CONDITION BASED MAINTENANCE

A CHANGE IN DIRECTION

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ABSTRACT

Marine engineers have been monitoring and maintaining their machinery by condition for a long time, it is doubtful however, if they have been achieving the full benefits of pursuing this strategy. This article looks at how condition monitoring of platform equipments has developed in the RN, and highlights the change in emphasis that has resulted from the introduction of electronic watchkeeping systems. New technologies now enable condition monitoring data to be processed more effectively, to give better quality and quantitative evidence to support the maintenance decision process, and ultimately lead to extended machinery life and greater savings.

Introduction

The introduction into the RN, during the early 1980s, of the policy of maintenance by condition was expected to:

- Result in increased ship availability.
- Reduce manpower and material costs.
- Lead to less maintenance of healthy machinery.

Despite the considerable experience gained from extensive development work and trials undertaken since Condition Based Maintenance (CBM) was formally introduced, it continues to be difficult to assess the full impact of the initiative. It is considered that the full benefits have not been achieved because ships have not had the tools to manage effectively the Condition Monitoring (CM) data. Insufficient data has been made available to justify properly work packages, and maintenance costs have remained isolated from the maintenance decision process. A change in direction has now occurred with a move away from the development of individual CM techniques towards the implementation of the integrated CBM system with improved data management facilities being given to the ships.

Development

CM relies upon the continuous collection of reliable and repeatable data, which in turn can be used to make well founded maintenance decisions by predicting equipment and machinery failure. The CM introduced as a result of this policy relied mainly on vibration analysis (FIG. 1) with only limited use of other techniques. Unfortunately, the engineer at sea was not given adequate instrumentation to determine the true condition of his machinery. That supplied was manpower intensive, in some cases inaccurate, gave little perceived gain, and in many instances was relegated to the back of the engine room cupboard. Hence, preventive maintenance remained in its pre CM form.

By 1983 it was clear that the policy for expanding the use of CBM was not working and The Naval Equipment Condition Monitoring Committee (NECMEC) was formed, with the aim of putting more drive and purpose into the introduction of the policy into the Fleet. The NECMEC consisted of representatives from:

MoD Headquarters.	Design staffs.
Operational authorities.	Research establishments etc.

