The Heart of the Matter – Dewatering Options

Dewatering Equipment Selection based on “fundamental filtration technology”

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BDP INDUSTRIES INC

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Agenda, Part 1:

1. **Introduction: Dewatering option available:** (Photos, explanation of how they function.)
   1. Sand Drying Beds
   2. Vacuum Drum Filter
   3. Centrifuge
   4. Belt Press
   5. Chamber Press

2. **Performance Factors / Optimization**
   1. Mechanical limitations.
   2. Typical Performance Parameters with the various types of Municipal Waste Treatment Sludges.
   3. Overall Plant Flowsheet Considerations
Agenda Part 2

3. Advantages and Disadvantages of the options to Considered

4. Operational Considerations: Operator Observations / Instrumentation / Control

5. Laboratory and Pilot Testing: Collect data specific to your evaluation

6. Procurement: Bid Specifications that ensure desired results are obtained.
Sand Drying Bed

- Civil Engineering firms
Sand Drying Beds: falling out of favor

- Odor issues with the community
- Poor Dewatering, Typically 90% moisture, Solids loading only range 2.5 to 10lb/ft² per hour.
- Muck out is labor intensive: loader / truck drivers
- Most landfills won’t take the cake.
- Large land area required ever for small plants
Rotary Drum Vacuum Filter

- A series of compartments are fabricated into a drum with internal piping to a center valve.
- Each compartment is covered with filter fabric.
- A vacuum pump pulls the liquid to a separating receiver.
- Dewatered cake is scrapped off the drum.
Rotary Drum Vacuum Filter

- Falling out of favor:
  - 10 to 20 times the energy require of other options
  - Emission / Odor issues
Solid Bowl Centrifuge

1) Feed
2) Feed Acceleration in Feed Zone
3) Solid Blanket
4) Clarified Liquid
5) Solids discharge
6) Liquid Discharge
7) Main Drive
8) Scroll Drive
Centrifuge

- Technically a classifier. If particles are same density as liquid no dewatering occurs.
- Works best on Primary Sludge, Very Poor on WAS
Belt Press

- This shows what a typical belt press
Key Belt Press Features

Gravity Zone

Wedge Zone

Pressure Zone
Belt Press: Key Components

• Feed Distributor
  – Uniform cake thickness / uniform pressure applied
Belt Press: Key Components

- Pressure zone design that produces increasing pressure on cake
Pressure Section Design

Pressure = \( \frac{2T \times W}{D \times \pi \times W \times \left(\frac{R}{360}\right)} \)

= \( \frac{2T}{D\pi(R/360)} \)

Where:
- \( T \) = Belt Tension
- \( W \) = Belt Width
- \( D \) = Roll Diameter
- \( R \) = Degrees of roll wrap

Notice outer belt has longer belt path than inside belt
Pressure Section Design

![Diagram showing pressure section design with time under pressure on the x-axis and cake pressure on the y-axis. The diagram includes extrusion area, material dewatering curve, decreasing roll diameters, and constant roll diameters.]
Chamber Press

- Cloth Shaker Assembly
- Recessed Plate
- Filter Cloth
- Cloth Wash Header
- Plate Support
- Filtrate Ports
- Feed Port
- Feed Manifold
- Overhead view
Chamber Press
Screw Press

Drive Unit

Wedge Wire Screen

Disassembled Screw Press Showing Tapered Auger
Screw Press Screen Wash Assembly
Rotary Press

Principle of operation

Image Source: Fournier Co. Product Brochure
Rotary Press
Dewatering Performance Factors

• Most Important Fact: “Filtration Area”
Filtration Area

• Adding “Thickening Filtration Area” is less expensive than “Dewatering Filtration Area”:  
  – Extending the gravity section of a belt press is less expensive than adding additional rolls in the pressure section.  
  – Adding a Rotary Drum Thickener in front of a Screw Press or centrifuge is less expensive than making the Diameter larger or extending the length of the Bowl.

