FATE OF MERCURY IN SYNTHETIC GYPSUM USED FOR WALLBOARD PRODUCTION

Statement of Project Objectives

A. OBJECTIVES

This project is intended to provide information about the fate of mercury in synthetic gypsum produced by wet FGD systems on coal-fired power plants, when used as feedstock for wallboard production. Wet FGD systems play a key role in current and future efforts to limit the air emissions of mercury control from coal-fired plants. Potential losses of mercury from FGD byproduct gypsum during wallboard production could limit overall mercury control levels achieved by the coal power industry. Furthermore, any adverse effects of elevated mercury levels in FGD gypsum on wallboard products could undermine the use of FGD gypsum as a feedstock for wallboard plants. This project will provide high-quality data on the extent and location of mercury release during the wallboard production process, and provide additional information on the potential for mercury leaching at the end of the wallboard life cycle, when it is disposed in municipal landfills.

B. SCOPE OF WORK

Data will be collected in commercial wallboard plants owned and operated by USG. A variety of synthetic gypsum sources will be investigated; all are from FGD systems on coal-fired power plants but reflect different coal and FGD conditions. Solid samples from various locations in the wallboard process, including the wallboard product, will be collected and analyzed for mercury content. Simultaneous flue gas measurements will be made using the Ontario Hydro Method to quantify any mercury releases to the atmosphere during wallboard production.

Any potential mercury releases from the synthetic gypsum solids are thought to result from thermal desorption. Most of the testing will be concentrated around the "mill" portion of the plant, where the synthetic gypsum is dried and calcined. It is in the mill portion of the process where the feedstock sees the highest process temperatures and where the evolution of waters of hydration may promote mercury desorption. A limited amount of testing will also be conducted in the downstream board plant where the calcined gypsum is slurried, mixed with proprietary additives and formed into wallboard.

The solid and flue gas mercury concentration and flow rate data will be used to calculate a mercury balance around the operating wallboard plant. Samples of each synthetic gypsum will be evaluated in laboratory simulated calcining tests to provide comparison data and evaluate a lab technique for screening synthetic gypsum samples. Also, wallboard produced from synthetic gypsum will be leached according to the Toxicity Characteristic Leaching Procedure (TCLP) to provide an indication whether wallboard disposed of in municipal landfills will have a tendency to release mercury into groundwater.

Five different power plant/FGD feedstock variations will be investigated in this project.
Each of these variables is thought to impact the amount of mercury in the synthetic gypsum feedstock and/or the stability of that mercury in the wallboard production process:

1. A feedstock produced by a power plant that fires high-sulfur bituminous coal and that has a limestone, forced oxidation (LSFO) FGD system that produces a wallboard grade gypsum byproduct; in addition, the power plant will have an operating SCR unit for NO_X control, which promotes mercury oxidation and thus, potentially greater mercury capture in the FGD byproduct;

2. A plant/feedstock configuration similar to the one above, except that the power plant will not be operating the SCR unit for NO_X control;

3. A plant/feedstock configuration similar to the two above, except that the LSFO system employs a gypsum fines blow down, which could potentially change the distribution of mercury in the synthetic gypsum (plant may or may not have SCR);

4. A plant that fires a low rank coal (Texas lignite) rather than bituminous coal; and

5. A feedstock from a plant that uses lime rather than limestone FGD reagent, and employing external rather than in situ forced oxidation.

To investigate all five plant/feedstock configurations, testing will be conducted at three different USG wallboard plants, since no one plant uses all five as a feedstock. The relationship between synthetic gypsum types and USG plants is summarized in Table 1.

Table 1. Proposed Test Matrix

Task	**1**	**2**	**3**	**4**	**5**
Utility Plant Location	PA	PA	AL	TX	WV
Coal Type	Hi-S Bitum.	Hi-S Bitum.	Hi-S Bitum.	Texas Lignite	Hi-S Bitum.*
FGD Reagent	Limestone	Limestone	Limestone	Limestone	Lime
Forced Oxidation Mode	In Situ	In Situ	In Situ	In Situ	External
Fines Blowdown?	No	No	Yes	No	Yes
SCR in Use?	Yes	No	TBD**	No	TBD**
USG Plant	A	A	B	C	A

*Will have to be blended with feedstock for Task 1 since wallboard plant cannot process 100% this material as a feedstock due to handling issues.
**TBD – to be determined later based on the timing of this test relative to "ozone" season.

The proposed test matrix encompasses the range of variables that would be expected in synthetic gypsum produced in U.S. coal-fired plants. While some of the variables listed appear to be confounded (e.g., comparing Task 1 to Task 5 the FGD reagent, forced oxidation mode, and gypsum fines blow down status all change), the proposed plants reflect typical synthetic gypsum produced in the U.S.

C. TASKS TO BE PERFORMED

The following text describes each of these tasks in detail. Task 1 includes the widest range of efforts and is described in the most detail. Tasks 2 through 5 are largely analogous to Task 1 but may involve slightly different sampling locations and procedures. Tasks 2 through 5 are structured such that they need not be conducted consecutively (e.g., they do not have to be performed in numerical order). Testing schedules will be based on plant operating conditions, availability of sampling personnel, etc., and will be structured to minimize disruptions in normal power plant and wallboard plant operating schedules.

