Properly sized dilution zone volume, stock residence time, dilution control, and adequately designed agitator ensure successful operation

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Dilution Zone Agitation Critical In Blowtanks, High-density Towers

ALTHOUGH ALL PULP STOCK CHEST AGITATORS must perform to expectations, most of the performance problems—either process or mechanical—can be found in such severe-duty applications as blowtanks and high-density towers. From a process viewpoint, the design of a blowtank or high-density tower agitator is dependent on the same parameters as other stock chest agitators plus a properly designed dilution water addition system. Of the several schemes for controlling dilution water, there is only one simple and logical method.

Mechanically, no other pulp and paper mill application places more demands on the agitator's mechanical design than a blowtank or high-density tower. The continuous variations in consistency that the agitator "sees" as it is dampening those variations, combined with the intermittent shock loads created by incoming chunks of high-consistency stock, cause a continuous, high-amplitude fluctuation in impeller blade forces. The effect of these forces must be included in the mechanical design to provide a reliably performing agitator.

The blowtank is the first agitated vessel for pulp manufacture. Historically, it has been a steel tank in either of two geometries (Figures 1 and 2). The cone bottom blowtank requires agitator location normal to the typical 60° wall. Both require bottom zone agitation and dilution control.

The high-density tower(s) are located further down stream. The reduced bottom zone geometry is depicted in Figure 3. Zone agitation was conceived by Lightnin in 1950, and the high-density tower configuration necked-down to the lower agitated zone was designed by the company in 1958. It is normally of tile construction.

Both blowtanks and high-density towers serve the purpose of storing 10 to 20% stock that plug flows downward into the controlled zone of agitation. From there it is diluted with water or whitewater to 3 to 6% bone dry consistency. The agitator allows the zone volume to be maintained with proper dilution water control and ensures desired consistency control of the pumped out stock.

AGITATOR SIZING PARAMETERS. Selection of a blowtank or high-density tower agitator depends on the same process parameters to be considered for any chest, whether it is a blend or machine chest. These parameters include the following:

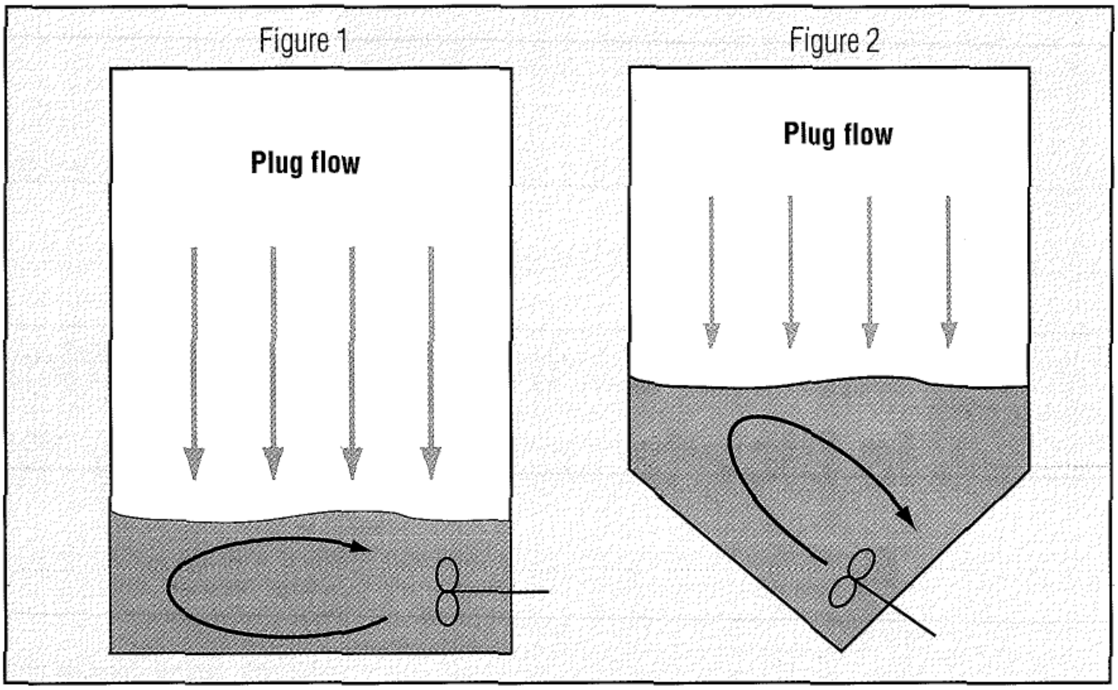
- Chest geometry
- Stock level
- Stock type
- Stock temperature
- Stock residence time
- Stock consistency.

