Particle Separator for Improved Flameless Pressurized Oxy-Combustion (FPO)

DOE National Energy Technology Laboratory

Project Number: DE-FE0031549

2/13/2018

Principal Investigator:

Joshua Schmitt

Federal Share: $881,217

Cost Share : $220,689

Total : $1,101,906

Project Team: SwRI, ITEA, GE Global Research, EPRI

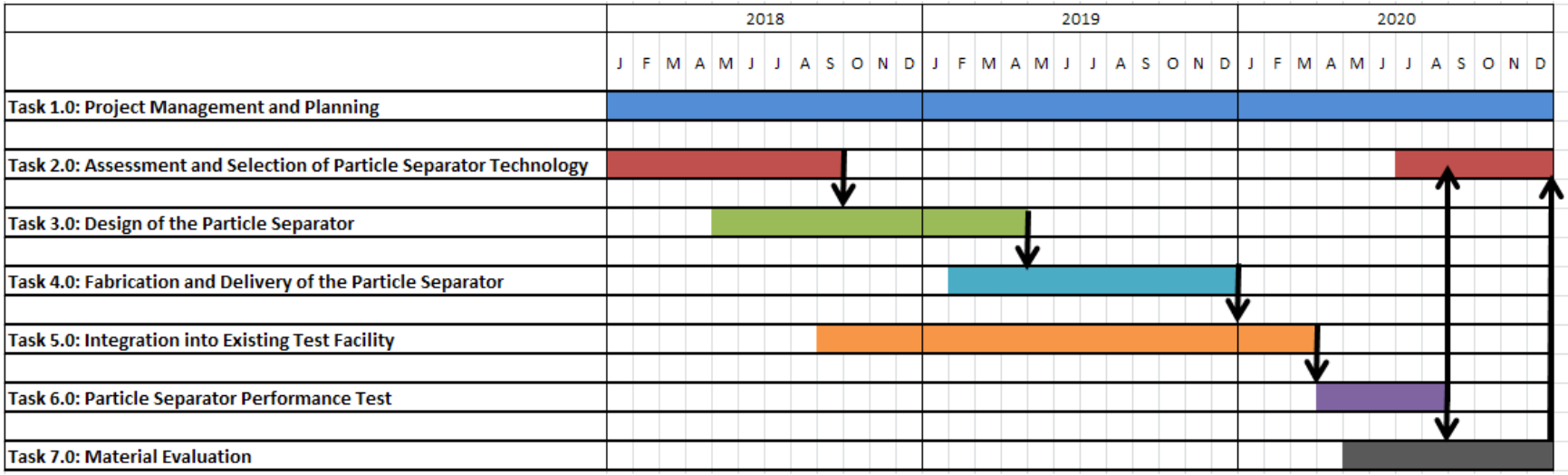
Overview

- Team, Budget, and Schedule Overview
- Objectives
- Background on the Technology
- Technical Approach
- Project Tasks
- Project Schedule
- Project Spending
- Reporting, Deliverables, and Risk

Project Team and Budget Overview

	Total
SwRI	$ 644,967
Itea	$ 248,258
GE	$ 109,139
EPRI	$ 99,542
Total	$ 1,101,906

Schedule Overview



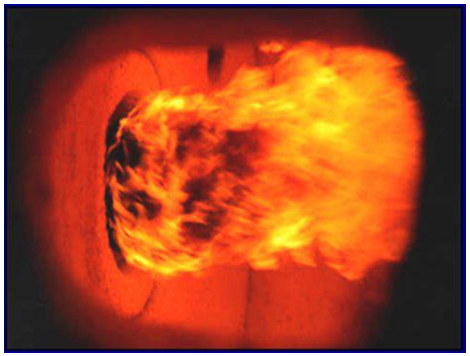
What are the objectives of the proposed project?

