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Project Summary

Development of a New Gravity Sedimentation Process for Dewatering Flue Gas Cleaning Wastes

A. R. Tarrer

This report gives results of a project to develop and test a novel system for dewatering flue gas cleaning (FGC) wastes at the pilot plant level. In this new system, the clarification and thickening functions are conducted in separate, but interconnected, pieces of equipment. The new system consists of a lamella clarifier and a conventional thickener that is smaller in diameter, but deeper (than the thickener/clarifier typically used to dewater FGC wastes), connected by a recycle stream between the two units to obtain a high degree of flexibility and control of operating conditions. Preliminary economic evaluation of this system indicates potential savings of 10 perent of the total capital costs and 6 percent of annual operating costs for the FGC waste management/ disposal system.

In pilot testing of this system, a completely new concept in thickener operation, known as "bang-bang" operation, evolved, in which the thickener underflow rate is set as low as possible without plugging the underflow lines. Periodically, the underflow rate is increased briefly to remove additional solids from the system at the concentration established by the (previously set) low underflow rate. This mode of operation appears to make it possible to maintain the maximum solids concentration in the underflow.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

In the mid-1970's, EPA's Industrial Environmental Research Laboratory in Research Triangle Park, NC, initiated several projects to solve problems associated with slowly settling, difficult-to-dewater flue gas cleaning (FGC) wastes. These problems were primarily attributed to small, thin "platelet" crystals of calcium sulfite ($CaSO_3 \cdot 1/2H_2O$) in these wastes. When present in significant quantities (more than a few percent), it was difficult to achieve greater than about 30 percent solids in a gravity settler, or about 50 percent solids with vacuum filtration. The approaches used to solve these problems included attempting to make larger calcium sulfite crystals, oxidation of the calcium sulfite to calcium sulfate ($CaSO_4 \cdot 2H_2O$), and improving dewatering equipment design. The project reported here involves equipment design improvements, and covers the period May 1, 1976, through June 15, 1983.

Phase 1 - A preliminary evaluation determined the direction of the program; i.e., limited sedimentation and filtration were studied to disclose which offered the better potential for improving dewatering efficiencies.

Phase 2 - A detailed process synthesis and development effort was conducted; i.e., fundamental concepts in gravity sedimentation and process dynamics were applied to develop a new system for dewatering FGC wastes.

Phase 3 - A feasibility analysis was done to estimate the maximum savings possible with the use of the new dewatering system. Also, equipment designs, layouts, etc. were made for a larger scale pilot evaluation of the new dewatering system.

Phase 4 - A pilot-scale system was constructed, transported, and installed at the EPA/TVA pilot FGC facility at the Shawnee Steam Plant near Paducah, Kentucky. Shakedown studies revealed needs for equipment improvement. Equipment was modified in cooperation with TVA, and final pilot-plant tests were performed. Objectives of these tests were to determine if the clarification function of the unit could be decoupled from its thickening function, to determine if the unit was capable of concentrating unoxidized FGC wastes to a high solids content, to identify design limitations, and to make operational recommendations.

Phase 1 Results

In Phase 1, settling data were collected, showing that the FGC wastes tested, containing a significant percentage of calcium sulfite ($CaSO_3 \cdot 1/2H_2O$), exhibit a settling behavior similar to that of weakly flocculating materials. Assuming that FGC wastes do form weak flocs while settling, the flocs appear to have a low yield strength, and the gravitational force (the weight) exerted by overlying layers of solids in the settling medium compresses underlying layers. This means that the operating depth of the blanket of settling waste in the thickener is an important process parameter: the deeper the blanket of settling wastes at the bottom of the thickener, the higher the solids concentration in the underflow; or, the longer the residence time of solids in the compression zone of the thickener, the greater the dewatering. However, in conventional FGC waste thickeners, a deep blanket of wastes usually resulted in a turbid overflow (insufficient clarification). These findings showed promise that the application of past studies in our laboratories could lead to a less expensive gravity sedimentation system for dewatering FGC wastes.