Chest geometry: Chest or tank size is important in that the required horsepower varies with the cube of the chest diameter (or the width of wall on which the agitator is mounted) if in a rectangular chest. A general rule is that the chest length not exceed L/W = 2. Stock acts as a Bingham plastic; that is, a threshold horsepower is required just to begin moving the entire mass.

Stock level: In a normal chest the agitator cannot move stock at a height greater than 1.3 times the chest diameter or wall width—e.g., a 13-ft. level in a 10-ft-dia chest. However, the agitator must be designed with sufficient horsepower. The most efficient use of horsepower is a stock level 80% of chest diameter or width. In a blowtank or high-density tower, because of the 10 to 20% consistency plug, the agitated zone height is one-half of the chest diameter. For example, the height of a 24-ft-dia zone is 12 ft.

Stock type: Required agitator horsepower is dependent on fiber length and its degree of processing. For example, short-fibered hardwood is easier to agitate than is long-fibered softwood. Other considerations are "refined" vs "nonrefined" and "bleached" vs "unbleached" pulps. Slash pine is more difficult to agitate than northern pines. Recycled fiber stock, such as old newspapers and old corrugated containers, have their own relative

FIGURES 1 and 2: *Blowtanks are typically made of steel and are made in two geometries—the flat bottom or cone bottom.*



horsepower requirements.

Stock temperatures: Hot stock requires less horsepower to agitate than cold stock. Horsepower is a direct function of temperature.

Stock residence time: Residence time is directly related to consistency control and required horsepower. Optimum measurable consistency control possible is +/– 0.1%. For example, if desired pump out consistency is 3.5%, the expected is 3.4 to 3.6%.

Fifteen min residence time is desired in an agitated zone to achieve +/– 0.1% control at the least horsepower. With the same horsepower and only 10 min residence time and the same plug variation input, consistency control of +/– 0.2% can be reached. In many situations this control may be satisfactory. If not, more horsepower is required to blend the stock faster and achieve the required +/– 0.1% with less time.

Consistency: Horsepower required varies as the cube of consistency. Therefore, it is one of the more important parameters. For example, a change in consistency from 4% to 5% bone dry will double the required horsepower.

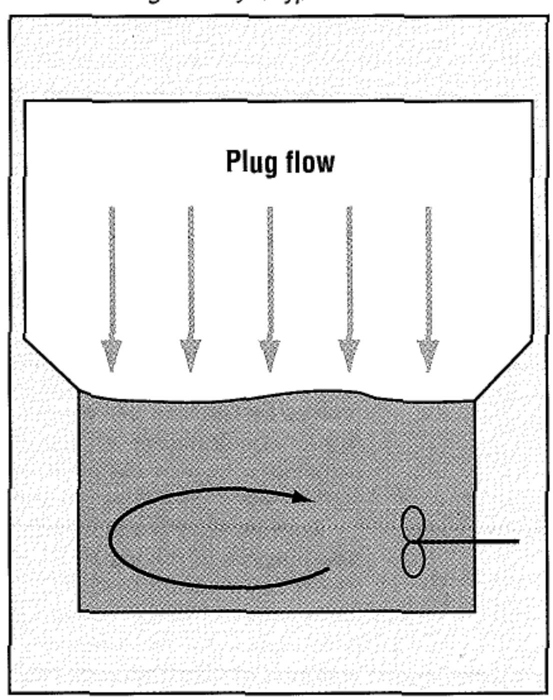
AGITATOR/PIPE LOCATIONS. Figure 4 shows ideal location of the agitator dilution and recirculation lines and pump suction. The dilution line must be located behind and above the impeller to be incorporated easily into the flow pattern.

