Final Report SRDC Project BS81S - A New Approach to Automatic Basecutter Height Control - 1997

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FINAL REPORT
SRDC PROJECT BS81S

A NEW APPROACH TO AUTOMATIC BASECUTTER HEIGHT CONTROL

by

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SD97006

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1. **SUMMARY**

The three and a half year project to develop a basecutter height controller utilising basecutter speed as the height sensor was completed in December 1995.

Initial testing of basecutter speed variations with basecutter height setting on both underslung and leg basecutters confirmed that there was sufficient sensitivity for use of basecutter speed as a control mechanism. These tests also indicated that an allowance should be made for harvester cutting speed effects on basecutter speed.

A prototype controller was developed based on the cane loss monitor circuitry from Agridry Rimik and fitted to the BSES harvester at Bundaberg. The proportional electric/hydraulic control valve fitted to the harvester was utilised in conjunction with the controller for adjusting basecutter height.

During the 1993 season testing of the prototype controller was carried out and a number of software changes were made to improve controller performance. Response time of the proportional valve was also reduced from 300 ms to 100 ms by fitting a faster controller. The controller was also modified to allow logging of the different control functions including basecutter speed, control setting, harvester forward speed and controller function. Checking of changes in basecutter speed with basecutter height and harvester forward speed allowed refinement of the control software. Ramp tests were also carried out to determine speed of response to sudden changes in row height. It was found that the controller took some time to adjust for these changes - approximately 8 m for a sudden lowering of row height and approximately 4 m for a sudden raising of row height. This means that the controller is not capable of adjusting for sudden changes in row height in the field such as washouts. This finding is likely to apply to all similar systems due to the need for averaging control signals and hysteresis in the control hydraulics.

Following the 1993 season the controller was modified and fitted to commercial harvesters at Bundaberg, Mackay and Proserpine. These included a wheeled Cameco, a full track Austof 7000 with an underslung basecutter and a full track Austof 7700 with leg basecutter, respectively. Field testing of the controller was carried out in each district and this highlighted two problems: basecutter speed was affected by the extra loading on the harvester in lodged cane and by large changes in soil hardness within a field. This caused the controller to raise the basecutter and leave stubble in lodged sections of the cane row or at boundaries of soil types within a block. A sensitivity adjustment was tested late in 1994 to attempt to overcome the soil type effect.

The project was extended into the 1995 season to allow full evaluation of the sensitivity control, and to test the value of adjusting the basecutter rpm set point for changes in engine rpm. It was felt that this may allow for the loading effect of lodged cane on basecutter rpm. During 1995 further testing was carried out at Bundaberg, Mackay and Proserpine. In mid season the Mackay controller was shifted to an Austof 7700 harvester in Tully to obtain mill soil in cane readings with and without automatic basecutter height control.
The 1995 trials indicated firstly, that lowering the sensitivity reduced the effectiveness of basecutter height control due to infrequent adjustment of basecutter height; and, secondly, that basecutter rpm and engine rpm were too closely linked for engine rpm to be effective in adjusting for lodged cane. The Tully trial comparing mill soil in cane readings with automatic and manual control of basecutter height showed a small reduction in soil levels with automatic control. There was also slightly more cane stubble left with automatic height control.

During the course of trials with the controller all operators indicated that they valued an automatic height control system but no operator used the controller on a regular basis. This was felt to be due mainly to the tendency to leave long stubble with sudden changes in soil type, crop density or harvester speed. It was also partly due to the need for approximate manual resetting of basecutter height on re-entering each row in addition to restarting the controller. It was concluded that the controller would therefore not be accepted as a stand alone aid for controlling basecutter height.

The project gave valuable data on control settings for any future height control system and on hydraulic design for height adjustment. The parallel study which developed a computer model of height control systems also provides a valuable tool for design and evaluation of future control systems.

2. BACKGROUND

Early BSES research by Henkel et al. (1979) showed the effect of basecutter height setting on levels of dirt in the cane supply and cane left in the field. More recent research confirmed the increase in dirt levels with low basecutter settings and an increase in stubble damage and cane losses when cutting above ground (Project BS20S Final Report, Ridge and Dick, 1992)

Research by SRI in conjunction with BSES on use of ultrasonics for basecutter height control (Project BS26S) showed that this is successful in burnt cane but there are difficulties with signal reflection in green cane. Preliminary testing of hydraulic pressure sensing for basecutter height control in this project and by Musumeci and Bitmead (1981) was not promising. A new approach to basecutter height sensing and control is therefore warranted.

Observations made on basecutter speed, using the BS38S cane loss monitor, suggest that the deeper the blades cut into the soil, the slower will be the rotational speed. This reduction in speed is easily observed and of significant magnitude. The rationale for the current project is that the change in rotational speed can be used to raise or lower the basecutters through a hydraulic control valve. The control method would not be fully automatic as the initial height would be set by the operator. The device would operate in a similar manner to an automotive cruise control with the objective being to maintain constant basecutter rpm (and therefore constant height). The operator could override the controller at any time by moving the height control valve, deactivating the controller; a
resume button would reactivate the controller. The electronics developed in the cane loss monitor project were considered to be an appropriate basis for the control system.

As a preliminary step it was proposed that sensitivity of basecutter speed to height setting should be assessed for both 'underslung' and 'leg' type basecutters. If this step was satisfactory it was proposed that the project should proceed jointly between BSES and SRI. BSES would be responsible mainly for modifying harvester hydraulics for the controller and arranging field testing; SRI would be responsible for modifying the Cane Loss Monitor to act as a height controller. The electronics modification would also involve a cooperative agreement between Agridry Rimik and the research bodies for use of Cane Loss Monitor technology.