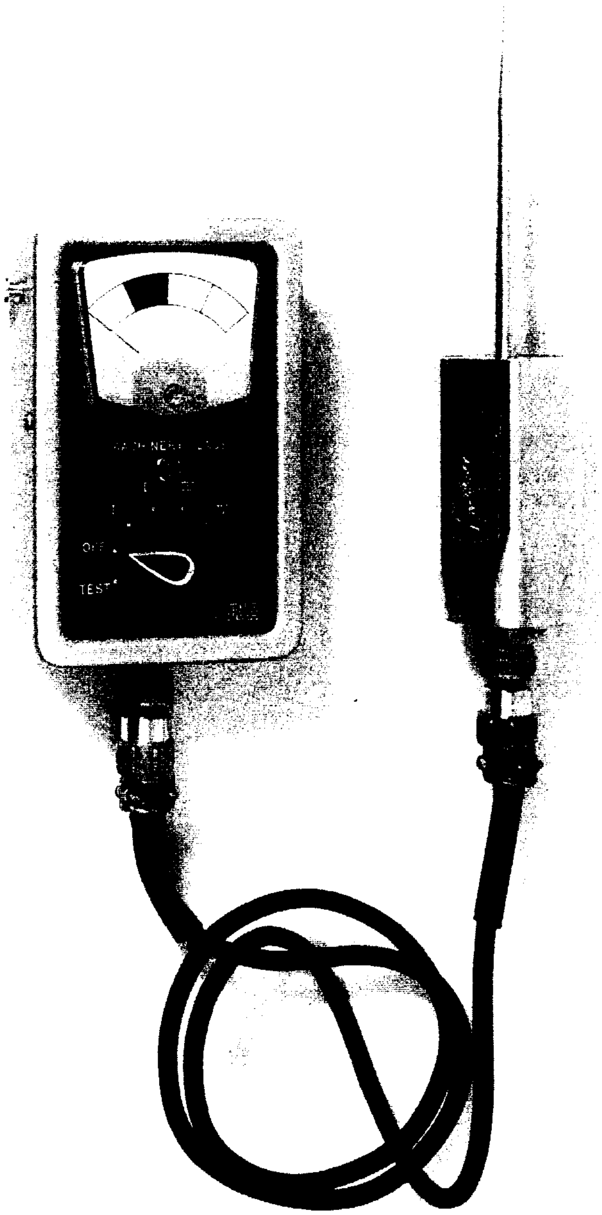

FIG. 1—VISIN METER

The results of the work and studies initiated by this committee led to the introduction into the Fleet of improved monitoring equipment, raised the awareness of the benefits of CM and established a consolidated trials programme. In conjunction with this was founded the principle on which much of todays work is based, that of putting the ability to determine the true condition of his machinery into the hands of the ship's Engineer Officer.

Along with NECMEC, the specialist equipment sections and Fleet teams undertook a large amount of work on assessing and devising ways of determining the condition of major equipments. Much of the work was aimed at engine health monitoring, which is closely related to CM and has a read across in many cases. Apart from advances in Vibration Analysis (VA) techniques, optical inspections, and oil and particle analysis, many of the more exotic techniques needed further extensive development to give them the level of reliability and accuracy required for RN use.

Improved VA monitoring equipment, introduced in the mid 1980's, allowed CinCFLEET engineering staff, as the then maintenance authority, to develop new procedures for routine collection and analysis of vibration data by ship's staff. The Fleet Vibration Analysis (FVA) teams, which were deployed in each of the major bases, were responsible for the overall supervision of the vibration monitoring programme throughout the Fleet. Every ship and submarine carried a number of hand held analogue overall vibration meters and portable spectral analysers, together with a technician trained in its use and in VA. Should the on board specialist not be able to resolve the problem, he called upon the services of the FVA unit, who had more sophisticated equipment and a deeper specialist knowledge.

Towards the late 1980s there were numerous condition monitoring techniques in use. The majority of these could either detect imminent failure or investigate the cause of failure. The engineer officer was thus able to base some of his maintenance decisions on CM information, however, the management of the data was manpower intensive and becoming a burden. In order to achieve more effective use of the CM data, methods of predicting time to failure were required, and more effective means of managing data were essential. Two further trials were therefore initiated in 1988 which had considerable impact on the overall development of CBM:

(*a*) *CM trial*

This was carried out with the aim of assessing the ability of CM techniques to predict failures of marine systems and equipments. It was undertaken in 4 submarine and 5 surface ships using hand held data collec tors to gather mainly vibration data, but also some process parameter from a limited number of equipments. The data was used, in conjunction with computer programmes, to identify:

- The onset of faults.
- Trends.
- Predict time to failure.

The data was collected at regular intervals and sent to an engineering consultancy, who produced a global data base and analysed the overall performance of the equipments. A number of successful predictions were made, cost benefits obtained, and the aims of the trial achieved.

(*b*) *Watchkeeping (W/K) data trial*

This was undertaken on two Type 42 destroyers, to investigate the possible application of computers for more effective management of the vast amount of data which was manually and routinely collected in registers and log books by W/K personnel. On some vessels up to 1000 parameters were manually recorded each day, with many of them being hourly readings. The trial assembled and made visible the sheer quantity of log sheets and registers which were being amassed and enabled the value of the data and frequency of which it was being collected to be scrutinized. Accessing the data was tedious and storage of the records was a continuous headache. The trial demonstrated the ability to replace the paper based W/K system with electronic data collectors and computer programmes to manage and utilise data more efficiently and effectively.

Engineering Audits

The success of both the CM and W/K data trial led to the development and introduction of an Electronic Watchkeeping (EW) system, and this was seen to be a suitable vehicle to incorporate the management of CM data. At the same time, it was also recognized that the earlier introduction of CM techniques into the Fleet had been somewhat piecemeal. New techniques had been added to the maintenance repertoire as they became available, often without being included in the Maintenance Management System (MMS) until considerable time after their introduction. In the main, an equipment and not a systems approach had been taken. Therefore, in conjunction with the design authorities, it was agreed that a systematic approach was required to determine the applicability of condition monitoring to platform equipments. This was called an Engineering Audit, which consisted of 5 main stages:

(*a*) *Criticality Assessment*

Assesses the contribution of each machine or system to the overall effectiveness of the platform. It identifies a justifiable requirement for maintenance, and rules out the more traditional and subjective means of assessing maintenance requirements (FIG. 2).