Task 1 – High-Sulfur Bituminous Coal, LSFO FGD, with SCR, No Fines Blowdown

Task 1 will involve testing the fate of mercury for synthetic gypsum from a high-sulfur-coal-fired power plant equipped with an LSFO FGD system that does not employ fines blow down. The power plant is also equipped with a Selective Catalytic Reduction (SCR) system that is operated during the summer months (typically May – September) to reduce the emissions of nitrogen oxides (NOx) from the power plant stack. As discussed below, this plant configuration was selected for the base program because it will most likely maximize the total mercury content of the synthetic gypsum feedstock, which will enhance the accuracy of the tests. Furthermore, previous laboratory tests funded by EPRI and initial full-scale tests by USG suggest that small measurable mercury losses could be expected from this feedstock during wallboard production. For all of these reasons, we believe that testing this FGD feedstock material as a base case would represent a reasonably common scenario for potential mercury losses during wallboard production and for mercury content in the wallboard product.

The effects of SCR operation on the mercury in the synthetic gypsum are thought to be twofold, or perhaps threefold. One is that SCR systems operating on bituminous coal flue gases have been observed to increase mercury oxidation percentages in the flue gas. Higher percentages of mercury oxidation typically correspond with increased mercury removal in FGD systems (hence more mercury in the synthetic gypsum), as it is the oxidized form rather than elemental form of mercury that appears to be scrubbed at high efficiency.

The second impact is that SCR systems operating upstream of wet FGD systems have been observed to reduce the incidence of a phenomenon called “mercury re-emissions.” In mercury re-emissions, a portion of the oxidized mercury in the scrubber inlet gas appears to be reduced to the elemental form within the FGD absorber, and this elemental mercury, being water insoluble, is released back into the flue gas leaving the FGD system. Evidence of mercury re-emissions is seen as higher elemental mercury concentrations measured at the FGD outlet than are measured in the inlet flue gas. Mercury re-emissions have been observed from at least three full-scale wet FGD systems, and measurements conducted by EPRI and NETL contractors have indicated that re-emissions are decreased when an SCR is in service upstream. By reducing the incidence of mercury re-emissions, SCR systems can further increase the amount of mercury present in the synthetic gypsum.

However, a third potential impact of SCR catalysts on mercury removed in FGD systems has been theorized. This impact may affect the potential for mercury emissions from the wallboard plant, the amount retained within the wallboard product, and the leachability of mercury from the wallboard after it is finally disposed in a landfill setting. The observed impacts of SCR catalysts on mercury re-emissions raise the issue: do SCR catalysts change the chemical form or oxidation state of oxidized mercury entering the scrubber? Such changes could explain why SCR catalysts reduce the incidence of mercury re-emissions from the scrubber, as alternate mercury species may react differently. As an example, it is widely assumed that the predominant form of oxidized mercury in the absence of SCR is mercuric chloride ($HgCl_2$). It is possible that other oxidized forms of mercury are formed on SCR catalysts, such as mercuric oxide (HgO) or mercurous chloride (Hg_2Cl_2). If so, these species, once removed in the FGD absorber and precipitated with the synthetic gypsum, may react differently with respect to stability during the wallboard manufacturing process or during leaching of the wallboard product in a municipal landfill.

The anticipated importance of gypsum fines blow down as a variable in this project also needs to be explained. Most synthetic gypsum used as a wallboard plant feedstock is subject to a number of quality control specifications by the wallboard producer, including maximum moisture content, minimum gypsum content, maximum chloride content, and particle size distribution. A number of FGD variables affect the ability to meet the solids particle size distribution specification. These variables include the gypsum crystal residence time in the FGD absorber loop, FGD reagent chemical composition, and the amount of physical abrasion to which the crystals are exposed as they are recirculated and dewatered. Some plants cannot meet their particle size specification unless they separate and discard the portion of the byproduct representing the smallest particle sizes. This separation is typically accomplished with hydrocyclones. The separated fines are either disposed of or sold for other uses. In other plants, there is no need to separate the fines and they are included in the byproduct sent to the wallboard plant.

Laboratory testing conducted by URS for EPRI has indicated that the mercury concentration in gypsum fines can be as much as an order of magnitude higher than in the larger particles that remain after fines blow down. This suggests that mercury precipitates or adsorbs at gypsum surfaces, since the fines have a much higher surface area to mass ratio than larger particles. In systems with fines blow down, half or more of the mercury removed by the FGD system can leave in the fines. Fines blow down therefore significantly lowers the mercury concentration in the overall gypsum byproduct going to the wallboard plant.

Since the base case plant does not employ fines blow down, it would be expected to have a higher mercury content in the synthetic gypsum byproduct than would a similar plant that excludes the fines blow down from its synthetic gypsum byproduct. Consequently, the “no blowdown” byproduct may thermally evolve more mercury in the wallboard mill than would a byproduct with the fines removed.

Two other features of the base case plant result in elevated mercury content in the synthetic gypsum. One is that bituminous coals, which typically contain chloride levels on the order of 0.1 wt% or higher, generally oxidize most of the mercury in the coal to an ionic form that is scrubbed in LSFO FGD systems at high efficiency. URS measurements at a plant similar to the base case plant showed mercury oxidation percentages in the range of 60 to 80%, and that this oxidized mercury was scrubbed at 87 to 95% efficiency in the LSFO FGD system.

A second attribute of the base case plant that results in elevated mercury content in the synthetic gypsum produced is that the coal fired there contains a higher than average mercury content. In testing conducted by URS at a nearby plant that fires a similar coal blend, that coal was measured to contain 0.22 to 0.55 ppm of mercury. The average mercury concentration in bituminous coals as determined in the 1999 EPA ICR program was closer to 0.1 ppm.