3. OBJECTIVES

The project objectives were as follows:

- develop a semi-automatic controller for setting basecutter height based on basecutter speed
- utilise the electronics developed for the cane loss monitor where appropriate
- assess the performance of the device under a range of field conditions
- design the device so that it is suitable for retro-fit installation on existing harvesters

4. METHODOLOGY

4.1 Stage I - Preliminary monitoring of basecutter speed versus height setting and ground speed

The first stage of the project was to evaluate basecutter speed variations with basecutter height on both leg and underslung basecutter drive systems.

As part of the project BS82S basecutter speed sensors were fitted to four harvesters with underslung basecutter drive systems and two harvesters with leg basecutter drive systems. Basecutter speed in relation to height settings was observed for a range of field conditions during the 1992 harvest season. Logging of basecutter speed in relation to harvester forward speed was also carried out to determine whether the software should include an adjustment for harvester speed.

4.2 Stage II - Development of prototype controller

A planning meeting for development of a prototype controller was held in November 1992 between Agridry Rimik, BSES and SRI. It was decided that the controller was to be based on the cane loss monitor circuitry and operate in a manner similar to a cruise control on a car, with manual setting of the operating basecutter speed for each block. The controller would include set, disengage and resume buttons and the facility to adjust the set point up
or down while operating. It would also automatically disengage whenever the operator manually adjusted the basecutter height, again similar to a car cruise control when the brake pedal is pressed. SRI would be responsible for developing the controller and BSES for modifying the harvester hydraulics for electric/hydraulic control of basecutter height.

Both the controller and the electric/hydraulic proportional control valve for adjusting basecutter height were available for preliminary testing prior to the 1993 season. The BSES harvester was modified to improve stability of the basecutter speed under load by increasing oil flow to the basecutter from 57 gpm to 62 gpm, taking the feed rollers and croplifters off the basecutter circuit and driving them from a separate ring on the pump.

4.3 Stage III - Testing and modification of the controller

Preliminary testing of the controller was carried out prior to the 1993 harvest season and it was found that some software modifications were required. It was also decided to improve the response time of the electric/hydraulic proportional valve by fitting a high speed controller. This reduced the response time from 300 mS to 100 mS.

After modification of the software and the proportional hydraulic valve controlling basecutter height settings field testing was carried out during the 1993 harvest season. Initially this involved comparative runs with manual and automatic control of basecutter height. Stubble height was recorded for each control system. A similar trial was conducted with surveying of row heights before and after cutting. Further software tuning was carried out during these trials.

Ramp tests to assess response time of the controller were also conducted by surveying row height at 0.5 m intervals before and after passage of the harvester over the ramp. Height of the stubble left by the harvester was also noted.

Midway through the 1993 season the controller was modified to allow computer logging of basecutter rpm, ground speed, and controller operation. Logging was carried out for a range of field conditions and basecutter height settings.

Further software refinements were carried out and the controller was retested late in the 1993 season on the BSES harvester. It was then transferred to a commercial harvester with a leg type basecutter and further logging was carried out. A further ramp test was conducted with the controller on the BSES harvester involving both an above ground ramp and excavating the interspace to determine the speed and accuracy of response of the controller. Further testing of the controller was carried out on a harvester with a leg type basecutter cutting plants in April 1994 and performance was logged on the computer.
4.4 Stage IV - Construction and testing of a semi-commercial controller

4.4.1 1994 test program

Discussions were held in June 1994 between Agridry Rimik, BSES and SRI regarding commercialisation of the controller. It was decided that two more units should be constructed for testing under semi-commercial conditions during the 1994 season. It was initially thought that it would be necessary to increase the memory capacity of the controller to carry out all the functions required in semi-commercial units from 2 kbytes to 12 kbytes necessitating a change in the CPU.

Several modifications were made to the previous controller for semi-commercial use. These included removal of the disengage switch on the operator panel, provision of three LEDs on the front panel for up/down/on, and replacement of the proportional hydraulic control valve with an on/off solenoid. It was also decided to obtain an ultrasonic height sensor for mounting in the cabin on the basecutter height indicator gauge if an inexpensive unit was available. This sensor would be used to reset the cutting height automatically on entering each row of cane. Unfortunately the only suitable unit found was considered too expensive to use in a commercial controller, and the sensor was only used for monitoring purposes.

Harvester contractors at Bundaberg, Mackay and Proserpine were approached to test the modified controllers and all three controllers were installed during the 1994 season. These included a Cameco and two Austoft 7000 harvesters. The proportional control valve used previously on the BSES harvester was replaced with a cheaper and faster on-off solenoid valve giving a response time of 100 ms.

Monitoring and logging of the operation of the three controllers was carried out during the last half of the 1994 season. Late in the season preliminary testing of a variable sensitivity setting adjustable for soil conditions was carried out.

4.4.2 1995 test program

Testing of the controllers was extended into the 1995 season to allow evaluation of the variable sensitivity setting, and to assess the effect of an algorithm for adjusting settings for changes in engine rpm under load.

These tests were carried out on a Cameco harvester at Bundaberg and an Austoft 7700 at Tully. At Tully soil measurements were obtained from the mill for both manual and automatic control of basecutter height settings. Logging of basecutter height, ground speed, basecutter rpm, control settings, engine rpm and controller operation was carried out for each harvester.
5. RESULTS AND DISCUSSION

5.1 Stage I - Preliminary monitoring of basecutter speed versus height setting and ground speed

Typical results for basecutter speed in relation to height settings and harvester forward speed are given in Figure 1. It was noted that there was some fluctuation in basecutter speed at a given height setting but in general it was possible to obtain good discrimination between different height settings for both types of basecutters. There were some problems with the underslung basecutter where hydraulics were worn, resulting in excessive fade in speed with varying crop conditions. These problems were not observed where hydraulics were operating to normal specifications.