SYSTEM	ESSENTIALITY RATING			SUPPORT RATING	CRITICALITY RATING	RANK
	ACTION	OPERATIONAL PATROL	HARBOUR SELF CONTAINED			
1. PROPULSION	10	10	1	3	24	4
2. CPP	10	10	1	1	22	5 =
3. STEERING GEAR	10	10	1	1	22	5 =
4. DIESO FUEL SUPPLY	10	10	3	3	26	3 =
5. MAIN PROPULSION S.W.	8	8	1	3	20	6 =
6. MAIN FORCED L.O.	8	8	1	3	20	6 =
7. H.P.S.W.	10	5	3	4	22	5 =
8. FIN STABILIZER	8	5	1	1	15	11 =
9. MAIN HYDRAULIC	8	6	3	1	18	8 =
10. CHILLED WATER	10	8	8	2	28	2
11. POWER GENERATION/DISTRIB.	10	10	10	10	40	1
12. STEAM & DRAIN/FEED & DISTILLED	3	6	5	3	17	9
13. HOT & COLD FW	2	6	8	3	19	7 =
14. HP AIR	8	6	3	3	20	6 =
15. LP/GS/DRY AIR	8	4	3	4	19	7 =
16. SPECIAL SERVICES AIR	8	5	1	2	16	10
17. AUXILIARY SW CIRC.	6	5	3	5	19	7 =
18. FILTERED & CONDITIONED AIR	10	8	7	1	26	3 =
19. BILGE & SULLAGE	1	5	6	1	13	12
20. OM 100	2	5	1	2	10	14 =
21. OM 33	2	5	1	3	11	13
22. OM 113	2	5	1	2	10	14 =
23. DIESO STORAGE, FILLING TRANSFER ETC.	7	10	1	2	20	6 =
24. AVCAT/HELICOPTER REFUELLING	10	8	1	1	20	6 =
25. REFRIGERATION	1	8	8	1	18	8 =
26. SEWAGE TREATMENT	1	5	8	1	15	11 =

FIG. 2—ENGINEERING AUDIT DATA

(*b*) *Equipment Failure Analysis*
Identifies the various modes in which equipment can fail, and takes into consideration the effect of this failure on the overall system. The differentiation between symptomatic and causal information make the analysis of historical data a difficult part of the process. However, these together with an understanding of the types and frequency of failures forms the basis on which to identify the requirement for CM.

(*c*) *Identify the Maintenance Strategy*
Statuary regulations and non critical equipments will still ensure that fixed time and corrective maintenance, form part of the overall maintenance strategy.

(*d*) *CM Parameters*
This identifies the parameters which will predict the onset of a fault, and determines the ability to trend towards failure. The inability to predict the onset of a fault must result in the retention of time based preventive maintenance.

(*e*) *CM techniques*
A thorough understanding of the fault parameters enables the most effective means of monitoring the machine to be derived, with data collected using hard wired or hand held systems.

The output from the audit produced the overall CM requirement for the platform equipment. It detailed CM techniques and the periodicity for collecting data for each item of platform equipments and systems, and this was able to be integrated with the EW data base.

EW systems

Following the successes of the W/K and CM trial, the WM Engineering Ltd MIMIC EW and CM system was developed for the T42s, and was first introduced as an Alteration & Addition in 1991. MIMIC (FIGS. 3&4) was developed to replicate the paper based system and provide more effective management of the

