Innovative materials and manufacturing processes and advanced knowledge of in-service damage and aging mechanisms are critical for safe, reliable, and cost-effective management of fossil and nuclear assets, as well as for successful deployment of higher-efficiency coal plants.

**STRATEGIC DRIVERS**
- Long-Term Operations
- Near-Zero Emissions

**INNOVATION TARGETS**
- Reduce capital costs
- Reduce O&M costs
- Enhance durability and reliability and extend lifetime
- Advance mechanistic understanding and predictive capabilities

EPRI is leading the development of powder metallurgy fabrication methods for large and complex components in fossil and nuclear applications, a creep-resistant austenitic stainless steel for advanced ultrasupercritical (A-USC) coal plants, and an alternative weld filler for mitigating primary water stress corrosion cracking (PWSCC) in pressurized water reactors. In addition, fundamental understanding is being advanced for corrosion fatigue, creep and creep fatigue, high-temperature solid-particle erosion, PWSCC, and irradiation-assisted SCC. Building on this program’s successful proof-of-concept study of PM fabrication, functionally graded compositional control methods are being pursued as a Breakthrough Technology for manufacturing higher-performance components (see EPRI fact sheet 1022767).

**Strategic Value**
If successful, this program will transfer advanced materials, processes, and knowledge to EPRI’s Generation and Nuclear Sectors for application-oriented development and field demonstration in collaboration with power producers and commercial manufacturers. Innovative materials and manufacturing processes could lead to a significant reduction in capital and life-cycle costs for components in high-efficiency coal plants and existing and new nuclear units—necessary baseload generation options for reducing the electric sector’s carbon emissions. New understanding and predictive tools for major damage mechanisms will enhance condition and remaining life assessment, helping power producers optimize operations and maintenance (O&M) practices while avoiding catastrophic failures. Results from this program also will support development of methods and materials for mitigating or preventing damage, with substantial savings and reliability and safety benefits.

**Technology Gaps**
Strategic work addresses the following critical capability gaps:
- Advanced fabrication methods for manufacturing large and complex components and using high-performance alloys
• Lower-cost, higher-reliability materials for A-USC plants, coal gasifiers, and nuclear applications
• Basic mechanistic understanding and remaining life assessment tools for key damage modes
• New analytical tools for understanding and optimizing materials performance at the atomic scale

R&D Highlights
For several key areas of ongoing strategic research, achievements to date and next steps are highlighted below. Contact the EPRI program manager for additional details on these projects and other work.

**Powder Metallurgy (PM) Fabrication.** Relative to conventional casting processes, PM fabrication offers breakthrough potential for faster, lower-cost manufacturing of high-performance components in replacement and new construction applications at both nuclear and fossil plants. In 2009 feasibility testing, EPRI used an austenitic (316L) stainless steel (SS) powder to produce a 12-inch-diameter valve body in near-net-shape form. The component incorporated intricate features, required no finish machining, offered exceptional toughness, a 15% improvement in mechanical performance, and superior inspectability relative to conventionally cast 316L components. Subsequently, valve bodies have been produced from multiple heats of 316LSS, creep-strength-enhanced ferritic (CSEF) Grade 91 steel, and nickel-based Inconel 625 alloy, representing a broad cross-section of materials used in nuclear plants and existing and advanced coal plants. Detailed testing is under way to verify inspectability and weldability and generate property and performance data for an ASME code case permitting use of PM/HIP for fabrication of large pressure-retaining components.

A field-testing and demonstration program at a nuclear plant is scheduled for launch in late 2012 or early 2013, and commercial PM manufacturing of power plant components could begin as early as 2013. This innovation could significantly reduce lead time and costs for critical nuclear plant components and alleviate major cost and fabrication challenges associated with the use of nickel-based components in advanced coal plants.

**2011-12 Milestones**
• Complete characterization of PM-manufactured components
• Assemble code case for ASME approval
• Initiate field-testing program for non-safety-critical applications

**Corrosion Fatigue of Steam Turbine Blades.** For low-pressure steam turbine blades and disks, life-limiting cracking often begins in corrosion pits subject to high steady and dynamic stresses. Building on years of fundamental research, EPRI is on the threshold of introducing a methodology for predicting and managing this critical failure mechanism. In 2010, an accelerated ultrasonic fatigue testing program was initiated to quantify the pit-to-crack transition in common blade materials. Imaging and other methods are being used to monitor the corrosion-fatigue damage progression, elucidate effects of environmental and operational conditions, and develop algorithms for the pitting, transition, and cracking stages. Life prediction criteria are initially being derived for 410SS, with benchmarking tests planned for 2012. Once incorporated in a blade life assessment code, predictive algorithms will allow power plant personnel to optimize O&M practices, extend lifetimes, and prevent failures based on in-service history and observed pitting for 410SS, 17-4PH steel, and alloy components.

