# Complex Coolant Fluid for PEM Fuel Cell Systems

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Project ID #
FCP 34

# Overview

## Timeline

**For SBIR Phase I & II Project**

- Project start date: 07-14-2004 (Phase I)
- Project end date: 07-12-2007
- Percent complete: 33% (Phase II)

## Budget

- Total project funding
  - DOE share: $847K (Phase I & II)
  - Contractor share: in-kind
- Funding received in FY05: $139K (Phase I & II)
- Funding for FY06: $375K (expected)

## Barriers

- Barriers addressed
  - Technical Barriers (Dispersion and thermal stability of the ion-exchange nanoparticles)
  - Cost Barriers (preliminary cost estimates)

## Partners

- Interactions/ collaborations:

Lehigh University (Subcontractor)
Penn State University (Subcontractor)
Plug Power (Supporting Activities)

# Objectives

**Overall**

To develop and validate a fuel cell coolant based on glycol/water mixtures and an additive package (with corrosion inhibitors and nanoparticles) that will exhibit less than 2.0 μS/cm of electrical conductivity for more than 3000 hours in an actual PEM Fuel Cell System. Demonstrate the potential for commercializing such a coolant at a price that is acceptable for a majority of fuel cell applications (i.e., < $8.0/gallon).

**2005**

Optimize nanoparticle chemistry (size, surface charge, stability)
Optimize corrosion inhibitors (type, concentration, combination)
Short-term tests (300 hours tests)

**2006**

Optimize nanoparticle chemistry (size, surface charge, stability)
Optimize corrosion inhibitors (type, concentration, combination)
Short-term and long-term tests (300 hours and 3000 hours)

# Key Technical and Economic Questions to be Answered

- **How is the electrical conductivity of the coolant related to the properties of the additives?**
- **Will the additives influence the heat transfer and pressure drop characteristics of the coolant?**
- **Is the coolant and its additives compatible with the fuel cell cooling system components?**
- **What is the raw material and production cost for the proposed 'Complex Coolant Fluid'?**

# Approach

- The proposed Complex Coolant Fluid consists of a base compound (glycol/water mixtures) and an additive package.

- The base compound mixture has a freezing point less than –40°C, is non-flammable, and can be used at temperatures up to 122°C.

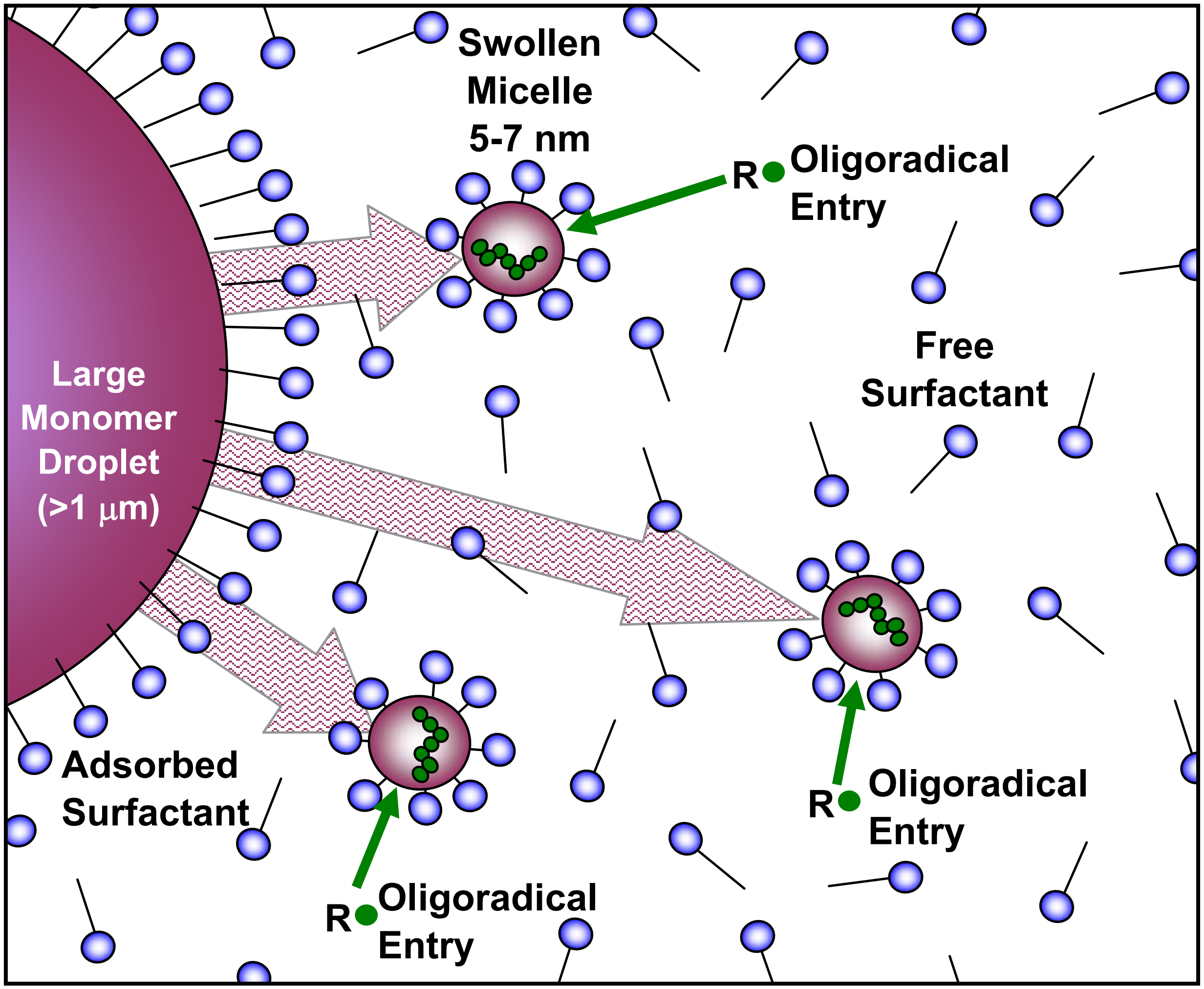
- The additive package consists of non-ionic corrosion inhibitors and ion-suppressing compounds (ion-exchange nanoparticles) to maintain the electrical conductivity of the coolant at a low level.