The recirculation line (which is recommended for purposes to be discussed later in the article) must be outside the dilution line or can be placed approximately 180° from the agitator. Note that in this position the recirculation line must be high in the zone to feed smoothly into the agitator's return flow pattern and not try to flow in against the pattern.

ZONE SIZING/THE HORSESHOE FILLET. The ideal agitated zone residence time is 15 min. If this is all the time that is available, then the entire zone volume must be used and a fillet is not an option. However, many blowtanks and high-density towers have zones with residence times far exceeding 15 min. The horseshoe fillet shown in Figure 5 then is an important option.

The purpose of a concrete or metal fillet is to allow use of a smaller agitated zone and less agitator horsepower without buildup of a stagnant

FIGURE 3. *For high-density towers, the reduced bottom zone geometry is typical.*



mill operations, and agitator failures can literally shut down a mill or a portion of it. These operations place more demands on the agitator's mechanical design than blend or machine chests, for example. The agitator "sees" continuous variations in consistency combined with intermittent shock loads created by incoming chunks of high-consistency stock. These cause continuous, high-amplitude fluctuations in impeller blade forces that must be included in design calculations.

Fluid forces on impeller blades cannot be calculated without reference stain-gauge or similar test research by the agitator supplier. This is especially true given the loading peculiarities of paper stock and the fluctuating loads encountered in blowtanks and high-density towers. In addition, upsets can occur that have "sanded in" the impeller. The agitator must also be able to operate cavitated, that is, at low-level coverage during startup and shutdown for sometimes long periods. All of these factors create a formidable design task for the agitator supplier.

It is prudent to recommend that a blowtank or high-density tower agitator have a shaft diameter of at least 4-in. and a service factor of 1.5 or greater.

Impellers are usually bolted to a hub to avoid excessively large manways or agitator openings. The bolting or fastening method is very important. Effective fastening is simple in that the only requirements are flat surfaces and proper torque. The agitator supplier should machine blade and hub surfaces, or otherwise ensure flat surfaces, and double-nut the hardware to proper torque. Do not allow tack welds, lock plates, lock washers, or safety wire. These are crutches that will fail rapidly without flat surfaces and correct torque.

TROUBLESHOOTING. Major problems that have occurred in blowtanks and high-density towers are poor consistency control, upsets, and agitator mechanical failure.

Poor consistency control: The most common cause of poor consistency control is incorrect main dilution water/trim ratio. Often the trim portion is too great. This shrinks the agitated zone and decreases stock residence time. The residence time in the pump is too short to overcome the poor control.

Nonuniform spreading of incoming high-consistency stock can allow the stock to pile up in one area and "rat tail" down the plug. This causes large chunks of stock to break off into the agitated zone. In addition other areas can stagnate.

Upsets: Numerous problems can occur in the dilution control loop that can cause poor consistency control. However, a major upset in the blowtank or the high-density tower can occur when the plug level drops to low. Then, the entire plug can flip over into the agitated zone. This not only causes consistency control problems, but can "sand in" the impeller and possibly cause agitator damage.

Agitator mechanical failure: Most agitator failures are caused by upset conditions in blowtanks and high-density towers. Some are caused by inadequate design. Plug flipover, as noted above, can damage the agitator if the motor overload does not trip it out quickly enough. Startup attempts can do more damage to the shaft and impeller by trying to free it with cheaters.

Another little-known reason for agitator failure is operation of two agitators in the zone in low-consistency stock. If the consistency is too low, the flow patterns from each agitator will adversely affect the other. The flow pattern of one agitator will overpower the other, starve it into severe cavitation, and cause mechanical damage very quickly. This damage can include blade loss and shaft and drive breakage. Meanwhile the other agitator will incur excessive blade force reversal, fluctuating motor loads, and possible damage.

