

Energy Performance Systems, Inc.

Owner & Developer of the Whole Tree Energy™ Technology

31 August 2012

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

Contract Number: RD-50 Milestone: 17 Report Date: 31 August 2012

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)

Project funding provided by customers of Xcel Energy through a grant from the Renewable Development Fund

MILESTONE 17 – SUMMARY REPORT Harvester Testing and Modification

Executive Summary:

Completion and testing of the EPS whole-tree harvester™ is vital to improving the overarching goal of increasing the efficiency of harvesting farm-grown trees for energy while reducing associated costs. The EPS whole-tree harvester™ is designed to harvest row trees much more rapidly than other tree harvesters and to keep the trees off the ground (thus dirt-free). The harvester can also handle a wide range of tree sizes and species, making it suitable for handling farm-grown trees for multiple markets (pulp and timber as well as energy).

Final fabrication and assembly work on the harvester began at Whirl-Air-Flow Co. in Big Lake, MN in October 2011 and continued through June 2012. Next, the harvester was partially disassembled and transported to a farm site near Graceville, MN, approximately 2 miles from the tree test site. The harvester was then reassembled and driven to the 40-acre tree site where it was successfully demonstrated. The test involved cutting approximately twenty, 5-year-old poplar trees in an outside row of the plantation. All trees were completely severed by the cutting discs and automatically pulled into the accumulator section of the harvester as the harvester moved through the row of trees. Although a few design and computer issues were identified during the test, it was considered a success. EPS is currently working through the issues in preparation for the final harvester test.

Technical Progress:

Milestone 17 Harvester Modification

Prior to milestone 17 testing, several components of the harvester fabrication and assembly were completed. First, fifty-six car body/paddle assemblies were built and installed in both the upper and lower rails, followed by the installation of a 150 hp hydraulic drive motor. The drive motor was then connected to an existing pump. Next, the hubs, shafts and sprockets were installed in the accumulator section of the harvester. Installation of the chains followed, connecting the paddles to the drive motor. This allowed for the harvester to accumulate cut trees into the skidpan while the machine was moving continuously along a row of trees. Figure 1 shows the carbody/paddle assemblies.

Following the accumulator section assembly, three large lift cylinders were added, two at the rear of the harvester and one toward the front of the harvester. The front 4-stage lift cylinder was modified to eliminate side-to-side movement. This keeps the harvester from moving left or right while the cylinder is actuated. The rear single stage, dual-acting cylinders were mounted, one on each side, with x-back bracing. All three lift cylinders aid in assembly and disassembly of the harvester and can also be used in the field for most harvester or track lifting needs. The two rear lift cylinders are shown in Figure 1.

The harvester is designed to accommodate a wide range of tree sizes. To efficiently handle small, fast growing trees such as five-year-old poplar, steel guides were mounted above the top paddles and just above the skidpan. These guides ensure that the smaller trees are steered toward the left side of the harvester as they are pushed off of the skidpan and do not get caught as the paddles accelerate through the turn on the back sprockets. A future modification of these guides may include adding springs or making them hydraulically actuated in order to account for different tree sizes. The steel guides are visible in Figure 1.

The harvesting head consists of two overlapping 49-inch cutting discs arranged in a fixed position. As the harvester moves forward the discs slice into the tree in a scissor-like manner, which affectively fells the tree with a continuous, smooth cut. In order to improve the positioning of the cutting discs and allow the harvesting head to track the trees while moving forward, a locking cylinder was added to the head that permits approximately 1.5 feet of horizontal movement, in either direction, and creates a spring effect of ± 6 inches during use. A gauge-wheel with another locking cylinder was also added for vertical adjustment.