# Technical Approach in Phase I

- **Development of the nanoparticles by emulsion polymerization**
  - Effect of preparation recipe on the electrical conductivity of the final coolant formulation
  - Study dispersion behavior in the coolant

- Building a dynamic test loop (4 L)
  - Short-term tests (electrical cond. Vs. time)

# Emulsion Polymerization



# Technical Approach in Phase II

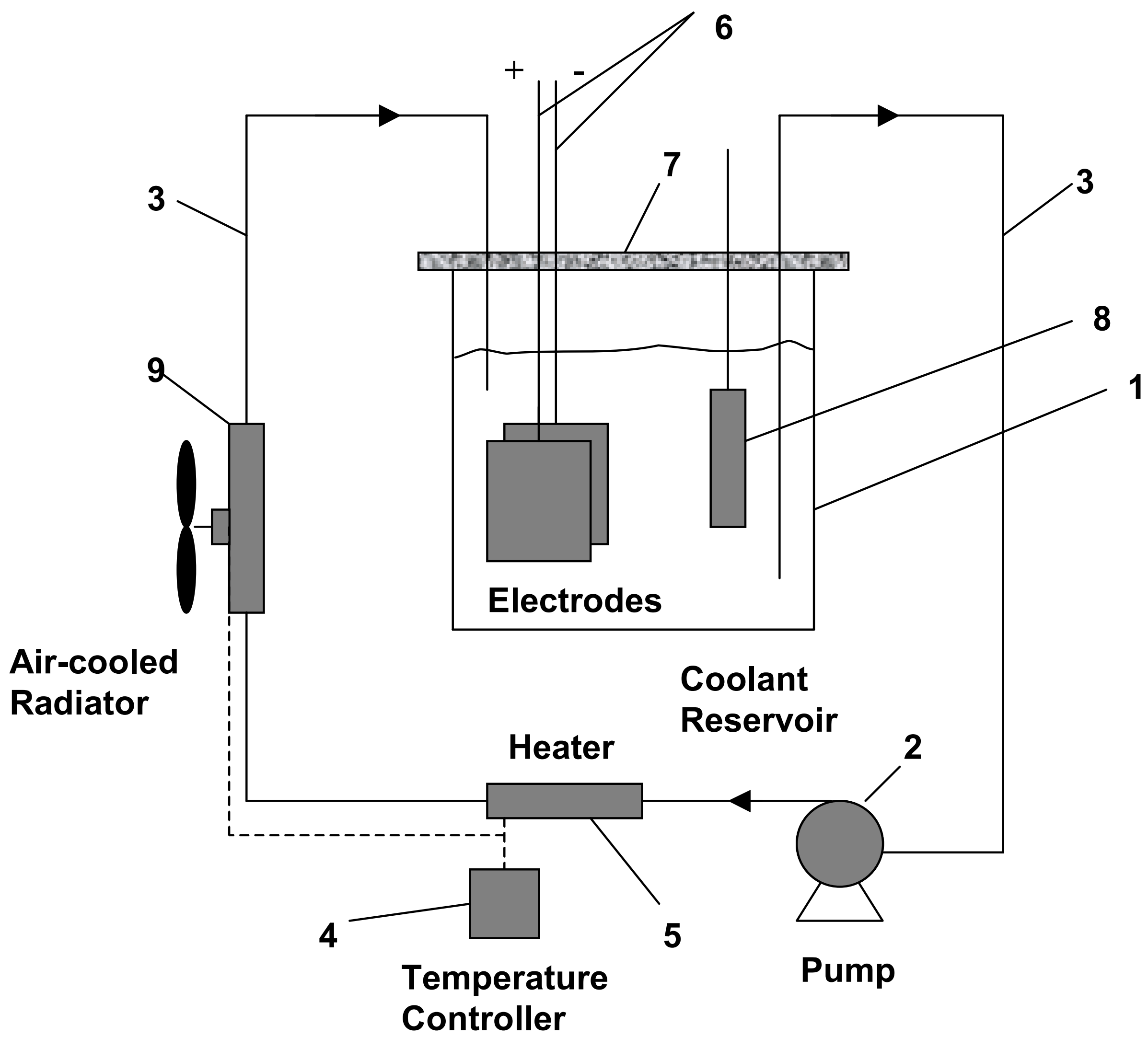
- **Optimization of the ion-exchange nanoparticles**
  - Effect of preparation recipe on the particle size, surface charge and dispersion behavior
  - Study dispersion behavior in the final coolant formulation

- **Short-term and long-term tests**
  - Electrical conductivity and pH vs. time