Limited filtration studies involved a 0.09 m^2 (1 ft^2) plate and frame filter press (see Figure 1). The filtration data collected did not show much promise that continued study of the filtration operation itself would yield much of an improvement over conventional filtration. Therefore, an alternate strategy was chosen: to improve the dewatering efficiency of the gravity sedimentation system, thereby increasing the solids concentration of the influent stream to the filters and lowering the filter dewatering load.

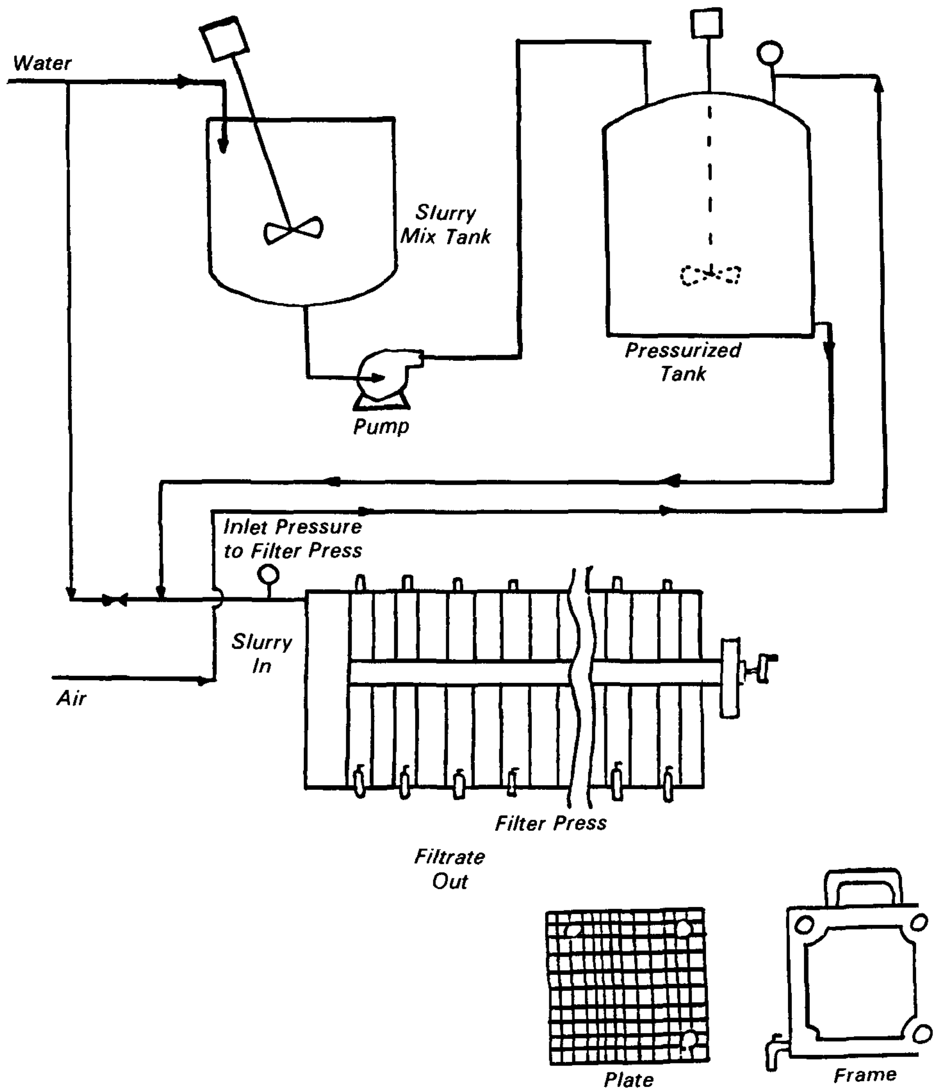


Figure 1. *Filter press apparatus.*

Phase 2 Results

In Phase 2, the major thrust of the bench-scale part of this research effort project was conducted. A new, more efficient gravity sedimentation system for dewatering FGC wastes was conceived, designed, and tested on a laboratory pilot scale. The system consisted of two units: a laminar clarifier (more specifically, a tube settler) and a smaller (in diameter) but deeper, conventional thickener. The units were connected uniquely, decouple the clarification and the thi ening functions of the system as much possible. A recycle stream between t two units was used to obtain a grea degree of flexibility and control operating conditions. The importa operating parameters for the syste were investigated by a series of batch a continuous settling experiments. Tl parameters included: the location of tl level of the solid/liquid interface in tl clarifier, the angle of inclination of tl clarifier, and the flow rates of the fe and recycle streams.

