

OPERATION AND PROCESS DATA: The Forgotten Predictor

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ABSTRACT

The focus in maintenance and reliability has been on using proven individual diagnostic tools:

- Vibration Analysis
- Thermographic Inspection
- Ultrasonic Inspection
- Motor Circuit Analysis
- Oil Analysis

This evolution of predictive tools has led to operating pressure, temperatures and other indicators captured by equipment operators, data loggers or maintenance personnel to be often overlooked. Open Standards such as OLE for Process Controls (OPC), the Machinery Information Management Open Systems Alliance (MIMOSA), and Open Operations and Maintenance (Open O&M), emerging technology and the internet allow us to now trend; analyze equipment data and PdM results to provide near real time enterprise asset analysis. The ability to quickly apply rule based analysis of process data enables continuous feedback to the diagnostic algorithms. Quick access to Key Performance Indicators (KPI's) enables system experts to provide maintenance action recommendations, remote troubleshooting analysis and improved Enterprise Operational Equipment Effectiveness.

The United States Navy surface fleet has implemented an enterprise solution for diagnostic decision support utilizing process and operational data and installed PdM technologies. Through the reverse distance support (RDS) initiative more than 90 ships transmit data to shore and subsequently receive maintenance action reports from shore based machinery subject matter experts providing enterprise diagnostic information. This has led to maximizing maintenance dollar expenditures, mitigation of ship visits by Tech Reps, and reduction in unplanned maintenance actions.

The U.S. Navy has developed and implemented an effective performance analysis reporting system by:

- Identifying the critical assets to be monitored

- Performing Fundamental Engineering, Gap and Data Analysis
- Analyzing the existing IT Infrastructure and Host Option Selection
- Validation and Testing of Rules and Data Integration
- Integrated System Deployment

INTRODUCTION

The U.S. Navy utilizes a machinery information data acquisition system known as the Integrated Condition Assessment System (ICAS). ICAS is a Commercial Off The Shelf (COTS) software product developed by IDAX Inc. for which the U.S. Navy holds the Government Purchase License Rights (GPLR). The Navy is currently feeding that ICAS information into an Internet Web tool known as the Maintenance Engineering Library Server or (MELS). The backbone of MELS is a diagnostic engine that provides a common framework for applying user-defined prognostic and diagnostic algorithms to data in order to produce high-level "Quick Look" system health assessments.¹

This information drives a detailed view of system/equipment diagnostic analysis results known as the Integrated Performance Analysis Report, (IPAR). The collection of the IPAR information is then consolidated into a view of system performance at the enterprise level. This Enterprise Performance Analysis Report or EPAR can then provide performance-driven analysis to support operation and maintenance decisions at the enterprise level. The analysis tool can easily progress from the enterprise level view down to the component level view. Expert analysis in the form of Reverse Distance Support (RDS) is the process where the Subject Matter Experts, (SME's) receive automated reports of a specific ship system health to provide expert analysis and recommendations back to the sailor/maintainer if needed.

EQUIPMENT OPERATING DATA AS MAINTENANCE DECISION SUPPORT TOOL

This success of IPARs and EPARS would not be possible without the ability to quickly analyze the equipment operating information. Many companies have data historians or distributed control systems that also capture

and log equipment operating information as well and could utilize similar analysis and reporting techniques as used by the Navy. Operators and maintainers have a wealth of information at their fingertips just like the individual sailor on a ship has the ability to view the majority of parameters affecting the operation and performance of their plant. In fact the average machinery monitoring system on a modern ship will have over 1000 sensors being automatically monitored and over 350 other parameters that can be entered by technicians using a PDA type device. This leads to the condition many of us have faced, the reality of being data rich and information poor.² Most machinery monitoring systems allow you to view the Air Conditioning plant chill water out of the system. Some of you may even have a system that allows you to trend the parameter for the last 30 days. But what maintenance decisions can be made from that information? Well not many, depending on your data historian you may be able to plot the parameter over the period and see fluctuations. Other than normal operating variations what is this information telling you? Not a lot, other than an indication of whether your unit is providing cold water.

