ADMINISTRATIVE INFORMATION

1. **Project Name:** Development of a New Class of Fe-3Cr-W(V) Ferritic Steels for Industrial Process Applications (CPS#1763)

2. **Lead Organization:** Nooter Corporation
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St. Louis, MO 63104

3. **Principal Investigator:** Dr. Maan H. Jawad, phone (314) 846-8808, fax (314) 846-3777
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4. **Project Partners:**

Nooter Corporation	Maan Jawad
ExxonMobil Chemical Company	Jeff Jones
BP Amoco	Don Chronister
DuPont	Bert Moniz
ISG Plate	Kenneth Orie
Ellwood Materials Technologies	Fred Venal
Plymouth Tube Company	Bob Curry
Stoody Company	Ravi Menon
Nooter Eriksen	Joe Schroeder
Oak Ridge National Laboratory	Vinod K. Sikka

5. **Date Project Initiated:** 9/30/2001

6. **Expected Completion Date:** 9/29/2004

PROJECT RATIONALE AND STRATEGY

7. **Project Objective:**

The objective of the project is to develop a new class of Fe-3Cr-W(V) steels with (a) 50% higher tensile strength up to 650˚C than current alloys, (b) potential for not requiring any postweld heat treatment (PWHT), (c) reducing the equipment weight by 25%, and (d) with impact properties of approximately 100 ft-lb of upper shelf energy and -10˚F (-20˚C) for ductile-to-brittle transition temperature (DBTT) **without tempering treatment**.

8. **Technical Barrier(s) Being Addressed:**

In order to meet the project objective, it is essential to understand the effect of various alloying elements on the microstructure and properties of Fe-3Cr-W(V) steels. Based on this knowledge, composition specifications are developed for melting and processing of commercial size (~50 ton) heats into forgings, plate, and tubing. Mechanical properties such as tensile, Charpy, and creep testing of the commercial size heats is essential to validate the results for commercial size heats and to develop the data base for the acceptance of the alloy by ASTM standards and ASME pressure vessel and boiler code committees.

In addition to base metal properties, it is also essential to demonstrate that the alloy is weldable by commonly used processes such as gas tungsten arc, gas metal arc, submerged arc, and shielded metal arc processes. In order to achieve the weld metal properties, there is a need for developing the weld filler metals. For the submerged arc and shielded metal arc processes, proper fluxes also need to be identified. Plates welded by each process need to be tested for tensile, impact, and creep properties.

Both base metal and weld metal properties need to be compiled and data packages required for presentation to ASTM and ASME Code committees. Some plant operating experience of the test articles fabricated from the new steel are also important for the development of new steel.

9. **Project Pathway:**

The project partners met and decided on several critical pathways to meet the project objectives.

- Identify alloy composition range and make every attempt to get international patent protection
- Focus the scale-up of new compositions to at least 50-ton heats
- Process the ingots from the large heats into shapes such as forgings, plate, and tubing, which are most likely products to find commercial applications
- Develop filler metals and identify fluxes for welding of the new steel compositions by commonly used welding procedures such as gas tungsten arc, gas metal arc, submerged arc, and shielded metal arc
- Develop mechanical property data base on both the base metal and weldments
- Prepare data packages for submission to ASTM and ASME Code committees

10. **Critical Technical Metrics:**

Baseline Metrics:

- Current alloy commonly used in the chemical industry is 2.25Cr-1Mo, known as Grade 22. Because of its low strength, the use of this alloy requires very thick components.
- Grades T23 and T24 are two higher strength versions of Grade 22 that have been developed in Japan and introduced in the United States. These steels have higher strength than Grade 22 but still lacked optimization for maximizing the properties for this class of steels.

Project Metrics:

- Develop steel compositions that have nearly 50% higher strength up to 650°C than the current best alloys such as Grades 23 and 24
- Use of new alloys to reduce the component weight by 25%
- Identify weld procedure that requires no postweld heat treatment
- Deliver improved properties on a very cost competitive basis

<u>PROJECT PLANS AND PROGRESS</u>

11. **Past Accomplishments:**

This is the third year of the project and significant progress has been made to date in the following areas:

- Alloy compositions have been optimized and patents applied for in the United States and for the international protection.
- Alloy compositions have been commercially melted into 50-ton heats and processed into forgings and plates.
- Heat treatment optimization has been completed for the plates.
- Tensile and impact testing of the commercial heats have been completed.