It was noted that one operator in the Ingham district was using basecutter speed to set basecutter height, resulting in an improved basecutter cut at ground level. In this machine the basecutter drive pump fitted as standard on the Austoft 7000 harvester has been replaced with a more efficient Haaglund-Denison vane pump which gives minimal fluctuation in speed at a given height setting.

Recording of basecutter speed in relation to harvester forward speed showed slowing down as forward speed increased. The change was approximately 9 rpm per 1 kph for the leg basecutter in the particular soil type tested. At this stage of the project basecutter speed was read through the cane loss monitor with some averaging of the signal. Direct logging of the signal was carried out later in the project.

5.2 Stage II - Development of the prototype controller

This stage involved development and fitting of the prototype controller, modification of the hydraulics of the BSES harvester to improve stability of basecutter speed, and fitting of an electric/hydraulic valve on the basecutter height control circuit. No testing was carried out during this stage.

The fitting of the controller required a contact closure whenever the operator manually adjusted the basecutter height (so that the controller could be disengaged). No such contact was available, and there was no suitable location for mounting a microswitch. Therefore an electronic circuit was designed and built to monitor the control signals from the manual control level, and operate a relay contact whenever the lever was operated.

5.3 Stage III - Testing and modification of the controller

Initial testing of the prototype controller in late April/early June 1993 showed some hysteresis in the hydraulic circuit in response to the move up and move down signals from the controller. The hysteresis was significantly reduced by installing a high speed proportional controller on the basecutter height control circuit.
FIGURE 1 - Variation in basecutter speed with basecutter height and harvester speed. Note that heights are indicated by sight gauge readings where 0.5 unit represents 24 mm.
In these initial tests, the basecutter rpm was calculated by counting pulses over a set period. For a relatively stable rpm reading to be obtained, the period had to be set to greater than one second. This was considered unsatisfactory and the software was changed to instead calculate basecutter rpm by timing the interval between pulses, giving a more accurate and faster responding reading. However this reading still required averaging before it could be used for control purposes.

Initial comparisons of stubble length and ground profile for manual and automatic control of basecutter height in August 1993 showed little difference in uniformity or average height of cutting. It was noted that the controller cut slightly higher when operating at a higher ground speed, confirming the need for adjusting the set point for changes in ground speed. It was also necessary to adjust the software to disengage the controller below a certain ground speed to prevent digging in of the basecutter when the harvester stopped. Without this feature, the load drops off when the harvester stops and the controller lowers the basecutter to keep the rpm at the set value.

In order to determine the performance of the controller, ramp tests were conducted where the harvester is driven over a defined ramp whilst cutting cane and the distance required for the controller to respond is measured.

The first ramp test conducted with wooden planks 75 mm high by 5 m long and a harvester speed of 5.2 kph showed that the controller had not compensated for the ramp by the end of the 5 m distance (Figure 2). Adjustment of the basecutter speed averaging period and the time interval between height adjustments to improve response time gave some control of height before the end of the ramp. Figure 2 compares calculated heights based on harvester geometry (assuming no control adjustment) with stubble heights measured in the field. In runs 1 and 2, respectively, the basecutter was set at 0.01 m and 0.02 m above ground level, and the comparison of stubble height with expected height based on harvester geometry indicates the degree of height control. In run 2 the controller was attempting to control back to 0.02 m before the end of the ramp and had achieved this adjustment by the end of the ramp.

Computer logging of the basecutter speed at different basecutter height settings and different harvester forward speeds was carried out in late September 1993. Typical results are given in Figure 3 and Figure 4, respectively. These show some noise in the basecutter speed signal but a clear change in basecutter speed with height setting and harvester forward speed. A change in sight gauge setting of basecutter height in Figure 3 of 0.5 unit represents 24 mm change in basecutter height. It was estimated that basecutter speed changed by approximately 25 rpm per 25 mm change in cutting height in sandy soil within ±25 mm of true ground level. In red soil the change was 40 rpm per 25 mm within ±12 mm of true ground level. Above 12 mm the change was 25 rpm per 25 mm. There was a change in basecutter speed of approximately 10 rpm per 1 kph change in forward speed at ground level. Note that the variation in basecutter speed with cutting height occurred when cutting below and above ground to at least 25 mm above ground.
FIGURE 2 - Controller adjustment of basecutter height in above ground ramp test
Figure 3- Effect of basecutter height setting on basecutter speed
Figure 4- Effect of harvester forward speed on basecutter speed
The time scale in Figures 3 and 4, and in all other figures in this report, are in 32.768 ms increments. This is the frequency at which data was logged from the controller. In other words the time scale is approximately 30 units per second.

The smoothing function for the basecutter speed readings was changed from a simple averaging function to a single exponential smoothing function in October 1993. This change came about from work on the computer modelling of basecutter height control, which formed part of this project, and is reported separately by Garson (1994). An integral function was also added to the controller at this time to cause it to respond quickly to large changes in basecutter speed and more slowly to small changes in speed.

In November 1993 the controller was retested in both the BSES harvester and a Toft 7000 harvester with a leg type basecutter. Figure 5 shows the variation in basecutter speed with basecutter height for the leg basecutter. The change in basecutter speed with basecutter height is reasonably clear cut but again there is considerable signal noise.

Two further ramp tests were conducted with the BSES harvester using the above ground 5 m x 75 mm timber ramp and an excavated below ground 10 m x 50-75 mm deep ramp. Plots of basecutter speed and control adjustments versus distance for the two ramp tests are given in Figures 6 and 7, respectively. For the above ground ramp the basecutter speed did not return to the control value until approximately 3 m beyond the end of the 5 m ramp. Response was more rapid with the below ground ramp with the basecutter speed returning to the control value within 5 m of the start of the ramp. After the harvester climbed out of the below ground ramp the basecutter speed took approximately 10 m to recover to the set value.

