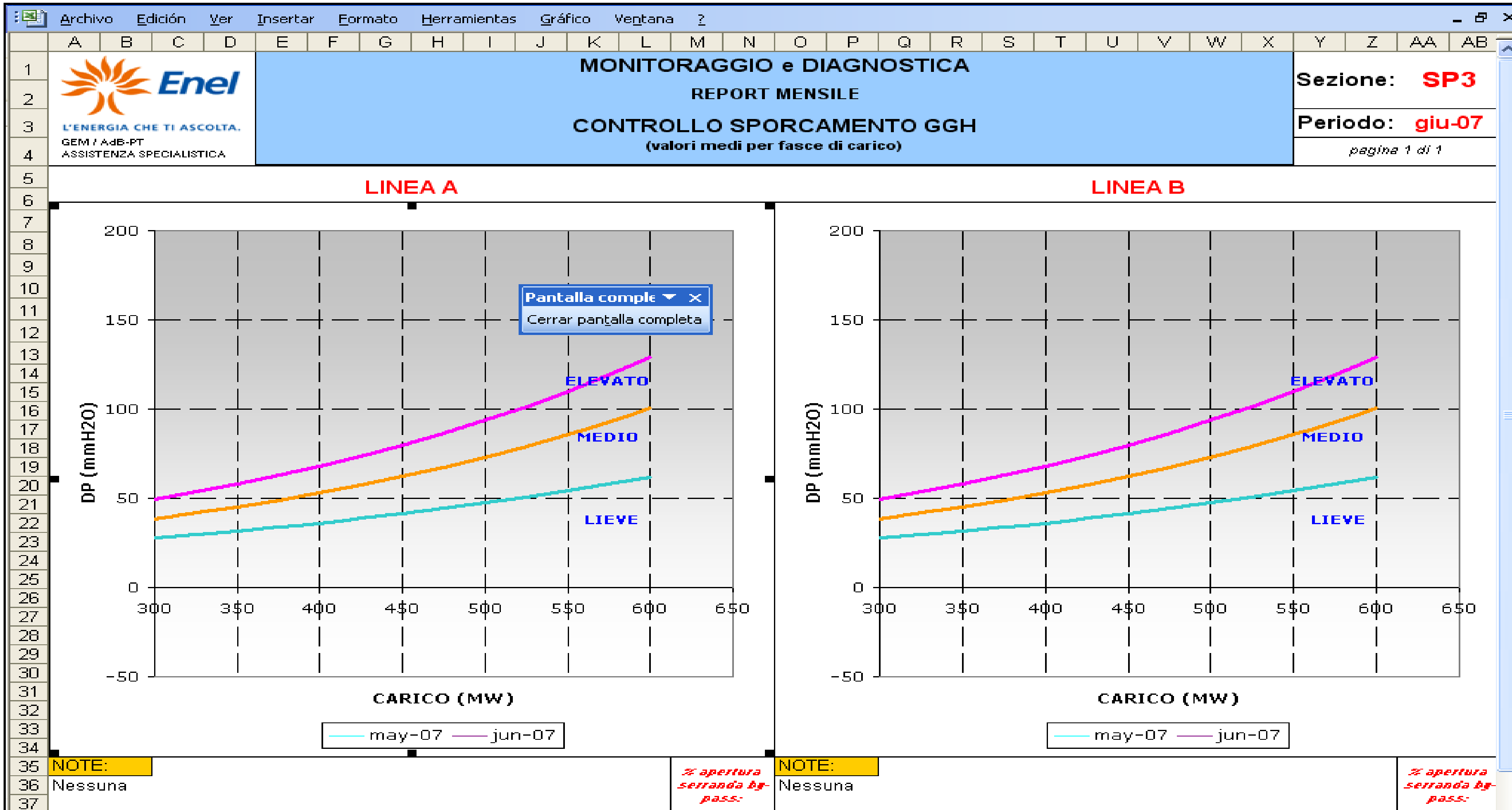
System Monitoring and Reporting Tool



Progress Energy System Engineer Desktop



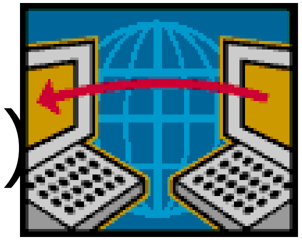
ENEL Conditioned-Based Maintenance (CBM)



Entergy Performance Monitoring & Diagnostics Center (PM & DC)

Mission: Support plant objectives to achieve fleet commercial excellence through improved unit performance, equipment condition, and operational risk management

Entergy's PM & DC PI Infrastructure



- PI Servers located at 16 plants
- Operations Information Systems (OIS) implemented on 30 units:
  - Real-time performance monitoring & diagnostics thru pre-built PI-Process Book displays and General Physics EtaPro^{TM}
- Advanced Pattern Recognition (APR) implemented for 33 units:
  - Anomaly detection and alerting via advanced pattern recognition software using near real-time data from the plant PI servers

Entergy PI Use in the PM & DC

- OIS/PI is primary means of accessing plant data for routine monitoring
- Build custom ProcessBooks and DataLinks for trip analysis, unit/equipment problem diagnostics and special monitoring
- Using PI Alarm View and PI ACE for PM&DC's Alarm Management System
- All based on the foundation of the PI data collected and stored at each plant

Entergy PM & DC Monitoring Tasks

- Unit trip monitoring and diagnostics
  - Plants can use extra eyes during upsets
- Unit Start-up monitoring
  - Complex process with many opportunities for error
- Routine monitoring
  - Looking for early signs of emerging equipment problems or failed instrumentation
- Purchased Advanced Pattern Recognition (APR) software to greatly enhance anomaly detection capability and data mining
- Performs special analysis requested by plants - lost MWs, performance issues, and equipment problems

Entergy PM & DC Benefits

- Early identification of changes in equipment physical, thermal, operational & environmental performance
- Improved ability to mitigate degrading equipment condition and unit performance
- Improved ability to maximize unit value considering current market opportunities
- Leverage expertise and technology
- Enhanced teamwork

Entergy PM & DC Results

- PM&DC Benefit to cost:
  - First year: 2 to 1
    - Including initial set up cost
    - O&M dollars only
  - Ongoing after first year 3 to 1
    - O&M dollars only
  - Ongoing after first year 8 to 1
    - O&M + fuel & replacement power)
- Catches:
  - First year 252
  - Ongoing 400-500 / yr

GenOn Driving Factors for OSIsoft Solution

Problem: Many disparate plant systems and the need to turn data into actionable information

- DCS, PLC, CEMS, Analyzers…
- Various timestamps
- Data accessibility & integrity

Solution: OSIsoft, Enterprise Wide Infrastructure

- Common real-time database
- Common visualization and analytic toolset
- Common technology for development and advanced analytics
- Leverage SMEs (Central & Plant)

