ABSTRACT

The aim of our project is to develop paperless wallboard materials from flue gas desulfurization (FGD) scrubber sludge (FGD gypsum), which are to be: (a) 2 to 4 times stronger than current commercial wallboard, (b) able to tolerate variability in the chemical and physical composition of FGD gypsum, (c) environmentally friendly, (d) repairable after the board has already been mounted, (e) easy to handle, (f) directly paintable, (g) formed in different colors, and (h) recyclable. In addition, our wallboard composites are to have better acoustical characteristics than currently available wallboards. Last year, we successfully established that our proposed technology was capable of forming paperless wallboard materials up to 2 feet x 2 feet x (0.1 – 0.2)” sizes. However, to demonstrate the potential commercial viability of the paperless wallboard, we are attempting to upscale the product size to 8 feet x 4 feet.

This year, five major issues were addressed, i.e., (a) mercury concentration and its fate during the processing of FGD gypsum, (b) reduction of the density of the paperless wallboard, (c) evaluation of thermal resistance of the product, (d) color of the product, and (e) development of infrastructure for the fabrication of full size products. Seven approaches were tested for the reduction of the wallboard’s density, i.e., concentration of baking soda and boric acid, concentration of commercial water reducer, drying approach, air entrapment, concentration of foamed glue, water-to-sludge ratio, and concentration of commercial air entrapment chemicals. By controlling the water-to-sludge ratio, the density of the product could be varied between 562 kg/m$^3$ to 1200 kg/m$^3$. The commercial water reducer chemicals were found unsuitable for controlling the density. However, air-entrapment chemicals derived from natural by-products showed considerable effectiveness. To understand how the additives incorporated into the FGD scrubber sludge affected the thermal conductivity of the paperless wallboard materials, we designed a heat cell in which the wallboard product could be insulated from the rest of the environment. This allowed us to measure the thermal characteristics of our product. Our thermal conductivity measurements suggested the commercial papered wallboard had a conductivity of 0.15 k (W/m x K), while hardened scrubber sludge had a conductivity of 0.17 k (W/m x K). We have also completed the design and fabrication of a 4 feet by 8 feet die and have successfully formed full size paperless wallboard sheets.
EXECUTIVE SUMMARY

The overall goals of our project are to:

1. design, develop, and generate technology which converts sulfate-rich scrubber sludge into recyclable paperless wallboard materials. These materials will be able to withstand the variabilities in the chemical and physical composition of scrubber sludge streams, and

2. mature the recyclable paperless byproduct structural wallboard composite fabrication technology into a pilot scale manufacturing phase, followed by commercialization of these composites.

More specifically, during the 2002-2003 year we had the following objectives in the pursuit of the aforementioned goals of building structural materials from FGD gypsum:

- To design and fabricate 24” x 48” x 0.1-0.2” and 48” x 96” x 0.2” molding dies for the formation of paperless wallboard materials.
- To enhance the mechanical strength of our large-sized wallboard material by systematically changing water-to-scrubber sludge (w/s) ratio, formation temperature, and concentration of additives. In upscaling our paperless wallboards, we were to be guided by the formation parameters we had generated for 6” x 6” x 0.1”, 12” x 12” x 0.2”, and 24” x 24” x 0.2” sized materials. The aim of this objective was to ensure that we attained flexural strength at least 3 times that of the commercial product.
- To undertake the development of 24” x 48” papered wallboard materials from sulfate-rich scrubber sludge.
- To carry out the economical and market evaluation of our technology for fabricating paperless wallboard.

To accomplish these objectives, six tasks were proposed:

Task 1: to evaluate the mercury content in the as-received scrubber sludge, in its hemihydrate phase, and in the final wallboard product,

Task 2: to enhance strength and workability of paperless wallboard and papered wallboard composites formed using the 24” x 48” x 2” molding die,

Task 3: to carry out comparative evaluations of paperless wallboard and commercial wallboards,

Task 4: to carry out comparative evaluations of papered wallboards fabricated from sulfate-rich scrubber sludge and commercial wallboard materials,

Task 5: to upscale both paperless and papered wallboards to commercial product size of 48” x 96” x 0.2-0.25”, and

Task 6: to undertake economic and market analyses and to propose technical parameters needed for a pilot scale manufacturing of our products.

