European Technology Development *Ltd*

Creep Rupture Strength of Abnormal P91 Materials and Welds

ETD Proposal No: 1338-gsp-prop14

A 'Group Sponsored Project' - (GSP)

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Proposal by:

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1. INTRODUCTION

Many utilities and plants have been discovering 'abnormal' (or 'aberrant') P91 base metal and welded joints in their plants. Although it is now well known that heat treatment is critical in achieving full strength in high Cr martensitic steels, it is clear that for various reasons many materials suppliers, manufacturers or welding companies have failed to realise this criticality. As a result, there is a worldwide problem with P91 base metals and/or whole welded joints that have not been heat treated to specifications and/or best practices, resulting in hardness below the acceptable limit and/or the microstructure is not in the correct, fully martensitic condition. In addition, it has been found that deviations from optimal chemical composition can also result in abnormal microstructural conditions.

Many abnormal P91 components/welds have only been found some years after entering service, either during scheduled inspection outages or sometimes because there has been a premature failure. Not all of the abnormal components/welds can be replaced in the immediate future and many will have to remain in service indefinitely. However, this presents a very serious problem because the plant owners / operators do not know how to treat these components in the absence of any material data or guidelines.

Few studies have been carried out on abnormal P91 materials/welds and the little information in the public domain tends to suggest that, for certain material conditions, the creep rupture strength level could be as low as that of ASME P9 steel, or as low as the Type IV strength level of P9 welded joints. However, life prediction based on P9 creep rupture strength may be overly conservative for many of the abnormal P91 materials/welds found in plant. Depending upon the particular condition of the abnormal material/weld, the long-term creep strength could be as low as P9 strength level or perhaps as high as the lower bound strength of normal P91 base metal (Figure 1).

2. OBJECTIVES

There is an urgent need to obtain creep rupture data that can be used to estimate the long-term strength of abnormal P91 materials and welds found in plant. There could be considerable variation in the strength level of different materials/welds as a result of the different ways in which heat treatment of base metal and/or welds may deviate from specification requirements. The objective of this project is to carry out *stress rupture* testing of abnormal P91 base metals and welds, which have been incorrectly heat-treated to produce a number of abnormal conditions (over-tempered, etc). Tests will be of durations up to 30,000 hours in order to obtain stress rupture data that can be used for predicting the long-term strength of the materials/welds, so that plant operators can establish the safe and reliable operating lifetime of their components.

8. COMPANY PROFILE AND SERVICES

ETD is an independent company registered in England. It is an engineering and consulting company whose expertise includes life extension and integrity assessment of power and other industrial plant (such as waste incineration, petrochemical, off-shore structures, etc). Engineering services, consulting, R&D and other technical projects are undertaken for individual organisations and power plants, government bodies (such as the ex-Department of Trade and Industry, UK) and international bodies (such as the European Commission).

The company and its staff are supported by a pool of internationally-known technical experts with background and expertise in Plant Services and R&D in energy, petrochemical and other industry sectors. The company has close links with various national and international technical bodies and standards committees.

ETD provides Asset Integrity Services to support continued operation of ageing plant, to quantify the remaining period of safe operation, and to advise on inspection, maintenance, repair or replacement strategies. It also regularly provides advice to its plant design and manufacturing clients on innovations in plant design to help them build new high-efficiency plants. In addition, ETD's Asset Integrity Services include:

- Defect/crack assessment
- Structural stress analysis
- Fitness-for Service
- Root cause failure analysis
- Weld assessment and weld repair issues
- High temperature corrosion in industrial environments.

ETD's Plant Consulting Services include provision of expert support in:

- Materials advisory and selection service for all types of high temperature plant.
- Root cause analysis of component damage and failures.
- Repair and replacement strategies.
- Risk Based Management/Maintenance / outage planning, inspection and plant overhaul management.
- Plant cycling and maintenance – issues and cost analysis for power plant subjected to steady load and cycling duties.

ETD experience with steel T91/P91 includes:

- Providing consultancy on P/T91 welding issues (during plant manufacturing stage) to a number of utilities and plant manufacturers, together with practical assessment of P/T91 welds at the manufacturing stage, including metallography, hardness checks, inspection of NDE records, and reviewing WPS and PQR for similar and Dissimilar Metal Welds.
- Non-destructive sample removal from P91 components using ***Electric Discharge Sampling Equipment (EDSE)*** and metallurgical analysis and testing of removed samples to resolve material quality issues and/or perform life assessment.
- Setting up (in 2006), co-ordination and leadership of the 'International P91 Users Group' for international industry.
- Worldwide reviews of P/T91 material, welding and fabrication issues, and plant operating experience.

- Investigations and root cause analysis of cracking and failures in T/P91 tube and pipe components and welds, in conventional boilers and HRSGs.
- Investigations of high temperature creep/fatigue crack initiation and growth in P91 large welded pipes tested both under creep and creep-fatigue conditions (both seam and butt welded pipes were investigated).
- Assessment and modelling of crack growth in P/T91 specimens and components.
- Assessment of repair welding techniques (including cold welding) and performance of repair welds in P/T91 components (pipes and T-pieces).
- Presenting a two-day Training Course on T/P91 base metal and weldment performance (annually in London since 2005; and in Houston, Texas, USA in 2010, Kuala Lumpur, Malaysia in 2010, Chicago, USA in 2011, and Manila, Philippines in 2014).
- Organising International Seminars on P/T91 and other new steels (held in London in 2005, 2007, 2008, 2009, 2011 and 2013; Houston, Texas, USA in 2010; and Chicago, USA in 2011).

ETD's client base includes, *for example*, companies from UK (Killingholme Power, Mott MacDonald, Derwent Cogeneration, Alstom Power, Barking Power Station), Ireland (ESB), Canada (Ontario Power Generation, Sask Power and TransAlta), Belgium (Electrabel and Laborelec), Italy (ENEL), USA (EPRI, Progress Energy, InterGen), South Africa (Eskom, SASOL), Germany (E.ON, Siemens), Pakistan (AES, HUB, KESC), Malaysia (Malakoff), Korea (Hyundai, Korea Power Services) and Japan (Kyushu Electric, Mitsubishi Heavy Industries, IHI, Sumitomo, Central Electricity Research - CRIEPI).

As ETD carries out both plant services/consulting and R&D type projects, including many joint venture projects in collaboration with world leading scientists and industries, this gives the company an unparalleled advantage over its competitors worldwide in that it can draw on the expertise of its leading R&D staff to provide best advice and innovative solutions to industrial problems when providing plant services and technical consultancy.