ASSET MANAGEMENT SYSTEM FOR GEOTHERMAL APPLICATIONS

K. A. LICHTI[1] & N. E. ROSARIA[2]

[1]Materials Performance Technologies, A part of IRL, PO Box 31 310, Lower Hutt, NZ
[2]PNOC Energy Development Corporation, Manila, The Philippines

SUMMARY: - This paper provides a synopsis of a MS Access™, Asset Management System (AMS) for tabulating and managing results of a Risk Based Inspection (RBI) programme for geothermal Fluid Collection and Reinjection Systems (FCRS). Demonstration results are given for FCRS operated by PNOC Energy Development Corporation, The Philippines. The software programme provides methodologies for predicting corrosion and metallurgical damage processes encountered in geothermal process fluids as used in energy plant and equipment. The AMS provides opportunity for risk minimisation through optimisation of inspection and maintenance practices by identifying critical and at-risk components. This allows planned maintenance and targeted process or plant configuration changes that minimise the consequences of failure.

1. INTRODUCTION

This paper is concerned with the development of software to track the results of and optimize the value of Risk Based Inspection (RBI) activities in a geothermal FCRS facility.

A MS Access™ database was developed as part of an MPT/PNOC EDC Asia Development Assistance Facility (ADAF) assignment on an Asset Management System (AMS) Incorporating RBI Methodologies for geothermal energy plant. ADAF is part of New Zealand's Overseas Development Assistance (ODA) programme.

The work included the development of an AMS database for information management, namely to capture and track detail for individual wells, pipelines and vessels and to provide high level overview reports to management that summarise the risk profile of pressure plant used for the geothermal Fluid Collection and Reinjection Systems (FCRS).

RBI is a tool that helps plant managers and engineers apply risk directed techniques to asset management in order to prioritise inspection and maintenance work (Lichti, 2002). It is both a qualitative and quantitative process for systematically combining the likelihood or probability of failure of individual components and the consequences of failure to provide an overall plant risk assessment.

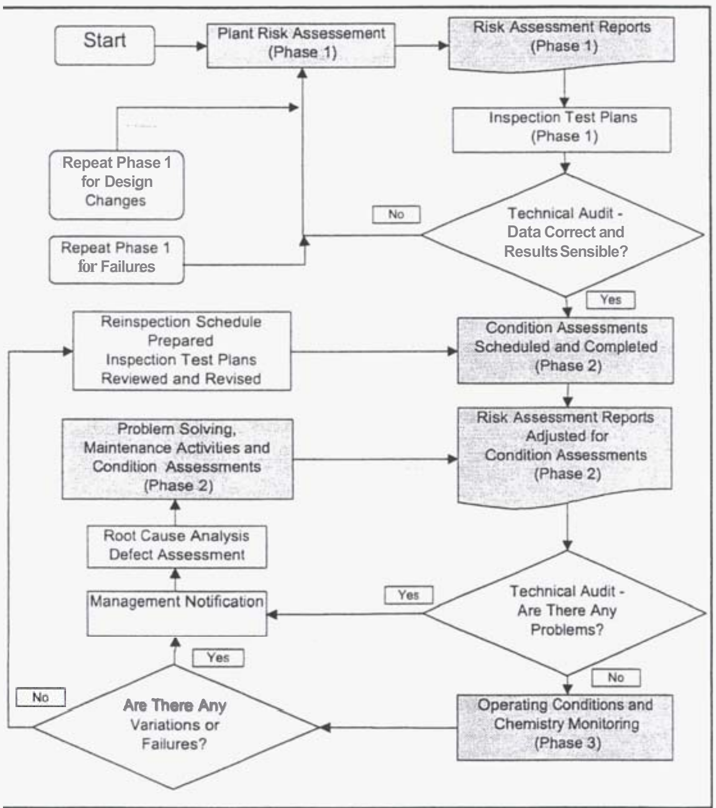

Figure 1: Example RBI Process Flow Diagram With AMs-RBI Data Management and Reporting Shaded.

™ Microsoft Corporation, USA

The AMS is integrated with the company maintenance practices using a process similar to that outlined in Figure 1. The AMS plant risk assessment can provide:

1. A measure of the current value of a facility.
2. A list of critical plant and reasons for their criticality.
3. Remaining life predictions for critical and non-critical plant
4. Opportunity to control risk by targeted maintenance or critical plant duplication and by monitoring of operating conditions.
5. Opportunity to reduce planned outage times and to increase time between inspections.