A net result of these attributes is that USG has measured the mercury content of the synthetic gypsum from this plant at about 1 ppm. A sample collected 5/22/03 of the synthetic gypsum to be used in Task 1 contained over 1 ppm of mercury, the second highest of all of the USG sources tested. The other 15 sources ranged from below the detection limit (0.03 ppm) to 1.6 ppm in mercury content, and averaged 0.4 ppm. As a comparison, in a study conducted by URS for EPRI, the mercury content in nine synthetic gypsum samples from a variety of other plants showed a range of 0.04 to 0.82 ppm mercury content.

Previous results by USG and EPRI suggest that a measurable amount of mercury will be released from this synthetic gypsum in the wallboard plant mill. Initial full-scale testing by USG with a similar material showed losses of nominally 5% of the mercury in the feedstock being evolved in the kettle calciner stack. Laboratory testing conducted by URS for EPRI under simulated gypsum calcining conditions showed that three synthetic gypsum samples from high sulfur bituminous coal, LSFO FGD systems lost greater than 5% of their initial mercury content during calcining.

The base case was chosen to represent the conditions that, for the reasons described above, was most likely to show measurable mercury losses during the wallboard production process. It is expected that the other four synthetic gypsum feedstocks will show reduced mercury evolution, as described later, but full-scale testing is required to confirm or deny such assumptions.

The following describes the subtasks included in Task 1.

Subtask 1.1 – Project Planning

This subtask includes all planning efforts required before the field efforts begin. A test plan will be prepared that will document key information. This will include the feedstock to be processed during the test, wallboard plant operating conditions during the test, data to be collected, sample collection locations and times, sampling and analytical procedures, etc. Included in this plan will be a separate Quality Assurance/Quality Control (QA/QC) section that will document data quality objectives; standard methods to be employed; sample and data chain of custody forms; blank, duplicate and QC sample collection and analysis; equipment calibration procedures; etc.

Also included in the planning effort will be a Health and Safety Plan that will address the safety of project team members and plant personnel during sample collection and analysis efforts. This plan will document process and ambient conditions to which project team members will be exposed, personnel protection equipment required, plant health and safety contact information, and emergency information. MSDS sheets will be attached for all chemicals that will be handled as part of the project implementation. The project planning task will also include the preparation of management planning documents required by NETL, such as Environmental Questionnaires, Milestone Plan, Hazardous Substance Plan, etc.

Finally, the project planning task will include a project kickoff meeting, to be attended by NETL, USG, EPRI and URS personnel. The kickoff meeting will be to review the project objectives and to discuss and revise details of the draft Test Plan as described above. It is expected that the kickoff meeting will be held at NETL offices in Pittsburgh.

Subtask 1.2 – Wallboard Plant Testing

The wallboard plant testing effort will consist of two days of sampling in the USG wallboard plant, with the first day in the mill and the second day in the board plant as described below. Figure 1 illustrates the wallboard production process. Process streams that will be sampled as part of the proposed effort, as described below, are marked with an "S" in the figure.