IPP, not a utility requires effective maintenance practices

GenOn OSIsoft Continuous Value Proposition

- Fleet Wide Deployment 2002
- Condition Based Maintenance on Critical Assets 2004
- Advanced Pattern Recognition Fleet-wide Rollout 2005
- Water Chemistry Automation 2007
- Automated Operator / Maintenance rounds 2008-2010
- Environmental Monitoring 2008
- Proactive Maintenance Data Gateway 2009-2011

Every phase a business value and positive ROI

GenOn Boilers Highest Lost Margin System

Boilers – "The Race Car Tire of Power Generation"

- Highest Lost Margin Opportunity
- Most outages / de-rates
- Improve Water Chemistry
  - Make visible via PI
  - Transformation of data
- Track Temperature Excursions

Highest LMO makes easy ROI with technology solution…

GenOn Water Chemistry Automation

- Improve and interface to analyzers
- Cycle Water Chemistry screens
- Response Procedure Reports (EPRI standards)
- Calculate minutes in / out of spec
- Notifications on limits

Transform and use data in a new way…

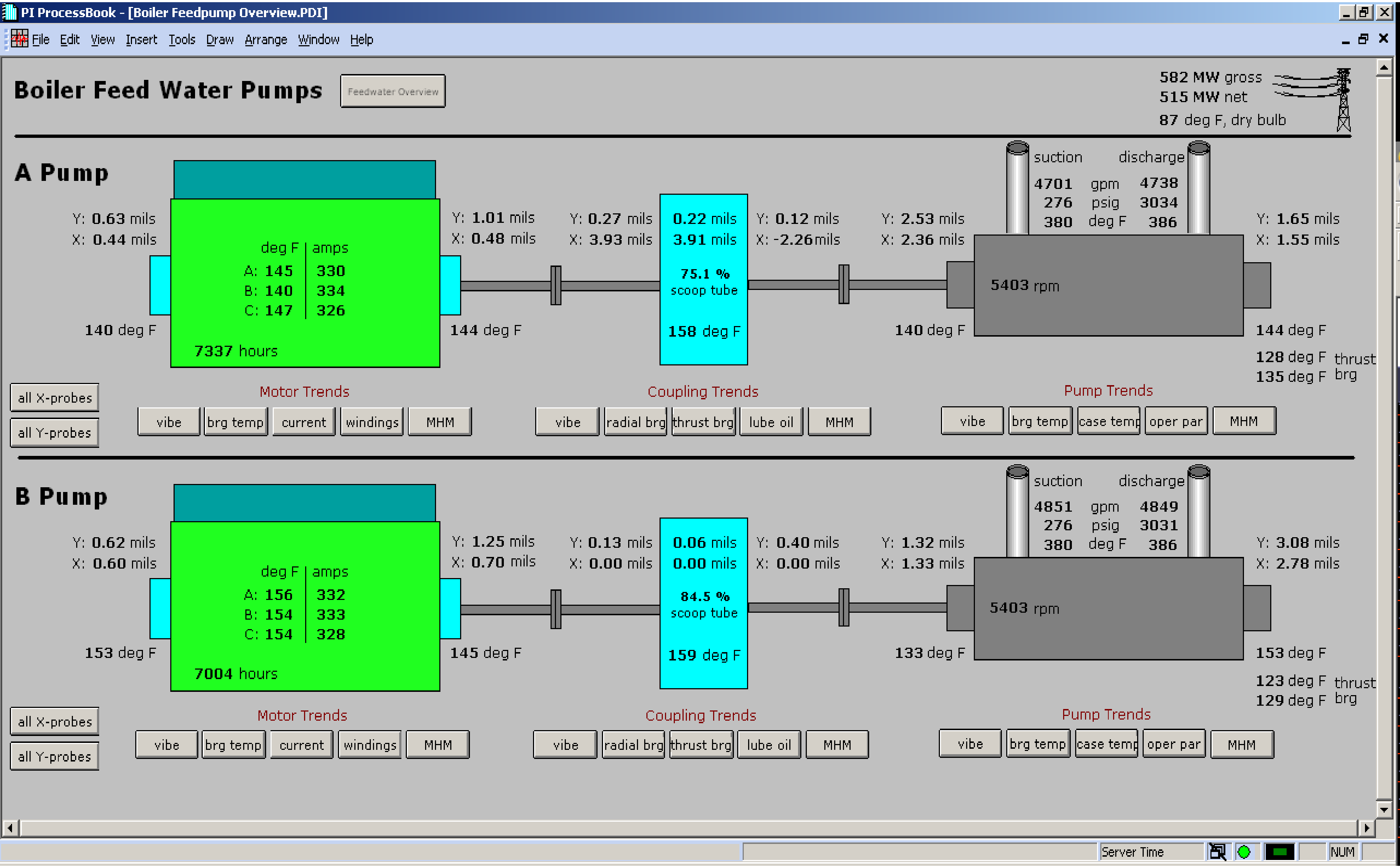
GenOn APR Modeling

Business case developed from history :

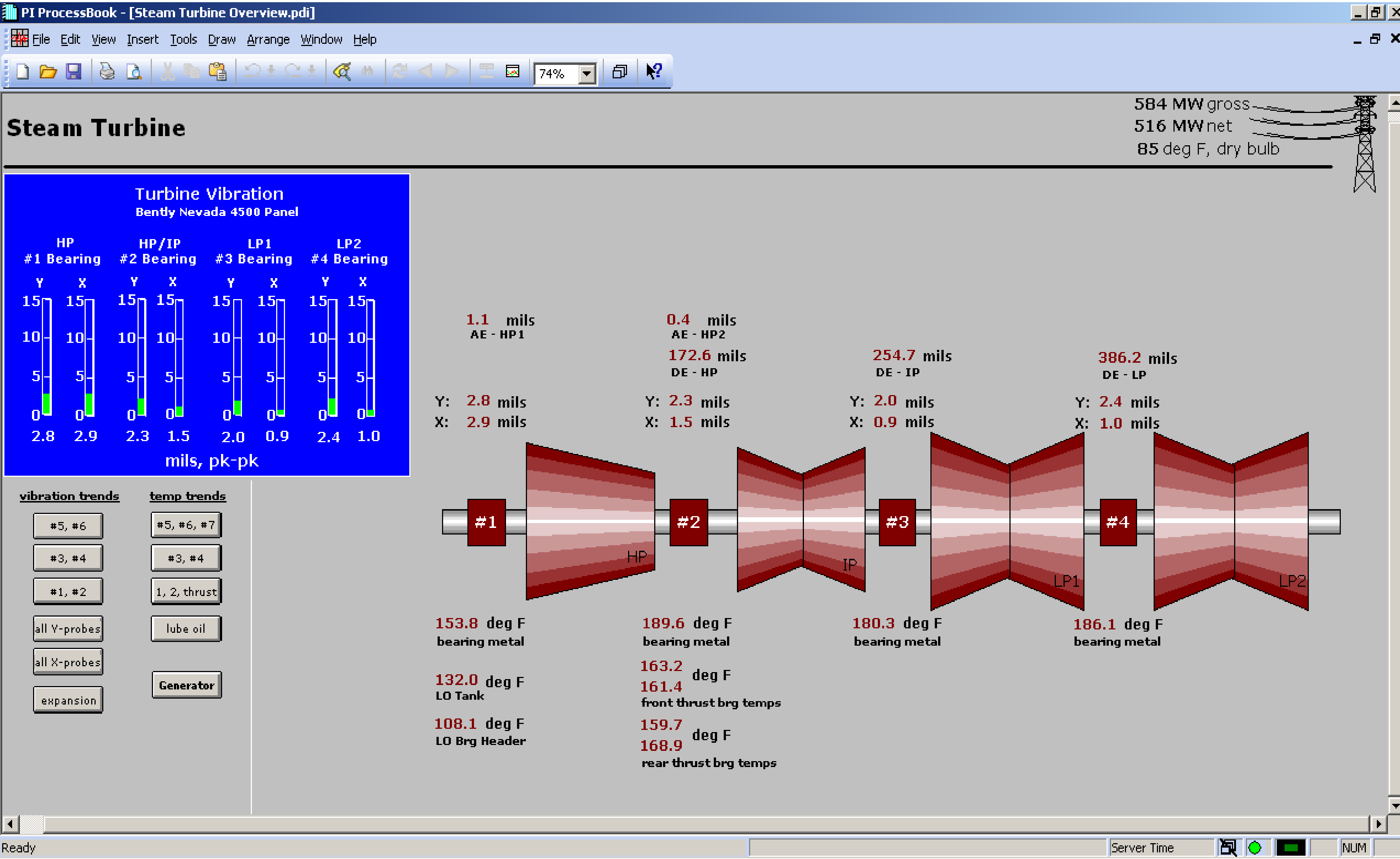
- Review equipment failures
- Outages and related lost margin
- Combined cycle plant pilot had 5 catches (~value $948K)
- Decision to apply fleet wide
- Model critical systems and equipment