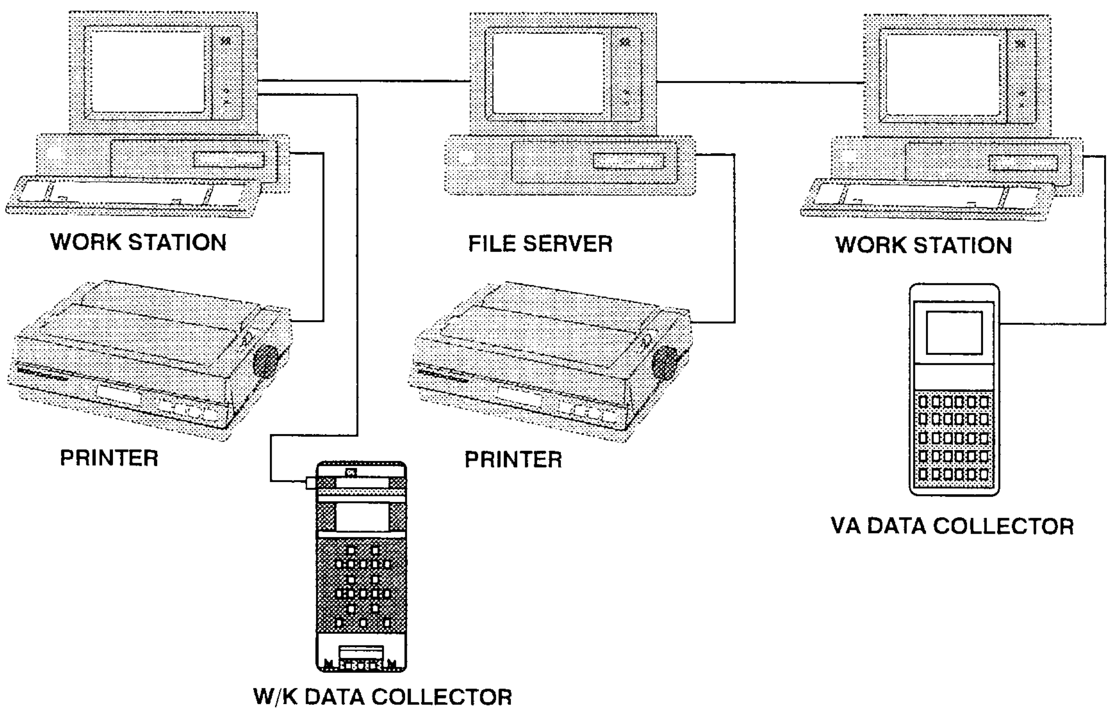

FIG. 3—MIMIC SYSTEM

Fig. 4—T42 SCC MIMIC terminal

W/K data. The system runs in a networked configuration of 3 PCs, that are located in the:

- Ship Control Centre.
- Combined Technical Office.
- After switchboard, which also acts as the file server.

In the event of the failure of the switchboard PC, each of the terminals is able to undertake the role of the file server. Each computer also has a removable hard disk for the storage of data. The whole system is supported by uninterruptable power supplies, which backup the data and enable information to be provided to the watchkeepers in the event of a total power failure. Hand held MIMICMATE data collectors are used to collect W/K data, and IRD Mechanalysis Ltd Fast Tracks VA analysers for CM data. In the T42 platform the system now monitors some 432 machines, and records around 5,800 parameters from 140 various W/K, CM, performance and inspection tours. The main system is menu driven and use is made of 6 main modules:

(*a*) Plant inventory.

(*b*) Tour creation.

(*c*) W/K.

(*d*) CBM.

(*e*) Historical records.

(*f*) System management.

Password control restricts access at various levels according to the identity of the user, and protects functions such as edit-create or edit-delete and those functions which modify parameter warnings and alarms. The Plant Inventory data base holds information on all the equipments managed by the MIMIC system, and this is held in a hierarchical structure:

Plant.
  Area.
    Unit
      Item.
        Measurement Point.
          Parameter (Including alarm levels and data compression codes).

The data base is supported by a code for each level, and this provides a method of identifying the ship, plant, item of equipment and parameter, and can be used to sort data into systems or groups of similar equipments.

Tour creation

W/K and CM involve the recording at specific intervals of selected parameters, these can be hourly, 4 hourly, daily, weekly and even monthly. The data is collected by tours, which are collections of measurements to be taken in order of visiting various locations and use the parameters as identified within the Plant Inventory. W/K and CM tours are created within this module and are given descriptions and unique identification numbers. In addition, view lists can be created which allow the Marine Engineer Officer of the Watch to view readings from similar machines, that are being recorded on different W/K tours or compare with other readings from the data base.

W/K

Machinery operating parameters are collected by the Marine Engineering Mechanics (MEMs), using ruggedised MIMICMATE hand held data collectors. Rounds routes are downloaded into the MIMICMATE from the host PC in the

FIG. 5—MEM ON WATCHKEEPING TOUR

control room, with the information transfer via a plug in lead. Cradle mounted communication facilities have also been developed to overcome the problem of cable terminal failures. The MEM carries out the rounds on the route as detailed by the prompts which appear on the MIMICMATE screen (FIG. 5). Readings or value of parameters are entered manually at each designated measurement point. At the end of the tour, the information collected is uploaded into the host PC. MIMIC will automatically display any missed readings and any parameter in warning or alarm from the tour which has just been completed. Numerous other facilities are available within MIMIC to present the data to the W/K team in different formats:

(*a*) Print of logsheets for last 4 hours.

