DESIGN OF DWPF AGITATION SYSTEMS

IN BINGHAM SLURRIES BY PILOT SIMULATION

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ABSTRACT

A method was required to determine the optimum agitator speed needed to produce overall motion of the Defense Waste Processing Facility (DWPF) high-level waste slurries in remote process cell vessels. Project schedule and limited process space required an accurate determination of agitator horsepower and size without the benefit of full-scale testing. The small-scale testing of a unique, clear, rheologically similar fluid is described, together with tests and scale-up procedures.

INTRODUCTION

The DWPF at the Savannah River Plant (SRP) is being designed and constructed to process high-level radioactive defense waste from liquid sludge to a vitrified borosilicate glass form (1). This paper describes the unique clear simulation and scale-up procedures that were used to confirm agitator design criteria in process vessels containing high-level radioactive Bingham-plastic slurries and glass frit particles.

Specially designed dense-packed heat transfer coils, vertical pumps, and miscellaneous instrumentation components present in these vessels create stringent agitation conditions.

The project schedule and budget did not permit full-scale agitation testing with actual high-level waste. For this reason, innovative clear simulations and small-scale opaque simulated slurries were utilized to predict and support full-scale design.

DISCUSSION

The remote process equipment now used in the H and F areas of SRP is designed to work with medium to low viscosity liquids that have very low abrasive characteristics. The present DWPF slurries consist of high-level Bingham-plastic slurries with abrasive glass frit particles (Bingham-plastic slurries do not flow until a definite yield point is reached). Since there is no correlation for predicting agitation characteristics of these new slurries, a different approach to process vessel design and determination of agitator criteria was required.

The most significant effect on agitation, other than the fluid's own mechanical properties, is the location of a removable coil assembly in the process vessel. There was concern that the thin tubing of the heat transfer coils of this assembly would be vulnerable to damaging impingement erosion from the glass frit particles, and to corrosion. The coils were therefore designed to be remotely replaceable without removing the vessel itself or other process equipment mounted on the vessel.

To achieve this, it was necessary to position the coils in a dense pack around the agitator (Fig. 1).