Very intelligent rules based monitoring of critical systems…

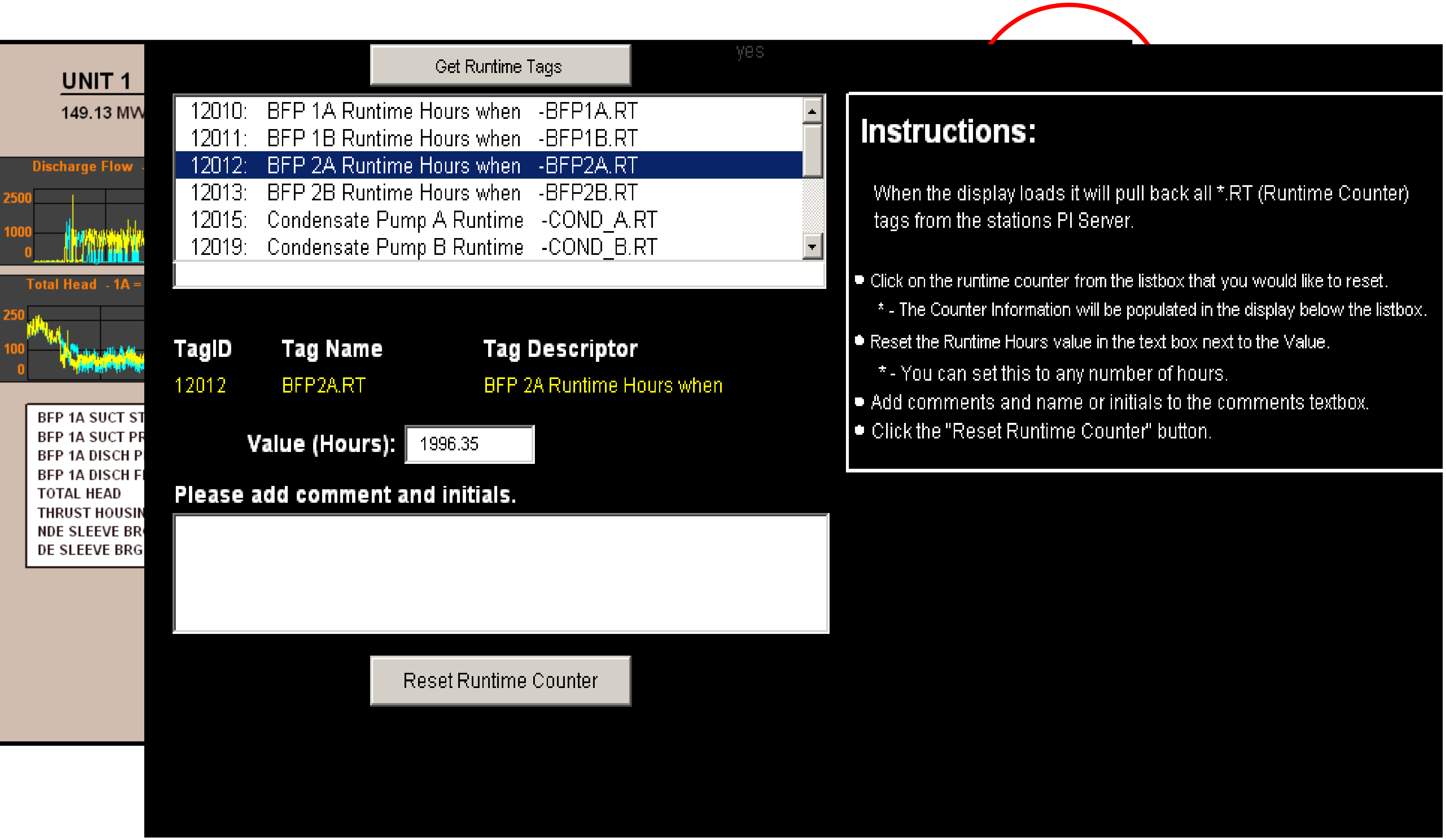
Proactive Maintenance Monitoring



Proactive Maintenance Monitoring



Condition Based Maintenance Screens

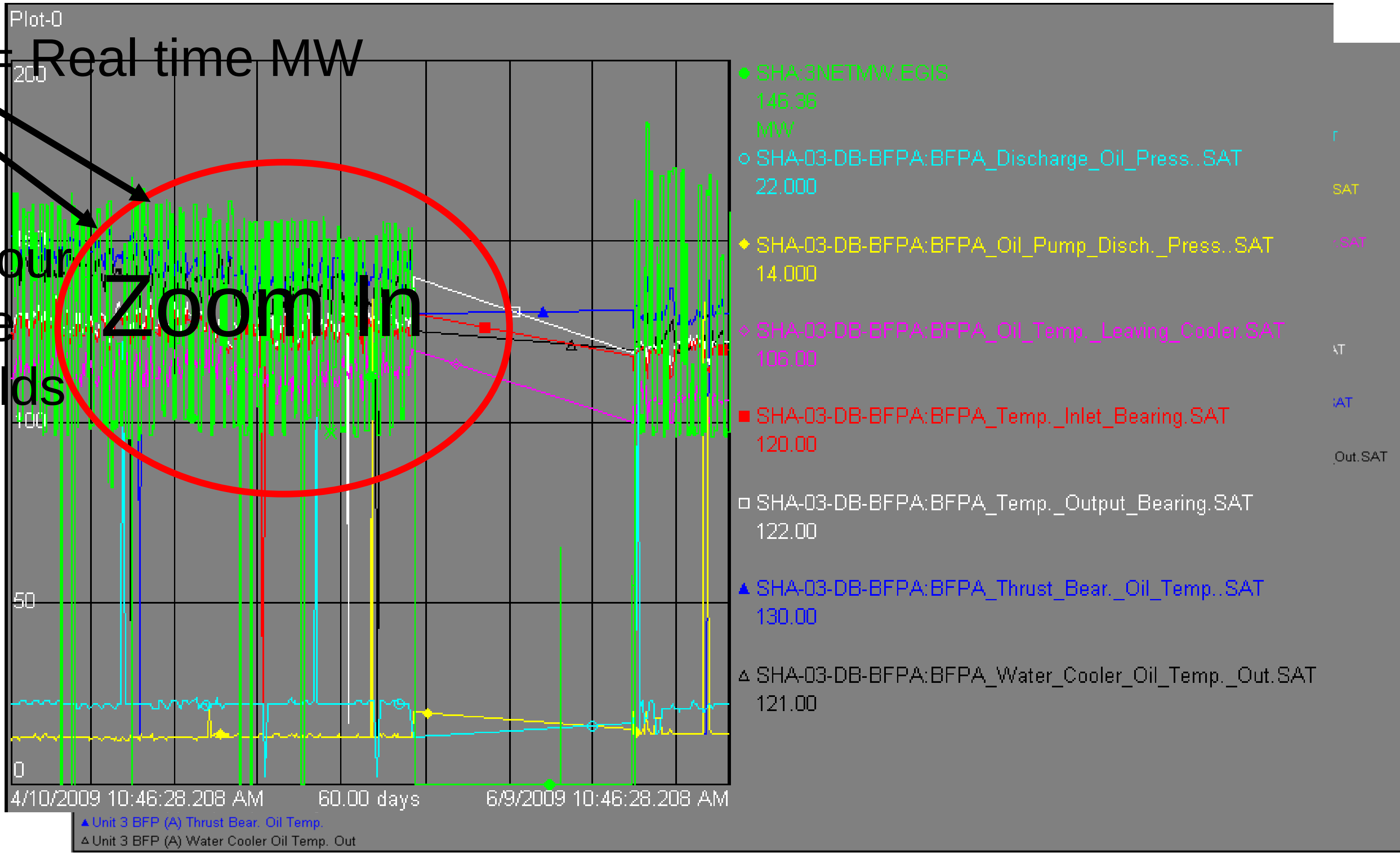


Manual Round Data Correlation

Green = Real time MW

Data Taken every hour from the handhelds

Zoom In



Boilers – Highest Loss Margin System

Most outages / de-rates are boiler related