• Additional thickening area improves performance.
Filtration Theory Factors

• Filtration Area
• Applied Pressure
• Time under pressure,
• Feed Distribution
• Effectiveness in cleaning filtration surface
Filtration Area / Pressure: Centrifuge:

- Filtration area:
  - Bowl Perimeter x Bowl length up to beach + area of the beach or cone.
  - Area of cone: $\pi(R_1+R_2) \times S$
    - $S=((R_1 - R_2)^2 + h^2)^{1/2}$
Filtration Area / Pressure:

Centrifuge:
- The Dewatering force is centrifugal acceleration, $m/sec^2$, and is calculated by:
  - $G = ((2\pi N)/60)^2 R$
  - Where $N =$ Rotational Speed,
  - $R =$ Radius of Bowl
- Time under pressure: the length of the bowl.
Filtration Area / Pressure

Belt Press

- Filtration area: Sum of Gravity Section, Wedge Section and Pressure Section
  - Gravity Section and Wedge Section: Effective Length x Effective Width
  - Pressure Section: Sum of the contact area of filter belt with rolls. \((\pi D_1 \times \% \text{ of wrap} + \pi D_2 \times \% \text{ of wrap} \ldots) \times BW\)
    - \(D = \) roll diameters
    - \(BW = \) effective belt width
Filtration Area / Pressure

Belt Press

- Time under pressure: Sum of Contact lengths of filter belt on each roll:
  - $\pi D_1 \times \%\text{ of wrap} + \pi D_2 \times \%\text{ of wrap}......$
Filtration Area / Pressure: Chamber Press

- Filtration Area = 2 x ((effective plate width x effective plate height) – area of core and stiffeners) x (number of plates - 1)
- Pressure: Pressure capability of feed pump
- Time under pressure: how long is the feed pump system is on.
  - (Must run long enough that the chambers are filled with dewatered solids. Opened early and there will be slurry discharged with the dewatered solids.)
Filtration Area / Pressure

Screw Press:

- Filtration area: Diameter of Perforated Drum x Drum Length
  - If unit has Rotary Thickener add this area.
- Pressure: Proportional to reduction in volume from feed to discharge, compression ratio.
- Time under Pressure: Length of perforated drum.
Filtration Area / Pressure

Rotary Press

• Filtration Area: Channel Area: \( (2((\pi (R_L^2 - R_S^2) - \text{Discharge Diverter area})) \times \text{by the number of Channels.} \)

• Pressure: Determined by feed pump capability and friction between cake and rotating screen and discharge restrictor.

• Time under Pressure: Channel length.
Feed Distribution

Belt Press

- These two photos show good and poor distribution
- Ideally you want an even flow, low shear, uniform distribution across the full width of the filter belt so the slurry is the same thickness from edge to edge.
- Good feed distribution requires careful attention to the design.
FEED DISTRIBUTION

• Uneven distribution causes:
  – Cake solids concentration is lowered
  – Premature clipper wire failure
  – Accelerated wear on roll coating
  – Belt misalignment
Poor Distribution: Clipper seam
Central Valley WWTP, Salt Lake City, UT
Central Valley Belt Press Discharge
Cake Solids Across Belt Width

Figure 6: Variations of Cake Solids Across Discharge
Feed Distribution

Centrifuge:

- Size and configuration of the feed ports.
- Want an even flow, low shear, uniform distribution.
Feed Distribution

Chamber Press

• Critical item for proper feed distribution is the feed pump system:
  – Requires two pumps: First stage is a high flow pump the Second stage is a low flow high pressure pump.
    • First stage: high velocity so material doesn’t settle out.
    • Second pump provides the high pressure to insure the cake is compacted.
  – Large center port and corner ports
Feed Distribution

Screw Press

- It is critical that the feed end is completely filled, otherwise there will be dead areas where there is no pressure applied.
- This shows a gravity feed, a pressurized feed will perform better.
Feed Distribution

Rotary Press

- Like the Screw Press it is critical that the feed end is completely filled, otherwise there will be dead areas where there is no pressure applied.
- Size of feed ports, feed pump and orientation are the important factors
Filter Media Cleaning

• Centrifuge: Not applicable
• Belt Press: Wash Manifold Details: Nozzle type, self cleaning, Cake Side or Non cake side or both, Operating Pressure, Containment Enclosure
• Chamber Press: Is there one, Learn Details
• Screw Press: Nozzle / Header Design, Stationary or Movable, Frequency
• Rotary Press: Not applicable
Performance Optimization

Balancing

Act

Cake Solids

Throughput

Polymer Dosage

Solids Capture
Dewatering Optimization usually focuses on Cake Solids but the way to high cake solids is through improved filtrate clarity:
What Should the Focus be to improve Dewatering???