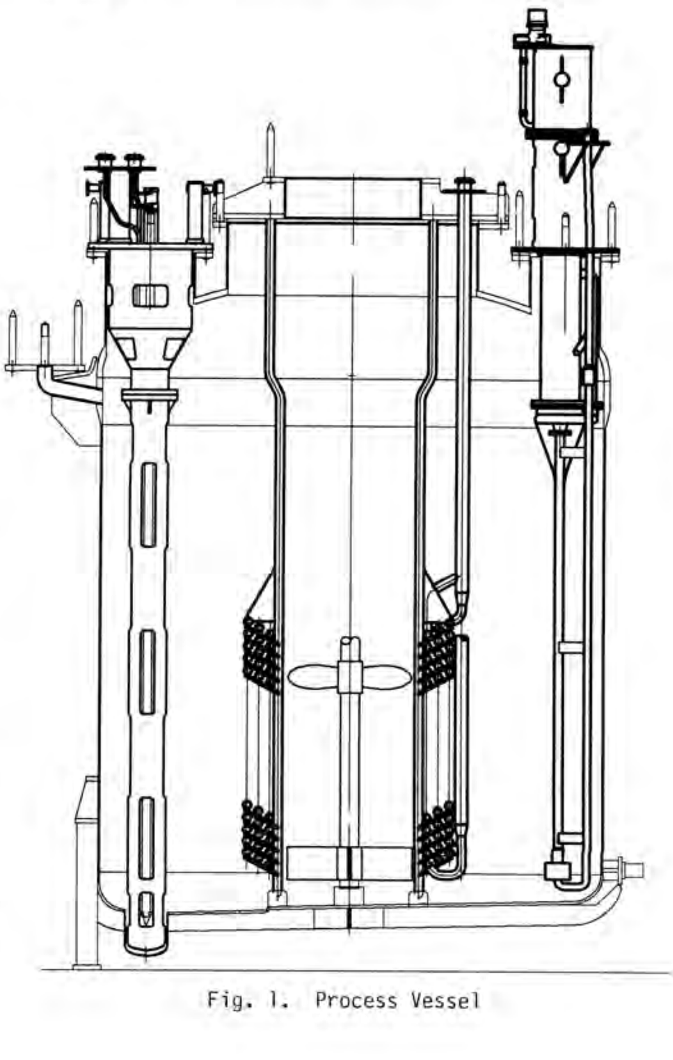

Fig. 1. Process Vessel

This coil configuration resulted in a relatively small agitator blade to vessel diameter ratio of 25 percent. This ratio, combined with the effects of other miscellaneous, vertically mounted equipment, including pumps and instrumentation, made it impossible to determine optimum speed and impeller configuration without experimental data. The constricted space available for vessel-mounted equipment necessitated that the agitator be properly sized before any serious in-cell design could begin. Small-scale testing was performed with a test fluid comprised of simulated non-radioactive slurries that matched the mechanical and rheological properties of actual DWPF high-level waste/frit slurries. The simulated slurry was made with an opaque, clay-like substance and borosilicate glass frit. The opaque nature of the simulated slurry made liquid surface profiles the only visible component of this test. Surface profiles and internal velocity profiles could not be correlated with any confidence, yet internal velocity profiles were required in order to realistically define any areas of potential flow stagnation. There was concern that non-moving frit and/or sludge would not only inhibit proper chemical adjustment but would also aglomerate in the vessels and eventually affect the process.

At the request of Bechtel and Dr. A. W. Etchells of Du Pont, Ekato Ruhr - Und Mischtechnik (agitator manufacturer) of Germany, agreed to take on the challenge of finding a clear mixture that would simulate the rheological characteristics of DWPF slurries. Ekato worked with a local German university to design an extremely close approximation of the required rheologies. It was agreed that the most important rheology component to simulate would be yield stress (Fig. 2).

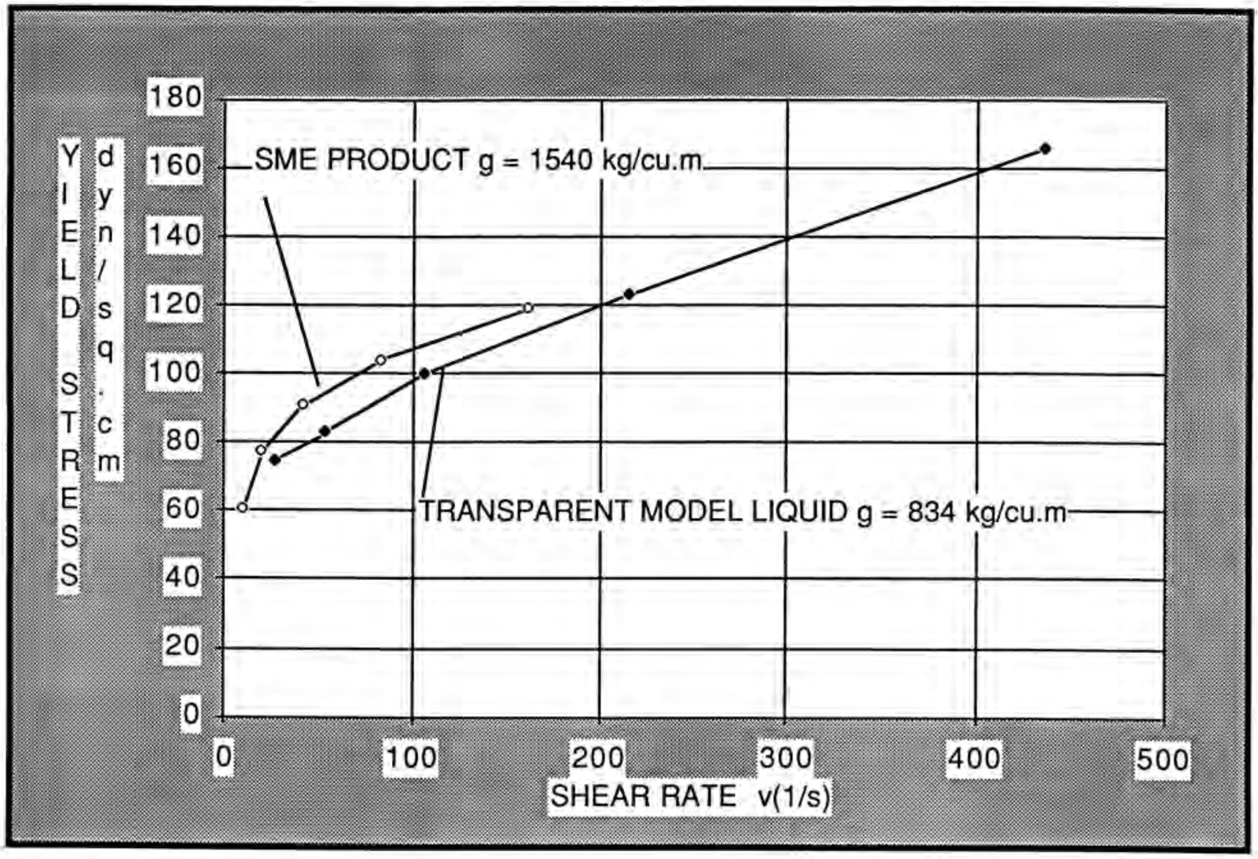

Fig. 2. Yield Stress Vs. Shear Rate For Non-Newtonian Fluids

The dual impeller configuration recommended by Dr. Etchells and Ekato was utilized successfully throughout the testing. The upper impeller consisted of a Kaplan-type axial blade design, while the lower impeller was the four-bladed radial type.