– Transformation of data to useful information

Water Chemistry

Improve and interface to analyzers

- Cycle Water Chemistry screens
- Calculate minutes in / out of spec
- Notifications on limits
- Make visible via PI system

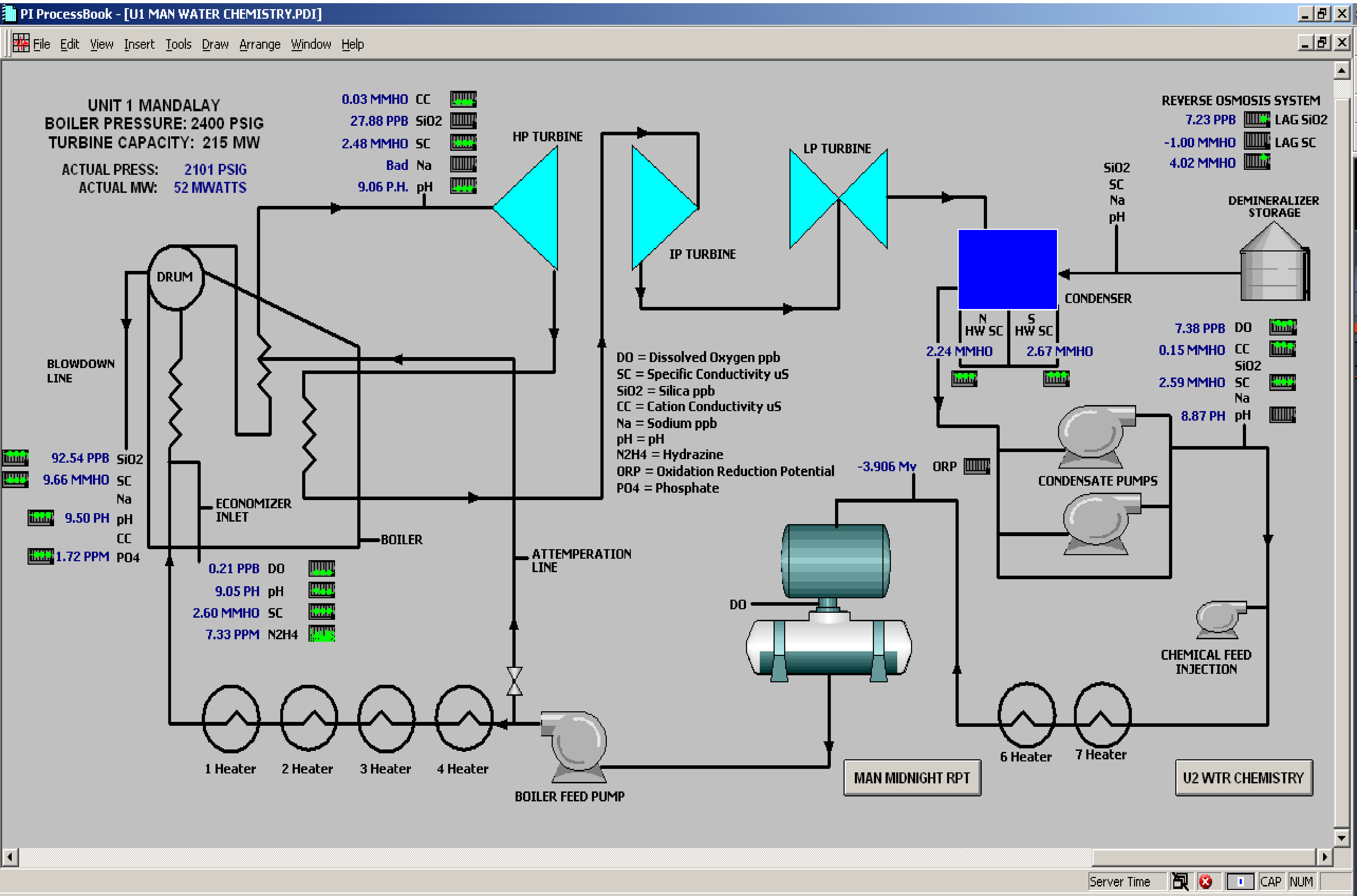
Boiler Tubes Temperatures

Systematically track:

- How many excursions?
- Length of excursions?
- Total time out of specification…
- Maintain instrumentation!