In this instance a 3-phase RBI process was used (Lichti, 2001, Lichti, 2002, Knowles and Lichti, 2002):

Phase 1 Plant Risk Assessment and Life Estimation

Phase 2 Condition Inspection of At-Risk Components and Revised Life Estimation

Phase 3 Monitoring Activities and Metallurgical Analysis

Methodologies for RBI and models for predicting corrosion and cracking in geothermal systems are well defined:

- Risk Based Inspection (ASNZS 3788:2001, ASNZS 4360: 1999)
- Hazard Risk Calculations (AS4343-1999)
- Geothermal Corrosion Models (Lichti, 2001)
- Geothermal Plant Risk Assessment Models (Lichti, 2001)
- Sulfide Stress Corrosion Cracking Guidelines (Lichti, 2001, NACE MR 0175)

The paper describes the development process, the database design and the benefits of the developed software.

2. AMS DEVELOPMENT PROCESS

The software development model used was cyclic, having Design, Review, Implement, Test, Review Design, Revise Implementation, Test and Revision stages (Lichti, 1997).

The development of an AMS for geothermal FCRS began with the preparation of an MS Excel^{TM} spreadsheet that documented the first stage of a **Risk** Based Inspection programme. The RBI Phase 1: Plant Risk Assessment and Life Estimation spreadsheet:

1. Captured critical parameters for individual plant items.
2. Used recognized models of damage accumulation to predict "Likelihood of Failure"
3. Identified hazard levels and impact of failure to quantify "Consequences of Failure"
4. Predicted "Remaining Life" defined by loss of corrosion allowance or time to first leak.

This spreadsheet model was then used to prepare inspection schedules and Inspection Test Plans (ITPs) for critical and at-risk plant in typical FCRS. RBI Phase 2 Condition Inspections were conducted using the ITPs and first results used to revise the models and methodologies. These were then incorporated in the first AMS prototype. This gave early opportunity for testing. Use of a database AMS overcame constraints of the spreadsheets:

1. Data management was difficult with linked spreadsheets.
2. Error tracking with stacked calculations.
3. Interrogation and reporting limitations.
4. Data security with multiple users.

A Resource Document was prepared to assist in the prototype development. The Resource Document provided:

1. High level Process Flow Diagrams for the RBI activities.
2. Story Board of envisaged system operation and reporting scenarios.
3. Tree Structure Diagrams for the input and output dependencies.
4. Tables of parameters for input data Forms.
5. Report outlines for formal system Queries.

The AMS prototype was loaded with data taken from the initially developed spreadsheets and revised to achieve equivalent results to the proven spreadsheets as a means of Quality Assurance.

Additions and revisions of the AMS were required once the RBI Phase 2 Condition Assessment results became available:

1. Wall thickness measurement results were tracked by location and time of measurement.
2. Rates of damage accumulation were based on measured changes rather than assumed initial properties.
3. Plant maintained or modified to give revised life was separately tracked from the original.
4. Additional models for calculation of risk were required for new damage mechanisms observed.
5. Data entry and reporting facilities were enhanced to allow the number of users to be increased.

6. Graphical presentations of key reports were added; Remaining Life, Likelihood, Consequence, Plant Risk Assessment.

The final **AMS** was supplemented by a series of guidelines, supporting documents and example reports as well as on-line help facilities for new and experienced users.

3. AMs-RBI DATABASE DESCRIPTION

The MS Access AMS-RBI database software inherits all of the features of MS Access 2000™, that was used for the development. The system has however been programmed so that all of the data is tabulated in separate files that are linked to a main **Front End,** The database development window where new tables, queries, forms and reports are created is hidden so that users do not need to be familiar with these facilities.

The **Title Bar** is set to display the Project name of the current open AMs-RBI system and the Windows™ Control-Menu Minimise, Restore/Maximise and Close buttons. The **Menu Bar** is customized to provide users with the needed functionality, Figure 2

The AMS windows provide a component navigator on the left of the screen and detail over the remainder.

Purpose designed data entry windows are programmed to appear as the user selects:

1. Component Details
   >Design Data,
   >Drawings,
   >Digital Photographs,
2. Operating Conditions
   >Physical Conditions,
   >Chemistry, Material Loss and Scaling Predictions
   >Corrosion Rate Predictions.
   >Scaling Rate Predictions,
   >Flow Rates and Erosion Predictions
3. Environmental and Commercial Conditions
   >Hazard Conditions
   >Fluid Type
   >Personnel and Inhabitants Access
   >Calculated Hazard (AS4343)
   >Commercial Conditions
   >Ability to Substitute Production
4. Condition Inspections
   >Material Loss
   >Scaling
   >Cracking
   >Events History
5. Calculations
   >Update Calculations
6. Reports
   >Tabulated Reports
   >Graphs
7. Help
   >**AMS** On-Line Manual