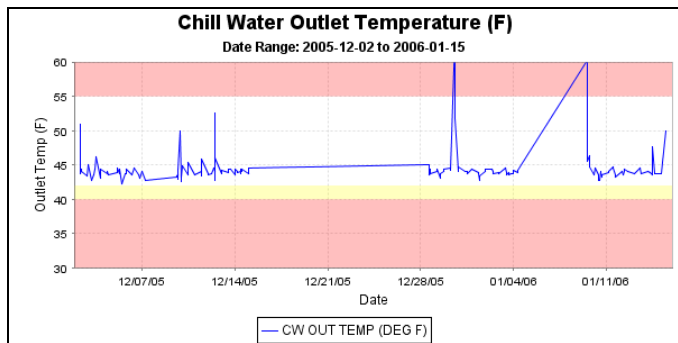


Figure 1 Chill Water Outlet Temperature Graph

You don't have any idea what other factors may or may not be contributing to the plant not producing chilled water. But, if you were able to get an indication that chill water temperature was high and other trended information like the load on the unit and liquid line temperature, over a defined operating period now you might have something. Armed with this data you may now have enough information for an informed assessment/analysis of system health. Well in the Navy that ability exists today with access to MELS.

Maintenance Engineering Library Server (MELS)

MELS is a web based server which allows access to machinery operational data in near real time. The ship specific operating data, logged via ICAS is imported into a COTS (Oracle) relational database. Once the data is uploaded the condition monitoring software is no longer needed since MELS is viewable through standard Internet browsers.

Once logged into MELS, a simple Header and Tree display allows for selection of the machinery system and ship information to be displayed.

IPAR Data Analysis Screens (DAS)

The display allows for selection of the machinery system and ship information to be displayed The IPAR Data Analysis Screen from an ARLEIGH BURKE (DDG-51) class ship's Air Conditioning (A/C) Plant is displayed. This could just as easily be displaying the information for the air conditioning plant at your facility. The viewer presented with a quick look checklist that shows the overall status of the entire A/C system as well as the individual A/C units.

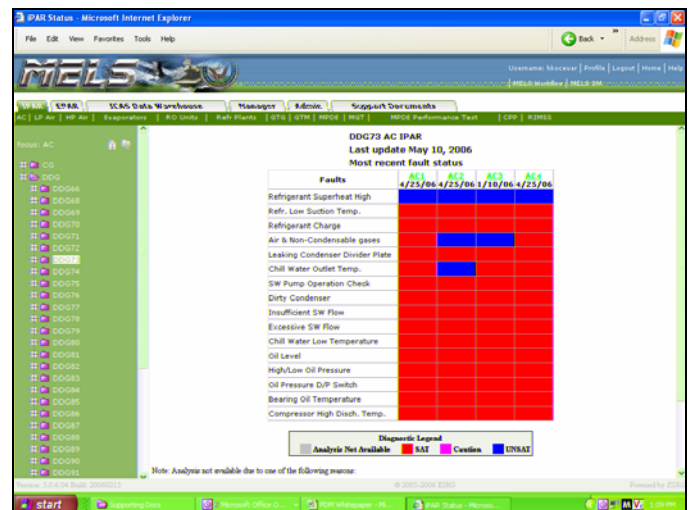


Figure 2 A/C IPAR Screen

Reverse Distance Support (RDS)

Remote monitoring is used to send data to a shore infrastructure and again provide close to near real time evaluation of monitored systems. This is where the real power of the IPAR is utilized in a work flow process called Reverse Distance Support (RDS). In the RDS process, the shore Subject Matter Experts (SMEs) provide feedback to the ship on problems identified or trends that require further investigation. This is accomplished when periodic reports of the systems covered by IPARS are automatically sent to expert technicians located at Regional Maintenance Commands who review the RDS status reports and comment back to the ships on abnormal conditions noted. The shoreside experts also have the ability to change the system health indicator color based upon their review.³

Additionally, the technical expert has the ability to start a work order request detailing recommended maintenance tasks needed to correct the indicated fault. This link is made to the existing Navy workflow system by starting the development of the Navy workflow form the OPNAV 4790.2K commonly called a 2Kilo.