Transform and use data in a new way…

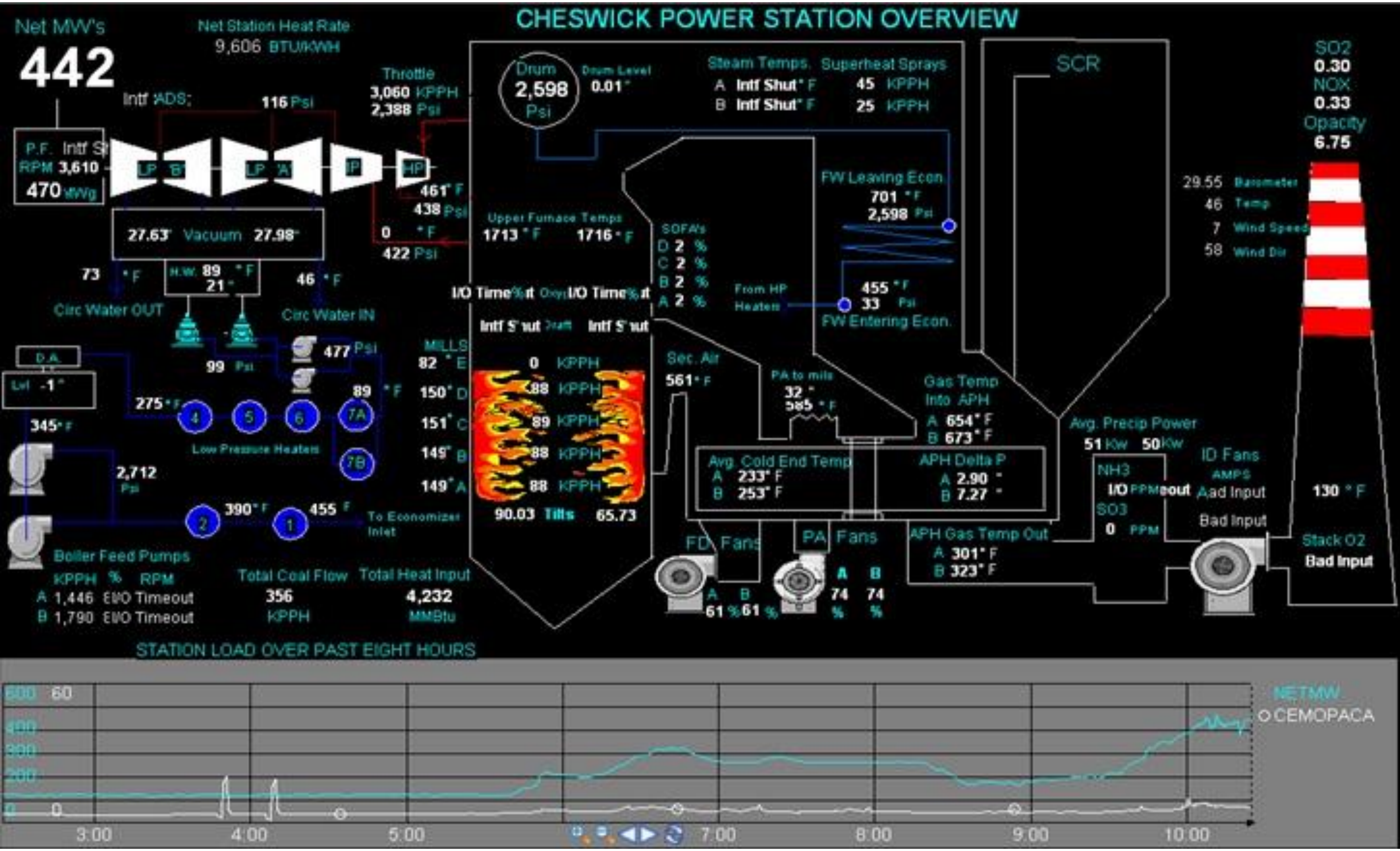
Water Chemistry Displays



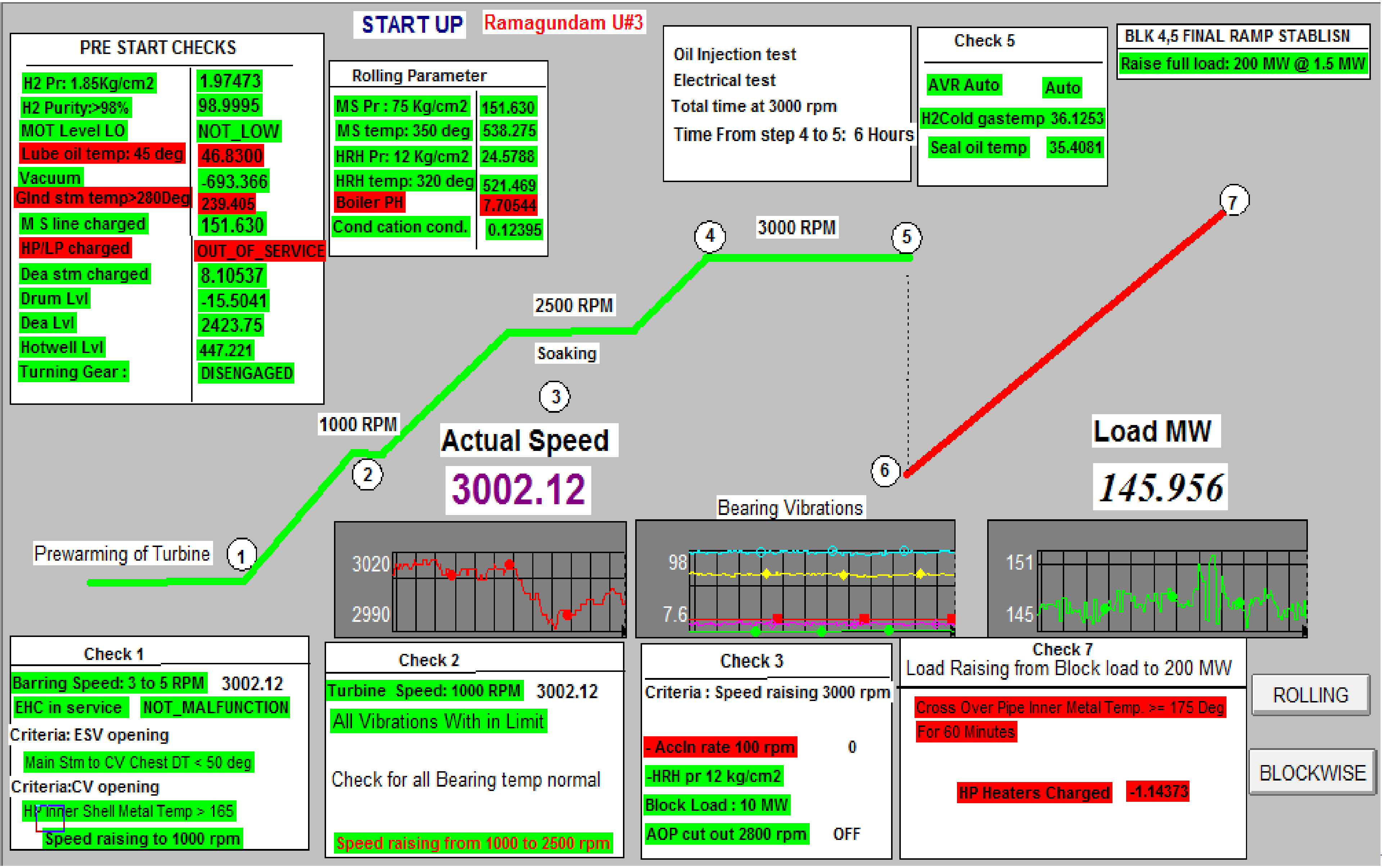
Water Chemistry - Reports

PARAMETERS:	EXPECTED RANGES	UNIT 1: MIN FOR DAY	AVG FOR DAY	MAX FOR DAY	MINS IN NORMAL	MINS IN ACTION LVL 1	MINS IN ACTION LVL 2	MINS IN ACTION LVL 3	MINS IN ACTION LVL 4
Condensate Pump Discharge									
pH	9.2 - 9.6	9.40	9.43	9.46	1440.00	0.00	0.00	0.00	0.00
CC - CPD A, µS/cm	< 0.2	0.09	0.10	0.11	1440.00	0.00	0.00	0.00	N/A
Dissolved Oxygen, ppb	< 10	2.55	3.03	3.53	1440.00	0.00	0.00	N/A	N/A
Sodium, ppb	< 3	0.09	0.09	0.10	1440.00	0.00	0.00	0.00	N/A
Boiler Feedwater									
pH	9.2 - 9.6	9.31	9.32	9.33	1440.00	0.00	0.00	0.00	0.00
Cation Conductivity, µS/cm	< 0.2	0.04	0.04	0.04	1440.00	0.00	0.00	0.00	N/A
Specific Conductivity, µS/cm	4 - 11	7.86	7.90	7.99	1440.00	0.00	N/A	N/A	N/A
Dissolved Oxygen, ppb	1- 10	8.57	8.99	9.82	1440.00	0.00	0.00	0.00	N/A
Sodium, ppb	< 3	0.12	0.13	0.15	1440.00	0.00	0.00	0.00	N/A
Boiler Water (Drum Blowdown)									
pH - T1Drum Blowdown A	9.2 - 9.6	9.13	9.16	9.21	158.35	1281.65	0.00	0.00	0.00
CC - T1 BLR 1 Water	< 1.0	0.20	0.22	0.24	1440.00	0.00	0.00	0.00	N/A
SC - T1 Drum Blowdown	4 - 11	5.26	5.30	5.38	1440.00	0.00	N/A	N/A	N/A
Silica - T1, ppb	< 60	41.69	44.11	49.17	1440.00	0.00	0.00	0.00	N/A
Sodium - T2, ppb	< 300	3.89	10.22	20.74	1440.00	0.00	0.00	0.00	N/A
Saturate Steam (Drum Steam)									
CC - T1 Drum Steam, µS/cm	< 0.2	0.13	0.14	0.15	1440.00	0.00	0.00	0.00	N/A
Degas CC - T1 Drum Steam, µS/cm	< 0.2	0.09	0.09	0.09	1440.00	0.00	0.00	0.00	N/A
SC - T1 Drum Steam, µS/cm	4 - 11	7.70	10.28	16.36	1027.47	412.53	N/A	N/A	N/A
Silica - T1, ppb	< 10	3.81	4.07	4.83	1440.00	0.00	0.00	0.00	N/A
Main Steam									
Degas Cation Conductivity, µS/cm	< 0.15	0.10	0.10	0.11	1440.00	0.00	0.00	0.00	N/A
Silica, ppb	< 10	4.99	5.51	6.39	1440.00	0.00	0.00	0.00	N/A
Sodium, ppb	< 2	0.11	0.12	0.13	1440.00	0.00	0.00	0.00	N/A