- Creep testing of the commercial heats is underway with over 30 tests that have already ruptured. Long-term tests to obtain data exceeding 5000 h are continuing.
- Initial welding trials of the plates have been completed by the gas tungsten arc, submerged arc, and shielded metal arc processes.
- Document for inclusion of the new alloy in ASTM was prepared and is being submitted during May 2004.
- Preliminary ASME Code package has been assembled.

12. **Future Plans:**

The major milestones to be accomplished are to:

- Submit the data package for inclusion of the new alloys in ASTM
- Continue long-term creep testing of the base metal at test temperatures ranging from 900 to 1300°F (482 to 704°C)
- Complete tensile and Charpy testing of welds prepared in plates from commercial heats
- Initiate creep testing of weldment specimens taken from the welded plates of commercial heats
- Initiate some component testing of the new alloy
- Prepare and submit the ASME Code package

13. **Project Changes:**

Under the current program there have been no changes in the project direction or timetable.

14. **Commercialization Potential, Plans, and Activities:**

The ferritic steels of this project has applications for hydrocrackers and hydrotreaters for the chemical and petrochemical industry and industrial heat recovery systems for many of the IOF industries including chemical, petrochemical, pulp and paper, steel, glass, aluminum, etc. Product forms to be used will include plate, tubing, piping, forgings, and castings. The ultimate market potential for this steel will be in **millions of tons per year**. The product of this research will be material property data and design allowable stress values approved by ASME Code. The product forms of this research will be installed for in-service operating experience at various application sites for the relevant IOFs. Nooter Corporation will commercialize the material through the current partners.

As part of the commercialization effort, several items are essential: availability of producers of steel, producers of various product forms, producer of weld filler metal, and component fabricators. The second aspect of commercialization is for the component designers to specify the new alloys for the replacement or new components. All of the product suppliers are already part of the current project team. The task of making the component designers familiar with the new alloy and having them to specify these for the components will take some effort. The next project review meeting on June 10-11, 2004 at ORNL will discuss the mechanism that will be used to accomplish this.

15. **Patents, publications, presentations:** (Please list number and reference, if applicable. If more than 10, please list only 10 most recent.)

2 Patents:

- A new invention disclosure (ID 1156, S-99,347) entitled "Improved Cr-W-V Bainitic/Ferritic Steel Composition," was filed on September 19, 2002.

- The invention (ID1156C) retitled "CR-W-V Bainitic/Ferritic Steel Compositions," has been filed in the U.S. Patent Office and foreign (PCT), December 16, 2003.

3 Publications:

- Vinod K. Sikka, Ronald L. Klueh, Philip J. Maziasz, Suresh Babu, Michael L. Santella, Maan H. Jawad, John R. Paules, and Kenneth E. Orie, "Mechanical Properties of New Grades of Fe-3Cr-W Alloys," 2004 ASME/JSME Pressure Vessel and Piping Meeting, July 2004.
- Vinod K. Sikka, Ronald L. Klueh, Philip J. Maziasz, Suresh Babu, Michael L. Santella, John R. Paules, Maan H. Jawad, and Kenneth E. Orie, "High-Strength Fe-3Cr-W(Mo) Steel for Petrochemical Applications," 2004 NPRA Maintenance Conference, May 2004.
- Kenneth Orie, "Mechanical Property Evaluation of New Fe-3Cr-Mo-W(Ta) Steel," ISG Plate, Coatesville, PA, March 26, 2004.

2 Presentations:

- Vinod K. Sikka, Ronald L. Klueh, Philip J. Maziasz, Suresh Babu, Michael L. Santella, Maan H. Jawad, John R. Paules, and Kenneth E. Orie, "Mechanical Properties of New Grades of Fe-3Cr-W Alloys," 2004 ASME/JSME Pressure Vessel and Piping Meeting, San Diego, CA, July 25-29,2004.
- Vinod K. Sikka, Ronald L. Klueh, Philip J. Maziasz, Suresh Babu, Michael L. Santella, John R. Paules, Maan H. Jawad, and Kenneth E. Orie, "High-Strength Fe-3Cr-W(Mo) Steel for Petrochemical Applications," 2004 NPRA Maintenance Conference, San Antonio, TX, May 25-28, 2004.