SURVEY OF ON-LINE MONITORING TECHNIQUES & RECOMMENDATIONS FOR BEST PRACTICES

(***Acronym***: On-Line Monitoring)

Final Report

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Executive Summary

In order to be competitive, plant operators must focus on increasing the efficiency, reliability and flexibility of their plant while reducing unscheduled and forced outages. Furthermore, because of the high cost of fabrication and erection of new plant, increasing efforts are being made to extend the life of existing units that may sometimes operate well above their original design specifications. Within these aged plants, the wide variety of material used (either in the original design or as replacement) coupled with ever-changing plant operation regimes mean that the potential damage mechanisms can be expected to be neither uniform nor fully predictable. As a consequence, during the last two decades there has been a trend for plant operators to rely on condition-based maintenance philosophies, using new and more effective on-line monitoring techniques and data analysis tools.

This report provides a state-of-the-art review of both existing and emerging on-line monitoring techniques, and presents guidelines and recommendations for on-line monitoring of power plant equipment (boilers, turbines and electrical / generator equipment). Detailed background information is provided on the sensors and technology available for measuring temperature, strain, pressure, vibration, corrosion, water chemistry, cracking, combustion efficiency, emissions, etc. The information has been obtained from the plant experience of ETD experts and consultants, personal contacts in the industry worldwide, feedback from some of the industrial sponsors, in-house reports, published literature, and information available from manufacturers of monitoring devices and equipment.

The information and guidelines in this report are aimed at the plant operators, and also the plant manufacturers, to provide an overview of the existing, emerging and future technologies for on-line monitoring. The report consists of individual sections dealing with the monitoring techniques for each particular parameter, i.e. temperature, strain, pressure, corrosion, etc, followed by guidelines and recommendations for on-line monitoring of power plant equipment.

The report starts by addressing ***temperature*** *measurement* and provides details of both contact and non-contact temperature sensors. Temperature is one of the key parameters to be measured throughout the plant, and hence the on-line monitoring of the temperature at selected locations/ equipment within the plant is of paramount importance with respect to plant safety, performance, reliability and availability. The measurement principles, sensor characteristics and applications of thermocouples, Resistance Temperature Detectors, infrared thermometers, and thermal imaging systems are discussed. Thermal scanning systems that have been developed for mapping the temperature and heat flux conditions of boiler furnace walls are described in detail. Such systems can potentially be used for control of Intelligent Soot-Blowing systems. The techniques for measurement of gas temperatures in boilers and furnaces are also discussed, including radiation pyrometers and acoustic pyrometry, which can be used for monitoring the Furnace Exit Gas Temperature (FEGT). The FEGT provides an indication of the efficiency of heat transfer within the boiler furnace, and hence measurement of FEGT has become an important aspect of boiler control systems.

Measurement of ***strain*** may be performed for the purpose of assessing the magnitude of the deformation itself or for determining the stress acting on a component. Strain is typically measured using resistance strain gauges, but capacitance strain gauges are effective for monitoring creep deformation in high temperature components. Alternative techniques

based on speckle image correlation methods have been developed for monitoring localised straining in weld heat-affected zones.

There are many areas where ***pressure*** monitoring is vital to plant operation both for safe and efficient performance of the plant. Techniques for monitoring pressure, flow and level monitoring in power plant are described, including boiler drum level measurement and turbine-generator bearing jacking oil pressure.

Measurement of ***vibration*** has become the most widely used approach for monitoring the condition of industrial machinery, and has enabled plant operators to move from a preventative to a predictive maintenance regime, thus increasing plant availability and reducing costs. Vibration measurements can be made using various types of sensing device, such as accelerometers and proximity transducers. Computerised vibration monitoring systems are very valuable in ensuring the long-term integrity of turbo-alternators and major plant auxiliaries such as feed pumps. They are also vital to diagnosing problems with the operation of the plant. Details of the sensors and vibration measurement principles are presented in the report, and examples of applications of computerised vibration monitoring systems on power plant are described.