Logging of basecutter speed versus ground speed with the leg basecutter showed a change of approximately 10 rpm per 1 kph which is similar to the value found earlier for the underslung basecutter on the BSES harvester.

Further testing of the leg basecutter in April 1994 confirmed the figure of 10 rpm change in basecutter speed per 1 kph change in ground speed which could be used to adjust the control setting of basecutter speed for changes in ground speed. It was noted that increased ground speed caused the controller to raise cutting height in the absence of an adjustment algorithm. The controller software was modified to include this adjustment. Basecutter speed changed by approximately 1 rpm for each mm change in basecutter height when the controller was not operating. This agreed with earlier measurements.

5.4 Stage IV - Testing of semi-commercial controllers

5.4.1 1994 test program

The controllers installed in harvesters at Bundaberg, Mackay and Proserpine were assessed during the 1994 season.
Figure 5- Change in basecutter speed with basecutter height in leg basecutter
Figure 6- Change in basecutter speed and control signals for harvester passing over a 5m above ground ramp

Figure 7- Change in basecutter speed and control signals for harvester passing through a 5m long excavated trench
5.4.1.1 Cameco harvester

Prior to installation of controller on the Cameco harvester at Bundaberg preliminary testing of basecutter stability and basecutter speed response to changes in basecutter height was carried out. Results of these tests are given in Figures 8 and 9, respectively. These tests indicate that basecutter speed is more stable in the Cameco than the Austoft 7000 and there is a good relationship between basecutter height and basecutter speed.

The controller was installed in September 1994 and a number of runs were logged with the controller operating. These indicated that the controller was functioning well but it was noted that the adjustment of the set point for changes in harvester forward speed was not adequate; and that the controller was lifting the basecutter height in lodged cane or in harder soil. (The majority of the soil was a loose sand). A typical test run is given in Figure 10.

5.4.1.2 Austoft 7000 - Mackay

The controller was installed in the Mackay Austoft 7000 in August 1994. This harvester was fitted with an underslung basecutter and basecutter speed was not as stable as for the Cameco harvester at Bundaberg which had a leg basecutter.

A typical log of basecutter speed and controller operation is given in Figure 11.

The driver of this machine found that the controller operated satisfactorily in even cane but tended to cut high in heavy lodged cane. The controller also made adjustments too often under some conditions and not often enough under other conditions. It was felt that a variable response time might overcome this problem.
Figure 8- Basecutter speed signal stability in Cameco harvester
Figure 9- Change in basecutter speed with basecutter height in Cameco harvester
Figure 10- Typical controller operation in Cameco harvester at Bundaberg-1994
Figure 11- Typical controller function in Mackay 7000 harvester- 1994
5.4.1.3 Austoft 7700 - Proserpine

The original prototype controller was installed at Proserpine in November 1994 in an Austoft 7700 harvester. The controller included a facility for varying response sensitivity and this was tested over several logging runs in November to December.

Again basecutter speed showed more variability under uniform cutting conditions than was found for the Cameco harvester. A higher sensitivity giving more frequent adjustment of basecutter height (Figure 12) appeared to give more effective regulation of basecutter height than a lower sensitivity (Figure 13).

Observation of the ground job left by the harvester under wet harvest conditions during the December tests showed apparently effective control of basecutter height with a minimum of stubble.

5.4.2 1995 test program

5.4.2.1 Cameco - Bundaberg

The Bundaberg controller was reinstalled in mid-August 1995 in the Cameco harvester and detailed logging of controller performance was carried out. Performance was fair, but was hampered by the narrow row spacing in the test blocks which caused the harvester basecutter to be positioned off centre on the cane row. A typical plot of controller functions for the Bundaberg harvester is given in Figure 14. This shows the relationship between basecutter rpm and engine rpm, and between the set point, harvester forward speed and engine rpm.

5.4.2.2 Austoft 7000 - Mackay

Preliminary testing of a modified controller incorporating logging of a sight gauge level sensor and the engine rpm was carried out in mid and late-July 1995 at Mackay. Further testing was carried out in mid-August, with a set point adjustment for varying engine rpm added to the control software. A simple percentage adjustment factor was used, with a (say) 10% reduction in engine rpm causing a corresponding 10% reduction in basecutter rpm set point.

The early testing with the height sensor (Figure 15) confirmed its effectiveness and the potential for use in a commercial unit to reset the height automatically on entering each row of cane. Logging of engine rpm and basecutter rpm showed a relatively close relationship, with engine rpm varying proportionately less than basecutter rpm (Figure 16). This suggests that load on the basecutter is affecting engine rpm, and use of engine rpm in correcting the basecutter rpm set point for the extra loading in cutting lodged cane may not be effective.
Figure 12- Typical controller function in Proserpine Austoft 7700 with higher sensitivity setting

Figure 13- Typical controller function in Proserpine Austoft 7700 with low sensitivity setting
Figure 14- Typical controller functions for Cameco harvester with engine rpm correction function - 1995

Figure 15- Typical controller operation and height gauge reading for Mackay harvester - 1995
Figure 16- Controller functions for Mackay harvester illustrating relationship between engine rpm and basecutter rpm- 1995

Figure 17- Controller function and height reading for Proserpine Austoft 7700 harvester- 1995
5.4.2.3 Austoft 7700 - Proserpine

The controller was reinstalled in the Austoft 7700 harvester in early August 1995 and logging of performance was carried out in September and October. This showed similar effects to the Mackay tests although engine rpm changed less with change in bascutter speed than at Mackay. This may be due to the larger engine in the Proserpine harvester. A typical plot of controller functions for the Proserpine harvester is given in Figure 17. Visual observation of the ground job with the controller operating showed satisfactory performance in relatively even cane.