- Select a design capable of separating FPO particles
- Perform a detailed design and integration with test facility
- Achieve particle removal with a low pressure loss at a high temperature
- Evaluate material properties of particles and impact on separator surfaces
- Assess economic potential of the separator technology

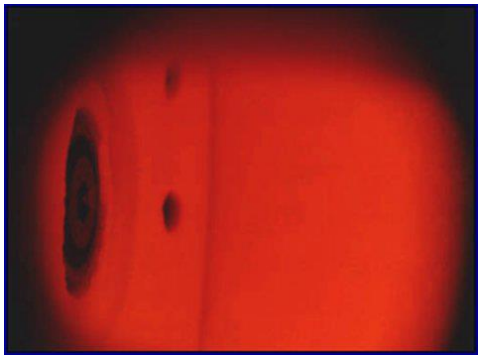
Background on FPO

- Pressurized atmosphere of water and CO_2 under "volume expanded combustion"
  - FPO combustion is more locally controllable with more uniform temperatures
  - Pressurized firing with oxy-combustion also improves cycle efficiency
- Chemical balance in combustion is near stoichiometric
  - Achieved through CO_2 recycle, water, and oxygen balance control
- Almost zero carbon content in incombustible products
  - Traditional: flying and falling ash particles
    - Must be filtered and collected from gas stream
  - FPO: slag with near-zero carbon content
    - Drains out the bottom of the combustor
    - Particulate still exists in exhaust but at reduced quantities and sizes

Traditional Combustion with Flame Front

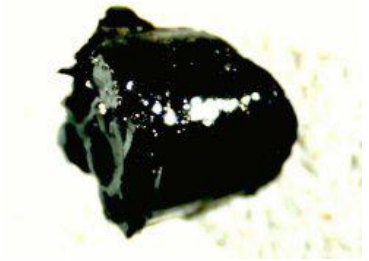


Flameless Pressurized Combustion



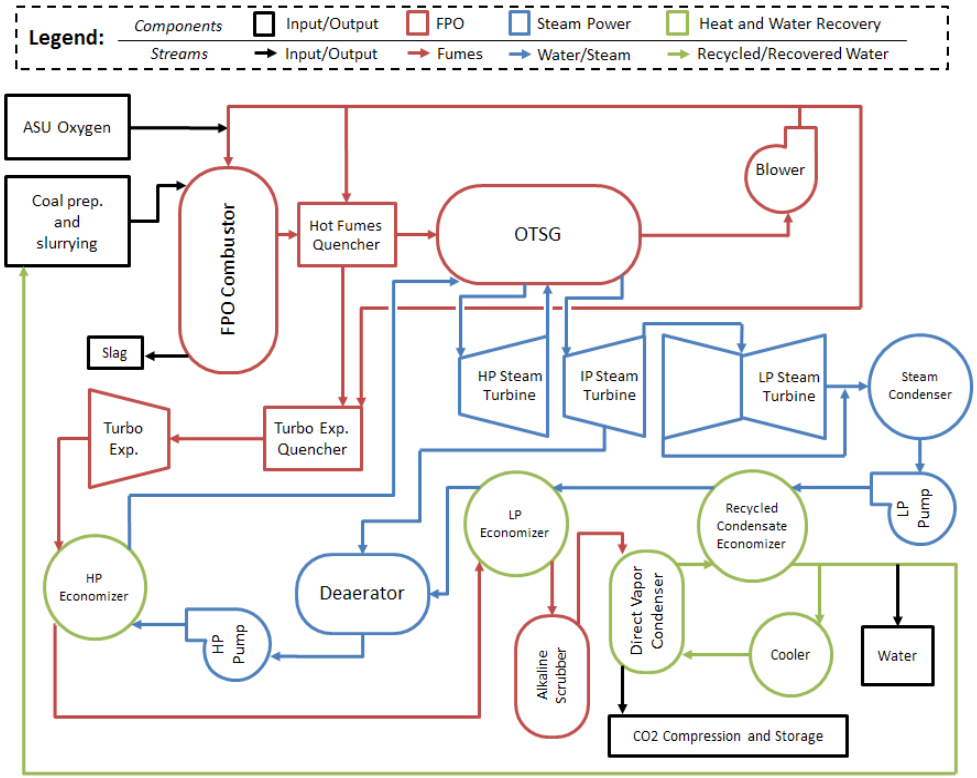
Traditional Combustor Products: Particulate