FIG. 6—FAST TRACK

(*b*) Print of log sheets for last 24 hours.
(*c*) Print of missed/alarm readings for last 24 hours.
(*d*) Display 48 hour trend graphs.
(*e*) Log of stop/starts for key equipments.
(*f*) Logistic records/night round report.
(*g*) Machine status reports.

CBM management

This module is similar to the W/K Module, but manages CM data. It operates with the same Plant Inventory and Tour Creation modules, but uses portable VA analysers to record both vibration spectra and process parameters, the latter being manually entered via a key pad (FIG. 6). Data transfer is by the same means as for the MIMICMATE. On completion of CM tours, the data is uploaded into the host PC, and can then be reviewed similarly to the W/K data, with warnings, trend displays and numerous facilities to display and assist the analysis of vibration spectra and other CM parameters (FIG. 7).

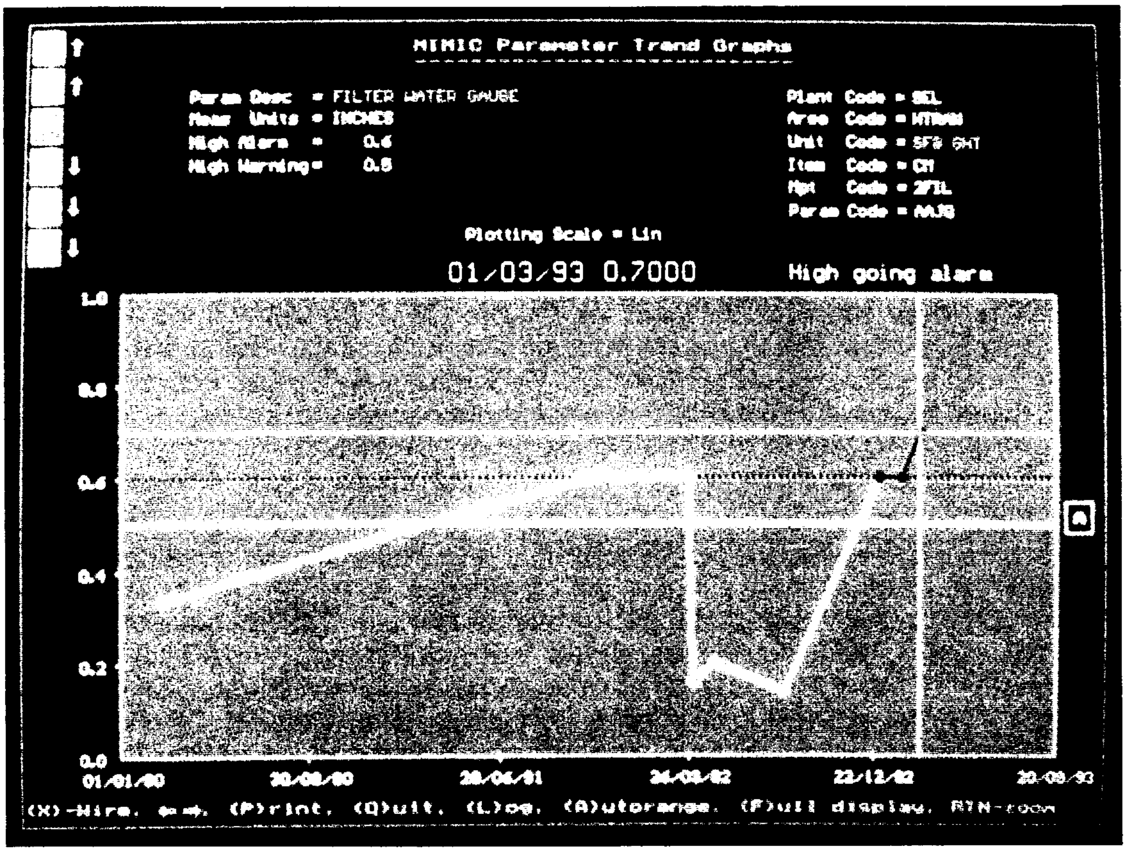

FIG. 7—MIMIC SREEN DISPLAY OF TREND GRAPH

History module

Historical records are created in this module. The MIMIC system is not intended to replace the existing MMS system, therefore ship's staff have been given freedom to make their own use of this module. However, it does not remove the responsibility to keep proper records within their ship equipment files.