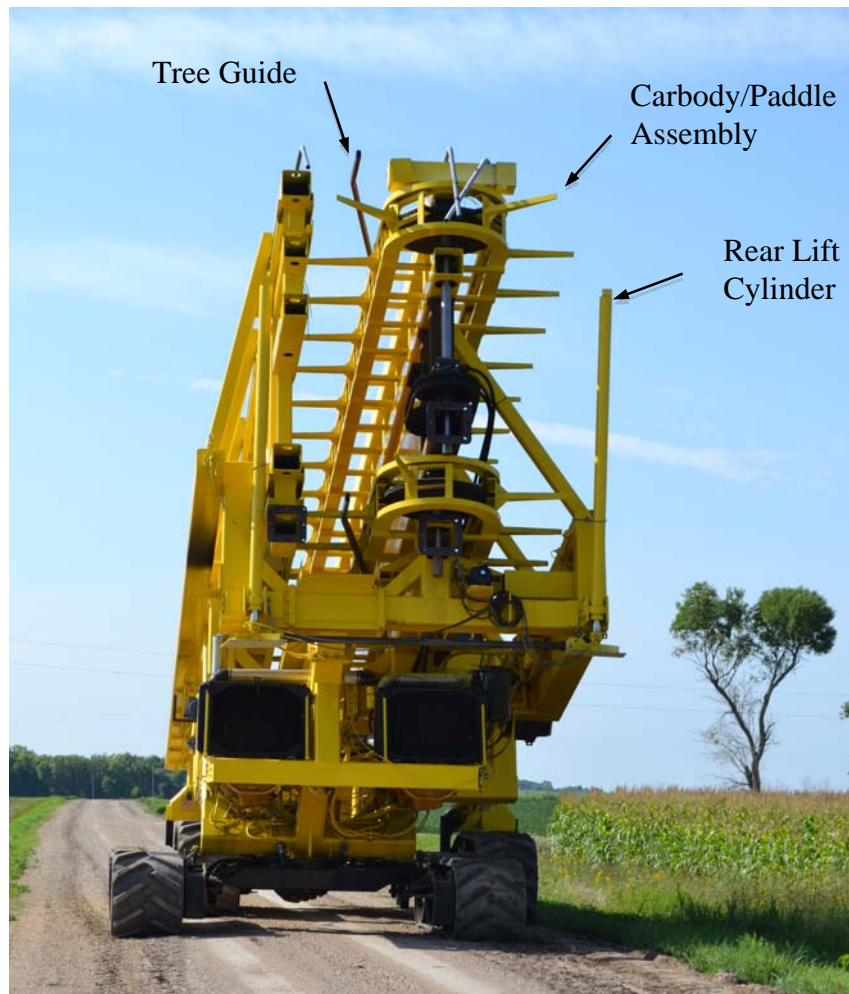


Figure 1. Rear of Harvester

Transportation to the Assembly Site

Due to the large size of the harvester, it was disassembled into four separate parts prior to moving it to the tree site. In order to maintain stability of the structure during transport, finding the center of gravity was necessary. This was determined by lifting the harvester several times on each end with two 50-ton jacks and finding balance points using a plum bob. The hauling assemblies were then positioned based on the center of gravity. The front structural part of the harvester was fitted with support beams that attached to a rear set of tandem-axle wheels. The rear of the harvester was fitted with three flanges that connected to structural tubing and a kingpin assembly. These fittings allowed the harvester body to attach to a trailer truck. Both the front and rear tracks were hydraulically driven onto a flatbed trailer using a remotely controlled hydropower pack. Figure 2 shows the harvester structure moving out of the fabrication shop in Big Lake, MN.



Figure 2. Move from Fabrication Shop

Finding a route and a hauler for the harvester structure quickly became a challenge. Out of date road construction information at MN DOT and a busy trucking season led to delays in the transportation of the harvester to the test site. After several different trucking companies withdrew from verbal and/or written hauling agreements, the harvester structure and rear tracks were finally hauled to the assembly site via T.J. Potter Trucking out of Becker, MN. Lange and Sons Transport, from Rogers, MN, hauled the front tracks. The harvesting head was loaded and hauled on a smaller trailer pulled by the EPS 3/4-ton pick up truck. A photo of the harvester during transport is shown in Figure 3.



Figure 3. Harvester in Transport Mode

Field Assembly of the Whole Tree Harvester™

Upon arrival at the assembly site near Graceville, MN, a crane operator was disassembling grain bins that were damaged in a recent storm. As a result, EPS was able to utilize the services of the crane in order to expedite reassembly of the harvester. First, the harvester structure was disconnected from the transport attachments. Next, the rear tracks were installed, followed by the front tracks. The use of the crane allowed all of this work to be completed in one day. The following days involved making all of the other structural, hydraulic and electronic connections. Figure 4 shows the crane helping with the assembly.

Once all of the connections were made, it was noted that one of the front track tie-rods was bent and needed repair. Case International in Graceville, MN restored the tie-rods to good working condition. Next, it was determined that the digital linear transducer, that provides feedback for the front track steering, was inoperable due to water damage and was replaced. The part was intended for outdoor use, so it is disappointing that the outdoor elements were able to adversely affect its performance. After the transducer was replaced, it was noted that there were problems with the computer logic that affected startup and steering. Work-arounds were implemented to allow operation of the harvester. A future re-write of the logic is necessary to optimize many design features of the harvester.