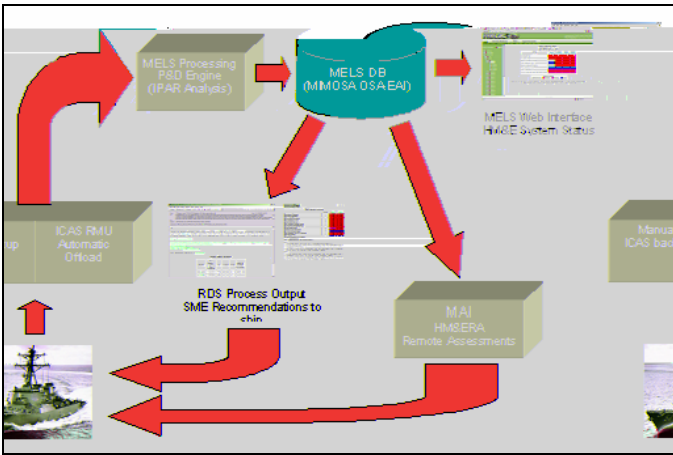


Figure 3 MELs Process Overview

**RDS IPAR Summary Report
System Status Summary**

IPAR includes data through 3/30/2006

System	SAT	Caution	UNSAT	Data not available for Review
AC	48	0	3	13
LP AIR	10	0	0	5
RO	19	0	1	0
REFR	21	0	5	4
GTG	18	0	0	15
GTM LO	22	0	0	10
GTM PAIR	0	0	0	6
GTM PERF	12	0	1	20
CPP	16	3	5	10

Figure 4 Sample RDS System Status

In addition to its open standard architecture, MELs is centered on two modules which present the data in a standard report format: The Integrated Performance Analysis Report (IPAR) and the Enterprise Performance Analysis Report (EPAR). The amount of information being analyzed requires that the performance data be presented in a concise, standard, repeatable method to minimize SME analysis time. Any SME with a Web browser can quickly logon to the system and determine how an individual machine is performing via the IPAR and/or compare that same machine from a fleet perspective by comparing performance with other similar equipment via the EPAR. In addition to storing the raw process data, MELs processing performs the following functions to ensure accurate analysis of equipment performance:

- Data validation
- Standard / Enterprise algorithm processing
- Web presentation of data
- Individual equipment diagnostics (iPAR)
- Fleet comparison diagnostics (ePAR)
- SME review of IPAR / EPAR
- Distribute RDS reports to ship and maintenance community

Enterprise Performance Analysis Report (EPAR)

The EPAR provides a compiled percentage of the selected system fault occurrences across the enterprise. It arranges the faults in a hierarchical order from the most prevalent fault to the least prevalent for the selected time interval. The EPAR view allows selecting the analysis for monthly, quarterly, semi-annual, or annual time periods.

This analysis view allows for the quick identification of common system abnormalities and their rate of occurrence during the selected time period.

This view also enables analysis of an individual facilities performance against the fleet average. This is accomplished with graphical representation using a Pareto chart. The EPAR view also allows viewing of fault distribution across the fleet via a pie chart, which is effective in focusing maintenance resources on the most critical assets.