System administration

This contains all the facilities to run successfully the MIMIC system. It is mainly used by the system manager to control password access and to make use of the general system housekeeping facilities. An important facility controlled by this module is the data back-up routines, which enable data to be saved on either the PC hard disks, to Bernoulli disk drive or a Floppy diskette.

THE FUTURE

T42 MIMIC system

MIMIC has now been at sea in the T42s for 4 years, and considerable operating experience and feedback has been accumulated during this period. Much of the success of the system has undoubtedly been achieved by the determined dedication of the users to make the system work. A system update programme has now been assembled, which hopefully will eliminate some of the shortfalls which continue to limit system utilization.

(*a*) The existing 386sx PCs will be replaced with 486 66Mhz machines, to give a significant increase in system operating speed. The new PCs are the same hardware that is being fitted for OASIS system updates, and will enable some rationalization of on board support and repair requirements. The new PCs will have removable hard disks with sufficient capacity to undertake all back up routines, and therefore remove the requirements for the troublesome Bernoulli drives.

(*b*) New uninterruptible power supply units will be fitted, which are more reliable and UK supported.

(*c*) The MIMICMATE data collectors are to be replaced by a new data collector which will overcome the problems associated with battery life and communication leads (FIG. 8).

(*d*) The Main Machinery Operating Profile (MMOP) application will be resident within the operating system. This reads machinery status codes, which are entered on the MIMICMATEs during W/K tours, and produces availability and reliability type data about equipment for export ashore. Diskettes to activate the MMOP are programmed ashore, and apart from loading on and off the system, no additional input is required from ship's staff.

Like all such systems, the full benefits can only become evident when they are correctly used and have the support and confidence of the operators. The above list of material improvements alone will still not enable the full potential of MIMIC to be achieved. Experience has repeatedly shown that training, understanding and commitment of the operators is the most important driver to achieving an effective system. Improvements have got to be pursued in general IT skills, the understanding of analysis techniques and a sound appreciation of the philosophy behind CM.

New systems

Technical specifications have been produced for Integrated Condition Monitoring Systems (ICMS) for both the CVGS and T22 platforms. Both specifications reflect experience gained from the T42s and MIMIC trial fits in H.M.S. *Ark Royal* and *Coventry*. The systems will be fitted primarily to manage CM data, however, in both cases EW will be an integral part of the system. Faster system operating speeds, multi-user functionality and improved data manipulation will be essential capabilities of these new systems. A reduction in the manual collection of parameters will be achieved by data being automatically imported

FIG. 8—OYSTER DATA COLLECTOR

from machinery surveillance systems such as the Decca Isis 250 system. Standardized data formats and compatible analysis equipment will enable data to be exported to shore authorities for further analysis and support purposes.

Modern relational data bases offer considerable potential for including other enhancements for the ICMS:

(*a*) *Knowledge based applications*

These can be used to enhance the diagnostic capabilities of the on board team, and can compensate for skill dilutions. The NSC is already benefiting from such systems, with the use of the Extended Diagnostics and Maintenance System by the Diesel Section. This is a rule based system, which aids the diagnosis of data outputs from the RN diesel engine Spectrographic Oil Analysis programme. A simplified system could form part of the overall ICMS for on board use.

(*b*) *Training*

Applications can be made available on the ICMS using computer based training programmes to cover:

- System operating procedures.
- Auxiliary machinery certificate training.
- Maintenance procedures.

(*c*) *Data repository*

Within the ICMS there will be a source of accurate information about the status of equipments and this could be interfaced with other on board IT systems to enhance the overall platform effectiveness.

Summary

The development of CM for platform equipment has by chance occurred in separate phases of technical activity. Early work concentrated upon individual CM techniques associated with measuring, sensing and recording of machinery parameters. Unfortunately the outputs from many of these processes led to overload by vast quantities of poorly configured data, and the techniques failed to make an impact on the preventive maintenance based MMS system. The introduction of the EW systems has provided the means to effectively record and manage significant quantities of data. These systems can be further enhanced to improve the ability to process, analyse and display data and enable well informed support decisions to be taken.