FPO Combustor Products: Near-zero carbon, neutral slag



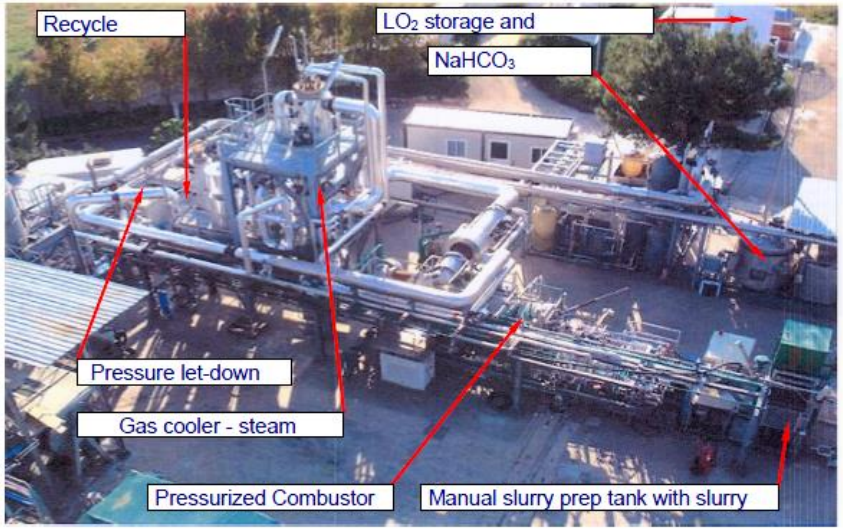
What is the FPO Cycle?

- Slurry of milled coal and water combusted under pressure
- Hot combustor gas is quenched through mixing
- Enters OTSG
- Portion of flow leaves the process with energy before the OTSG and is expanded
- A large percentage of combustion products are recycled
  - Some recycled flow used for quenching
  - The remainder of recycled flow is mixed with pressurized oxygen and injected into the combustor



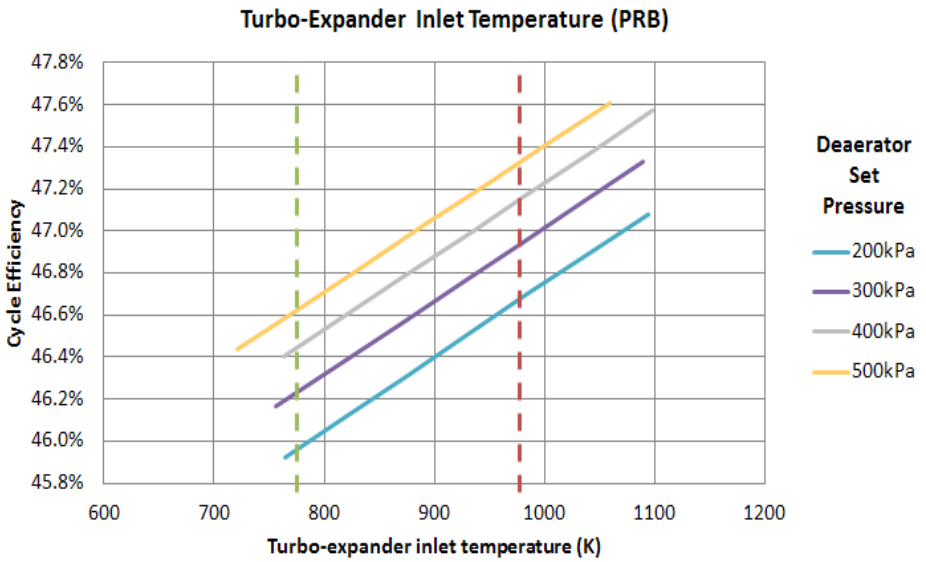
What is the State of the Technology?

- 5 MWth plant in Italy
  - Capable of 4 bar (58 psi) pressure
  - Over 18,000 hours of testing experience
  - Technology proven with high and low rank coals
  - Test location for the particle separator
- Techno-Economic assessment at the commercial scale
  - In process under another DOE FPO development process
  - Continued assessment will be developed by the same team at EPRI and SwRI



Why Particle Separation?