❑ Critical Parameters are:
  ❑ Cake Solids wt %
  ❑ Hydraulic Loading, gpm
  ❑ Chemical Dosage, lb/ton.
  ❑ Solids Capture, wt %.

❑ All Intricately Linked
Solids Capture

• What is Solids Capture: (Percentage of suspended solids in the feed that ends up in the discharge)

• \% Capture = \left( \frac{C}{F} \right) \left( \frac{(F-E)}{(C-E)} \right) \times 100\%

• Where:

• C = Dewatered Sludge Total Solids (% TS)
• F = Feed (% TSS); excluding any dilution from polymer solution flow
• E = Filtrate (% TSS); excluding any dilution from polymer solution and belt wash water flows

• Easily seen on a Belt Press:
Low Solids Capture

Hey, That’s a Loop
## I Want Numbers

<table>
<thead>
<tr>
<th>Plant Information</th>
<th>VALUE</th>
<th>VALUE</th>
<th>VALUE</th>
<th>UNITS</th>
</tr>
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<tr>
<td>Average Plant Flow</td>
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<td>3</td>
<td>10</td>
<td>MGD</td>
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<tr>
<td>Yearly Sludge</td>
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<td>450</td>
<td>1500</td>
<td>Dry Tons per Year</td>
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<tr>
<td>Solids Throughput - Yearly</td>
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<td>900000</td>
<td>3000000</td>
<td>Dry Pounds per Year</td>
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<td>Solids Throughput - Weekly</td>
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<td>17308</td>
<td>57692</td>
<td>Dry Pounds per Week</td>
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<table>
<thead>
<tr>
<th>Solids Capture</th>
<th>VALUE</th>
<th>VALUE</th>
<th>VALUE</th>
<th>UNITS</th>
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</thead>
<tbody>
<tr>
<td>Recycled at 60% capture</td>
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<td>360,000</td>
<td>1,200,000</td>
<td>lbs returned to head of plant (yr)</td>
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<td>Recycled at 80% capture</td>
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<td>180,000</td>
<td>600,000</td>
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<td>Recycled at 98% capture</td>
<td>6,000</td>
<td>18,000</td>
<td>60,000</td>
<td>lbs returned to head of plant (yr)</td>
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</tbody>
</table>
On a Broader Scale Poor Solids Capture Causes:

- Higher energy costs for plant
- Lowers plant performance
- Creates additional particles that are difficult to dewater.
  - Bacteria type, filamentous
  - Colloidal Particles
  - Particles with poor surface chemistry for flocculation
- Best to get these out in the first pass
# Cake Solids vs. Type of Sludge

## Average Cake Solids (%)

<table>
<thead>
<tr>
<th>Equipment / Sludge Type</th>
<th>Average Cake Solids (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Waste Activated</strong></td>
<td>Chamber Press: 25%</td>
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<tr>
<td></td>
<td>Centrifuge: 15%</td>
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<tr>
<td></td>
<td>Belt Press: 20%</td>
</tr>
<tr>
<td></td>
<td>Screw Press: 18%</td>
</tr>
<tr>
<td><strong>Aerobic Digested</strong></td>
<td>Chamber Press: 35%</td>
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<tr>
<td></td>
<td>Centrifuge: 30%</td>
</tr>
<tr>
<td></td>
<td>Belt Press: 28%</td>
</tr>
<tr>
<td></td>
<td>Screw Press: 26%</td>
</tr>
<tr>
<td><strong>Anaerobic Digested</strong></td>
<td>Chamber Press: 33%</td>
</tr>
<tr>
<td></td>
<td>Centrifuge: 32%</td>
</tr>
<tr>
<td></td>
<td>Belt Press: 30%</td>
</tr>
<tr>
<td></td>
<td>Screw Press: 28%</td>
</tr>
</tbody>
</table>