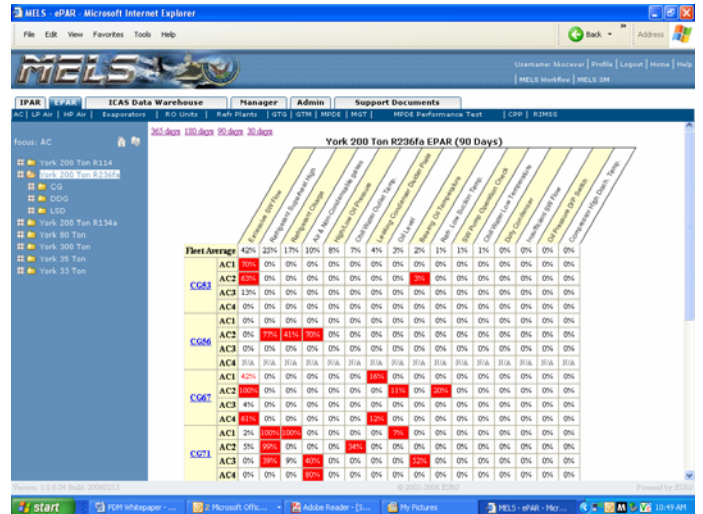


Figure 5 EPAR Page View

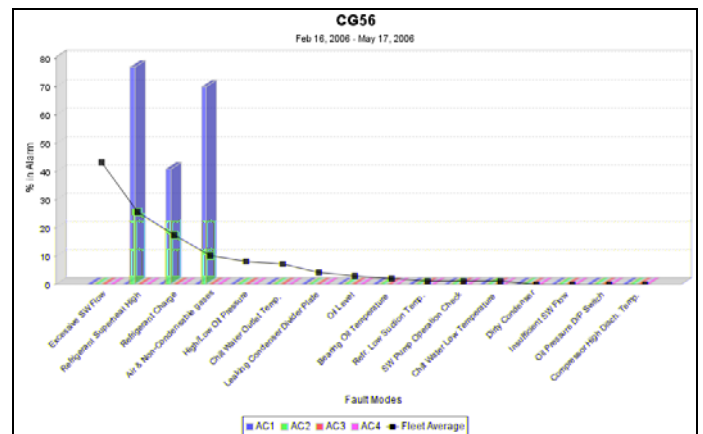


Figure 6 EPAR Fleet Average Pareto

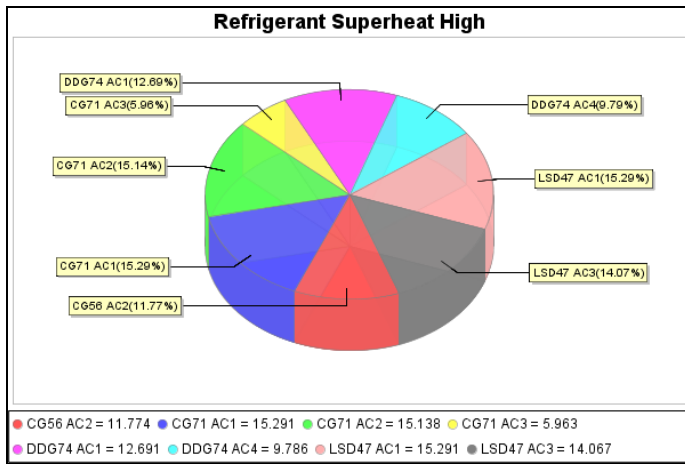


Figure 7 Fleet Fault Distribution Chart

CONCLUSION

Utilizing operating data from the machinery monitoring coupled with expert analysis and the use of other predictive maintenance technologies enables the U. S Navy to now use the wealth of data available to make informed decisions and expert analysis with near real time data from any workstation in the world.

MELS allows for optimum utilization of the maintenance resources to be focused where needed most. Additionally the ability to link the analysis with the work management system creates a closed loop system from enterprise analysis to system work completion.

Future enhancements

The Navy is experiencing much of the same problem as the rest of industry in the aging of the work force and many of the expert technicians are nearing retirement age. Having recognized this loss of knowledge an emphasis has been placed on capturing this system expert knowledge, from technicians whom possess over 30 years of preventive and corrective maintenance experience.

As RDS replies to IPAR analysis conditions found are made a library of standard replies are being compiled. This library will lend itself to being the expert foundation that future standard statements will be built upon. Also this library of replies lends itself to further use in reliability centered maintenance analysis.

This effort is the linchpin in building a 24/7/365 expert system available at a keystroke or mouse click.

However, no sensor or analysis system has yet been found that will replace the senses or reasoning skills of an experienced technician. These analysis tools and knowledge bases are just another tool for the modern technician to have at their fingertips.

Added Value

Utilizing the MELS/RDS process the productivity of machinery assessments has increased dramatically. From June 2005 until May 2006 over 42,000 continuous

assessments have been completed using the MELS/RDS process. By comparing the resource hours required to conduct assessments on just the A/C plants on the participating ships the NAVY has realized a significant saving in resource hours while increasing the probability of early detection of a system fault.³

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2. BP Frontiers Magazine April 2005 The Power of Prediction
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Mr. Krooner, President ESRG, LLC, is a graduate of Old Dominion University (BS Engineering Technology). He has over ten years of experience in operations, planning, and program management in the marine engineering field. He has over seven years experience with designing, developing, and implementing condition based maintenance (CBM) and condition based operations (CBO) strategies within the Navy and commercial industry, using the Integrated Condition Assessment System (ICAS) and the Maintenance Engineering Library Server (MELS) as the primary enabling technology.
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Definitions, Acronyms, Abbreviations

A/C	Air conditioning
COTS	Commercial Off The Shelf
DAS	Data Acquisition System
EPAR	Enterprise Performance Analysis Report
GPLR	Government Purchase License Rights
ICAS	Integrated Condition Assessment System
IPAR	Integrated Performance Analysis Report
KPI	Key Performance Indicator
MELS	Maintenance Engineering Library Server
MIMOSA	Machinery Information Management Open Systems Alliance
Open O&M	Open Operations and Maintenance
OPC	OLE for Process Controls
Pdm	Predictive Maintenance
RDS	Reverse Distance Support
SME	Subject Matter Expert

¹ Enterprise Remote Monitoring, (ICAS & Distance Support) Tomorrow's Vision Being Executed Today
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² BP Frontiers Magazine April 2005 The Power of Prediction

³ ETS 2006 - *Engineering Ships for an Affordable, Integrated Force Reverse Distance Support: Fleet Experience for At Sea Operations*
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