Two agitators can be operated in cylindrical vessels such as blowtanks and high-density towers at higher consistencies, where the internal stock viscosity dampens the flow pattern interference. When in doubt, the blowtank or high-density tower should be operated with only one large agitator and possibly an installed nonoperating spare. ■

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10-ft over the agitated zone. With the discharge pump still on 100% recirculation and the consistency control loop in operation, the entire system will reach an equilibrium; that is, the agitated zone will be at its design volume and at its design consistency.

The feed of high-consistency stock should continue until the stock level is at or near the desired level. At this point, the discharge pump can gradually be changed during a one-hour period from 100% recirculation down to the design recirculation rate. In other words, actual tower pumpout can begin.

The one-hour gradual transition from 100% recirculation to the design recirculation rate (or tower pumpout) is recommended to allow the tower to stabilize rather than going to instantaneous draw down. During this transition period, the rate of feed of high-consistency stock should be controlled so that the 10-ft minimum level of high-consistency stock is maintained. This level will prevent upsets as explained in the troubleshooting section.

BLOWTANK/HIGH-DENSITY TOWER OPERATION. The blowtank process is the most difficult to maintain properly, and mills tend to operate them differently. Ideally, once started the blowtank operates continuously with "blows" added frequently enough to maintain a 10-ft high plug and does not shut down except for annual maintenance. The authors have seen blowtanks shut down and left stagnant for eight to 24 hours every month.

It is difficult to predict the rate of plug settling or dewatering when stagnant with the agitator not operating. Knots and other debris are difficult to move around in the agitated zone. If knots settle, gather, and form a natural fillet, the agitator rarely can resuspend them. An adage is that "one cannot have enough horsepower in a blowtank." Prudence dictates that agitator horsepower be selected conservatively.

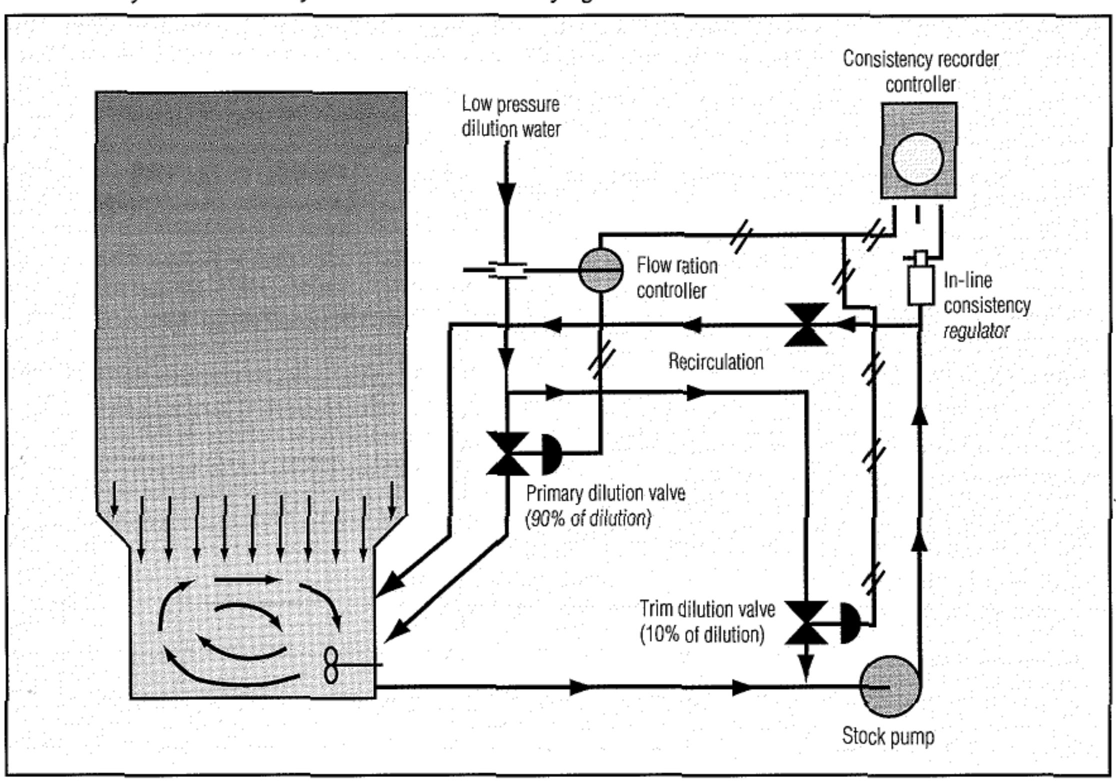
Pumpout consistency is usually 3-1/2% bone dry, and control desired at +/− 0.1% to feed the knotters. The 90/10 dilution water, main/trim ratio is important to maintain. If too much trim dilution is used, starving the main dilution, the agitated zone will decrease and cause consistency control problems.