35% Lime and 8% Ferric Chloride

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EPA 832-F-00-053, September 2000
Polymer Dosage vs. Type of Sludge

Polymer Dosage, lb/ton

Polymer Dosage, lb/ton

Centrifuge  Belt Press  Screw Press

Centrifuge  Belt Press  Screw Press

Centrifuge  Belt Press  Screw Press

Waste Activated  Aerobic Digested  Anaerobic Digested

Equipment / Sludge Type

EPA 832-F-00-053, September 2000
Questions
3. Advantages and Disadvantages of the options to Considered

4. Operational Considerations: Operator Observations / Instrumentation / Control

5. Laboratory and Pilot Testing: Collect data specific to your evaluation

6. Procurement: Bid Specifications that ensure desired results are obtained.
General: Advantages

- Centrifuge:
  - Typically higher cake solids.
  - Highest unit capacity, reduces number of units for large plants, small foot print.
  - Containment of odor and process fluids.
  - Lower operator attention.
  - Easier to keep operational area clean.
  - Maintenance no higher than belt press, but big ticket item when required.
  - Maintains cake solids at higher than design loading, although solids capture suffers.
  - Smaller building.
General: Advantages

- Belt Press:
  - Least expensive.
  - Simple to Operate and Maintain.
  - Lowest energy requirement.
  - Lowest polymer dosage.
  - Easy start up and shutdown amenable to intermittent operation, a few hours daily.
  - Maintenance can be done by plant personnel.
  - Operators can easily be trained to properly operate unit.
  - Process is observable allowing quick operator response to unstable conditions to avoid upsets.
  - Most repairs can be made in a couple of hours.
General: Advantages

- Chamber Press:
  - Highest filtration pressure: 100 to 225psi.
  - Usually higher cake solids.
  - Containment of odor and process fluids.
  - Maintenance can be done by plant personnel, most repairs can be made in a couple of hours.
  - Excellent solids capture when conditioned properly.
  - Conditioning chemical costs can be lower.
  - Amenable to daily operation. Must insure 2 hr. cycle can be completed.
General: Advantages

- **Screw / Rotary Press:**
  - Containment of process fluids
  - Low energy consumption, similar to belt press.
  - Lower maintenance costs than a belt press.
  - Less operator attention than a belt press.
  - Insensitive to coarse material.
  - High system availability.
  - Low noise level.
  - Most maintenance can be handled by staff.
  - Facility easy to keep clean.
  - Easy start up and shutdown amenable to intermittent operation, a few hours daily.
General: Disadvantages

- **Centrifuge:**
  - Highest energy consumption, largest carbon footprint.
  - Highest Capital Cost, typically 2 to 3 times the cost of Belt Press.
  - Highest usage of polymer.
  - Down time for repairs can usually take weeks.
  - Start-up and Shutdown must be done carefully to avoid major damage to unit.
  - Operation must be continuous.
  - Performance difficult to monitor and make proper adjustments.
  - Special structural requirements for equipment foundation.
  - Noisy.
  - Solid capture can be poor.
General: Disadvantages:

Belt Press

- Containment of odor and process fluids requires special enclosures.
- Lower unit capacity requires many units for large plants.
- Frequent maintenance and cleaning.
- More frequent operator attention to monitor and make adjustments.
General Disadvantages

- Chamber Press:
  - Operation is batch.
  - Cake discharge is all at once.
  - Performance difficult to monitor and make proper adjustments.
  - Special structural requirements for equipment foundation.
  - Complicated System with many components.
General Disadvantages

• Screw Press / Rotary Press
  – Lowest capacity per unit.
  – Lower solids capture than belt press.
  – Can’t maintain solids loading if influent concentration is low.
  – Can’t clean blinded filtration surface without shutting down and emptying.
  – Every 2,000hrs of operation, must disassemble unit and replace brushes on tips of flights in order to maintain capacity.
Operational Observations / Instrumentation / Controls

• Filtrate clarity
• Discharge Cake / Ohaus Scale for rapid measurement of cake solids
• Magnetic Flow Meters: For Polymer and Feed
• Provisions to insure stable feed solids concentration
• Belt Speed / RPM / Torque
• Discharge Cone Pressure
Operational Characteristics: Centrifuge