About 22 million tons of FGD byproducts are produced in the USA every year. Unfortunately, only a small fraction, i.e., less than 18%, is economically utilized with the rest going to disposal ponds. This presents the electric power utilities, using FGD technology to burn high sulfur Illinois coal, with a serious byproduct disposal problem. In fact, among all the coal combustion byproducts produced, i.e., fly ash, bottom ash,
slag, and FGD residues, it is the FGD byproducts, which have found the least amount of economic utilization. To overcome this problem, we initiated a number of research projects in 2000 in which we are attempting to convert scrubber sludges into marketable products. Among these initiatives, one research approach is to convert sulfate-rich scrubber sludge into environmentally friendly paperless wallboard composites. Our proposed technology is immune to the problems associated with the utilization of scrubber sludge by the wallboard industry, e.g., the lack of a good bond between the sludge core and paper, poor crystallization of the sludge, and effects of impurities on crystal growth.

In 2001-2002, we proposed to develop a paperless wallboard material of size 2 feet x 2 feet x 0.2 inch from CWLP power plant’s FGD scrubber sludge, which would be: (a) 2 to 4 times stronger than current commercial wallboard, (b) able to tolerate variability in the chemical and physical composition of FGD scrubber sludge material, (c) environmentally friendly, (d) repairable after the board had already been mounted, (e) easy to handle, (f) directly paintable, (g) formed in different colors, and (h) recyclable. In addition, our wallboard composite would have better acoustical characteristics than currently available wallboards. We did successfully establish that our proposed technology was capable of forming paperless wallboard materials up to 2 feet x 2 feet x (0.1 – 0.2) inch sizes, and our materials were much stronger than commercial products. However, to demonstrate the potential commercial viability of paperless wallboards, we needed to upscale the product size to 8 feet x 4 feet and generate the needed technology transfer parameters to ensure the products’ success in pilot/demonstration phase.

This year, five major issues were addressed, i.e., (a) mercury concentration and its fate during the processing of FGD gypsum, (b) reduction of the density of the paperless wallboard, (c) evaluation of thermal resistance of the product, (d) color of the product, and (e) development of infrastructure for the fabrication of full size products. We briefly summarize below what was accomplished during 2002 – 2003:

- The as-received but air dried FGD gypsum typically had a mercury concentration in the range of 120 to 135 µg/kg. As the processing temperature increased, the mercury concentration in the heated calcium sulfate showed a parabolic decrease in the range 50°C – 250°C.
- It appeared the rate of mercury re-emission could be divided into two different temperature phases, i.e., 50°C – 150°C and 150°C – 200°C. The rate of re-emission was much higher in the higher temperature range than in the lower temperature range.
- Because our proposed technology of developing paperless wallboards is significantly different from the current papered wallboard manufacturing technology, our approach necessitated the need to establish that it is possible to fabricate large-sized samples. Therefore, we designed and built 4 feet by 2 feet and 8 feet by 4 feet molding dies in the physics department’s workshop for fabricating our paperless wallboard materials. We successfully demonstrated that it was feasible to form 4 feet by 2 feet and 8 feet by 4 feet paperless wallboard sheets, which could be directly painted and could be mounted on wooden studs using conventional drywall screws.
• An experimental procedure was developed for measuring the thermal conductivity of wallboard materials, and our initial results suggested that our paperless wallboard had similar thermal parameters to those observed for commercial products. However, we made no attempt to improve the insulation characteristics of our paperless wallboard materials this year. The effect of additives on the thermal conductivity will be investigated in 2003 – 2004.

• Extensive experiments were conducted this year to develop technology which reduced the density of our paperless wallboard product yet retained significant flexural strength. In pursuit of this, we attempted different approaches and additives. In particular the following variables were tested:
  • concentration of baking soda and boric acid,
  • concentration of commercial water reducer,
  • drying approach,
  • air entrapment,
  • concentration of foamed glue,
  • water-to-sludge ratio, and
  • concentration of commercial air entrapment chemicals.
Our results provide evidence that the air entrapment chemicals used in the cement industry inhibited the crystallization of hemihydrate into gypsum phase, therefore, they were not suitable for drywall products. Systematic experiments did suggest that water-to-sludge ratio, foamed glue, and chemical treatment could successfully control the bulk density of our paperless wallboard products.

• The hardened gypsum developed from FGD hemihydrate typically had a light yellowish color. Adding white paints, along with the water, did not improve the color of the hardened gypsum. However, our experiments did suggest that it is feasible to fabricate paperless wallboards in different colors, and these colored wallboard can be painted if so desired.

• As expected, we also demonstrated that it is feasible to develop recycled newspaper papered wallboard materials from FGD gypsum. However, it was felt that in view of the higher strengths of our paperless wallboard products this approach may not be desirable.

The remainder of this report contains proprietary information and is not available for distribution except to the sponsor of this project.