The clear liquid simulation consisted of the following three components:

77.4% WT	Polyisobutylene
17.8% WT	Benzene
4.8% WT	Aerosil (finely dispersed SiO2)

Test Arrangement

The testing was performed in two different vessel sizes (2):

1. "Small" Vessel

   o Diameter: 6.29"
   o Volume: 1.32 gal.
   o Bottom shape: flat

   o Impellers:
     - One three-bladed draft tube propeller, dia. 1.97"
     - One lower flat-bladed turbine with 4 blades, dia. 2.36"
     - Height of blades: .472"

   o No baffles are used.

   o geometrical arrangement - same as for "Pilot".

2. "Pilot" Vessel

   o Diameter: 15.75"
   o Volume: 13.2 gal.
   o Bottom shape: flat

   o Impellers:
     - one three-bladed draft tube propeller, dia. 4.33"
     - one lower, 4-bladed flat-blade turbine, dia. 4.33"
     - height of blades: 1.17"
     - distance from bottom of test vesselto bottom of draft tube: 1.30"
     - distance from bottom of test vessel to bottom of flat blade impeller: .079"
     - distance between impellers: 5.90"
     - draft tube diameter: 4.92"
     - draft tube length: 6.61"

   o To simulate the process vertical pump, a solid shaft of .98" dia. is attached 1.77" from tank wall.

   o Liquid height: 15.75"

Testing of both the slurry and the clear simulation was performed in both scale test vessels. The addition of colored plastic particles in the clear simulated liquid provided a means to measure the direction and magnitude of flow vectors in and around simulated coils and other submerged equipment.

The key agitation parameter that was held constant for scale-up extrapolation to full size design, was the minimum or "critical" speed that produced overall motion in the vessel.

Surface characteristics of vortex formation and surface eddys were noted at each scale critical speed for rough comparisons with full-scale prototype testing. This is significant since full-scale testing with actual radioactive fluid is not practical.

RESULTS

The critical speed values obtained from the small scale tests were successfully used in scaling up to full scale parameters. Figure 3 presents the "small" and "pilot" scale results plotted at the respective critical speed values on a log-log graph. When extrapolated up to a 144" dia. vessel, an agitator speed of approximately 130 rpm is indicated, with a power number of 6, and an impeller diameter of 36"; the calculated power is 55 kW.

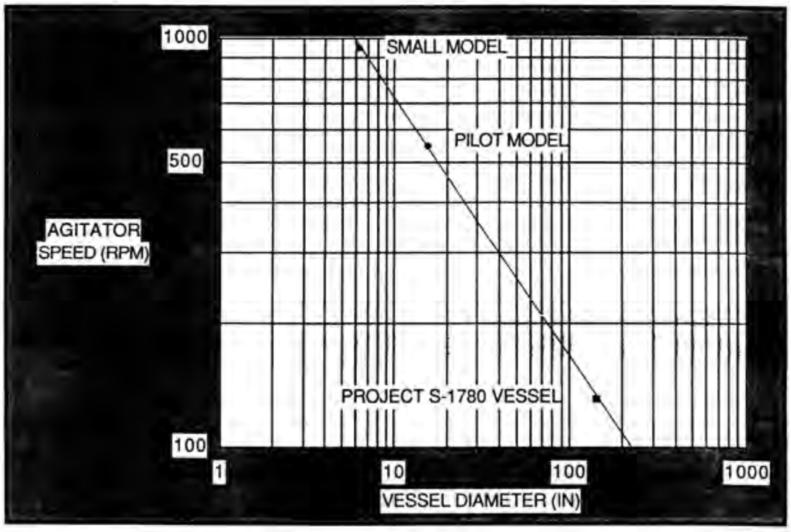

Fig. 3. Agitator Speed (RPM) Vs Vessel Diameter (In)

Vortex formations and surface eddys in the large 144" diameter vessel were similar to those noted in small scale testing and indicated that overall motion was more than adequate at the predicted shaft speed.

The information gained during clear simulation testing provides a high level of confidence that the full scale opaque mixture is completely homogenous. The effect of this early prediction of agitation criteria and sizing allowed critical in-cell design to begin on schedule.

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REFERENCES

1. R. Maher, L. F. Shafranek, J. A. Kelly, and R. W. Zeyfang, "Solidification of Savannah River Plant High-Level Waste" Trans. AM. NUCL. SOC., 34, 228 (1981).

2. Dr. K. Kipke "Agitator Test Run for Blending of Atomic Waste", Ekatao Ruhr - Und Mischtechnik GMB, November 23, 1982.