# Characterization of Nanoparticles

- Conversion
  - Gravimetric Analysis
- Particle Size
  - Dynamic Light Scattering (Nicomp)
  - Capillary Hydrodynamic Fractionation
  - TEM
- Cleaning
  - Serum replacement
  - Ion exchange resin (mixed bed)
- Surface Charge Density
  - Conductometric titration

# Dynamic Test Loop for Coolant Testing




1: Coolant Reservoir
2: Pump
3: Piping
4: Temperature Controller
5: Heater
6: Electrodes
7: Head
8: Probes for pH and cond.
9: Radiator
(total system volume: 4 L)

# Dynamic Test Loop for Coolant Testing

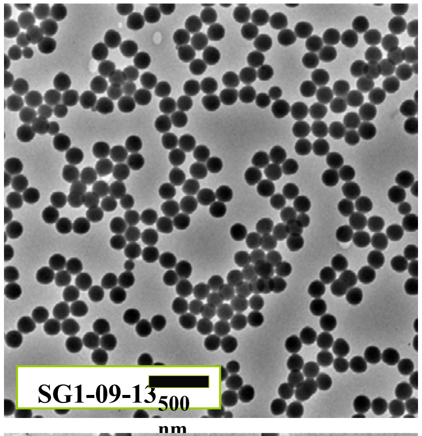
# Results from Phase II

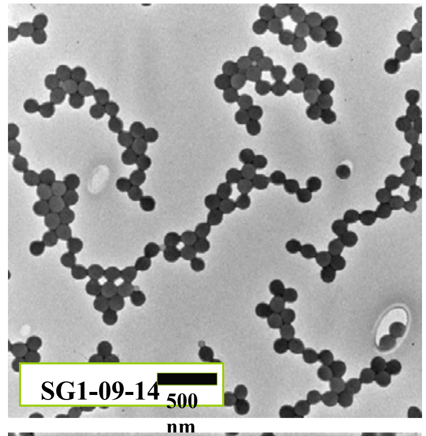
**Table 1:** Particle size of model anionic nanoparticles [(a)] using TEM