- Feed Pump: Progressive Cavity, rotational balance requires stable constant flow and feed solids concentration.
- Pre treatment conditioning: grit should be removed to avoid accelerated wear on scroll.
- Differential Speed - Bowl / Scroll: Important control variable, determines solids retention time and therefore discharge solids concentration and torque. Maximum cake solids obtained with the lowest speed differential, provided solids conveying capacity adequate.
Operational Characteristics: Centrifuge

- **Feed**: Performance significantly impacted by variations in feed solids / mass flow. Changes in mass or solid loading requires adjusting the scroll speed. Feed is usually thickened with RDT or GBT.
- **Wear**: Mainly scroll
- **Clean up**: Must clean out internals very thoroughly to avoid unbalanced loading on start up.
Operational Characteristics

BELT PRESS

- Pre-treatment conditioning: Must remove tramp material, particles larger than ½” damage belts.
- Belt Speed: Higher speed increases capacity, lowers cake solids. Can handle wide range in capacity although cake solids is impacted.
- Belt Tension: Marginal impact of higher tension on cake solids.
- Polymer Dosage: Bell type optimization curve, with significant drop in capture and cake solids on either side of optimum.
Operational Characteristics

BELT PRESS

- Filter Cloth: Cake Release is the most critical item, not capture / or porosity.
- Belt Washing: Critical, must have adequate pressure to keep clean.
- Wear: Plows / Scrapper: Avoid smearing of plows and make sure scrapper contacts entire belt width.
- Clean up: Important to avoid corrosion.
Operational Characteristics
Chamber Press

- Usually two pumps: centrifugal then diaphragm or piston type, flow starts very high then drops to nothing. Typical flow ratio: $Q_i / Q_f = \sim 20$
- Difficult to employ inline flocculation, usually must floc the entire batch in a feed tank.
- Complicated system with many components: Feed Tank / Pump system, filtrate tank, core blow tank and compressor, many automated valves.
Operational Characteristics
Chamber Press

• Cake Discharge requires operator to dislodge cake and clean each plate.

• Plate blow out can occur, ending cycle and must discharge wet cake. Frequency depends on diligence of operator.
Operational Characteristics
Screw Press / Rotary Press

- Pre-treatment conditioning: Not sensitive to tramp material. Dilute feed severely impacts capacity due to limited thickening area, recommend pre-thickening.
- Screw Speed: Must match mass flow to provide stable discharge and avoid plug formation requiring shut down to remove.
- Polymer Dosage: Similar to belt press although not as sensitive to over-flocculation.
- Wear: Clearance between flight and screen critical, to much clearance blinds screen surface and reduces conveying capacity.
Laboratory Testing

- Chemical Characteristics:
  - BOD
  - SVI
  - Suspended solids concentration
  - PH
  - % Volatile Solids or Ash
  - Slurry Density
  - Particles Size
  - Temperature
Laboratory Testing

- **Conditioning:**
  - Pre treatment: Grit, thickening etc.
  - Polymer testing
  - Special conditioning requirements.
Laboratory Testing: Equipment Sizing based on Test Results

- **Operational Frequency**: days/week, hr./day
- **Redundancy**:
  - Standby unit
  - Excess Capacity
  - Parts Inventory
- **Desired performance criteria**: cake solids, solids capture, etc.
- **Available Operating Labor**
- **Maintenance**: Capability / Schedule. Important to understand what is required of each option.
- **Where does material go after dewatering.**
Based on Testing Require: Equipment References

• Require References / contacts from similar process installations:
  – Survey Questions:
    • Process parameters:
      Max / Average
      – feed flow / concentration
      – Polymer usage
      – Discharge cake solids
Based on Testing Require: Equipment References

Survey Questions:

- Did actual performance meet promised performance.
- Start up / Shutdown Procedures and time required
- Operator Attention Required Daily / Monthly: what, when, frequency
- Typical maintenance: Daily / Weekly / Monthly
- Maintenance problems / issues
- Maintenance costs per year
- Reliability: has there been an issue
- What do you like best / Least about the unit
- Anything else they feel important.
Based on Test Results: Narrow Down Equipment Type: Consider

