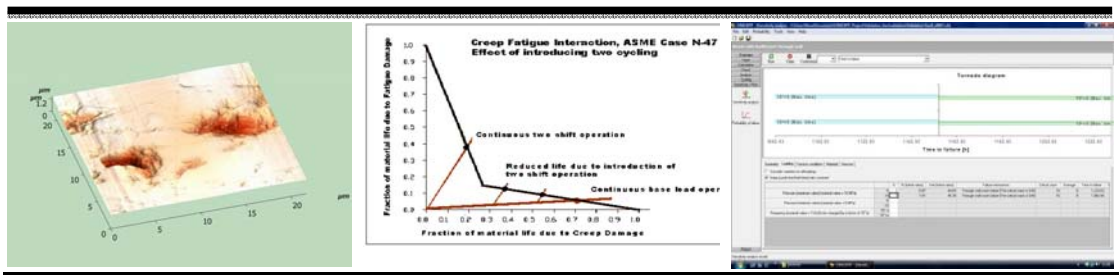
A Compendium of Lifing Procedures for Steam Power Plants



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MANAGEMENT OVERVIEW & INTRODUCTION

This document was originally aimed to be a Lifing Procedure for power plant boilers, steam turbines and Heat Recovery Steam Generators (HRSGs) but years of hard work by the dedicated European and Japanese experts instead resulted in what has now been more appropriately named as a Compendium of Lifing Procedures. This compendium incorporates procedures for the assessment of the integrity and life of components without pre-existing defects, components with manufacturing or service induced defects/cracks, probabilistic integrity/ life and crack assessment procedures, procedures for weld repairs, procedures for miniature specimen testing, risk based maintenance procedures etc. The compendium has also been produced in electronic format for the ease of use and for facilitating on-line calculations of some of the functions such as life calculations from oxide thickness measurements, assessment of crack initiation and growth under creep, fatigue or creep-fatigue interaction conditions etc. The compendium has therefore been appropriately named *e-Lifing* (short for electronic lifing procedure). Furthermore, the electronic format has helped to incorporate features which would have been impossible or impractical to incorporate otherwise. Thus 1,000 replica images of the microstructures of old plant components with known operation history have been incorporated to help compare the microstructure of the user's old plant components with the *e-Lifing* database and get an indication of the remaining life of his plant.

The significance of life assessment of older power plant components has taken on a new impetus in the present competitive environment where scrapping of a plant is the last thing that an owner wishes to do or can afford to do. Moreover, due to the use of the deterministic methods for plant design many of the components are designed very conservatively and experience has shown that most plant can operate way beyond their design life and all that needs to be done is to repair or replace a few of the critical components. Thus the development of *e-Lifing* is very timely. This is especially so since for nearly two decades or more no such development has come to light in spite of the new developments in many of the life assessment methodologies and technologies. These include, for example, experience with the successful use of probabilistic assessment methodologies, developments in the assessment of crack initiation or long term rupture strength predictions from short time tests, new and more sensitive ultrasonic techniques, recent developments in small punch testing etc. etc.

The experts involved in the development of *e-Lifing* have themselves been involved in large European or Japanese groupings that have had the responsibility for the development of various methodologies involved in plant lifing. So they were charged with the task of reviewing and incorporating the latest technologies and methodologies to ensure that the user benefits from the new developments as much as possible and that the *e-Lifing* does not need a revision for at least a few years to come. The lifing techniques and methodologies for high Cr martensitic steels is also much sought after due to the wide use of 9Cr steels in

high temperature plant and the equally widespread, though unexpected, problems that these steel has been facing after short to medium term service. Again this aspect has been dealt with in detail as ETD had access to the latest developments in this field due to its own involvement in collaborative R&D projects in the development of such methodologies. In short *e-Lifing* covers a very wide spectrum of issues that an engineer comes across when involved in plant integrity and life assessment. These range from the humble but essential guidelines on how to make replicas and their interpretation to very sophisticated and complex fracture mechanics equations using probabilistic methodologies.