The dewatering efficiency of the ne system was evaluated on a labora pilot scale (see Figure 2). The pilot th ener was 15.24 cm (6 in.) in diameter and about 4.6 m (15 ft) long. Tube settlers (clarifiers) were used; these were 4.445 cm (1.75 in.) in inside diameter, 1.98 m (6.5 ft) long, and inclined at an angle of 30°. The pilot tests showed the new system to be effective in obtaining high underflow concentrations (30 to 60 percent) and a clear overflow at high throughput rates while requiring a smaller settling than typical conventional thickeners used in this application.

Phase 3 Results

In Phase 3, efforts were directed toward an eventual scale-up of the system. Sizing studies, based on a flux plot developed to help estimate the settling area required for a desired level of final concentration, showed that the new dewatering system would require only about 59 percent of the area required by conventional thickeners to achieve the same amount of separation and concentration. Alternately, for about the same settling area, the degree of concentration achieved is about 60 percent greater.

Preliminary economic studies were also performed by TVA at the request of EPA; these studies showed reductions in capital costs of about 10 percent, and reductions in annual operating costs of about 6 percent, for an entire FGC waste management/disposal system (not just the dewatering portion of the system).

To evaluate the feasibility of the system so that it could eventually be used on a

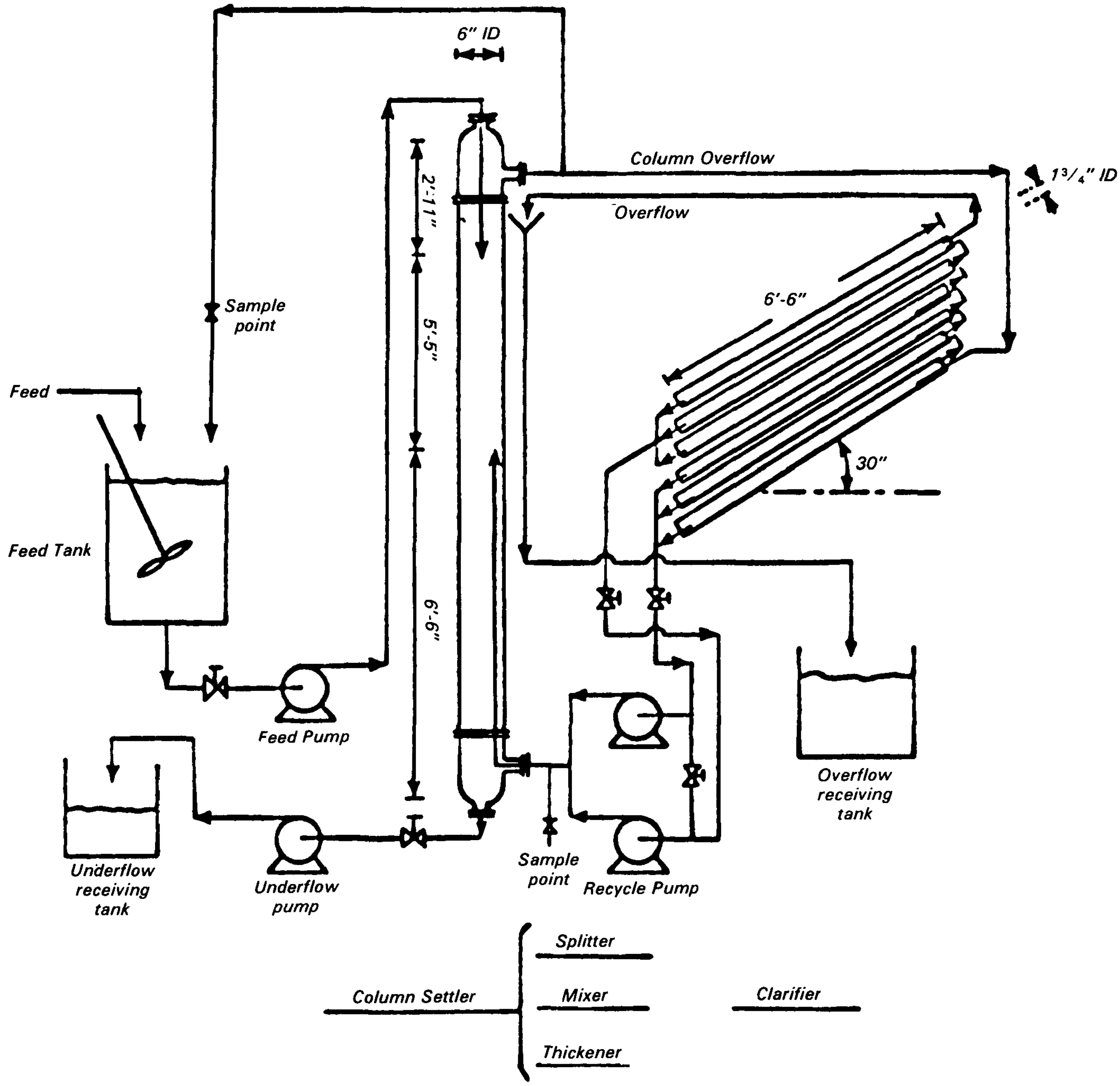


Figure 2. Laboratory pilot scale clarifier/thickener system.

commercial scale, equipment design, layout, etc. were made for a large pilot scale version evaluation, and the pilot dewatering system was fabricated. In addition, studies were performed on the effects of shear on the settling behavior of the sludge. It was hypothesized and experimentally established that mixing of the FGC wastes causes a more rapid settling and a greater final concentration. However, it was also established that vigorous mixing could fracture the solid waste crystals, resulting in many fine particles which would settle slowly. Based on these results, a positive displacement pump was selected for the recycle stream from the clarifier to the thickener.