High-density storage tower pumpout usually ranges from 3% to 6% bone dry. Consistency control requirements vary. This depends primarily on the requirements of the downstream chest. Often, the tower pumpout can be +/- 0.2% or greater. This knowledge is mandatory for proper agitator selection.

High-density tower operation should not be difficult if proper dilution control is maintained and the plug level kept at 10 ft or higher. This presumes that the agitated zone volume/residence time is sufficient for the consistency control requirement.

AGITATOR MECHANICAL DESIGN REQUIREMENTS. Once the blowtank or high-density tower agitator has proved satisfactory for the zone agitation process, mechanical reliability becomes paramount. Blowtanks and high-density towers are critical

FIGURE 6: *A consistency control loop is recommended so that the addition of dilution water is automatically controlled by the consistency in the lower low-density agitated zone of the tower.*



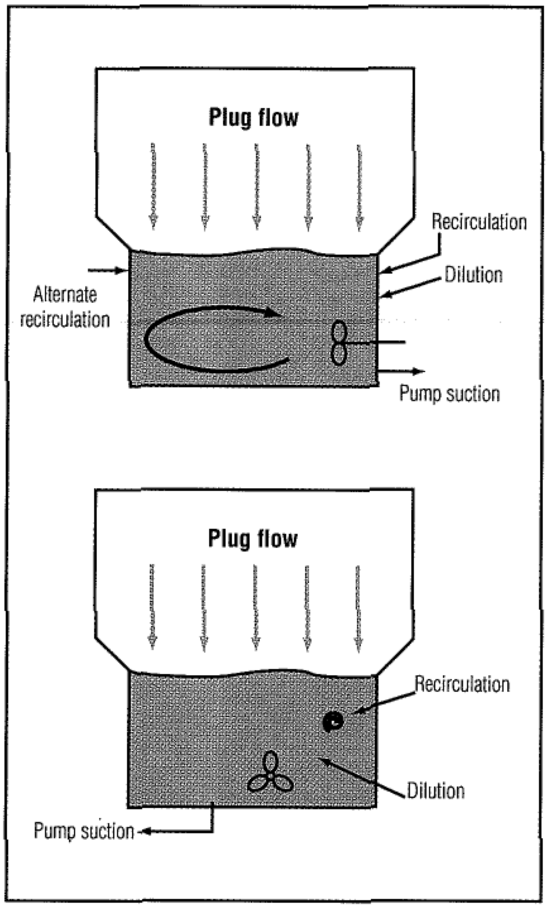


FIGURE 4: *Diagrams show the ideal location of the agitator dilution and recirculation lines and pump suction.*