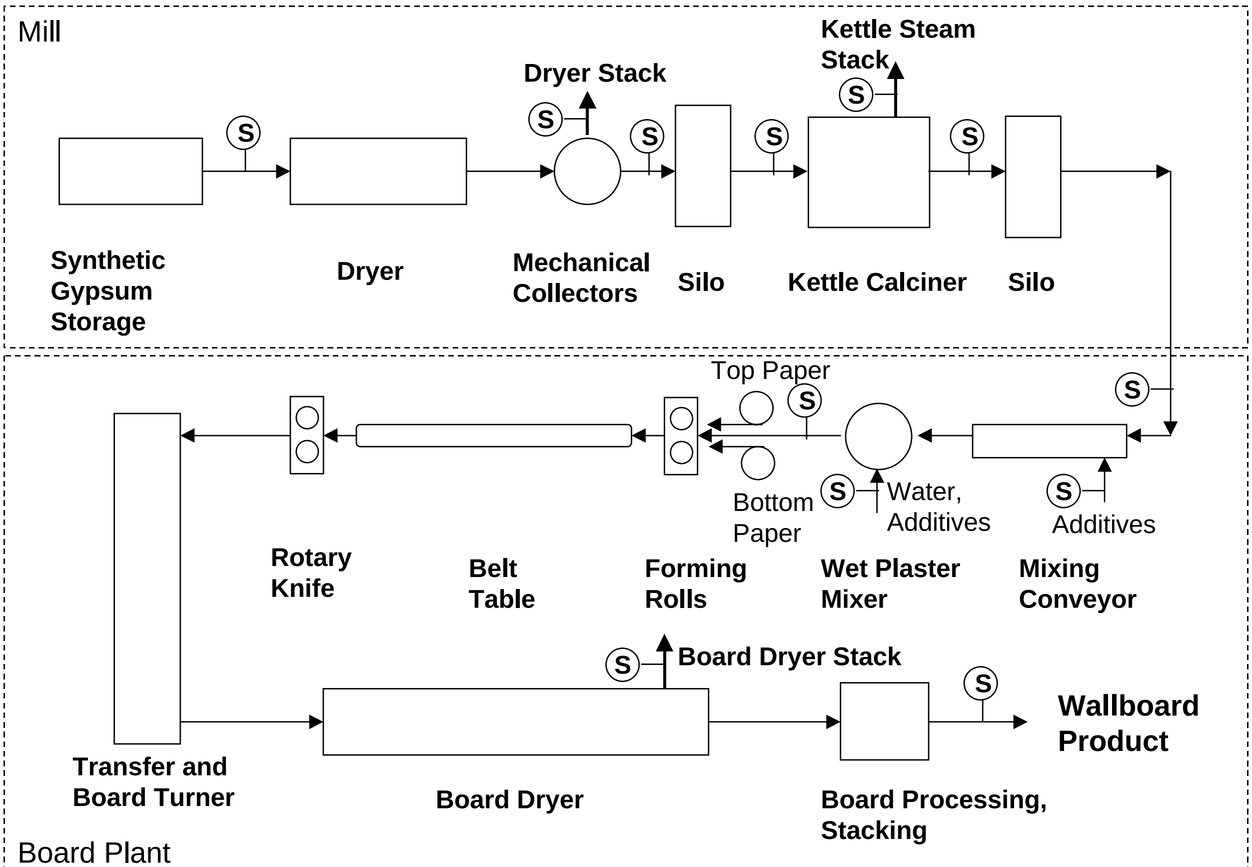

Figure 1. Schematic of Wallboard Plant Showing Planned Sampling Locations.

Day 1 – Mill Testing. On the first test day, simultaneous gas measurements will be conducted using the Ontario Hydro Method (ASTM D6784-02) on a gypsum dryer vent and the downstream kettle calciner vent on a single train of the plant. Triplicate, simultaneous runs will be made at each of these two locations. The kettle calciners are indirect fired vessels. The gaseous stream from the calciner that could contain mercury from the synthetic gypsum is the "steam stack," which is a mixture of the water calcined from the gypsum when forming stucco ($CaSO_4 \bullet ½H_2O$) and air induced through the kettle. This stream is significantly wetter than and does not contain species present in coal flue gases (e.g., CO_2, SO_2 and HCl), for which the Ontario Hydro Method was developed and validated. Consequently, the method may have to be modified slightly to ensure proper sampling and speciation under these conditions. Any such modifications will be proposed as part of the test plan for this project and will be discussed during the project kickoff meeting. The dryer is direct fired, so its stack gas is a true flue gas and the standard Ontario Hydro Method should be appropriate for sampling this stream.

During each of the three runs, process samples will be collected of the dryer feed solids, dryer product solids, calciner feed solids, and calciner product stucco. Process data will also be collected, including dryer and calciner feed rates, air flows and exit gas temperatures. These triplicate test samples will subsequently be analyzed for mercury content at an off-site laboratory.

Day 2 – Board Plant Testing. On the second test day, triplicate Ontario Hydro Method measurements will be made on the board dryer stack gas. The timing of the second day measurements will be coordinated with the plant to best correspond with the processing of stucco material calcined the previous day. This timing will take into account residence times in intermediate storage bins between the mill and board plant.

During each of the triplicate Ontario Hydro runs, samples will be collected of the feed stucco, the slurry fed to the board forming machine, and the product wallboard. Water and a number of proprietary additives are added to the stucco when mixing the slurry prior to the board forming step. The water, each of these additives, and the paper used during board forming will also be sampled in triplicate, to evaluate their impact on the mercury content of the slurry that gets formed into wallboard and the wallboard itself. However, because the composition and dosages of the additives are considered quite proprietary, the results of sampling additives will only be reported as their percent contribution to the total mercury content in the slurry. No individual additive feed rate or mercury concentration data will be reported, nor will the chemical compositions or names of these additives.

As for the Day 1 testing effort, key process data will be collected throughout the test day. For the board plant these data will include the stucco feed rate, additive feed rates (which will not be included in the report), the board production rate, the dryer exit gas temperature and flow rate.

As the two-day sampling effort is completed, all process and Ontario Hydro Method samples will be recovered, stabilized, and labeled according to the test plan, and shipped to URS' Austin, Texas laboratories for mercury analyses. Method blanks and reagent blanks for the Ontario Hydro Method samples will be included with the sample sets.

In concert with the efforts at the wallboard plant, corresponding coal samples and power plant and FGD process data will be collected by the utility producing the synthetic gypsum being evaluated. The coal samples will be analyzed for ultimate and proximate analyses, chlorine and mercury content. The coal data along with the power plant and FGD process data will be used to document the conditions under which the synthetic gypsum evaluated was produced.

Subtask 1.3 – Off-site Sample and Data Analyses

In this subtask, all of the samples collected as part of Subtask 1.2 will be analyzed for mercury content and for other parameters. Other parameters will include gypsum moisture content, particle size distribution, specific surface area, and chloride content, and coal ultimate and proximate analyses, according to provisions that will be included in the test plan. These analytical results, along with the process data, will be used to construct a mercury balance around the mill and the board plant. The mercury balances will show individual stream flow rates and mercury concentrations (except for the additives used in the board plant), the percentage of the total mercury entering and leaving the plant in each process stream, and overall mercury mass balance closures. Data will be shown for individual sampling runs and as averages for the triplicate measurements.

The coal data, power plant data, and FGD process data from the power plant producing the synthetic gypsum evaluated will also be tabulated along with the material balance data.

Subtask 1.4 – Mercury Leaching Stability in Wallboard from Synthetic Gypsum

The wallboard samples collected during the Subtask 1.2 effort will be evaluated in the laboratory by the TCLP procedure, to determine the propensity of the mercury remaining in the wallboard product to leach out in a simulated landfill aqueous environment. The TCLP leachate will be analyzed and reported for all seven RCRA metals, including mercury.

To make the results of this effort more broadly applicable, nine other sets of synthetic gypsum feedstock (or feedstock blends) and corresponding wallboard product samples will be collected from USG plants that process synthetic gypsum to produce wallboard. These nine samples will be selected to represent the range of synthetic gypsum sources currently being processed into wallboard by USG. To the extent possible, the nine samples will include the other synthetic gypsum feedstock and plant combinations proposed under Tasks 2 through 5 in this proposal.