5.4.2.4 Austoft 7700 - Tully

The controller from the Mackay harvester was installed in an Austoft 7700 harvester at Tully in October 1995. Logging of performance was carried out in November with a range of gain settings on the controller. The engine rpm control function was turned off during the trials due to occasional anomalous high readings which affected both the set point and control function. Control was more effective following this adjustment and a comparison of soil levels at Tully Mill with and without the controller operating was obtained. Results are given in Table 1. This showed a small reduction in soil levels with the controller operating, but there was also slightly longer cane stubble. Quality of the ground job was considered to be satisfactory.

<table>
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<th>Harvester setting</th>
<th>% soil in cane</th>
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The operator was satisfied with the ground job given by the controller in most situations but was not prepared to use it consistently due to the need for resetting at the ends of rows. He was also concerned about the long stubble left occasionally in lodged cane.

Logging of the controller functions gave similar results to the Proserpine harvester.

6. **DIFFICULTIES ENCOUNTERED DURING THE PROJECT**

A major difficulty encountered during the project was the lack of published previous work on control systems for adjusting harvester hydraulics. Control systems were developed on a trial and error basis in the early stages of the project and with some assistance from SRI
modelling studies in the later stages of the project. Hydraulics were improved as the project progressed to improve response times and control algorithms were also refined.

A second serious difficulty was that basecutter speed was less stable than originally thought from observations using the cane loss monitor which incorporated averaging of the signal. There was also variation in stability between types of harvesters according to basecutter type and hydraulic circuitry. This affected signal averaging times and speed of response to changing field conditions.

The final difficulty which ultimately prevented commercialisation of the controller was that factors other than basecutter height affected basecutter speed. These included lodged cane, changes in soil hardness and harvester speed. An attempt to correct for the extra load on the machine in lodged cane by adjusting the set point using engine rpm was not successful. Similarly provision of a sensitivity control for adjusting for different soil conditions reduced the effectiveness of basecutter height control. The adjustment of the set point for changes in harvester speed was relatively successful but in some situations the adjustment factor needed to be changed to prevent changes in basecutter height with changes in harvester forward speed.

7. RECOMMENDATIONS FOR FURTHER RESEARCH

Following from this research and modelling work it appears that using a direct measurement of basecutter height close to the basecutter for controlling basecutter height would be most effective. The previous suggestion by Garson (1994) of using a transverse beam to sense hill height eg an ultrasonic beam, appears to be the most promising approach. Information gained during the current project on control algorithms and hydraulic design would be directly transferable to a new control system. Any new system should incorporate a feature for automatic return to the previous cutting height on entering each cane row.

8. APPLICATION OF RESULTS TO THE INDUSTRY

As mentioned above it is felt that principles developed for control software and design of hydraulic circuitry would be directly applicable to other basecutter height control systems or other similar control systems on harvesters. A control system based on basecutter speed settings would be a useful aid to drivers under uniform harvesting conditions but it is felt that the shortcomings in lodged cane or variable soil conditions preclude commercialisation of the system on a stand alone basis.

9. PUBLICATIONS ARISING

Results of the project have not been published to date due to concerns about commercial confidentiality.
10. REFERENCES


11. ACKNOWLEDGMENTS

The funding support from the Sugar Research and Development Corporation for this project is gratefully acknowledged, together with assistance from harvester operators in testing the control system.
12. APPENDIX A - CONTROLLER DESCRIPTION

HARDWARE

The basecutter height controller is a modified version of the Cane Loss Monitor manufactured by Agridry Rimik Pty Ltd. It contains a Motorola MC68HC711E9 microprocessor and uses the input/output signals listed in Table A1. The signals listed as internal are internal to the controller and are connected to switches or lamps on the front panel. Those listed as external are connected to external devices (e.g., switches, solenoids, sensors) via connectors at the rear of the controller. In addition to the signals listed in the table, the controller has two four-digit LED displays on the front panel.

| TABLE A1  |
| Controller input and output signals |

<table>
<thead>
<tr>
<th>INPUTS</th>
<th>Internal</th>
<th>Analog</th>
<th>Sensitivity knob</th>
<th>Digital</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Up button</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Down button</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cal/Display button</td>
<td></td>
</tr>
<tr>
<td>External</td>
<td>Analog</td>
<td>Ultrasonic sight gauge height</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Digital</td>
<td>Set button</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Resume button</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disable button</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manual up</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manual down</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Basecutter rpm sensor</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ground speed sensor</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Engine rpm sensor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OUTPUTS</td>
<td>Internal</td>
<td>Digital</td>
<td>Up lamp</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Down lamp</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Auto lamp</td>
<td></td>
</tr>
<tr>
<td>External</td>
<td>Digital</td>
<td>Move up</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Move down</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>RS232 output</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SOFTWARE

Basecutter RPM

The rotational speed of the basecutters is calculated every 32,768 ms (the real time interrupt, or RTI, period of the microprocessor). The speed is calculated by determining the average pulse period (i.e., time between pulses) over the RTI period. This is done by counting the pulses and noting the elapsed time between the last pulse of the previous RTI
period and the last pulse of the current RTI period. A calibration value is used to convert the average time between pulses into revolutions per minute (rpm).

The rpm value is then filtered using single exponential smoothing to reduce the noise component of the signal. Single exponential smoothing is explained by Garson (1994) and is described by the algorithm:

\[ F_t = \alpha X_t + (1-\alpha) F_{t-1} \]

where 
- \( F_{t-1} \) is the smoothed value at the previous time increment \((t-1)\);
- \( F_t \) is the smoothed value at the current time increment \((t)\);
- \( X_t \) is the measured value at the current time increment \((t)\); and
- \( \alpha \) is the smoothing parameter in the range 0 to 1.