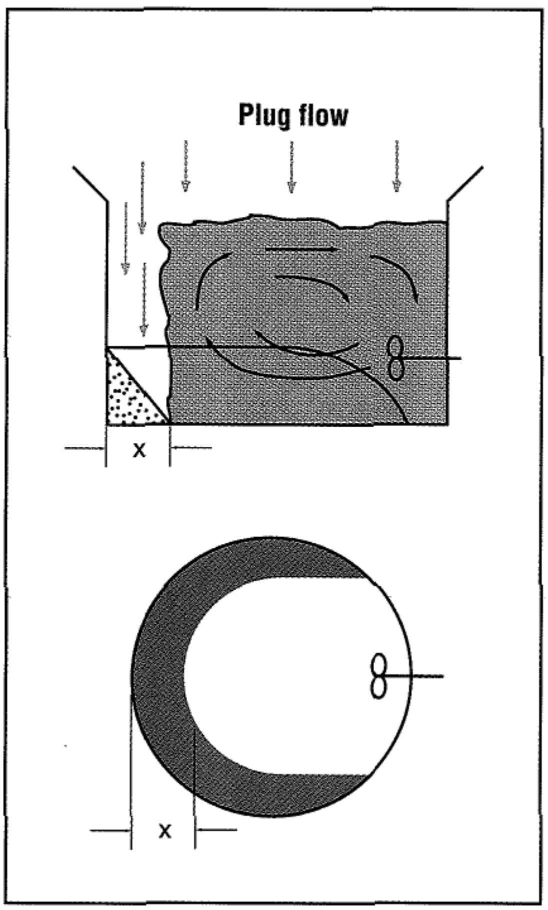


FIGURE 5: *The purpose of a concrete or metal horseshoe fillet is to allow use of a smaller agitated zone and less agitator horsepower without buildup of a stagnant stock fillet.*

stock fillet. The agitator horsepower is selected based on the distance to the toe of the fillet rather than the chest diameter. The agitated zone becomes a cylinder of less diameter. The flow pattern erodes the plug above the fillet and above the cylinder. The fillet is a horseshoe shape with 45° slope throughout. It must encompass the "side" areas to prevent stock stagnation.

A general economic guideline for maximum fillet size is one-third chest diameter. For example, a 24-ft-dia chest could accommodate an 8-ft fillet. In Figure 5, "X" dimension would be 8 ft. However, concrete expense is a consideration. Normally fillets are 25% or less of chest diameter. Another reason to minimize fillets is anticipation of future higher stock throughput and therefore less residence time.

BLOWTANK/HIGH-DENSITY TOWER STARTUP. To properly start up and operate a high-density tower, it is essential that the addition of dilution water be automatically controlled by the consistency in the lower low-density agitated zone of the tower. The consistency control loop shown in Figure 6 is recommended for this important function.

The control loop requires the addition of dilution water in both the agitated zone (main dilution) and upstream of the pump suction (trim dilution). The recommended ratio of main dilution to trim dilution is 9:1; that is, 90% of the dilution water should go to the agitated zone and 10% to the pump. The amount of main dilution flow is a function of the throughput of the tower and the required consistency in the agitated zone. In addition to the dilution water requirement, a provision for a pump recirculation line should be made to facilitate startup and normal operation.

Once the tower has been completely erected and the agitator properly installed, it is common practice to fill the tower with water to check for leaks. Once this test proves satisfactory, the tower should be drained down to the top of the agitated zone (one-half of the lower zone diameter). At this point the agitator must be checked for proper impeller rotation. Horsepower draw should not be checked, since the reading will be meaningless. With this low impeller coverage in water, the impeller will draw in air and cavitate to some degree. With the tower agitator and consistency control loop approved for startup, the agitator should be left running in the water-filled zone. The discharge pump should be operating at 100% recirculation and the consistency control loop activated.

High-consistency stock can now be added to the tower. The feed mechanism should be a rotary device to spread the stock uniformly. This will prevent "rat-tailing" of the high-consistency stock and enhance uniform plug flow. As this stock is incorporated into the agitated zone, the consistency will rise to design consistency, at which point the dilution water will automatically maintain the consistency at the design level.

The addition of high-consistency stock should continue until the tower is filled to a minimum of