These nine feedstock and product sample sets will first be analyzed for mercury content, to determine the extent to which the mercury in the feedstock appears to be reflected in the wallboard product. This will only be an approximate comparison, because during these sample collection efforts it will be difficult to determine the exact blend ratios of gypsum feedstock sources and to coordinate feedstock material with specific wallboard product.

Subsequently, the additional nine wallboard products will be evaluated by the TCLP procedure to determine the propensity of the mercury remaining in those products to leach out in a simulated landfill aqueous environment.

The mercury analysis and TCLP results for these additional sample sets will provide some input into the decision of which feedstock materials and plants to sample in Tasks 2 through 5 as described below. However, mercury losses from synthetic gypsum during wallboard production are likely to be less than 20% of the original mercury content. It is expected that the ability to achieve mercury balance closure across these plants by analyzing feed stream and product mercury concentrations in grab samples will be no better than ±20%, even in the event where there are no mercury losses during wallboard production. In plants where multiple feedstock sources are used and exact blend ratios are difficult to quantify, the closures may not even be within ±20%. Thus, these grab sample analyses would not likely eliminate any of the proposed synthetic gypsum feedstocks from consideration for full-scale evaluation in Tasks 2 through 5. The grab sample analyses might, however, identify feedstocks where mercury losses appear to be greater than 20% and where full-scale testing would be particularly warranted.

Finally, this subtask will include analyses of natural gypsum feedstocks for mercury content. A total of ten natural gypsum samples from a geographically diverse set of mines supplying USG wallboard plants will be sampled and analyzed for mercury content. Corresponding wallboard product samples will also be collected simultaneously. These samples will be used for comparison between the mercury content of synthetic versus natural gypsum feedstocks and their corresponding wallboard products. It is expected that the mercury content in wallboard produced from natural gypsum will be very low, at or below analytical method detection limits, so no TCLP evaluation of these samples has been included in the estimate for this task.

Subtask 1.5 – Laboratory Simulation of Mercury Losses During Calcining

In this subtask, URS will test an aliquot of the synthetic gypsum feed to the mill collected as part of Subtask 1.2 in a laboratory gypsum calcining simulation. The procedure was developed as part of an EPRI-funded laboratory evaluation of the stability of mercury in FGD byproducts (calcium sulfite sludges as well as gypsum byproducts).[1] The results of the laboratory evaluation will be compared to the full-scale mill results as to the percentage of the mercury in the original sample that is evolved during feedstock drying and calcining. Similar comparison testing is proposed as part of Tasks 2 through 5. If good correlation is found in comparing these field and laboratory results, it may prove to be possible to use the laboratory experiment as a screening tool to predict mercury losses from candidate synthetic gypsum samples that are being considered for wallboard production. The availability of such a screening procedure could be invaluable in the future as new wallboard-grade gypsum producing FGD systems come on line or as existing wallboard gypsum system are modified to alter mercury removal in the FGD system, such as with an SCR retrofit.

Subtask 1.6 – Management and Reporting

This subtask includes the preparation of periodic and final reports that present, summarize, discuss and interpret the results from Subtasks 1.2 through 1.5. Data will be presented in tabular and graphic form to the extent possible to aid the reader in understanding the project results. Due to the proprietary nature of the results, USG wallboard plant locations and the synthetic gypsum suppliers are indicated with anonymous identifiers (e.g. Plant A, Source A). Deliverables and project briefings are further described in Sections D and E of the Statement of Project Objectives.

The management effort will also include test coordination. This will involve arranging for specific feedstock material to be shipped to the wallboard plant from the power plant source, scheduling the test with the wallboard plant operations personnel, scheduling sampling and analytical personnel, etc.

The proposed project will be implemented by a team consisting of individuals from USG Corporation, URS Corporation, and Shaw Environmental. Figure 2 illustrates the project organization for Task 1, the base project. Any other tasks funded would be organized in a similar manner.

USG will serve as the prime contractor and will manage the overall project effort. URS will support USG by managing the sample and data collection efforts at each plant, and by conducting off-site laboratory investigations, process and impinger sample mercury analyses, and data reduction and reporting efforts. URS will also conduct the Ontario Hydro sampling of process stacks at USG wallboard plants B and C as part of Tasks 3 and 4, respectively. Subcontractor Shaw Environmental will conduct the Ontario Hydro measurements at the USG wallboard plant A as part of Tasks 1, 2 and 5.

