A Novel Unit Operation to Remove Hydrophobic Contaminants

Contract Number: DE-EE0005772

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Project Period: 4/1/2015 to 6/30/2017

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U.S. DOE Advanced Manufacturing Office Program Review Meeting
Washington, D.C.
June 13-14, 2017

Project Objective

- Develop a new unit operation called Bubble Nucleation Flotation (BNF) to remove hydrophobic contaminants like stickies (arising from pressure sensitive adhesives, hot melts, ink and coating binders) from paper mill process streams.

- To accomplish the separation without the use of additional chemicals.

- Stickies affect paper machine operation and product quality.

- Relatively small size stickies (microstickies), less than 100 mm diameter, are not effectively removed by conventional processes like screens, hydrocyclones, dispersed air flotation and dissolved air flotation.

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PSA

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Technical Innovation – Current Practice

- Current practice is to use dissolved air flotation (DAF) or froth flotation (FF) for the separation of hydrophobic particles.
- In both DAF and FF, the separation of small size particles is not very effective due to relatively large bubble size.
- Additionally, in both DAF and FF external chemical addition is necessary for the efficient separation of hydrophobic particles.

Technical Innovation

Comparison of flotation processes

	Froth Flotation	Dissolved Air Flotation	Bubble Nucleation Flotation (BNF)
Separation	Selective separation	Collective separation	Selective separation
Mechanism	Bubble attachment to hydrophobic particles	Bubble entrapment in flocks	Bubble nucleation on hydrophobic particles
Chemistry	Surfactant	Coagulation-flocculation agents	None
Bubble size	0.1 to 1.0 mm^2	0.01 to 0.1 mm^2	0.001 to 0.01 mm^2
Fluid mechanics	Controlled turbulence	Somewhat quiescent	Somewhat quiescent
Air	Introduced by mechanical dispersion	Air introduced by dissolving at elevated pressure	Removal of dissolved air and other gases.

Technical Innovation

- Microstickies accumulate, agglomerate and deposit on paper machine wires, felts and drier cans. Strong acid, kerosene or other solvents and high pressure showers are used to dislodge these deposits. Pacifying additives like talc, used to stabilize microstickies are not always effective.

- Patented process **(March 2010)** was successful in laboratory and mill trials for measuring microstickies.

- Implementaion of process will reduce paper machine downtime, use of harsh chemicals and improve overall mill economics.

Technical Approach

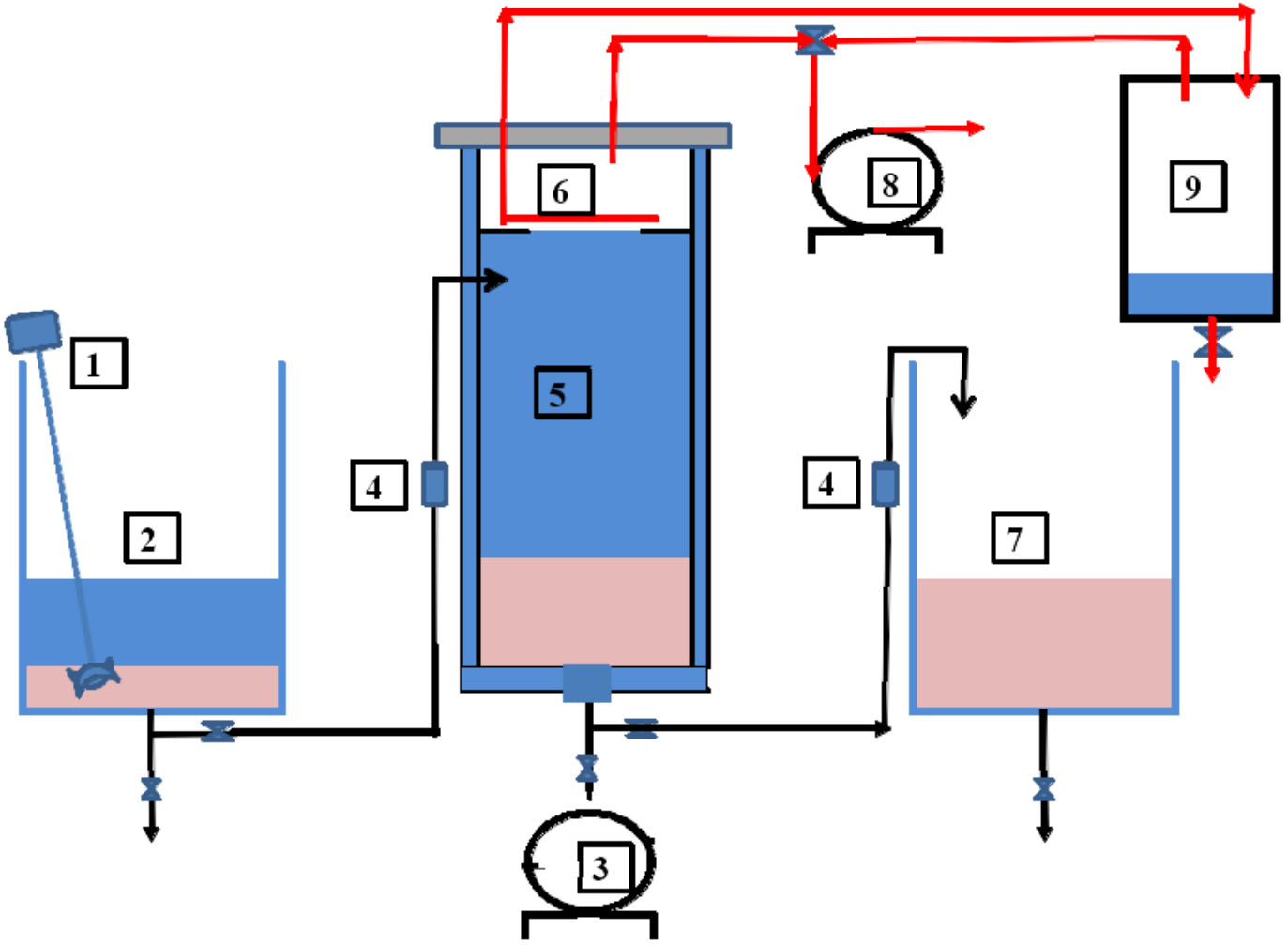
- Bubble nucleation flotation is a relatively new process for the removal of hydrophobic contaminants from process water.
- Hypothesis is that when pressure is reduced, dissolved gas bubbles will nucleate on hydrophobic particles and float to the surface for easy removal.
- The removal efficiency depends on many parameters like the magnitude of pressure reduction, residence time, temperature, solids concentration (consistency), pH, conductivity, particle size, bicarbonate ion concentration, and dissolved gases content.