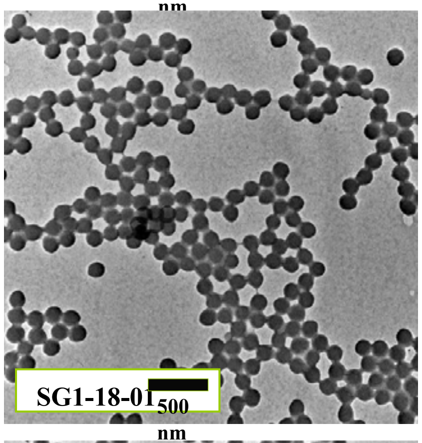
| Latex | NaSS / St [(b)] | Shot-growth stage % conversion [(c)] | $D_n$ (nm) | $D_w$ (nm) | PDI |
|---|---|---|---|---|---|
| SG1-09-13 [(d)] | 0 | N.A. | 136.6 | 139.1 | 1.019 |
| SG1-09-14 | 0.09 | 93.0 | 134.7 | 136.8 | 1.016 |
| SG1-18-01 | 0.18 | 90.3 | 136.1 | 138.6 | 1.018 |
| SG1-27-01 | 0.27 | 92.3 | 128.7 | 131.3 | 1.020 |
| SG1-36-01 | 0.36 | 91.9 | 127.4 | 129.2 | 1.014 |

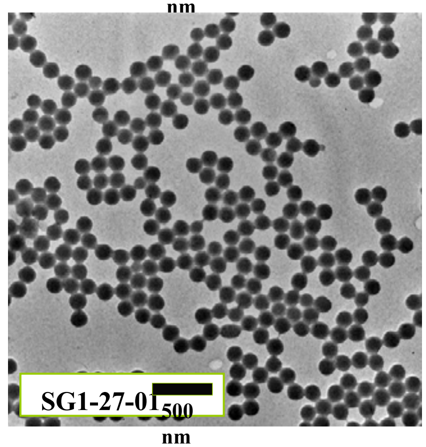
(a) All latexes used were cleaned before the characterization.
(b) The weight ratio of NaSS to St used in the shot growth stage
(c) Conversion at which second stage monomer mixture was added.
(d) SG1-09-13 was prepared only by the first stage of polymerization.