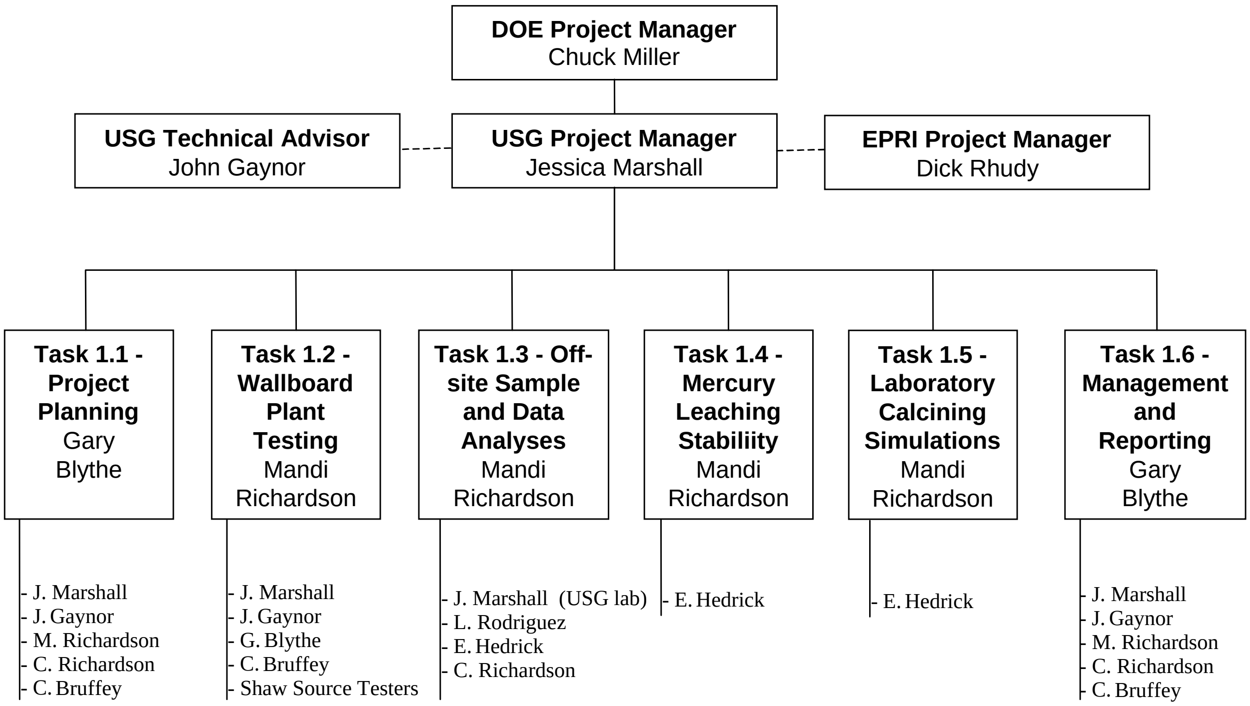

Figure 2. Project Organizational Chart for Task 1 (charts for Tasks 2 – 5 will be analogous)

Ms. Jessica Marshall will serve as USG's Project Manager, and will provide coordination between the wallboard plant operations personnel and subcontractors URS and Shaw Environmental. Ms. Marshall is a Product Safety Manager at USG, and has a Masters of Science degree in Public Health in Industrial Hygiene.

Mr. John Gaynor of USG will serve as a technical specialist for the project. Mr. Gaynor is a Chemical Engineer with over 23 years of experience with USG, and he is their Manager of Synthetic Gypsum. Mr. Gaynor will provide coordination between the utilities producing the synthetic gypsum being tested and the wallboard plants. He will also provide expertise in the wallboard production process, particularly related to the use of synthetic gypsum feedstock.

Mr. Gary Blythe will be URS' Project Manager for their proposed subcontracted effort. He will be responsible for the successful and timely execution of URS' portion of the project, and will be the Task Leader for test planning and project reporting. Mr. Blythe has over 27 years of experience conducting and managing R&D for the control of SO_2, SO_3 and mercury from coal-fired plants. Since 1992, he has managed a number of successful SO_2, SO_3 and mercury control research projects for NETL. He brings expertise to the project in the areas of coal-fired power generation, FGD process engineering, production of synthetic gypsum from FGD, and conducting mass balance measurements on operating, full-scale production plants.

Ms. Mandi Richardson will be URS' Principal Investigator. She will be the Task Leader for the field efforts at all five sites and associated laboratory efforts. She will participate in developing test plans to determine the number, location, and types of samples to be collected, and will take the lead in preparing the QA/QC plan. She will schedule and coordinate test and sampling personnel, lead the field efforts, coordinate off-site analytical work, and communicate QA/QC requirements to all involved parties to ensure data quality. She has a Bachelors degree in Chemistry, and has worked at URS seven years. Her experience conducting Hg removal research and field sampling efforts, and her analytical skills will help ensure the success of the proposed project. Ms. Richardson will be assisted in the laboratory efforts by Ms. Lori Rodriguez and Ms. Emily Hedrick. Both have a B.S. degree in Chemistry.

Dr. Carl Richardson will serve as a technical specialist and peer reviewer for URS. Dr. Richardson is a nationally recognized expert in the field of mercury measurement and control technology. He has a PhD in Physical Chemistry and over 12 years of experience at URS. He will provide peer review of sampling and analytical techniques and QA/QC plans, and will provide a data review function. He will also assess the adequacy of the Ontario Hydro Method for sampling the kettle calciner steam stack and recommend any modifications, if needed, to adapt the method to this non-flue-gas process stream.

Mr. Chuck Bruffey will serve as the Principal Investigator for Shaw Environmental, Inc. Mr. Bruffey has over 26 years of experience conducting source characterization work for government and industry, and has participated in a number of sampling method development and validation efforts for the U.S. EPA and other agencies. Mr. Bruffey will supervise the efforts of the Shaw Environmental staff conducting Ontario Hydro Method measurements as part of Tasks 1, 2 and 5.

Mr. Dick Rhudy will be EPRI's Project Manager for the laboratory investigations they will cost share. Mr. Rhudy has a degree in Chemical Engineering and for over 25 years has managed EPRI research at bench, pilot, and full scale related to the control of emissions from coal-fired power plants.

