13 November 2012

Project Title: “Improving the Efficiency of Planting, Tending and Harvesting Farm-Grown Trees for Energy”

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Principal Investigator: L. David Ostlie, 763-428-0646

Congressional District: 3 (Corporate Office; Rogers, MN)
Congressional District: 7 (Farm Location; Graceville, MN)
Congressional District: 6 (Equipment Building Location; Big Lake, MN)

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MILESTONE 24 – SUMMARY REPORT
Harvest Trees to Obtain Yield and Cost Data

Executive Summary:

Several modifications were made to the Whole Tree Harvester™ following MS 17 testing. Many of the modifications involved adding to the structure of the harvester to protect vital parts from tree branches and directing the trees as they make their way up and off of the skidpan. In addition to those modifications, repairs to the rear track axles and harvesting head cylinder were made. Lastly, the harvester logic system required changes and updates in order to better control the steering and paddle speed. This took several days to adjust.

The harvester test involved cutting down a row of trees at a rate of approximately 1.6 trees per second. The trees were cut cleanly and traveled smoothly up the skidpan and off of the rear of the harvester. As in MS 17 testing, some of the smaller trees (less than 3” in diameter) fell onto the skidpan, rather than moving along the skidpan in an upright position. The small trees affect not only the performance of the accumulator section of the harvester, but also the productivity since productivity improves as tree size increases.
Because of the size of the trees harvested for this test, the data obtained does not represent the potential of the harvester in terms of cost and productivity. MS 13 testing demonstrated the successful cutting of a 12” tree with the harvester; so extrapolating current results shows that the harvester is capable of reducing harvesting costs by at least a factor of 3 when compared to current harvesting methods. This level of savings and efficiency could help save the dwindling paper and pulp industry in MN, as well as other areas of the country.

Technical Progress:

Whole Tree Harvester™ Modifications and Repairs

Prior to the second field test of the Whole Tree Harvester™, repairs and modifications were necessary. The broken torsional welds on the rear track stub axles, found during MS 17 testing, were repaired by repositioning the axle in the housings and then welding them into place. In addition, tie rods were added to provide additional stability, as shown in Figure 1.

![Figure 1. New Tie Rods on Rear Tracks](image-url)
Other modifications to the harvester included the addition of a transition piece between the harvesting head and the skidpan in order to allow the trees to move smoothly into the skidpan. At the top end of the skidpan, a trip tube and supports for the tree guides were added to improve off-loading of the trees. This is shown in Figure 2.

![Trip Tube and Guide Supports](image)

**Figure 2. Trip Tube and Guide Supports**

Eleven-gauge (~1/8 in thick) sheet steel was then welded along the inside of skidpan in order to protect the hydraulics as well as the diesel engines from damage and risk of fire. This is shown in Figure 3. In order to direct trees into the accumulator and protect the fuel tank fittings, nose deflectors were fabricated and welded to the left side structural tubes (12 inch square tube) at the front of the harvester.
In addition, a second gauge wheel apparatus was built and installed in order to improve the harvesting head tracking. Figure 4 shows the deflectors and gauge wheels. Seals were then replaced on the harvesting head locking cylinder, since it was leaking hydraulic fluid. Next, the harvesting head was lowered so that the cutting blades were within 2 inches of the ground. This required removal of the lower portion of the transport mode tandem connection flange in order to provide the necessary clearance to lower the head.
The digital control system that runs the harvester took several days to modify. The steering controls, as well as those that run the paddles, were adjusted in order to take advantage of many design features. These changes corrected issues with the skid steering that allows harvesting in a crab-position. Consequently, the harvester is capable of harvesting rows as narrow as 5 ft. Additional changes made to the programming allow for paddle to ground speed synchronization and as a result, better loading and off-loading of trees.
Description of the 2012 Harvester Test

The second field test of the harvester proved to be a success. Harvesting was performed in a crab position with a cutting rate of approximately 1.6 trees per second. The trees ranged from 2 to 5 inches in diameter at breast height (dbh) and were spaced 5 feet apart. The 9 feet of vertical separation between the upper and lower paddles proved to be too much for the smallest trees (less than 3 inches dbh). Instead of sliding up the skidpan in an upright position, they tended to fall back into the skidpan. They also had trouble making it over the trip tube at the back end of the skidpan since the tops of the trees were either too short or too flimsy for the upper paddles to direct them off the back of the harvester. The larger trees easily slid up the skidpan and off the back as intended.

Although the data gathered from trees cut with the Whole Tree Harvester™ is not ideal in terms of harvester potential, the ability to cut larger trees was proven during MS 13 testing. At that time, the harvester successfully cut through a 12” diameter tree, leaving no doubt that the harvester could quickly and easily harvest rows of trees that size. In fact, the Whole Tree Harvester™ was designed for larger trees (up to 30 inches in diameter).

The productivity rates for the Whole Tree Harvester™ are directly related to the size of the harvested trees. To illustrate this, Figure 5 shows the productivity rates increasing as tree volume increases. This graph assumes a harvesting speed of 1.6 trees per second, which is the actual speed at which the harvesting for MS 24 was performed.

![Figure 5. Potential Productivity Relative to Tree Size](image-url)
As harvester productivity increases, costs associated with harvesting (on a per ton basis) decrease significantly. Trees harvested during MS 24 testing were too small to show the efficiency and resultant lower costs associated with the Whole Tree Harvester™; however, Table 1 illustrates the diminishing effects of fixed costs with increased productivity. The Whole Tree Harvester™ cost estimates include capital, labor, fuel and maintenance costs. Payment estimates for harvesting methods currently used in the US are around $18 per ton. Conservative cost estimates for cutting 8” trees with the Whole Tree Harvester™ are between $2.44-4.62 per ton.

**Table 1. Whole Tree Harvester™ Potential Revenue and Costs Relative to Tree Size**

<table>
<thead>
<tr>
<th>Tree Size (inches)</th>
<th>Harvest Speed (fps)</th>
<th>Tree Spacing (ft)</th>
<th>Cut Rate (trees/sec)</th>
<th>Oven Dry Tons Per Hour</th>
<th>Oven Dry Tons Per Year</th>
<th>Annual Revenue per Year</th>
<th>Harvesting Cost per Year</th>
<th>Harvesting Cost per ton</th>
<th>Net Before Taxes (NBT)</th>
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<tbody>
<tr>
<td>3.5</td>
<td>8</td>
<td>5</td>
<td>1.6</td>
<td>86</td>
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<td>$258,785</td>
<td>$576,773</td>
<td>$10.03</td>
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<td>4</td>
<td>10</td>
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<td>180</td>
<td>119,808</td>
<td>$539,136</td>
<td>$554,080</td>
<td>$3.17</td>
<td>$239,834</td>
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</table>

The slow growth in the plot where trees were harvested for MS 24 resulted in data that is not representative of peak harvester performance. The slow growth is likely due to poor soil condition at that particular tree plot. Yield data for the harvester test site shows an average value of 2.7 ODT/acre/year, which is significantly lower than other test sites. Detailed yield data will be included in the report for MS 26.

**Additional Milestones:**

Reports for Milestone 26 and Milestone 27 are currently in progress.

**Project Status:**

Data analysis and report preparation are all that remain for the last two milestones. All testing and data gathering for this project are complete.

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1 Assumes 4160 hours per year with an 84% off-loading downtime.