- Demonstrated improved performance of pressurized cycle with recovered energy
- Applicable to technologies other than FPO
- Limits of the turbo-expander inlet temperature could be improved to the red line
  - Requires demonstrated ability to withstand high temperatures
- Goal to minimize pressure drop in order to maximized pressure ratio of expander



Technical Approach: Selection of Design

- Initial evaluation of available particle separator technologies
  - Select based on pressure loss, removal potential, and high temperature performance
- Assess ability to remove mass from flue gas stream with preliminary analysis
- Develop an economic case for a particle separator
  - Based on initial performance estimates and final results

Technical Approach: Detailed Design

- Based on chosen selection, begin analytical evaluation
  - Flow analysis showing minimized pressure loss
  - 3D modeling with mechanical analysis of strength
- Develop detailed design
  - Analysis of pressure boundary and seals
  - Detailed drawings for fabrication
- Develop integration plan with existing 5MWth test facility

Technical Approach: Testing

- Testing at 5MWth facility
  - 3.45 kg/m^3 density gas
  - With 0.13-0.27 m^3/s at the boiler exit
- Monitoring of Combustion Products
  - Particle speed and velocity: Electrical Low Pressure Impactor
  - Gas: Continuous process analyzers
    - Non-Dispersive Infrared Sensors
    - Hydrogen Flame Ionization Detector for Total Organic Content
  - Separated and Unseparated particles collected with batch filtration
    - SEM and x-ray diffraction for particle microstructure
    - Dynamic Light Scattering and SEM for particle size analysis
  - Analysis of impact and wear on separator surfaces

Project Tasks Overview

- **Task 1.0** – Project Management and Planning
- **Task 2.0** – Assessment and Selection of Particle Separator Technology
- **Task 3.0** – Design of the Particle Separator
- **Task 4.0** – Fabrication and Delivery of the Particle Separator
- **Task 5.0 –** Integration into Existing Test Facility
- **Task 6.0** – Particle Separator Performance Test
- **Task 7.0** – Material Evaluation

Task 1.0 - Project Management and Planning

- Manage project according to Project Management Plan (PMP) to meet all technical, schedule, and budget objectives and requirements
- Documentation of project plans, results, and decisions, and project reporting and briefing requirements are satisfied
- Update the PMP 30 days after award and as necessary
  - Changes to the technical basis, cost, and/or schedule for the project
  - Significant changes in scope, methods, or approaches
  - As otherwise required to ensure that the plan is the appropriate governing document for the work required to accomplish the project objectives
- Management of project risks
  - Identify, assess, monitor, and mitigate technical uncertainties and schedule, budgetary, and environmental risks
  - Document and report updates to major risk factors

Task 2.0 – Assessment and Selection of Particle Separator Technology

- Subtask 2.1 – Review and Selection of Existing Particle Separator Technology
  - Research a broad spectrum of existing particle separator technologies.
    - Assess the technology readiness of these particle separators when exposed to FPO flue gas
    - A set of evaluation criteria will be developed to eliminate candidate technology (potential for clogging, service life, among other criteria)
    - The members of the selection team will evaluate the technology options with these established criteria, weighting them and scoring them based on the most desirable factors needed for commercialization
    - If there is no clear winner based on the weighted criteria, the team will vote between the top two candidate technologies

Task 2.0 – Assessment and Selection of Particle Separator Technology

- Subtask 2.2 – Evaluate Future Market Opportunities
  - Produces the Market Evaluation Report
  - Will provide a preliminary picture of the market potential for this technology, including other coal processes beyond FPO
- Subtask 2.3 – Assess Impact of Testing Results
  - The impact of test results will be analyzed at the commercial scale.
  - This will expand upon and update the effort in subtask 2.2, providing a final picture of the potential of the tested particle separator
- Subtask 2.4 – Develop Test Plan
  - Produce a test plan for the selected design that includes the flows, pressures, temperatures, coal type, duration of the test, required sensors, test schedule, required staffing, and other important factors