A value of \( \alpha = 1 \) corresponds to no smoothing and a value of \( \alpha = 0 \) corresponds to infinite smoothing.

**Engine RPM**

The rotational speed of the engine is calculated every RTI period (32.768 ms) in a manner similar to the basecutter speed. It is also filtered using single exponential smoothing with the same smoothing parameter as for basecutter speed.

**Ground speed**

The ground speed of the harvester is calculated every time a ground speed pulse is received. It is calculated using the time between the previous two pulses and a calibration value to convert to kilometres per hour. The ground speed value is not filtered. However it is set to zero when no pulses have been received for five seconds. It is also recalculated every 131 ms (the system timer overflow period) if the time since the last pulse is greater than the time between the previous two pulses. This recalculation uses the time since the last pulse, rather than the time between the two previous pulses, and improves the response of the system to reducing ground speeds.

**Set point**

The basecutter rpm set point is calculated each time the SET button is pressed. It is set to the average filtered rpm value over a two second (adjustable) period. The set point value is also adjusted for varying ground speed and, if engine speed control is on, for varying engine speed. Varying ground speed alters the set point by a set amount (default 10 rpm) for every one km h\(^{-1}\) change in ground speed, with increasing ground speed decreasing the set point. Varying engine speed alters the set point by an amount equal to the proportional change in engine speed, eg a 5% reduction in engine speed produces a 5% reduction in set point.

The variance for ground speed and engine speed is achieved by storing the set point as an equivalent value at 0 km h\(^{-1}\) ground speed and 2 000 rpm engine speed, and then adjusting
the set point at each time interval for the current ground speed and engine speed. This variance for ground and engine speeds is also done while calculating the set point when the SET button is pressed. ie The set point is the average filtered basecutter rpm value adjusted for 0 km h\(^{-1}\) and 2 000 rpm.

Sensitivity knob

The front panel sensitivity knob is read every second RTI period (65.536 ms). Its position is read as a number between 0 and 255 and converted to an ‘error limit’ between 10 and 4000 to use in the control loop as explained below.

Ultrasonic sight gauge height

When an ultrasonic sensor is fitted to the basecutter height sight gauge, its value is read every second RTI period (63.536 ms). (The sensitivity knob and ultrasonic height values are read on alternate RTI periods.) The ultrasonic height is read as a number between 0 and 255 and is shown on the front panel display when requested and sent via the RS232 port as described below. It is not used in any control algorithms.

RS232 output

Every RTI period (32.768 ms) a string of 12 bytes is sent via the RS232 port indicating the current status of the controller. The sequence of bytes sent is as follows:

1+2 basecutter rpm 
2+3 engine rpm 
4+5 basecutter rpm set point 
6+7 error limit 
8 ground speed (units of 0.1 km h\(^{-1}\)) 
9 ground speed pulse count (0-255) 
10 ultrasonic sight gauge height reading (0-255) 
11 control flag 0 = controller off 
                     1 = basecutters moving down 
                     2 = controller on - basecutter height constant 
                     3 = basecutters moving up 
                     -2 = calculating set point

All two byte numbers are sent with the high order byte first.

Control loop

The control loop is executed once every RTI period (32.768ms). The control function is a form of proportional-integral (PI) control. If the controller is disabled, or the ground speed is less than the minimum specified, then no control action is undertaken. Otherwise the following actions are performed.
• The set point is adjusted for the current ground speed and, if engine speed control is enabled, for current engine speed.

• If the difference between the basecutter speed and the set point is less than the preset ‘dead band’ (default 10 rpm), then no further action is undertaken.

• The rpm error value is accumulated in an error variable. The rpm error is the difference between the current basecutter rpm and the set point ± dead band.

• If the absolute value of the accumulated error is less than the error limit (as set by the front panel sensitivity knob), then no further action is undertaken.

• Otherwise the basecutters are driven up or down until either

  a minimum time period has transpired and the basecutter rpm error falls within the dead band, or

  a maximum time period has transpired.

The minimum time period is set to move the basecutters approximately 5 mm. The maximum time period is set to move the basecutters approximately (error/max.error * 25) mm where

error is the difference between the current basecutter rpm and the set point (but limited to max.error) and

max.error is the rpm error value, as set in the calibration routine, (default 100 rpm) required to move the basecutters the maximum 25 mm.

The times required to move the basecutters up and down by 5 mm and 25 mm are set in the calibration routine. This causes the basecutters to move a minimum of 5 mm and a maximum of 25 mm, both of which are adjustable, each time an adjustment to the cutting height is made.

• The accumulated error variable is then cleared, and further control action disabled for a period of time specified in the calibration routine (default 200 ms).
INTRODUCTION

The Basecutter Height Controller is a device which automatically adjusts the basecutter height control hydraulics to try to achieve a constant ground cut. It does this by monitoring the rotational speed (ie rpm) of the basecutter discs and adjusting the cutting height to keep the rotational speed constant. If the basecutters start cutting too low, the basecutter speed will drop and the controller will lift the basecutter. Conversely if they start cutting high, the speed will rise and the controller will drop the basecutter.

In practice, the Basecutter Height Controller operates in much the same manner as a car cruise control. The operator must first manually adjust the basecutters to the correct cutting height, then press the SET button. The controller will then attempt to keep the cutting height constant. The controller can be disabled at any time by manually adjusting the basecutter height, or by pressing the optional DISABLE button (if installed). The controller can then be re-engaged at the previous set point by pressing the RESUME button.