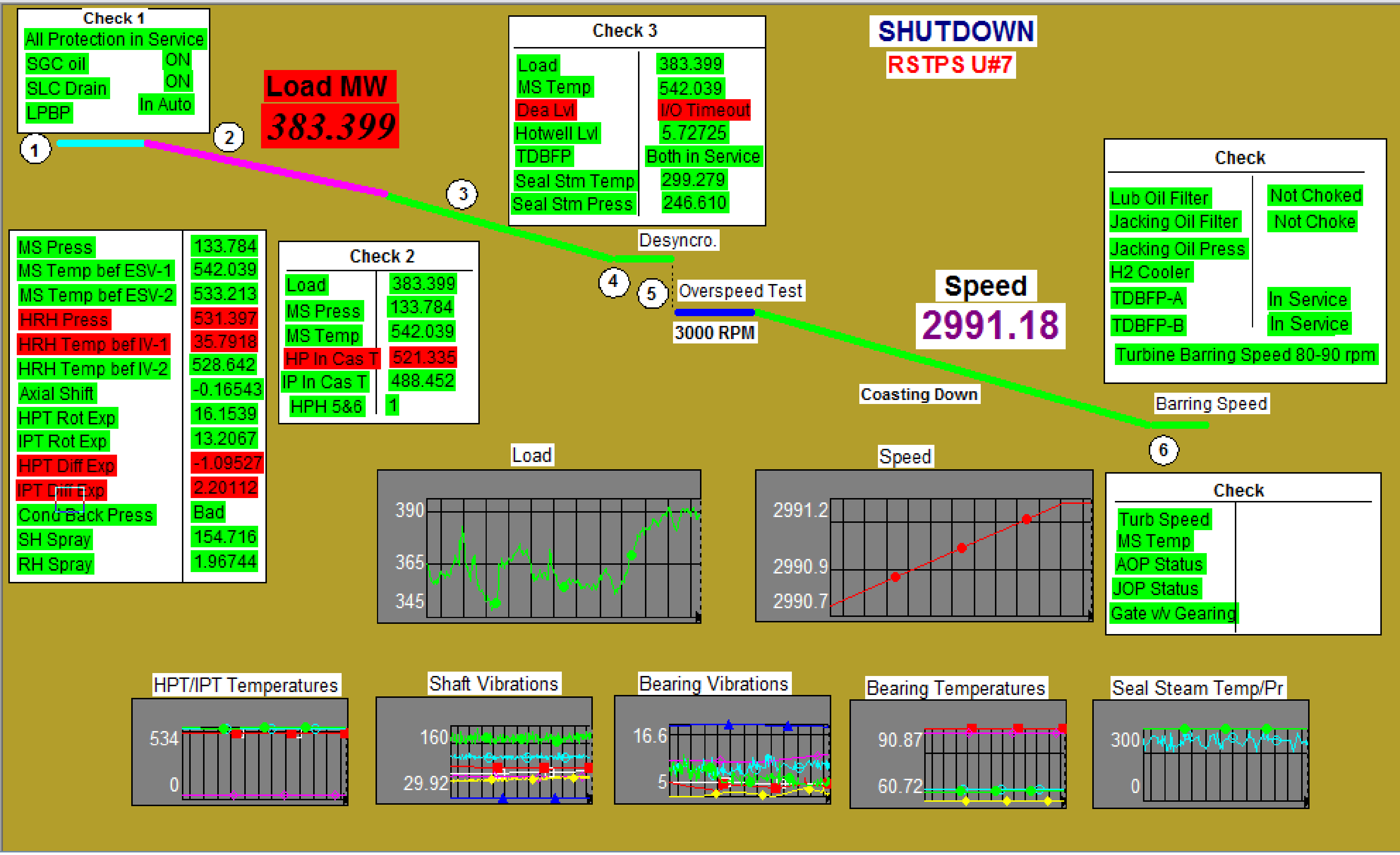
Operations


CHESWICK POWER STATION OVERVIEW
Net MW's
442
Net Station Heat Rate
9,606 BTU/KWH
Throttle
3,060 KPPH
2,388 Psi
Drum
2,598
Psi
Drum Level
0.01
Steam Temps.
Superheat Sprays
45 KPPH
25 KPPH
SCR
SO2
0.30
NOX
0.33
Opacity
6.75
FW Leaving Econ
701 °F
2,598 Psi
Upper Furnace Temps
1713 °F
1716 °F
SOFA's
From HP Heaters
455 °F
33 Psi
FW Entering Econ.
Circ Water OUT
Circ Water IN
Low Pressure Heaters
MILLS
Sec. Air
561 °F
PA to mills
Gas Temp Into APH
A 654 °F
B 673 °F
Avg. Precip Power
51 Kw
50 Kw
ID Fans
AMPS
Bad Input
Avg. Cold End Temp
A 233 °F
B 253 °F
APH Delta P
A 2.90
B 7.27
NH3
SO3
APH Gas Temp Out
A 301 °F
B 323 °F
Stack O2
Bad Input
FD Fans
PA Fans
Boiler Feed Pumps
KPPH % RPM
A 1,446 I/O Timeout
B 1,790 I/O Timeout
Total Coal Flow
356
KPPH
Total Heat Input
4,232
MMBtu
To Economizer Inlet
90.03 Tilts 65.73
29.55 Barometer
46 Temp
7 Wind Speed
58 Wind Dir
130 °F
STATION LOAD OVER PAST EIGHT HOURS
NETMW
CEMOPACA
3:00
4:00
5:00
7:00
8:00
9:00
10:00