Task 3.0 – Design of the Particle Separator

- Subtask 3.1 – Flow Analysis
  - Optimize design geometry and provide an analytical estimate of the pressure loss of the flue gas
  - Performance of commercial scale-up will be demonstrated in this subtask
- Subtask 3.2 – Stress Analysis
  - Using pressures and temperatures expected for the test, an analytical model of the stresses in the separator will be created
  - The stresses will be assessed to a certain degree of safety based on the material strength, fatigue, and creep life
  - Performance of commercial scale-up will be demonstrated in this subtask
- Subtask 3.3 – Detailed Design of Particle Separator
  - From the results of the analytical methods, a detailed and fully-featured three-dimensional (3D) model will be developed
  - This model will include all parts required for integration into the existing FPO facility.
  - Once sufficient detail has been added to the design and the analytical models are complete, a design review of the analysis, parts, and assembly will occur to complete this subtask

Task 4.0 – Fabrication and Delivery of the Particle Separator

- Subtask 4.1 – Detailed drawings for Fabrication of the Particle Separator
  - The parts resulting from the detailed design from task 3.0 will be made into drawings
  - Drawings of each part, the overall assembly, and the bill of materials will be produced
- Subtask 4.2 – Fabrication of Parts
  - The drawings from subtask 4.1 will be delivered to selected fabrication shops
  - Fabrication shops will be selected based on quotes and experience, targeting affordability and reliability
  - The produced parts will be inspected for accuracy
- Subtask 4.3 – Assembly and Delivery of the Particle Separator to the Test Location
  - Fabricated parts will be assembled into the particle separator test piece
  - After inspection for accuracy and assembly, the particle separator will be securely packaged and shipped to the 5 MWth test location

Task 5.0 – Integration into Existing Test Facility

- Subtask 5.1 – Develop Facility Modification and Order Parts
  - This subtask will assess the existing 5 MWth facility infrastructure and develop a plan for modification
  - The existing flow loop will require some additional piping and valving to accommodate the particle separator
  - This allows the team to utilize existing combustion equipment and flow analysis instrumentation, saving cost
  - The plan will give the required parts, labor, and estimated overall costs for installing the particle separator.
  - Standard and custom parts will be ordered
  - Based on the facility modification plan and the detailed separator design, any drawings required for modifying the 5 MWth facility will be produced
- Subtask 5.2. – Modify Facility and Install Particle Separator
  - All activities to modify the 5 MWth facility will be carried out under this subtask
  - This includes receipt of the particle separator and installation in Italy

Task 6.0 – Particle Separator Performance Test

- Subtask 6.1 – Perform Test, Record Data, and Collect Samples
  - The tests will be performed according to the plan developed in subtask 2.4
  - This testing is expected to occur over two testing periods
  - The second testing period will make any corrections or adjustments necessary to ensure the quality of the data collected
  - The test will measure the particle characteristics of the input coal, the pressure loss and flow rate of the flue gasses, and the separated and entrained particulate characteristics
  - The data will be processed and evaluated for accuracy and uncertainty
- Subtask 6.2 – Processing and Evaluation of Test Results
  - The data being collected during the test campaigns in subtask 6.2 will be analyzed as part of this subtask
  - Under this subtask the Particle Separator Test Report will be developed