FRONT PANEL DISPLAYS

The front panel contains two 4-digit numerical displays, and three indicator lights.
Left Display

The left hand side display always shows the current basecutter rotation speed in revolutions per minute (rpm).

Right Display

The right hand side display can be set to show ground speed in kilometres per hour (to 0.1 kph), the basecutter rpm set point or the engine rpm. The display can be rotated between these three functions by repeatedly pressing the CAL/DISPLAY button. The presence of a decimal point in the display indicates that ground speed is being displayed, and the absence indicates that either set point or engine rpm is being displayed. On power-up the display initially shows ground speed.

The display will also show an L in the first column whenever the controller is activated, but the ground speed is too low for the controller to operate.

In addition, by pressing and holding the CAL button for a minimum of 2 seconds, the right hand side display can be made to display one of three additional functions (a distance counter as a number from 0 to 255, the setting of the sensitivity knob as a number between 10 and 4000, and the reading from an optional ultrasonic sensor mounted on the basecutter height sight gauge as a number between 0 and 255). The display of these values is not required during normal operation, and the function is included mainly for use by researchers.

AUTO Indicator

This indicator lights up whenever the controller is activated, i.e. when it is controlling the cutting height.

Up Arrow Indicator

The up arrow indicator lights up whenever the controller is lifting the basecutters.

Down Arrow Indicator

The down arrow indicator lights up whenever the controller is lowering the basecutters.
FRONT PANEL CONTROLS

There are five control switches on the front panel, one toggle switch, three push button switches and a rotary knob.

**ON/OFF Switch**

This is the main power switch for the controller.

**UP Button**

The up button is used to raise the controller set point, i.e. to lift the basecutters when controlling. Each time the button is pressed, the set point is increased by 5 rpm. This corresponds to approximately 5 mm in cutting height.

The up button is also used to adjust the calibration values when in calibrate mode (see CALIBRATION below) and to adjust the display intensity (see CAL/DISPLAY below).

**DOWN Button**

The down button is used to lower the controller set point, i.e. to lower the basecutters when controlling. Each time the button is pressed, the set point is decreased by 5 rpm. This corresponds to approximately 5 mm in cutting height.

The down button is also used to adjust the calibration values when in calibrate mode (see CALIBRATION below) and to adjust the display intensity (see CAL/DISPLAY below).

**CAL/DISPLAY Button**

In normal operation, this button is used to change the right hand side display between ground speed, basecutter set point and engine rpm. In addition it has other functions as described below.

Pressing and holding the button for 2 seconds causes the right hand side display to show three additional functions (see Right Display above).

Pressing and holding the button while switching the power switch on causes the controller to enter Calibrate Mode (see CALIBRATION below).
Pressing and holding the UP or DOWN button whilst the CAL/DISPLAY button is being held will cause the intensity of the display panel (i.e. brightness) to increase or decrease. On power-up the display is initially set to maximum intensity.

**Sensitivity Knob**

Turning this knob clockwise (towards the Slow setting) will cause the controller to react slowly to changes in basecutter speed. Turning the knob anti-clockwise (towards the Fast setting) will cause the controller to react more quickly to changes in basecutter speed. It is recommended that the knob be initially set at about the halfway mark, and then adjusted depending on whether the controller seems to be acting too quickly or not quickly enough.

**OPERATOR CONTROLS**

In addition to the front panel controls, there are three operator control switches. These are the switches which are normally used to operate the controller. Two of the switches (SET and RESUME) are always fitted, but the third switch (DISABLE) is optional and may not be fitted in all installations.

**SET**

Pressing the SET button activates the controller at the current cutting height. It causes the current basecutter rpm to be transferred to the basecutter set point, and switches the controller on.

In addition, pressing the SET button when in calibrate mode with the left display showing CAL? causes the controller to enter test mode. In test mode the up and down front buttons can be used to drive the basecutter up and down directly (see TEST MODE below).

**RESUME**

Pressing the RESUME button activates the controller at the previous set point. This is the button which will normally be used to resume controlling when entering a row.
DISABLE (optional)

The DISABLE button is an optional button, and may not be present on all installations. Pressing the DISABLE button immediately disables the controller. To resume controlling, the RESUME button should be pressed.

The manual raising or lowering of the basecutter will also disable the controller in exactly the same manner.

In case of emergencies, the power on/off switch can also be used to immediately disable the controller. In this case, however, the set point will be lost.

CALIBRATION

The controller has a calibration mode which is used to set various calibration values and control parameters within the controller. Calibration mode also contains a test mode which allows the basecutters to be driven up and down directly via the front panel up/down switches.

To enter calibration mode, press and hold the CAL button whilst switching the power switch on. The left side display should show CAL?. The various calibration values can then be cycled by repeatedly pressing the CAL button. For each calibration value, the left display will show CAL followed by a letter indicating the current calibration variable, and the right display will indicate the current value for that variable. The calibration variables are:

<table>
<thead>
<tr>
<th>CAL t</th>
<th>Display Update Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAL S</td>
<td>Ground Speed calibration</td>
</tr>
<tr>
<td>CAL r</td>
<td>Basecutter RPM calibration</td>
</tr>
<tr>
<td>CAL E</td>
<td>Engine RPM calibration</td>
</tr>
<tr>
<td>CAL u</td>
<td>Minimum Up pulse time</td>
</tr>
<tr>
<td>CAL U</td>
<td>Maximum Up pulse time</td>
</tr>
<tr>
<td>CAL d</td>
<td>Minimum Down pulse time</td>
</tr>
<tr>
<td>CAL D</td>
<td>Maximum Down pulse time</td>
</tr>
</tbody>
</table>

Each of these is described in more detail below. The UP and DOWN buttons can be used to adjust the value of each variable. To exit calibration mode, press and hold the CAL button until the system resets (approximately 0.5 seconds).
Display Update Time (CAL t)

Default: 10 Minimum: 1   Maximum: 60   Units: 32 ms

This variable sets the frequency at which the front panel displays are updated. A value of 1 will update the display approximately 30 times per second, while a value a 60 will update the display approximately every 2 seconds. The default value of 10 will update the display approximately 3 times per second.

