ADMINISTRATIVE INFORMATION

1. **Project Name:** High-Strength/High Alkaline Resistant Fe-Phosphate Glass Fibers as Concrete Reinforcement

2. **Lead Organization:** MO-SCI Corporation
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3. **Principal Investigator:** Mariano Velez
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4. **Project Partners:** University of Missouri-Rolla, Materials Sci. & Eng. Dept., Richard K. Brow, brow@umr.edu, (573) 341-6812

AGY Holding Corporation
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HTR-Group
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5. **Date Project Initiated:** May 2004

6. **Expected Completion Date:** April 2007

PROJECT RATIONALE AND STRATEGY

7. **Project Objective:** Develop alkaline-resistant iron-phosphate glass fibers for use in reinforcing concrete and cement products and which can replace silica-based alkali-resistant glass fibers. These iron-phosphate glass fibers offer the potential for 40-60% energy savings compared to higher melting silica-based alkaline-resistant glass fibers.

8. **Technical Barrier(s) Being Addressed:** The barriers to achieving the energy savings offered by the lower melting (1100 to 1250 °C) iron phosphate glasses are their dark color and greater fluidity when molten. Their dark color inhibits heat transfer by radiation so alternative melting techniques, such as induction or electrical resistance heating, suitable for commercial production may be needed. Similarly, the viscosity and crystallization properties of iron phosphate melts require tighter control of the melt temperature and fiberization conditions, compared to the more viscous silicate-based melts.

9. **Project Pathway:** The overall approach is to apply our existing knowledge of the structure and properties of iron phosphate glasses to identify candidate compositions possessing the needed combination of chemical durability, mechanical properties (elastic modulus) and ease of fiberization that equals or exceeds the high melting temperature, alkali-resistant, silica-based glass fibers now commercially available. Fibers pulled from promising iron phosphate melts will be used to reinforce various concrete products whose mechanical strength will be measured and compared with equivalent concrete products made with fibers of silica-based glass. This processing information and property data will be transferred to our industrial partner (AGY Holding Corp.) who will undertake glass melting and fiber production experiments on a commercial scale.

10. **Critical Metrics:** Success will be achieved by:

- Demonstrating that fibers useful for reinforcing concrete or other products can be produced from iron phosphate melts, using less energy than what now is required to produce alkaline resistant, silica-based fibers,
- Developing iron phosphate fibers that are equivalent or better in alkaline resistance and mechanical properties to the incumbent, foreign produced, silicate alkali resistant glass, and
- Achieving a successful transfer of the technical information and technology to a company wanting to produce iron phosphate glass fiber for commercial use.

PROJECT PLANS AND PROGRESS

11. **Past Accomplishments:** We have manufactured iron-phosphate glasses with chemical durability to alkaline environments similar to commercial-based silica glasses and with similar elastic properties (June 2005 Milestone). These iron-phosphate glasses have been successfully melted at temperatures between 1100 and 1250 °C, using commercial alumino-silicate crucibles, and then pulled into continuous fibers (15-40 microns diameter) using platinum bushings at temperatures between 1000 and 1200 °C. These temperatures are 100-200ºC lower than those used for manufacturing alkaline-resistant silicate-based glass fibers, thus demonstrating the potential for significant energy savings.

We have fabricated iron-phosphate fibers using alumino-silicate crucibles with ceramic nozzles at temperatures between 1000 and 1200 °C, which is lower in comparison with the manufacturing of alkaline-resistant silica-based glass fibers (June 2006 Milestone).

We have used Ca-phosphate recycled powders from fluorescent lamps (from HTR-Group, Lake Ozark, Missouri) as raw materials in iron-phosphate glasses formulation and developed glasses with chemical durability to alkaline environments similar to commercial-based silica glasses and with similar elastic properties (June 2006 Milestone).

12. **Future Plans:**

Date	Milestone/Deliverable	Partner Activities
June 2005	Manufacture iron-phosphate glass fibers with similar or better mechanical properties than commercial alkaline-resistant silica-based glass fibers	UMR will modify composition to improve mechanical properties of iron-phosphate glasses. Best compositions will be pulled into fibers at Mo-Sci Corp
June 2006	Fabricate iron-phosphate glasses in less expensive metal bushings and/or at reduced temperatures in comparison with the manufacturing of alkaline-resistant silica-based glass fibers.	Mo-Sci Corp is testing fiber pulling in platinum bushings and in ceramic bushings demonstrating that lower temperatures are used for manufacturing the iron-phosphate glass fibers.
June 2006	Use waste or recycled materials as a raw material in iron-phosphate glasses formulation	UMR will include phosphate-based waste materials in the iron-phosphate glasses formulation. Best compositions will be pulled into fibers at Mo-Sci Corp
June 2007	Incorporate iron-phosphate glass fibers in concrete mixes	Mo-Sci Corp is testing best iron-phosphate glass fibers in concrete for long-term assessment.
June 2007	Manufacture iron-phosphate glasses in pilot-scale operation	AGY will be conducting pilot-scale glass fiber manufacturing in 2007.

13. **Project Changes:** An additional task is to evaluate the laboratory-scale melting procedure to design the industrial melting method of the iron-phosphate glasses.

14. **Commercialization Potential, Plans, and Activities:** The anticipated product is an iron-phosphate glass fiber that would replace commercial silica-based alkaline-resistant glass fibers for concrete reinforcement (GFRC) or as reinforcement in other products. The iron-phosphate glass fiber is to be fabricated eventually by the glass company partner AGY. Reinforced concrete is used today for making low-weight panels for buildings exterior, window frames, pipes, and permanent formwork. Other applications include permanent formwork for bridge works, retaining walls, sewer linings, utility boxes, drainage channels and tanks for agriculture. Nearly all products historically made of asbestos-cement such as general purpose flat sheet for buildings, roofing tiles or slates, are being replaced by GFRC. The estimated production of alkaline-resistant silica-based glass fibers is of 20,000 tons/year, with an estimated value of $50 million/year and reinforcing 400,000 to 600,000 tons of concrete.

15. **Patents, Publications, Presentations:**

- R.K. Brow, S. Reis, M. Velez and D.E. Day, ALKALINE RESISTANT PHOSPHATE GLASSES AND METHOD OF PREPARATION AND USE THEREOF, U.S. Provisional Patent Application, No. 60/745,036 filed on April 18, 2006.

- S.T. Reis, J. Shi, R.K. Brow, M. Velez, and D.E. Day, ALKALINE-RESISTANT GLASS FIBERS FOR CONCRETE REINFORCEMENT, UMR-UTC Winter 2005 Newsletter (University Transportation Center), http://campus.umr.edu/utc/newslet/vol2issue2/Newsletter3.htm

- T.E. Day, presentation to the DOE Materials Project and Portfolio Review Meeting, USE OF HIGH STRENGTH, HIGH ALKALINE RESISTANT IRON-PHOSPHATE GLASS FIBERS AS CONCRETE REINFORCEMENT, Industrial Technology Program, Chicago, May 31-June 2, 2005.

- J. Shi, R. K. Brow and S. T. Reis, ALKALINE-RESISTANT PROPERTIES OF CALCIUM-IRON-PHOSPHATE GLASSES, presented at the Spring Meeting of the Glass & Optical Materials Division of the American Ceramic Society, Greenville, SC, May 16-19, 2006.