Phase 4 Results

In Phase 4, the pilot dewatering system was fabricated, shipped to TVA's Shawnee Steam Plant near Paducah, Kentucky, and installed at the EPA/TVA pilot FGC facility for shakedown testing and final pilot plant evaluation testing. The FGC waste introduced to the system contained a significant amount of calcium sulfite.

After the shakedown test, several modifications were made to the pilot unit. The main modification was adding more settling plates in the clarifier. Other modifications had to do with operational considerations such as safety and ease of operation. Figure 3 is a schematic of the system.

The initial goal of the pilot tests was to establish a baseline for comparison. At baseline coditions, the underflow concentration was about 45 percent solids; the underflow rate was set at about 10.6 to 11.4 l/min (2.8 to 3.0 gpm). The average feed rate was about 49.2 to 53 l/min (13 to 14 gpm), with a solids concentration of about 15 percent solids.

Prior to start-up, the thickener was filled with solids from the existing dewatering unit; the clarifier was not prefilled with solids. As a result, during the initial period of operation, solids accumulated in the clarifier.

As the clarifier began to fill with solids, it became necessary to increase the thickener underflow rate periodically to maintain a clear clarifier overflow. It was discovered that the feed rate to the system was being periodically increased and corresponding increase in thickener underflow rate was necessary to keep the velocity in the clarifier below about 0.037 m/min (0.12 ft/min). By adding a splitter in the feedstream, the feed rate was held fairly constant at about 49.2 to 53 l/min (13 to 14 gpm), and the thickener underflow rate could then be set as low as possible without plugging the underflow lines.