Technical Approach

- **Task 1:** A 20 liter batch unit was used to evaluate the effect of temperature, filler content, magnitude and duration of vacuum on the removal of hydrophobic particles. Results were used to design a continuous 20 liter unit.
- **Task 2:** The continuous unit was tested extensively on laboratory made synthetic samples as well as on mill samples. The removal of 60-80% of hydrophobic particles was targeted and achieved.
- **Task 3:** A 200 liter pilot unit with valves, pumps and controls was built for mill trials. (See Photo and Flow Diagram on next 2 slides).

Technical Approach – Pilot Unit

1 = Blender
2= Feed Tank
3= Accept Pump
4= Flow meters
5= Treatment Tank
6= Foam Sucker
7= Accept Tank
8= Vacuum Pump
9= Reject Tank



Applied for Provisional Patent, April 2017

Unloading Pilot Unit at Mill Site

Transition (beyond DOE assistance)

- Attractive features of the process include low reject rate, (1-2%), no need for coagulating/flocculating chemicals or surfactants, virtually no moving parts and the removal of air from process water.
- Successful implementation of bubble nucleation flotation (BNF) in paper recycling mills will increase paper machine efficiency, improve product quality, and reduce the use of cleaning solvents.
- Currently paper mills have shown interest in reducing fresh water use. Implementation of BNF can achieve this objective.
- Plan to work with a vendor to commercialize and collaborate for further process upgrade based on input from customers.

Measure of Success

- Cost savings on paper machines due to reducing stickies deposits can be about $500,000 per year per paper machine ***without accounting for downtime, increased fiber yield and reduced energy costs (1).***
- BNF can potentially reduce paper machine downtime by at least 1 hour/week (highly conservative estimate) resulting in energy savings of 1.45 Trillion BTU/year.
- Reducing paper machine downtime by 1 hour/week will result in average savings of $50,000 or about $2.5 million per year recovering the BNF installation investment in less than 4 months.