**2011-12 Milestones**
• Complete laboratory testing and develop and benchmark remaining life assessment algorithms for 410SS
• Initiate laboratory testing of 17-4PH steel and key alloy materials

**Creep-Resistant Steel for A-USC Plants.** Nickel-based alloys planned for coal plant headers and piping operating at 650°C and higher are costly and pose fabrication and welding challenges. CF8C-Plus, a creep-resistant austenitic stainless steel currently available only in cast form, offers potential as a more durable, less expensive alternative. In initial EPRI work, a CF8C-Plus ingot was worked to simulate the extrusions required to
fabricate thick-section piping and headers. Relative to as-cast material, the wrought CF8C-Plus offered a 20% strength increase and higher creep rupture ductility at 700 to 800°C. It also exhibited creep resistance comparable to that of solid-solution nickel-based superalloys at 600 to 900°C. Ongoing research involves detailed characterization of large-diameter CF8C-Plus pipe extrusions to develop an ASME code case for wrought header and piping applications, with in-plant test loop demonstration scheduled to begin in 2013. At an estimated cost 5 to 7 times less than nickel-based alloys, CF8C-Plus could provide capital savings of $10 to $30 million per A-USC plant. Additional applications are anticipated in lower-temperature coal plants and gas turbine, fuel cell, and advanced nuclear fission reactor systems.

2011-12 Milestones
• Complete characterization of large-diameter pipe extrusions
• Assemble code case for ASME approval

Alternatives for Alloy 52 Weld Filler. Weldability limitations for the Alloy 52 materials widely used for mitigating PWSCC in welds joining the reactor pressure vessel with coolant piping have created costly problems. In efforts to develop alternative fillers, computational thermodynamics and a novel method for accelerated weldability testing are being applied to screen high-chromium materials and fine-tune their composition. Goals are to optimize PWSCC resistance, base metal compatibility, and weldability while achieving requisite mechanical properties. In 2013, candidate fillers will be produced in sufficient quantity to support evaluation of experimental weldments and qualification testing for nuclear plant applications. Advanced fillers would yield significant benefits, as weldability problems associated with Alloy 52 have caused outage extensions and convinced some utilities to forestall PWSCC remediation.

2011-12 Milestones
• Complete computational modeling and experimental screening
• Initiate production and refinement of test heats for Alloy 52 alternatives

Internal Oxidation and Surface Film Degradation: Characterization of Damage Processes Prior to Crack Initiation & Surface Films Using Nanoscale Methods. The earliest stages of SCC in nickel-based alloys in nuclear plant primary water system components remain poorly understood. In long-term fundamental research funded by and conducted in collaboration with organizations from around the world, EPRI is developing and applying advanced analytical tools to elucidate properties that determine whether a surface film allows initiation of intergranular SCC under primary water conditions, as well as to assess whether internal oxidation represents the dominant PWSCC mechanism.

Relationships between the surface characteristics of Alloy 600 and 690 and the composition and electrochemical properties of their oxide films are being examined. In addition, Alloy 600 and 690 samples are undergoing mechanical testing, with oxygen penetration along grain boundaries being tracked and characterized during accelerated aging studies under strain. Fundamental

EPRI employs technology readiness level (TRL) metrics to monitor the status of individual technologies as they advance through its innovation process and transition into its sector programs toward commercial application. (Gen = Generation Sector; P65 = Steam Turbines-Generators and Auxiliary Systems Program; P66 = CoalFleet for Tomorrow—Future Coal Generation Options Program; P87 = Fossil Materials and Repair Program)

### Startup Conditions, End-of-Year 2011 Status and Sector Transitions

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= Anticipated Progress Through EOY11  
= Anticipated Progress at Transition Point
research in these and other areas is expected to continue through 2014-15, with nanoscale characterization tools delivering unprecedented atomic-level insights into key processes. If continuing investigations prove successful, a sound mechanistic understanding of PWSCC will finally be available as the first step toward development of practical damage mitigation and elimination strategies.

**2011-12 Milestones**

- Characterize surface films on Alloys 600 and 690, including electronic and ionic properties
- Conduct mechanical testing and characterize oxygen penetration along grain boundaries for Alloys 600 and 690 and for weldments incorporating Alloy 52 as a filler

**SCC Initiation and Propagation Modeling: Alloy 182 & Irradiated Stainless Steel.** Since 2007, EPRI has been collaborating with major research institutes to conduct controlled laboratory tests and incorporate state-of-the-art knowledge in predictive crack growth rate models for Alloy 182 weld metals in primary water conditions and for neutron-irradiated stainless steels. Final verification testing is scheduled for completion in 2012. The new models will provide more accurate remaining life predictions than the current empirical approaches.

**2011-12 Milestones**

- Complete validation studies and transition models to Nuclear Sector for regulatory review and nuclear plant demonstration

**For more information**

For more information, contact the EPRI Customer Assistance Center at 800.313.3774 (askepri@epri.com).

**Contact**

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EPRI employs technology readiness level (TRL) metrics to monitor the status of individual technologies as they advance through its innovation process and transition into its sector programs toward commercial application. (Nuclear = Nuclear Sector)

**Startup Conditions, End-of-Year 2011 Status and Sector Transitions**

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