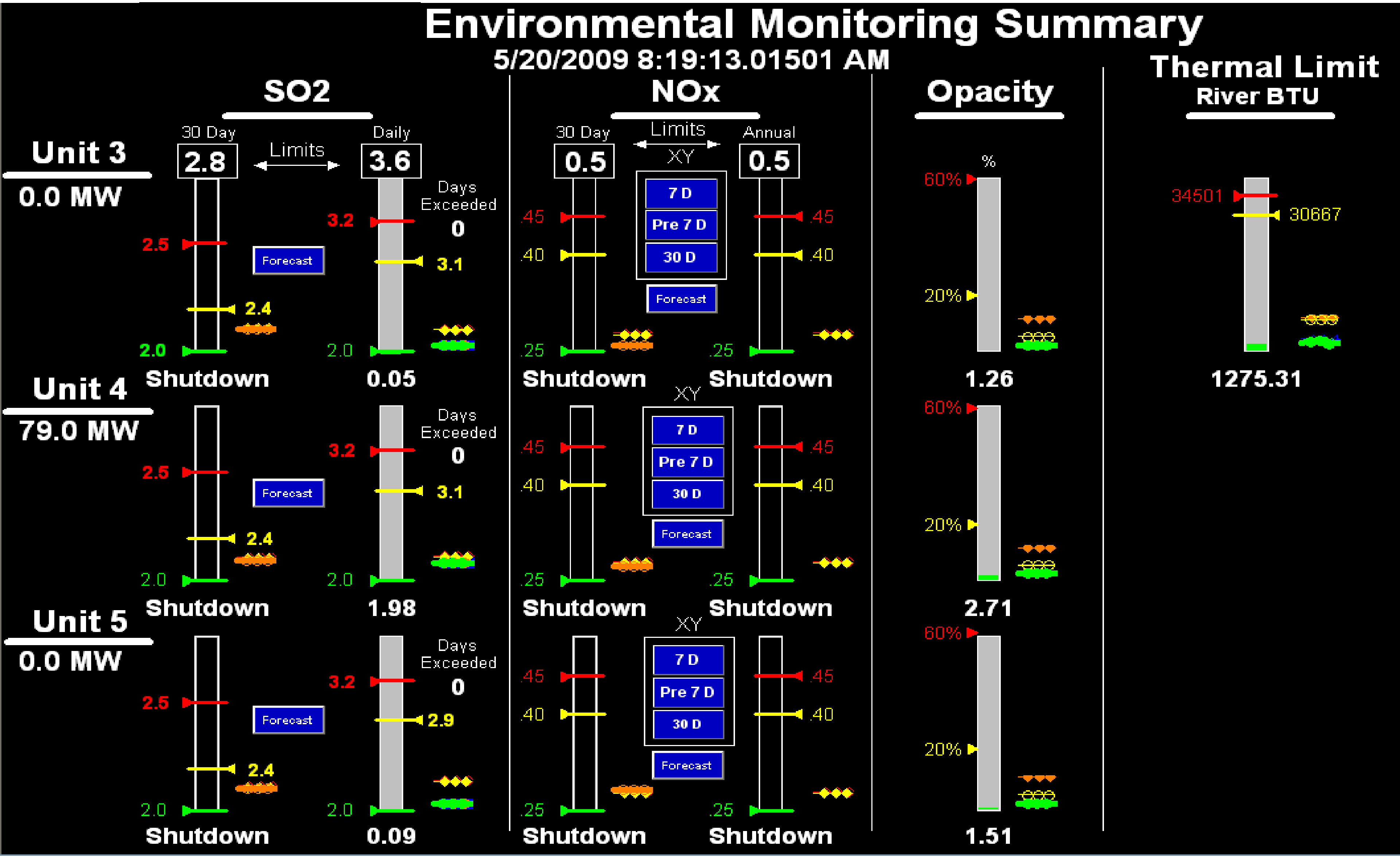
Non-routine Operations : Start-Up



Non-routine Operations : Shut-Down



Environmental Monitoring



Advanced Pattern Recognition (APR) Modeling

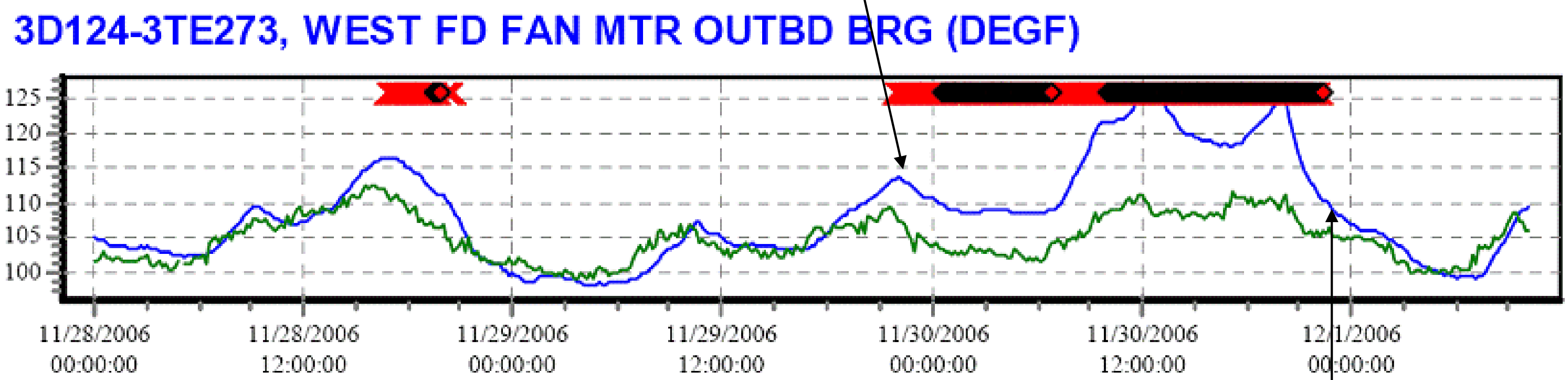
Predictive Analytics leverages the PI system

- *Computers working for you!*
- Reduces Manual Monitoring
- Detects anomalies across a fleet of assets
- Early detection of slow developing failure
- Multiple sensor models, not just a single signal
  - Avoiding failures
  - Supporting Operations
  - Optimizing Maintenance

Rules based monitoring of critical systems.
Computer models watching the data all the time.

Catch- Fan Motor Bearing

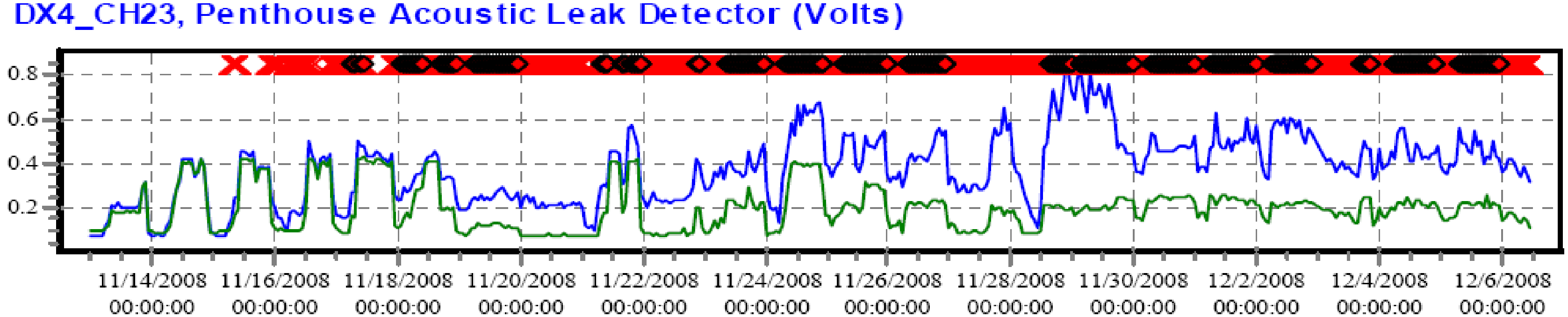
This is a pretty significant movement on FD Fan Motor outboard bearing (about 17 degrees above expected currently).



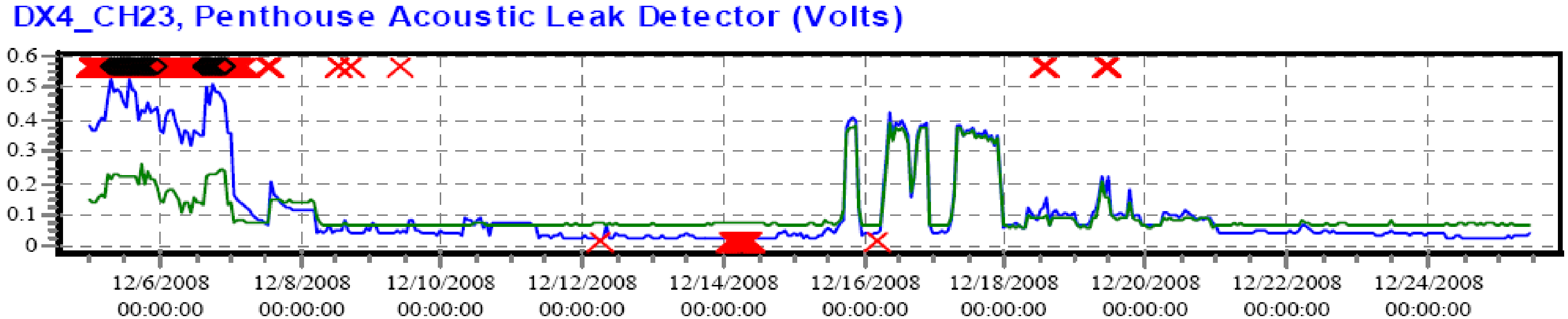
After detection, the filters were found dirty, replaced, and the oil level and temps are dropping on the motor after the change out.

Cool Catch PI & SmartSignal

Background: A boiler acoustic detector system was installed and the data was integrated into OSI PI. A SmartSignal model was created from the statistical data. The Plant engineer noticed an increase in the Unit Penthouse Acoustic Leak Detector.



Resolution: The problem was looked into while the unit was offline and a small tube leak was discovered in the penthouse. The leak was repaired and the penthouse acoustic leak detector has returned to historically normal levels, avoiding a potential forced outage.



In Conclusion…

- PI System can support condition monitoring straight out of the box
- The goal is to “get everything” in the operation, create a comprehensive and time synchronized correlated database (including PdM data)
- Everything means DCS, analyzers, PdM data, CEMS (emissions), PLCs, weather, market prices, …
- The more dynamic the information, the better
- Condition monitoring forms the foundation for predictive analytics where big ‘catches’ can be made
- Condition Monitoring forms the foundation for Conditioned Based Maintenance which is core to a Proactive Maintenance culture
- Proactive Maintenance insures a safe, available and highly reliable asset operated at the lowest life cycle cost

Quotes: Mahatma Gandhi

“Strength does not come from physical capacity. It comes from an indomitable will.”

“You must be the change you want to see in the world.”

“Whatever you do will be insignificant, but it is very important that you do it.”

“An ounce of practice is worth more than tons of preaching.”

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