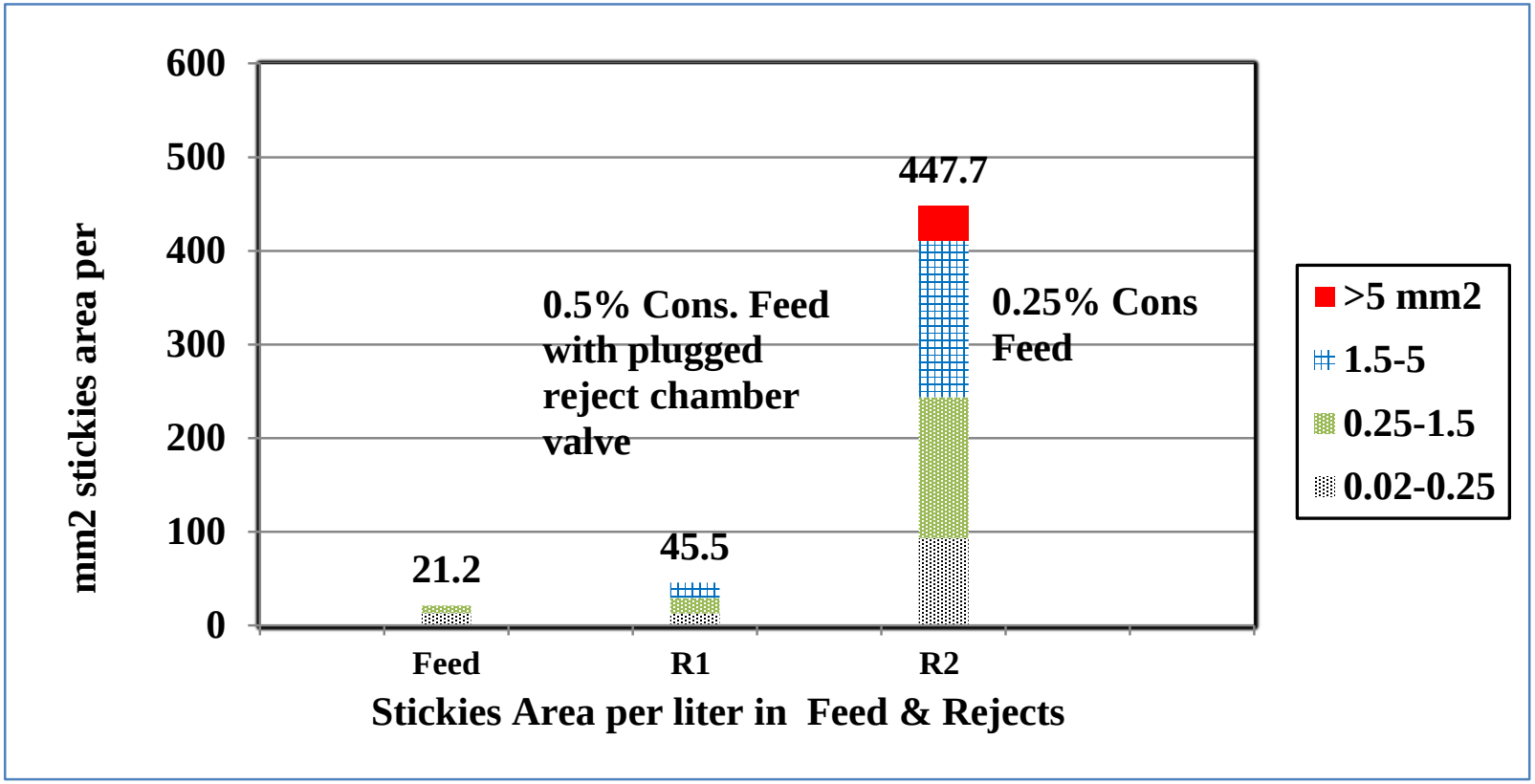
(1) Web site of Cesco Solutions:
http://www.cescosolutions.com/index.php/pulp_paper/case_studies/case_study_8

Project Management

- Project duration: **April 1, 2015 – June 30, 2017**
  - Test Batch Unit: **4/1/15 - 8/31/15**
  - Test Continuous Unit: **9/1/15 - 3/31/16**
  - Test Pilot Unit for Mill Trial: **4/1/16 - 12/31/16**
  - Mill trials: **March - April, 2017**
- Progress measurement:
  - Achieving >80% Contaminant Removal in lab trials
  - Achieving >60% Contaminant Removal in mill trials

Total Project Budget	
DOE Investment	$341,000
Cost Share	$104,000
Project Total	$445,000

Results and Accomplishments



Pilot unit run with synthetic process stream performed well at 0.25% consistency but not at 0.5% consistency due to a plugged valve .

Results and Accomplishments

- All milestones completed.
- Paper mill screen rejects tested in pilot unit with 81% contaminant removal at 0.1% consistency and feed flow rate of 40 liters/minute.
- Paper machine white water tested in paper mill at 25 liters/minute with 1 liter/min rejects. Considerable amounts of hydrophobic materials removed.