Task 7.0 – Material Evaluation

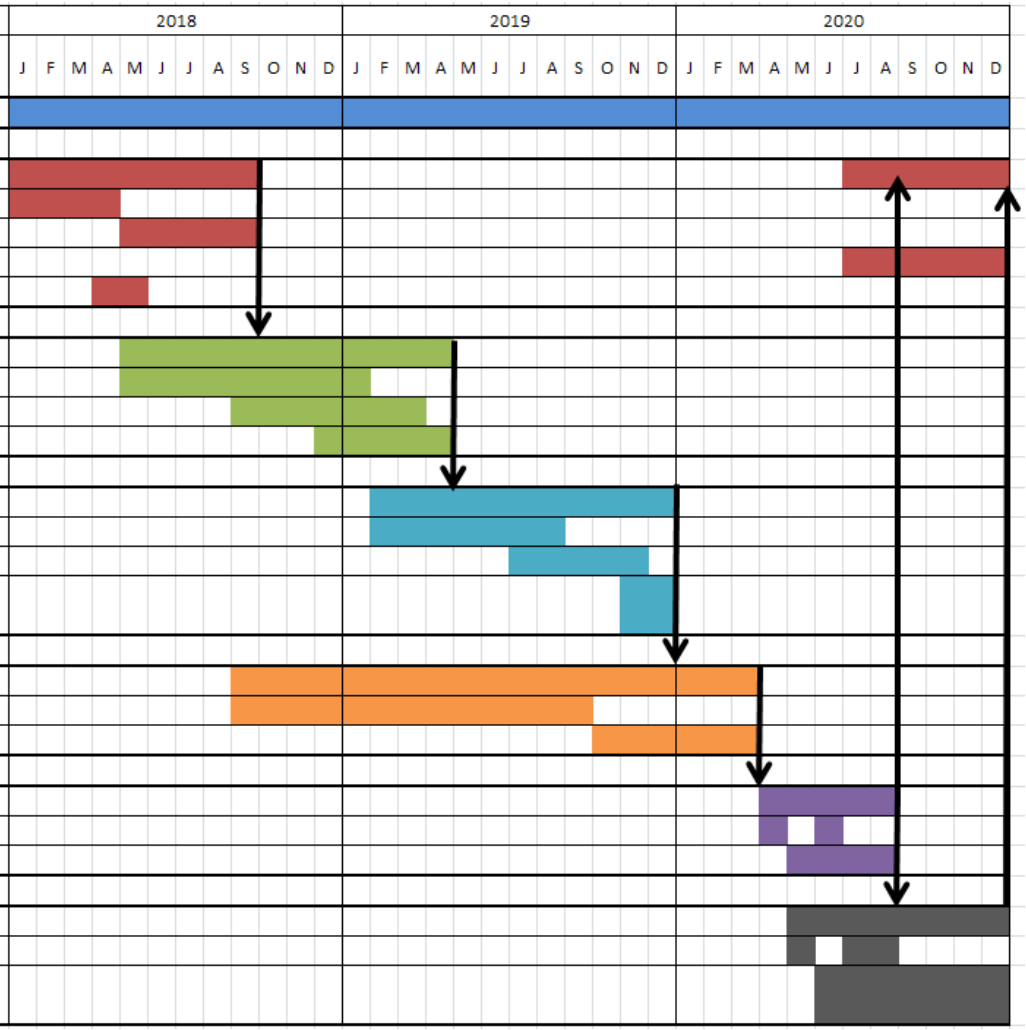
- Subtask 7.1 – Deliver Samples to Material Test Location
  - Collection and cataloging of the particulate will first take place at the 5 MWth facility. The samples of separated and entrained particulate will be sealed in containers and delivered to SwRI for evaluation
  - Deliver the collected particulate and affected test components to SwRI's material evaluation laboratory
  - Deliver the Material Evaluation Report
- Subtask 7.2 – Characterize Particulate Materia and Evaluate Damage to Particle Separator Surfaces
  - At the SwRI's material evaluation location, the particles will be analyzed
  - Study the composition, morphology, and size distribution
  - Particle separator surfaces will be inspected and examined for any signs of damage from the FPO particles and flue gas
  - Particle distribution and inspection of surfaces will assist in assessing the performance and expected life of the particle separator and any components downstream of the separator