Figure 4. Installing Front Tracks During Field Assembly

Once field assembly was completed, the harvester was driven to the tree site. Within the first few hundred yards of the drive to the trees, a small sensing hose with a reduced hydraulic rating, burst and was replaced with a cap. It was then noted that there were several other underrated hoses attached that need to be replaced, but they did not cause any problems during testing.

Throughout the trip to the test site and the first tree harvest, the track steering proved to be a challenge. The rear tracks overcorrected when making turns, whereas the front tracks took 40 feet to make a 15-degree correction. This made it difficult to maneuver in relatively tight spaces. Both of these steering issues are logic settings that can be adjusted.

Along the way to the tree site, Traverse Electric Co-op, Inc. was called to move two utility lines out of the path of the 28 ft tall harvester. Once the harvester was at the test site, the harvesting head, with the gauge wheel, was installed and adjusted to the appropriate height. An analog control system for the tree accumulator was also installed with the intent to integrate it with the logic system at a later date.

At the test site, it was discovered that torsional welds, that keep rear track axle from turning in the housing, were broken on each side. In addition, a stabilizing pin on the right track was broken. Custom Fabrication in Morris, MN made a new pin for installation prior to testing. The welds were not addressed prior to the first test, but will be repaired prior to the second harvester test.

Description of the 2012 Harvester Test

The first field test of the Whole Tree Harvester™ was successful. It included cutting approximately 20 small trees on an end-row of the tree plantation. Figure 5 shows a photo of one of the tree stumps after the harvester pass. The harvester cut cleanly through the trees at approximately 3 inches off of the ground and the paddles pulled the trees onto the skidpan as the harvester moved continuously forward. Throughout the test, trees from approximately 1.5 to 4 inches in diameter (measured at the base of the tree) were easily severed by the twin cutting disks. A gap between the cutting head and the skidpan proved to be a catching point for the smaller trees and caused several trees to lie down rather than stand as they slid along the skidpan. The trees that made it across the gap were pulled up the skidpan and delivered off the back of the harvester, where they fell to the ground. As the small trees in the prone position filled up the skidpan, they began to block larger trees as well. The harvesting was then stopped in order to keep the prone trees from damaging the hydraulic and electronic lines running along the inside of the harvester structure. All remaining trees were cleared from the skidpan by hand.

The harvester ground and paddle speeds were not synchronized for this test. Separate manual speed adjustments for the paddles and tracks made it difficult to adequately load trees.



Figure 5. Stump From Whole Tree Harvester™ Cutting

During this test, it became clear that a few minor modifications are necessary prior to the final test. These modifications include:

1. install a transition piece between the harvesting head and skidpan to allow for the trees to move smoothly onto the skidpan
2. synchronize the paddles with the ground speed of the harvester
3. install trip tube and support for tree guides to ensure appropriate off-loading of trees
4. install steel strap for the inside of the harvester along the skidpan to prevent tree branches from damaging hydraulics, etc.

Additional Milestones:

Milestone 24 is currently underway and involves using the harvesting machine to harvest trees from the Graceville test plot to obtain yield and cost data.

Project Status:

The next harvester test date is not yet determined. Modifications to the harvester that were identified during field-testing are now underway. The few mechanical modifications that needed work have been completed, however some control issues have emerged and require more investigation and repairs.

Legal Notice

THIS REPORT WAS PREPARED AS A RESULT OF WORK SPONSORED BY NSP. IT DOES NOT NECESSARILY REPRESENT THE VIEWS OF NSP, ITS EMPLOYEES, OR THE RENEWABLE DEVELOPMENT FUND BOARD. NSP, ITS EMPLOYEES, CONTRACTORS, AND SUBCONTRACTORS MAKE NO WARRANTY, EXPRESS OR IMPLIED, AND ASSUME NO LEGAL LIABILITY FOR THE INFORMATION IN THIS REPORT; NOR DOES ANY PARTY REPRESENT THAT THE USE OF THIS INFORMATION WILL NOT INFRINGE UPON PRIVATELY OWNED RIGHTS. THIS REPORT HAS NOT BEEN APPROVED OR DISAPPROVED BY NSP, NOR HAS NSP PASSED UPON THE ACCURACY OR ADEQUACY OF THE INFORMATION IN THIS REPORT.