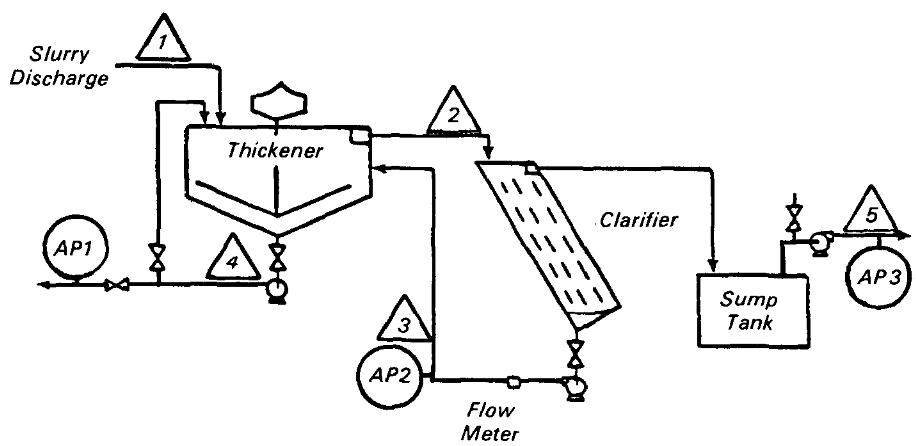
Each time the thickener underflow rate was decreased, the underflow concentration increased significantly. When the thickener underflow rate was decreased from the baseline value of ~10.6 l/min (~2.8 gpm) to less than 3.8 l/min (1 gpm), the underflow concentration increased to as high as 56 percent solids.

No significant changes in the lamella clarifier concentration was observed when its underflow rate was decreased from ~76 l/min (~20 gpm) to as low as 5.7 l/min (1.5 gpm). However, a significant response in separation efficiency (percentage of water in feedstream that left in clear overflow) was observed; it increased significantly each time the clarifier underflow rate was decreased.

While operating at a very low thickener underflow rate (~5.3 l/min or ~1.4 gpm) and a high underflow solids content (~53 percent), the underflow rate was increased significantly for about 2 hours. During this time, about 1.2 m (4 ft) of concentrated sludge blanket was dumped. The underflow rate was then reset at its original low setting. This period of rapid dumping, followed by resetting the underflow rate to its original low level, had little effect on the underflow solids content, because of the relatively constant solids concentration in the large compression zone in the thickener.

On the basis of this observation and the observed strong inverse dependence of underflow concentration on steady-state (continuous) underflow rate, the concept of "bang-bang" thickener operation was proposed, in which the thickener underflow rate is set as low as possible without the underflow lines plugging. Periodically, the underflow rate is stepped up briefly to maintain an overall solids flowrate in the thickener. Using this mode of operation it should be possible to maintain a maximum underflow concentration.

The dewatering system was observed to be operationally versatile. Any possible plugging in the clarifier due to its overdesign, for example, should be easily avoided by simply increasing the clarifier underflow rate. This could be done without having to lower the overall system underflow concentration because further concentration would occur in the thickener.



Stream No.	1	2	3	4	5
Description	Slurry Discharge	Thickener Overflow	Clarifier Underflow	Thickener Underflow	Clarifier Overflow
Rate, lb/hr	2186	3923	2332	595	1591
Rate, gpm	4.00	7.18	4.00	0.82	2.18
% Solids	15.0	14.9	25.0	55.0	----
Spec. Gravity	1.093	1.092	1.165	1.451	1.000

Figure 3. Large pilot dewatering unit.

Conclusions

The FGC waste dewatering system developed in this work in effect decouples the clarification function from the thickening function. Using this system, it is possible to concentrate FGC wastes containing significant quantities (greater than a few percent) of calcium sulfite to a high solids concentration (~56 percent) without the addition of additives or vacuum filters and with reasonably sized equipment. Because the clarification and thickening functions are effectively separated, but at the same time interconnected by "internal recycle," the system offers flexibility for wide variations in waste dewatering behavior created by changes in FGC system operating conditions. The system operates most effectively in the "bang-bang" mode, with the thickener underflow set, for most of the "bang-bang" cycle, as low as possible (without plugging the underflow lines). On reaching the maximum feasible concentration, the underflow rate is increased significantly for a brief period, then the cycle is repeated. Preliminary economic evaluation of this system indicates potential savings of 10 percent of the total capital costs and 6 percent of annual operating costs for the FGC waste management/disposal system.

A. R. Tarrer is with Auburn University, Department of Chemical Engineering, Auburn, AL 36849.
***Julian W. Jones** is the EPA Project Officer (see below).*
The complete report, entitled "Development of a New Gravity Sedimentation Process for Dewatering Flue Gas Cleaning Wastes," (Order No. PB 84-231 448; Cost: $20.25, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Industrial Environmental Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

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