The rate of ***corrosion*** dictates how long any plant component can be usefully and safely operated. However, corrosion rarely takes place at a steady rate for prolonged periods, and usually there are some short periods of very aggressive attack and relatively long periods of little or no attack. The periods of high corrosion rate often go unnoticed until significant damage or failure has occurred. Subsequent analysis of the damaged/ failed component may not be able to confirm what was the root cause and when it happened, whereas on-line monitoring of corrosion rate can provide the answers. Electrical Resistance (ER) and Linear Polarization Resistance (LPR) corrosion probes are the most common techniques for on-line monitoring of metal loss or corrosion rate. Newer and more accurate electrochemical techniques, such as Harmonic Distortion Analysis (HDA) and Electrochemical Noise (ECN), are also being employed. Measurement of *general* and *localised corrosion* is now possible on-line and in real-time. Details of these low-temperature corrosion monitoring techniques are provided in the report, and applications in the petrochemical and process industries are described. The emerging techniques for high-temperature corrosion monitoring, based on ER and ECN techniques, are also discussed. In addition, the report includes details of the application of the corrosion scanner systems that can provide corrosion maps of boiler furnace walls.

On-line instrumentation is used for monitoring various characteristics of the ***water chemistry*** in power plant boilers, demineralisation plant, and industrial process plant. In power plant, the chemical condition of the feedwater, boiler water and steam has to be controlled in order to avoid unacceptable rates of corrosion and deposit accumulation, which would affect the reliability and efficiency of boiler and steam turbine components. Monitoring provides reassurance that the water chemistry is being controlled within specified target limits. This report provides detailed information about the instruments used for monitoring the key parameters of conductivity, pH and dissolved oxygen content, as well as other parameters, such as silica content and sodium ion concentration.

Experience with high temperature plant has clearly identified that certain equipment parts, particularly the weldments, have an inherent risk of premature failure. Traditionally, the monitoring of the damage/cracking was done off-line through periodic inspections, however

with the increase of the equipment age, the frequency of the inspection can become significantly higher, resulting in excessive maintenance costs. A less costly long-term solution is the use of on-line ***crack monitoring*** techniques. Acoustic emission (AE) has been widely used in various industries for on-line detection and monitoring of cracking. Quantitative Acoustic Emission (QAE) is a recent development of AE that can be used for periodic monitoring and pre-outage screening for creep damage. Recently, the electrical potential drop method has been applied to crack monitoring on plant components, and the ACPD (alternating current potential drop) technique has shown potential for monitoring creep cavitation damage. The principles and applications of AE and ACPD methods are described in this report.

As well as monitoring the parameters that affect the in-service degradation and cracking of plant components, this report also provides information on the sensors and measurement techniques used for monitoring flue gases for both ***emissions monitoring*** and ***combustion efficiency monitoring***.

Combustion of sulphur-bearing fuel results in the oxidation of the sulphur to form sulphur dioxide and then sulphur trioxide, which combines with moisture in the process gas to form sulphuric acid. If the temperature at the 'cold end' of a boiler falls below the acid dew point temperature, then sulphuric acid solution will condense on the component surfaces. Measurement of the ***acid dew point temperature*** of the flue gas is discussed in this report.

Monitoring and diagnostics plays a vital role in the competitive operation of power plants by improving performance, reliability and availability, by enabling the optimal scheduling of maintenance activities, and by minimizing the risk of costly, unscheduled outages. Traditionally, local-to-plant monitoring was used mainly for performance analysis and remote-from-plant monitoring by technical specialists provided longer-term diagnostic and early warning support. Many systems have been developed and used successfully for monitoring and diagnostics of, for example, gas turbines and electrical generators. There are also a number of boiler component life utilisation ***software systems***, which use on-line monitoring data as inputs for calculations of creep and fatigue damage accumulation. The software systems are discussed in this report.

The ***concluding sections*** of the report provide guidelines and recommendations for monitoring of power plant equipment, under the following headings:

- Boilers and Heat Recovery Steam Generators (HRSGs)
- Steam Turbine
- Condenser Performance
- Gas Turbine
- Electrical / Generator Equipment

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