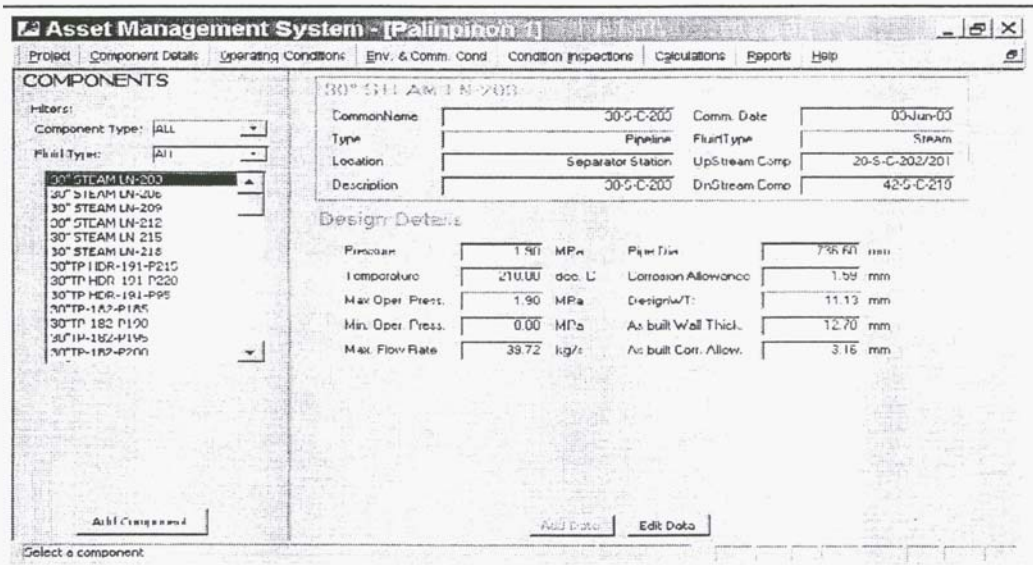

Figure 2: Illustration of AMS Menu System and Data Entry Form.

The system calculates the likelihood, consequence and risk using predicted and actual results. If **actual** results are available these take precedence over **predicted** results. The data is combined using **5** range factors for input and output parameters. The scale used for the **5** range factors is Logarithmic being 0.01, 0.1, 1.0, 10 and 100. Some standards and other authors use letter and number ratings rather than the logarithmic rating system shown here. The logarithmic rating has the advantage that the user recognizes immediately severity of the values shown for likelihood, consequences or risks. Figure 3 illustrates the process of combining likelihood and consequences. If more than one input contributes to the rating (eg corrosion vs erosion for Material Loss) the system identifies and uses the worst case parameters.

Risk Levels Shaded to Show Severity Ranges Assigned for Input Combinations

Likelihood					
100 Almost Certain	10	10	100	100	100
10 Likely	1	10	10	100	100
1 Possible	0.1	1	10	100	100
0.1 Un-likely	0.1	0.1	1	10	100
0.01 Rare	0.1	0.1	1	10	10
	0.01	0.1	1	10	100
	Insignificant	Minor	Moderate	Major Consequencs	Catastrophic
				Consequences	

Figure 3: Typical risk characterisation matrix (after AS 4360:1999).

Initially, in Phase 1 **Plant Risk Assessment,** limited actual measurement data may be available. In these instances the system guidelines provide users with models for **predicting** the value of required input parameters if these are not calculated. from other input data. These values tend to be conservative and if either the likelihood, consequences or the combined risk are high then **actual** measurements need to be made to confirm or refute the estimated values.

The **predicted** values provide the initial risk profile and the aim is to conduct RBI Phase **2 Condition Assessments** that provide **actual** data for the at **risk** components. In this way the risk is better defined by the Phase 2 data that is obtained from the inspections that were focused on the high risk areas.

Calculations are made using coded equations in the MS Access software. The data, as noted previously, is held in separate data files from the Front End. If the systems were allowed to update every time data was entered, the data entry would take an excessive amount of time as users would need to wait while the system calculates and updates reports. This problem is avoided by giving the user control over when calculations should be made and by storing calculated results in separate tables.

Calculation results can be individually requested from a pulldown list so the user can check the data or view all calculated results in tabulated format, once "Update Calculations" is performed. A pre-programmed "Query" set of reports and graphics is then updated and these reports and graphics can then be instantaneously recalled to the screen and printed. Figure 4 illustrates a tabulated report and Figure **5** shows a portion of a graphic presentation of results.