- Odor Containment
- Building Size / Structure
- Energy usage
- Polymer Usage
- System Complexity
- Noise
- Maintenance Complexity
- Probably under available Budget
- Operational Characteristics acceptable
- Achieve required cake solids
Budget Capital Comparison

• Materials of Construction
• Electrical Classification
• Accessories: Make sure budget scopes are the comparable.
  – Feed Pump / Tank
  – Wash Pump system
  – Controls: Manual, Automatic, Operator Interface PLC based or Relays/Timers, etc.
  – Cake Discharge: conveyor, storage etc.
  – Polymer make up and metering system
  – Filtrate collection and pumping
• Installation / Start up and Performance Test
“Budget” Capital Cost Comparison

• Process Performance Guarantee:
  – Based on Laboratory Testing require a process performance “Warranty”:
    • Flow rate, solids loading: gpm and lb/hr
    • Flocculent Usage: lb/ton, Polymer details
    • Solids Capture
    • Discharge Cake Solids

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<th>700</th>
<th>1,200</th>
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<td>Dry Solid, lb/hr/m</td>
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<td>Hydraulic at 1.2%, gpm/m</td>
<td>50</td>
<td>100</td>
<td>185</td>
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<tr>
<td>Polymer:</td>
<td>H309</td>
<td>H309</td>
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<tr>
<td>Polymer Dosage, lb/ton</td>
<td>12 to 14</td>
<td>12 to 14</td>
<td>12 to 14</td>
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<tr>
<td>Discharge Cake Solids:</td>
<td>20% to 23%</td>
<td>18 to 20%</td>
<td>17 to 18%</td>
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<tr>
<td>Solids Capture Rate, %</td>
<td>+96</td>
<td>+96</td>
<td>+96</td>
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“Budget” Operational Cost Comparison

- Manufactures statement on Operating Labor
- Manufactures statement on Maintenance Schedule and labor required.
- Recommended spare parts inventory:
  - Start up
  - After Five Years

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<tr>
<th>ITEM #</th>
<th>REQD PER PRESS</th>
<th>DESCRIPTION</th>
<th>QTY. OF SPARES UNDER ELAPSED TIME</th>
<th>PRICE PER UNIT</th>
<th>COST OF SPARES UNDER ELAPSED TIME</th>
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<td></td>
<td></td>
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<td>1 YEAR</td>
<td>5 YEARS</td>
<td>10+ YEARS</td>
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<td>BEARINGS</td>
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<tr>
<td>3</td>
<td>2-7/16&quot; 2-BOLT PILLOW BLOCK BEARING</td>
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<td>$405.22</td>
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<td>2-7/16&quot; TAKE-UP BEARING</td>
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## “Budget” Total Cost Comparison

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<th>Cost Category</th>
<th>Cost ($)</th>
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<tr>
<td>Estimated annual operating cost ($/yr.)</td>
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<td>Estimated annual maintenance ($/yr.)</td>
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<td>Estimated annual parts ($/yr.)</td>
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<td>Polymer cost ($/yr.)</td>
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<td>Electrical cost ($/yr.)</td>
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<td>Hauling costs ($/yr.)</td>
<td>$226,000</td>
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<tr>
<td>Total Initial Capital Cost</td>
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<td>Annual Costs Land Application Cost</td>
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<td>Net PW for Annual Costs Land Application</td>
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<td>Land Application 20-year Net Present Worth ($)</td>
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## Weighted Decision

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<th>Score (1 to 10)</th>
<th>Weight (1 to 5)</th>
<th>Weighted Score</th>
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<td>Feed Distribution</td>
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<tr>
<td>Total Weighted Score</td>
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</tbody>
</table>
Bid Specifications:

• Equipment Parameters that ensure desired performance is realized:
  – Filtration Area: Bowl diameter / length, etc.
  – Gravity Zone Area
  – Feed Distribution System
  – Pressure Area Zone
  – Tensioning System capability
  – Belt Drive System
  – Factors that determine performance
Bid Specifications

• Make bidders understand there will be penalties for not meeting performance:
  – NPV of additional polymer costs
  – Additional haulage / disposal costs for not meeting cake solids.
  – ETC.
Questions