Task 2 – High-Sulfur Bituminous Coal, LSFO FGD, no SCR, No Fines Blowdown

Task 2 will investigate how mercury emissions are affected by changes in the conditions under which the synthetic gypsum feedstock to the wallboard plant is generated. In Task 2, the only change from the Task 1 case will be that the synthetic gypsum will be generated while the SCR is not in operation at the power plant. For reasons discussed under Task 1, the synthetic gypsum produced under Task 2 is anticipated to be lower in total mercury content than the synthetic gypsum produced under Task 1; however, the potential for mercury re-release under high-temperature conditions in the wallboard plant under Task 2 may be somewhat different (and perhaps greater) than in Task 1 because of differences in the chemical form or oxidation state of mercury-containing compounds (e.g., $HgCl_2$ in Task 2 versus perhaps HgO or Hg_2Cl_2 in Task 1.)

The efforts proposed to be included in Task 2 are similar to those previously described for Task 1 above. The subtasks included in Task 2 are described below.

Subtask 2.1 – Project Planning

A test plan addendum will be generated for Task 2 that will address all of the items included in the original plan, but specific to the Task 2 effort.

Subtask 2.2 – Wallboard Plant Testing

The wallboard plant testing effort will consist of one day of gas sampling in the USG wallboard plant in Pennsylvania, concentrating on sampling in the mill as described below. Process samples will be collected over a two-day period (mill samples the first day, board plant samples the second day).

Simultaneous testing will be conducted by the Ontario Hydro Method on a gypsum dryer vent and the downstream kettle calciner vent on a single train of the plant. Triplicate, simultaneous runs will be made at each of these two locations. During each of the three runs, process samples will be collected of the dryer feed solids, dryer product solids, calciner feed solids, and calciner product stucco. Since the dryer feed material will be blended from two sources, samples will be collected of each of the individual feed materials as well as the blend going to the dryer. Process data will also be collected, including dryer and calciner feed rates, feedstock blend percentages, air flows and exit gas temperatures. These triplicate sample tests will subsequently be analyzed for mercury content in an off-site laboratory.

On the second test day, process samples will be collected of the board plant feed stucco, slurry, and wallboard product. The collection of these samples will be time phased to correspond with when the material produced in the mill on the previous day is fed to the board plant. Assuming the results from Task 1 show minimal or no measurable mercury emissions from the board dryer stack, no Ontario Hydro measurements have been included in Task 2 for the board plant.

As the two-day sampling effort is completed, all process and Ontario Hydro Method samples will be recovered, stabilized, and labeled according to the test plan, and shipped to URS' Austin, Texas laboratories for mercury analyses.

In concert with the efforts at the wallboard plant, corresponding coal samples and power plant and FGD process data will be collected by the utility producing the synthetic gypsum being evaluated. The coal samples will be analyzed for ultimate and proximate analyses, chlorine and mercury content. The coal data along with the power plant and FGD process data will be used to document the conditions under which the synthetic gypsum evaluated was produced.

Subtask 2.3 – Off-site Sample and Data Analyses

In this subtask, all of the samples collected as part of Subtask 2.2 will be analyzed for mercury content and for other parameters such as moisture content or coal ultimate and proximate analyses, according to the provisions in the test plan. These analytical results, along with the process data, will be used to construct a mercury balance around the mill and around the board plant. The mercury balances will show individual stream flow rates and mercury concentrations (except for the additives used in the board plant), the percentage of the total mercury entering and leaving the plant in each process stream, and overall mercury mass balance closures. Data will be shown for individual sampling runs and as averages for the triplicate measurements.

The coal data, power plant data, and FGD process data from the power plant producing the synthetic gypsum evaluated will also be tabulated along with the material balance data.

Subtask 2.4 – Mercury Leaching Stability in Wallboard from Synthetic Gypsum

The wallboard samples collected during the Subtask 2.2 effort will be evaluated in the laboratory by the TCLP procedure, to determine the propensity of the mercury remaining in the wallboard product to leach out in a simulated landfill aqueous environment. The TCLP leachate will be analyzed and reported for all seven RCRA metals, including mercury.

Subtask 2.5 – Laboratory Simulation of Mercury Losses During Calcining

In this subtask, URS will test an aliquot of the synthetic gypsum feed to the mill collected as part of Subtask 2.2 in a laboratory gypsum calcining simulation. The results of the laboratory evaluation will be compared to the full-scale mill results as to the percentage of the mercury in the original sample that is evolved during feedstock drying and calcining.

Subtask 2.6 – Management and Reporting

This subtask includes the preparation of a section in the project final report that presents, summarizes, discusses and interprets the results from Subtasks 2.2 through 2.5. Data will be presented in tabular and graphic form to the extent possible to aid the reader in understanding the project results.

Task 3 –High-Sulfur Bituminous Coal, LSFO FGD, with Fines Blow Down

This task would vary from the Task 1 effort in that the synthetic gypsum source would be an LSFO FGD system that employs fines blow down, whereas the FGD source for Task 1 did not. The anticipated impacts of the FGD system employing fines blow down on synthetic gypsum used for wallboard manufacturing were described earlier for Task 1. Because of where USG feedstock gypsum is produced and wallboard plants are situated, it is likely that the Task 3 sampling effort will be conducted in the state of Alabama. SCR may or may not be in operation at the gypsum source, depending on whether testing takes place during the “ozone season” (typically May – September) or not. The subtask structure and work efforts for Task 3 are otherwise exactly the same as for Task 2, and are not repeated here for the sake of brevity.

Task 4 – Texas Lignite Gypsum Test

The testing in Tasks 1 through 3 was proposed for wallboard plants processing synthetic gypsum from high-sulfur, bituminous-coal-fired plants with FGD systems. This is appropriate because most synthetic gypsum processed in wallboard plants come from bituminous coal sources. However, a growing amount of wallboard is produced from synthetic gypsum produced in scrubbed power plants that fire low-rank coals such as Powder River Basin (PRB) or lignite fuels.