Milestone Log

Number	Budget Period	Task/Sub-task No.	Milestone Description	Planned Completion	Verification Method
M1	1	1.0	Updated PMP, DMP, TMP	1/31/2018	PMP, DMP, TMP files
M2	1	1.0	Kickoff Meeting	2/13/2018	Presentation file
M3	1	2.1	Selection of candidate technology	04/30/2018	Candidate Technology Selection presentation file
M4	1	3.0	Detailed design of particle separator	04/30/2019	Particle Separator Design Report
M5	1	4.0-5.0	Fabrication, assembly and installation of particle separator into test facility	03/31/2020	Fabrication, Assembly, and Installation presentation file
M7	1	6.0	Complete separator performance test	12/31/2020	Particle Separator Test Report
M8	1	7.0	Complete material analysis of particles and metal surfaces	12/31/2020	Material Evaluation Report
M6	1	2.2 - 2.3	Complete market evaluation of technology	12/31/2020	Market Evaluation Report
M9	1	1.0	Closing Meeting	12/31/2020	Presentation File

Detailed Project Timeline

	Participating Organization(s)
Task 1.0: Project Management and Planning	SwRI
Task 2.0: Assessment and Selection of Particle Separator Technology	
Subtask 2.1: Review and Selection of Existing Particle Separator Technology	EPRI, GE, SwRI
Subtask 2.2: Evaluate Future Market Opportunities	EPRI
Subtask 2.3: Assess Impact of Testing Results	EPRI
Subtask 2.4: Develop Test Plan	SwRI, Itea, GE
Task 3.0: Design of the Particle Separator	
Subtask 3.1: Flow Analysis	SwRI
Subtask 3.2: Stress Analysis	SwRI
Subtask 3.3: Detailed Design of Particle Separator	SwRI, GE, Itea
Task 4.0: Fabrication and Delivery of the Particle Separator	
Subtask 4.1: Detailed drawings for Fabrication of the Particle Separator	SwRI
Subtask 4.2: Fabrication of Parts	SwRI
Subtask 4.3: Assembly and Delivery of the Particle Separator to the Test Location	SwRI
Task 5.0: Integration into Existing Test Facility	
Subtask 5.1: Develop Facility Modification and Order Parts	SwRI, Itea
Subtask 5.2: Modify Facility and Install Particle Separator	Itea
Task 6.0: Particle Separator Performance Test	
Subtask 6.1: Perform Test, Record Data, and Collect Samples	Itea
Subtask 6.2: Processing and Evaluation of Test Results	SwRI, GE
Task 7.0: Material Evaluation	
Subtask 7.1: Deliver Samples to Material Test Location	Itea, SwRI
Subtask 7.2: Characterize Particulate Materia and Evaluate Damage to Particle Separator Surfaces	SwRI, GE