For the ease of use and understanding this large document, the Compendium has been divided into four parts and each part sub-divided into a number of sections and subsections.

Part 1 covers introduction to the life assessment issues including the detailed descriptions of various damage, cracking and failure mechanisms ranging from creep, fatigue, corrosion and corrosion-stress related mechanisms, and descriptions of materials and their understanding including the behaviour of the welded components.

Part 2 is the largest part of *e-Lifing* and covers analytical assessment and integrity issues both for the defect free and defect containing components. It also covers the probabilistic assessment procedures with worked examples and shows how this approach can be used for more realistic and less conservative life assessment thus saving the plant owners and operators a fortune in not replacing or repairing components prematurely. The development of the probabilistic approach to crack assessment is relatively new but is now reasonably well established and users can benefit from it with confidence. This part of *e-Lifing* also covers life assessment techniques such as the hardness, metallography, post-exposure creep testing, strain based and other such methods.

Part 3 is the actual life assessment methodology with flow charts, procedures and dos and don'ts of life assessment. It covers procedures for the lifing of various major and critical components of power plant boilers, steam turbines and special issues dealing with HRSGs, weld repairs etc.

Part 4 covers financial, management and risk based methodologies and procedures. This 'non-technical' part was included in recognition of the fact that any life assessment needs to take into account the financial aspects in the present competitive electricity industry market. For a technical life assessor the understanding of the basic concepts of financing can only improve his ability to do his job with a better overall understanding of the implications of such methodologies and their application. This part covers the life management and outage planning issues with emphasis on 'risk based' rather than the traditional 'prescriptive' approaches. It also covers issues such as the cyclic operation of power plants and the extra costs involved in this.

One innovative and user friendly aspect of this compendium of procedures is that many of the methodologies have been well illustrated with worked examples so that the user can understand their application without ambiguity and can comfortably use *e-Lifing* to assess the integrity and life of his plant. It is well known that in high temperature plant the welds

are the weakest link in the chain and much of the cracking and many of the failures are associated with the welds or associated microstructures. Therefore detailed discussion of the weld related issues is well covered in the *e-Lifing* procedure.

The initial comments on the draft procedure by the industrial project sponsors have been excellent and they have described it as an excellent training tool for their engineers. ETD is involved in many new developments through its R&D projects in collaboration with industry and research institutes in Europe, Japan, North America and elsewhere. We thus intend to update *e-Lifing* as and when new developments come to light.

Birdseye View of e-Lifing

I. OVERVIEW

- Introduction to life assessment (review of the principles and practices in operation).
- Introduction to design life of steam power plant components (international codes and standards, design of welded components, weld factors, use of cross-weld properties).
- Introduction to the construction materials for boiler tubing, headers, steam pipework and steam turbines.
- Introduction to damage mechanisms and component failure modes (introduction to fracture mechanics).

II. LIFE ASSESSMENT METHODOLOGIES & TOOLS

- Analytical assessment methods (deterministic and probabilistic life assessment) for defect-free and cracked components.
- Metallographic methods.
- Hardness measurement method.
- Strain measurement method.
- Post exposure (ex-service) creep rupture testing.
- Miniature specimen testing methods.
- Methods based on temperature estimation (oxide thickness, microstructures as a function of temperature and time).
- Creep-fatigue life consumption software.
- Advanced techniques (Potential drop, NDE, Corrosion monitoring).

III. COMPONENT LIFE ASSESSMENT

– Levels I, II, and III

(including case studies)

- Remaining Life Assessment (RLA) for boiler tubes and headers.
- RLA for HRSGs.
- RLA for steam pipework.
- RLA for repaired welds (and repair techniques).
- RLA for Steam turbine components.

IV. PLANT LIFE MANAGEMENT

- Cost effective strategies.
- Risk Based Inspection/Maintenance (RBI/M).
- Financial risk optimisation.
- Cost of plant operation in cyclic mode.