The recent use of low NOx burners in fossil-fired power plants has led to increased potential for corrosion of waterwall panels. Operation in a low NOx environment results in enhanced sulfide scale stability, and this causes a higher rate of deterioration of the underlying boiler tube material. Weld overlay coatings have shown good potential for erosion and corrosion protection of boiler tubes. With the weld overlay approach, the required mechanical properties are provided by the relatively inexpensive Cr-Mo steel boiler tube, while a thin layer of high alloy coating material is applied for corrosion and erosion protection. Despite many advantages of weld overlays, experience from field application shows that thermal distortion and cracking of waterwall panels due to the weld overlay process is a potential problem with this technology. The ERC is in the process of initiating a new project to develop guidelines for minimizing thermal stress problems arising during application of weld overlay claddings to waterwall tube panels. The principal investigators in this project will include Dr. Arnold Marder and John DuPont, specialists in metallurgy and materials and Dr. Herman Nied, a faculty member from Mechanical Engineering and Mechanics.

Several types of coatings are available for protection of boiler tubes. Of these, only weld overlay and thermal spray coatings can be applied in both shop and field conditions and are suited for both new and exposed tubes. Preliminary field observations of thermal spray and weld overlay coatings indicate that of the two, weld overlay alloys appear to exhibit superior corrosion resistance and are less susceptible to peeling and corrosion.

A crack formed between the weld layer and the tube substrate because of stresses which developed during the welding process and service exposure. The high hardness levels in the heat affected zone (HAZ) of this weld also contributed to the cracking tendency.
flaking. Weld overlay coatings can easily be applied free of porosity, with a strong metallurgical bond to the substrate. This improves their corrosion resistance and helps to minimize the possibility of delamination.

Despite these advantages, there are still two main concerns which may limit widespread application of weld overlay coatings. First, the localized heating and cooling associated with the welding process, coupled with the application of a coating with a thermal expansion coefficient which does not match the substrate, causes residual stresses and distortion of the waterwall panels. The amount of distortion can be quite significant and modification of the waterwall supports is often required to accommodate the displacements. The magnitude of the residual stresses and distortion depends on such factors as the welding procedure (e.g., welding parameters, deposition sequence), substrate and overlay properties (e.g., modulus and coefficient of thermal expansion), degree of restraint imposed on the waterwalls (e.g., boiler design), and water-wall geometry (e.g., tube thickness and diameter).

In addition, all of the commercially available overlay alloys which are suitable for this application develop a hard martensitic layer at the coating-substrate interface. This brittle region may be prone to cracking under the influence of thermal cycling conditions. The figure shows an example of this failure mode in a stainless steel weld overlay exposed to actual field service conditions. In this case, a crack propagated along the brittle coating-substrate interface. The hardness traverse taken across an as-deposited stainless steel weld overlay showed a region at the interface which is approximately 75 µm wide, where the composition varies from the substrate to the weld overlay. The intermediate nickel and chromium concentration levels in this region, combined with relatively high cooling rates, produce a brittle martensitic region upon cooling from the elevated temperatures of the weld thermal cycle. This brittle interface can develop exceptionally high hardness values. The material is thus less ductile and more susceptible to cracking under thermal cycling. In addition to this brittle interface region, there is often a significant difference in the thermal expansion coefficients of the coating and substrate. This thermal expansion mismatch induces additional stresses during service which are superimposed on the residual stresses which develop during the welding process, thus causing thermal fatigue cracking. These combined factors are responsible for the interfacial failure observed in this coating specimen.

The ERC's new project will develop weld processing methods and alloy selection guidelines to minimize the problems of residual stresses, distortion, and thermal fatigue cracking in boiler tube overlay welds. To accomplish this, the project team will be investigating the stresses and distortions which develop in waterwall panels during application of a weld overlay coating. In addition, parallel studies will be conducted to evaluate the relative thermal fatigue resistance of commercially available weld overlay alloys.

In carrying out the waterwall panel stress and distortion study, Nied will utilize a finite element stress analysis computer code to determine the effects of welding procedure variables, substrate and overlay properties, boiler design, and waterwall geometry on the formation of residual stresses and distortion in waterwall panels. The computer simulations will be used to identify processing conditions which reduce the magnitude of residual stresses and overall waterwall panel distortion. With this approach, practical processing methods for minimizing distortion, such as choice of overlay alloy and deposition sequence, can be explored via computer modeling rather than through use of expensive and time consuming laboratory and/or field trials.

The alloys to be studied will be selected based on the results of corrosion studies currently being conducted by Marder and DuPont. Previous studies at the ERC had shown the temperature gradients which develop across the waterwall tube thickness due to sootblowing or rapid slag removal can lead to transient stresses large enough to promote cracking. To determine how well the various alloy coatings resist thermal fatigue failure, laboratory experiments will be performed in a special thermal fatigue test apparatus which can simulate the stresses which develop in boiler tubes during slag falls and soot blowing operations.

According to Marder, "We are extremely enthusiastic about our progress with weld overlay coatings. We have identified coatings with excellent properties for mitigating waterwall tube wastage. Combined with the welding process and alloy selection guidelines which we will be developing in this new project, we believe we will be able to provide results to our utility sponsors which will enable them to use weld overlay coatings with much more success than is currently possible."

The ERC wishes to identify utilities with an interest in participating in the upcoming weld overlay project. For information, please contact either John DuPont or Arnold Marder at (610) 758-4090.