Low-rank coals differ from high-sulfur bituminous coals in a number of manners that impact mercury in the synthetic gypsum. For example, low-rank coals typically have lower chloride content than bituminous coals, which results in lower mercury oxidation percentages in the FGD inlet flue gas. This could result in lesser amounts of mercury being removed in the FGD systems. However, from the standpoint of mercury concentrations in the synthetic gypsum, this effect is offset to some degree by the fact that the lower rank coals typically have lower sulfur content, and hence produce less gypsum per mass of coal or lignite fired.

There is evidence, at least from one laboratory evaluation, that synthetic gypsum from low-rank coals behaves differently when dried and calcined in a wallboard plant than that from bituminous coal. In a laboratory study conducted for EPRI by URS, calcining simulations were conducted on five different synthetic gypsum samples. In these studies, synthetic gypsum samples from a Texas lignite fired power plant and from a PRB plant showed measurably lower percentage mercury losses than three samples from high-sulfur, bituminous coal plants.[1] This observed difference may have been coincidental, since the number of samples from each coal type was small. However, these results suggest that coal rank could be an important variable to investigate as part of this project.

Task 4 is proposed to be conducted on a wallboard plant processing synthetic gypsum produced at a power plant in Texas that burns lignite coal.   This material is going into use for wallboard production in the near future, and will only be processed at a USG plant in Texas. Therefore, Task 4 will be conducted at that power plant and wallboard plant. Otherwise, the subtask structure and work efforts for Task 4 are exactly the same as for Tasks 1, 2, and 3, and are not repeated here for the sake of brevity.

Task 5 – Mg-Lime Synthetic Gypsum Source Test

This task will investigate the effects of significant changes in the conditions under which the synthetic gypsum feedstock to the wallboard plant is generated. Changes from the base case include that the FGD system uses high-magnesia lime (Mg-lime) as the FGD reagent, the gypsum is produced from calcium sulfite slurry in an external oxidation tank, and the FGD system employs gypsum fines blow down. SCR may or may not be in operation at the gypsum source, depending on whether testing takes place during the “ozone season” (typically May – September) or not.

The change to external forced oxidation is typically required when producing gypsum as a byproduct from a Mg-lime system. Mg-lime systems rely on high dissolved sulfite ion concentrations (enabled by high soluble magnesium ion concentrations) to enhance liquid-phase alkalinity in the FGD absorber slurry. In situ forced oxidation, such as in LSFO systems, would eliminate this advantage of the Mg-lime system design by converting all of the dissolved sulfite to sulfate, which is not an alkaline species. Consequently, Mg-lime systems that produce wallboard-grade gypsum byproducts must first produce calcium sulfite in the FGD absorber loop, then the blow down slurry from the absorber is acidified and oxidized to the gypsum form in a separate reaction tank.

The external forced oxidation process appears to impact how much mercury is in the gypsum byproduct. The EPRI-funded evaluation of mercury stability in FGD byproducts conducted by URS included slurry and byproduct samples collected from a Mg-lime, external forced oxidation FGD system. These samples showed evidence that a substantial fraction of the mercury removed in the FGD system is evolved from the byproduct solids in the external oxidation tank.

If a portion of the mercury present in the FGD byproduct is already evolved during the external forced oxidation process, it raises the question of how this impacts subsequent evolution during gypsum calcining in the wallboard plant. Similarly, does the fact that mercury is first removed in the FGD system as a precipitate on calcium sulfite solids, which are subsequently converted to gypsum, impact the leaching stability of mercury in the wallboard produced?

One limitation on the Task 5 effort is that the Mg-lime based synthetic gypsum cannot be used as the sole feedstock for the wallboard plant because of process and material handling issues. Consequently, the mill feedstock during Task 5 will actually be the "richest" blend of the Mg-lime synthetic gypsum mixed with the Task 1 feedstock that the plant can run.

The subtask structure and work efforts for Task 5 are exactly the same as for Tasks 1 through 4, and are not repeated here for the sake of brevity.

D. DELIVERABLES

The NETL Cooperative Agreement requires preparation and submission of quarterly technical progress reports. Other periodic, topical, and final reports required shall be submitted in accordance with the "Federal Assistance Reporting Checklist" contained in the NETL Cooperative Agreement and the instructions accompanying the checklist. Such reports include routine project management reports such as the Federal Assistance Management Summary (DOE F 4600.5) and other reports as specified in the Cooperative Agreement. If the project involves reports/deliverables other than those identified on the "Federal Assistance Reporting Checklist," the Recipient shall provide a list of these reports/deliverables.

E. BRIEFINGS/TECHNICAL PRESENTATIONS

The Recipient shall prepare detailed briefings for presentation to the COR at the COR's facility located in Pittsburgh, PA or Morgantown, WV to explain the plans, progress, and results of the technical effort. It is anticipated that at least one "kickoff" briefing within 60 days after award and one final briefing near the conclusion of the project will be required. It is anticipated that this end-of-project data review meeting will be held at USG's Chicago offices, and will be attended by USG, EPRI, URS, and DOE project team members. The NETL Cooperative agreement also requires presentation of project results at two conferences as specified by the NETL Project Manager. One such conference is assumed to be a 2004 NETL Mercury Contractors meeting (if such a meeting is held), and/or at national professional meeting(s) related to mercury control and/or coal byproducts.