Likelihood of Damage

- Listing by Component

Component	Location	Last Insp. Date	Likelihood of Corrosion	Likelihood of Scaling	Likelihood of Cracking	Likelihood of Damage
30" STEAM LN-203	Separator Station	01-Sep-01	0.1	0.1	0.1	1
30" STEAM LN-206	Separator Station	01-Sep-01	0.1	0.1	0.1	1
PN20DSB	Upper Pad East	15-Nov-00	10	0.1	0.1	10
PN16DPL-10	Upper Pad East	15-Nov-00	0.01	0.1	0.1	0.1
PN15DPL-16	Lower Pad East		1	0.1	01	1

Figure **4**: illustration of pre-programmed report

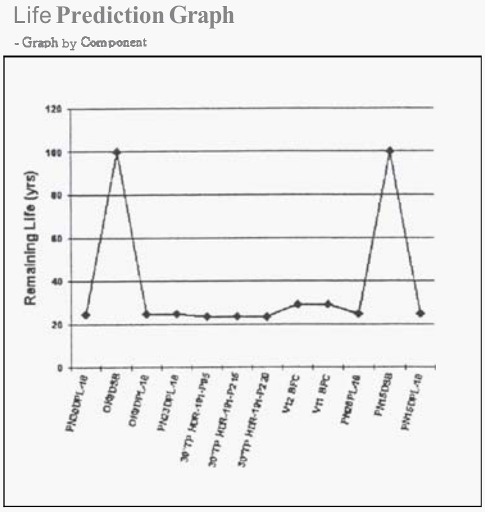

Figure 5: Portion of pre-programmed graphical result for FCRS Plant Components

4. Benefits of AMS and RBI

Application of AMS and RBI methodologies provide a number of benefits:

- Opportunity for extended time between inspections using data management systems that meet the requirements of QA systems such as ISO 9001:2000.
- Plant components that potentially impact on reliability and critical plant that needs to be maintained are continually identified.
- Opportunities to reduce risk are highlighted; adding redundant plant (reduce consequences of failure), process or materials changes to reduce damage accumulation rates (reduce likelihood of failure).
- Institutional memory is retained and readily accessible.
- Results for all relevant reports are extracted and recorded with opportunity for archiving.
- Greater numbers of staff including management are provided with access to the information.
- Asset value is readily identified at any time.
- Simplified data management over paper based systems.

5.0 Future Developments

The use of MS Access^{TM} allowed rapid prototype development and revision to final working system by engineers with skills in database development. The current system is however constrained to single computers at each site and the system has not been networked. PNOC EDC use ORACLE for intranet style databases and the AMS will be converted to ORACLE in 2004. This will provide greater opportunity to link the AMS to other databases that provide input for:

1. Geochemistry of fluids for corrosion and scaling predictions.
2. Production rates used for estimation of consequences of failure.
3. Operating conditions for monitoring validity of the RBI, Phase 3 Monitoring data entry.

6. ACKNOWLEWDGEMENTS

The authors express their thanks to New Zealand Ministry of Foreign Affairs and Trade, Asia Development Assistance Facility and to PNOC Energy Development Corporation for financial support of the work reported here and for permission to publish this overview. Contribution to the work from PNOC EDC and MPT staff and management, too numerous to mention, is gratefully acknowledged.

7. REFERENCES

ASNZS 3788:2001, Australian/New Zealand Standard, Pressure equipment--In-Service inspection.

AS4343-1999, Australian Standard, Pressure equipment—Hazard levels.

AS/NZS 4360:1999, Australian/New Zealand Standard, Risk management.

Lichti K A. (1997) A Project Team Approach to Development of Materials Performace Expert Systems, Corrosion Reviews, Special Issue on Applications of Computers in Corrosion, Vol 15, Nos 1-2, pp 119-149.

Lichti, K A (2001) Application of Risk Based Inspection Methodology to PNOC EDC Geothermal Fluid Collection and Disposal Systems: A Progress Report, 22nd Annual PNOC EDC Geo Conf, 13 and 14 March, Manila, Makati City, The Philippines, pp 231-238.

Lichti K A (2002) "Risk Management and Risk Based Inspection of Aging Geothermal Energy Plant" GRC Trans, Vol26, Sept 22-25, pp 461-465.

Knowles, D M and Lichti, K A (2002) Application of Risk Based Inspection Methodologies in Industrial Plant, New Zealand Metals Industry Conference, 31 Oct to 2 Nov, Rotorua, New Zealand.

ISO 9001:2000, Quality management systems – Requirements.

NACE MR0175 NACE Standard Material Requirements, Sulfide Stress Cracking Resistant Metallic materials for Oilfield Equipment. (re-issued annually).