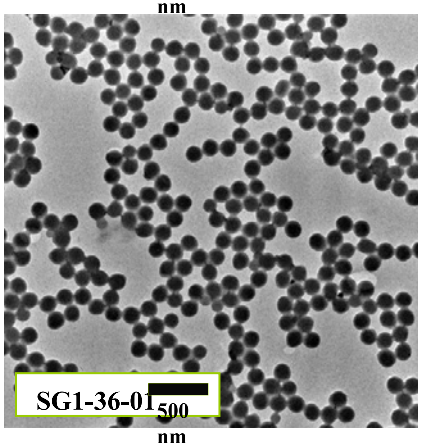
# Results from Phase II



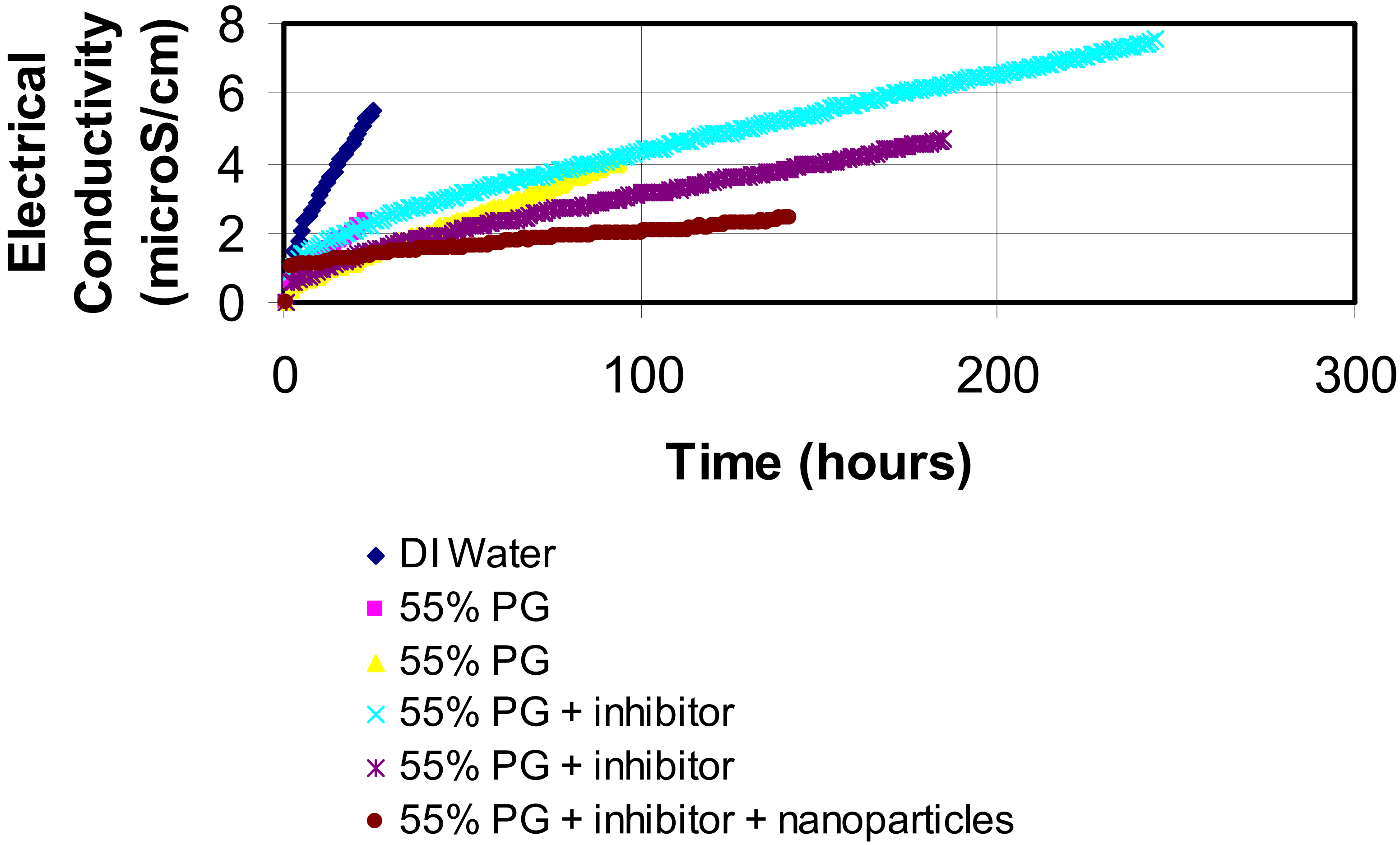

TEM pictures of the anionic nanoparticles

# Results from Phase II

**Table 2:** **Surface charge densities of model anionic nanoparticles**

| Latex | NaSS / St | $N_c$ (μeq./g) | $\sigma_c$ (μC/cm$^2$) | $P_c$ (Å$^2$/$SO_3$) |
|---|---|---|---|---|
| SG1-09-13 | 0 | 29.5 | 6.8 | 234.4 |
| SG1-09-14 | 0.09 | 94.2 | 21.5 | 74.5 |
| SG1-18-01 | 0.18 | 161.7 | 37.3 | 42.9 |
| SG1-27-01 | 0.27 | 219.9 | 48.0 | 33.4 |
| SG1-36-01 | 0.36 | 306.4 | 66.2 | 24.2 |

# Results from Phase II




**Electrical conductivity of coolant formulations as a function of time in the dynamic test system at 70 °C.**

# Discussion and Conclusions

- **Uniform particle size distribution of the nanoparticles have been obtained by optimizing the recipe.**
- **High surface charge density (> 300 μeq./g) can be obtained with high monomer concentration.**
- **Coolant formulations with non-ionic corrosion inhibitor and nanoparticles has lower rate of increase in electrical conductivity than DI water, glycol/water, and glycol/water/inhibitor mixtures.**

# Future Work

- In 2006, the nanoparticles will be optimized further to reduce coagulation
- Several non-ionic corrosion inhibitors will be evaluated
- Electrodeposition rate of additives on the electrode surfaces will be determined
- Material compatibility tests will be carried out
- Optimized coolant will be tested in real fuel cell systems
- Cost of the coolant will be evaluated

# Acknowledgements

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