Risk and Mitigation

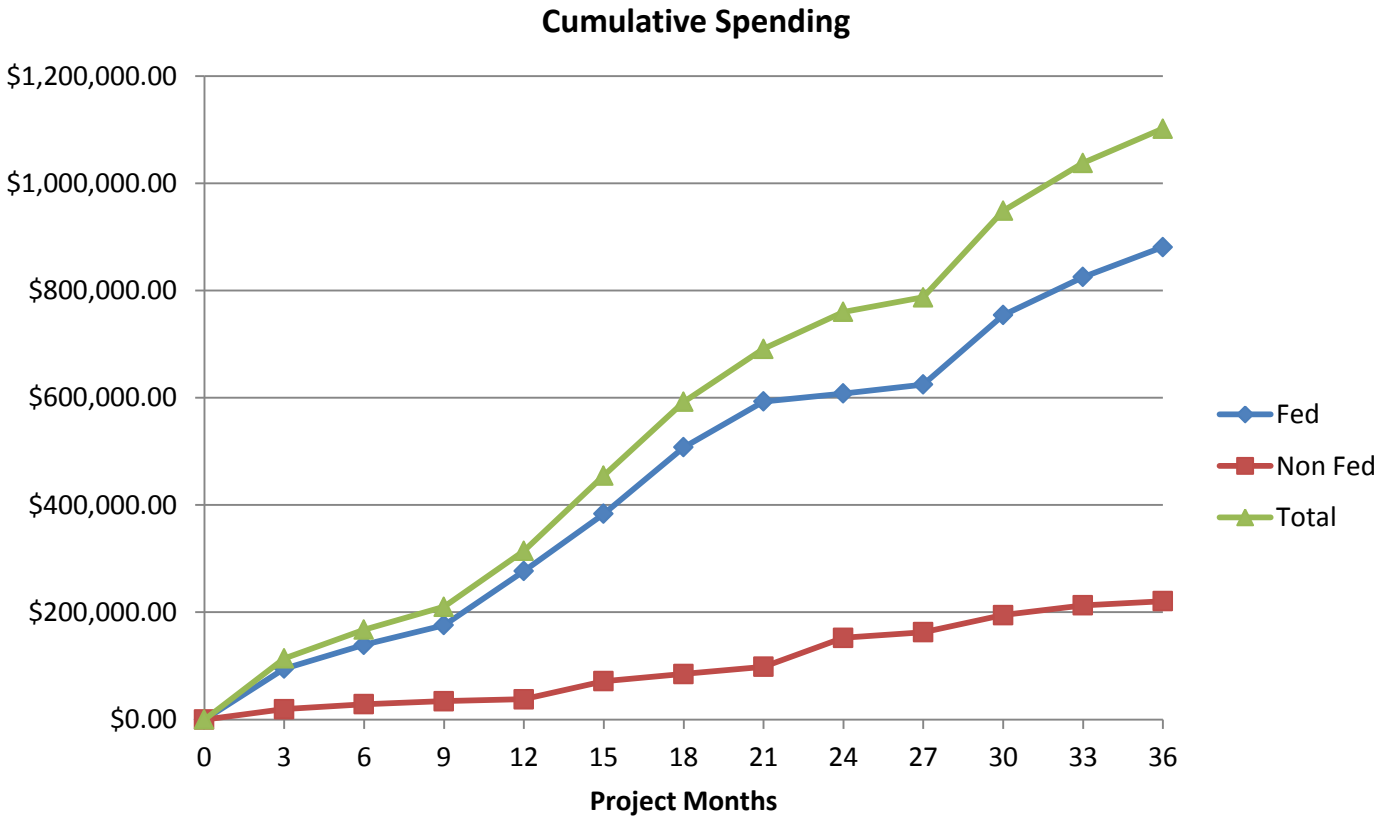
Description of Risk	Probability (Low, Moderate, High)	Impact (Low, Moderate, High)	Risk Management (Mitigation and Response Strategies)
Technical Risks:			
Analytical results do not meet performance goals	Low	High	Return to separator selection results and choose the next best candidate design
Sensors provide incomplete or inaccurate data	Low	High	All sensors will be calibrated and signals will be verified before testing
Resource Risks:			
Incorrectly manufactured parts	Moderate	Moderate	Inspect all parts for accuracy; use contracts with fabrication companies to ensure replacement at no cost
Damage or loss of parts in transit	Moderate	High	Package all parts and assemblies securely and Insure all of critical material shipments
Analysis equipment unavailable or inoperable	Low	Moderate	Develop contingency plan; seek other facilities that can provide similar analysis capabilities
Management Risks:			
Geographically separated groups do not coordinate efforts	Moderate	High	Utilize regular meetings to coordinate efforts; use regular status reports to gauge results and document milestones

- **Miscommunication and duplication of work** - Regular meetings and reports
- **Overspending** – Real time tracking with project management system, competitive quotes
- **Shortage of resources** – SwRI has over two million square feet of lab space and over 3,000 employees

SwRI

PROPULSION MACHINERY

Projected Spending



Reporting and Deliverables

- Additional Reports
  - Market Evaluation Report (Subtask 2.2 and 2.3)
  - Particle Separator Design Report (Task 3.0)
  - Particle Separator Test Report (Task 6.0)
  - Material Evaluation Report (Task 7.0)
- Quarterly Reporting (within 30 days)
  - Research Performance Progress Report (RPPR)
  - SF-425 Federal Financial Report
- Final Scientific/Technical Report (within 90 days)
  - Final SF-425, Invention Certification (within 90 days)
  - Subject Invention Reporting, Invention Utilization Reporting
  - Final Property Report (SF-428, SF-428B)
- Reports within 5 days of event
  - Special Status
  - Journal Article-Accepted Manuscript
  - Scientific/Technical Conference Paper/Presentation or Proceedings

Thank You