Ground Speed Calibration (CAL S)

Default: 81 Minimum: 27   Maximum: 255   Units: pulses/100m

This variable sets the calibration for the ground speed readings. It is set as the number of ground speed pulses received every 100 metres.

The calibration value can either be entered directly, by using the UP and DOWN buttons, or by using the following calibration procedure.

1. Measure out a 50 metre section of ground.
2. Ensure that the controller left display shows CAL S.
3. Position the harvester at the start of the section then press the SET button. The right side display should reset to zero.
4. Drive the harvester towards the end point of the 50 metre section. The right side display should show a count of the ground speed pulses.
5. When the 50 m point is reached, press the CAL button. The value in right side display should double to show the correct calibration as a number of pulses per 100m.

The above calibration procedure can be aborted by pressing the UP, DOWN or RESUME button.
Basecutter RPM Calibration (CAL r)


This variable sets the calibration for the basecutter rpm readings. It should be set as the number of pulses generated by the basecutter sensor every basecutter revolution.

Engine RPM calibration (CAL E)

Default: 156 Minimum: 1 Maximum: 255 Units: pulses/rev

This variable sets the calibration for the engine rpm readings. It should be set as the number of pulses generated by the engine rpm sensor every engine revolution.

Minimum Up Pulse Time (CAL u)

Default: 3 Minimum: 1 Maximum: 100 Units: 32 ms

This variable sets the duration of the minimum pulse that the controller will send to the solenoid valves to raise the basecutter. It should be set to move the basecutters approximately 5 mm.

Pressing the SET button whilst calibrating this variable will cause the basecutters to move up the calibrated distance (i.e. a pulse of the specified width will be sent to the up control valve).

The following procedure should be used to set the value.

1. Ensure that the left display reads CAL u.
2. Momentarily press the SET button.
3. Measure the distance that the basecutters move with each press. Because of possible hysteresis effects it is usually best to measure the distance moved for, say, 5 presses and then divide the answer by 5.
4. If the distance is between 4 and 6 mm, then the calibration is finished. Otherwise the calibration value should be increased or decreased (by pressing the UP or DOWN button) and steps 2-4 repeated until the correct calibration is set.
Note that the basecutter height can be manually adjusted whilst this procedure is being carried out. This allows the basecutters to be dropped between each calibration check if required.

**Maximum Up Pulse Time (CAL U)**

Default: 10  
Minimum: 1  
Maximum: 100  
Units: 32 ms

This variable sets the duration of the maximum pulse that the controller will send to the solenoid valves to raise the basecutter. It should be set to move the basecutters approximately 25 mm.

A similar procedure to that described above for the minimum pulse should be used to set this value, except that the left display should show **CAL U** and the distance moved should be between 20 and 30 mm.

Note that the maximum pulse width can't be set less than the minimum pulse width.

**Minimum Down Pulse Time (CAL d)**

Default: 3  
Minimum: 1  
Maximum: 100  
Units: 32 ms

This variable sets the duration of the minimum pulse that the controller will send to the solenoid valves to lower the basecutter. It should be set to move the basecutters approximately 5 mm.

A similar procedure to that described above for the minimum up pulse should be used to set the correct value, except that the left display should show **CAL d**.

**Maximum Down Pulse Time (CAL D)**

Default: 10  
Minimum: 1  
Maximum: 100  
Units: 32 ms

This variable sets the duration of the maximum pulse that the controller will send to the solenoid valves to lower the basecutter. It should be set to move the basecutters approximately 25 mm.

A similar procedure to that described above for the minimum up pulse should be used to set this value, except that the left display should show **CAL D** and the distance moved should be between 20 and 30 mm.
Note that the maximum pulse width can’t be set less than the minimum

**CONTROL PARAMETERS**

In addition to the calibration values described above, a number of control parameters can be set within the calibration routine. With the possible exception of the minimum ground speed for control, it is unlikely that these parameters will need to be changed from their default values.

The control parameters are:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ctl b</td>
<td>Dead band</td>
</tr>
<tr>
<td>Ctl F</td>
<td>Filter value</td>
</tr>
<tr>
<td>Ctl P</td>
<td>Settling Period</td>
</tr>
<tr>
<td>Ctl g</td>
<td>Gain</td>
</tr>
<tr>
<td>Ctl I</td>
<td>Set point averaging Interval</td>
</tr>
<tr>
<td>Ctl A</td>
<td>Ground speed Adjustment</td>
</tr>
<tr>
<td>Ctl L</td>
<td>Minimum (Low) ground speed</td>
</tr>
<tr>
<td>Ctl E</td>
<td>Engine rpm control on/off</td>
</tr>
</tbody>
</table>

Each of these parameters is described in more detail below. To display or adjust any of these parameters, first enter calibration mode (by switching the power on with the CAL button pressed) then press the RESUME button. The left side display should change from **CAL** to **Ctl**. The various control parameters can then be displayed by repeatedly pressing the CAL button, and can be adjusted by pressing the UP and DOWN buttons as with the calibration values.

**Dead Band (Ctl b)**

Default: 5  Minimum: 0  Maximum: 255  Units: rpm

This parameter sets the basecutter rpm dead band. If the basecutter rpm is within this many rpm of the set point, then no adjustments will be made to the cutting height.

**Filter Value (Ctl F)**

Default: 10  Minimum: 1  Maximum: 100  Units: percent

This parameter sets the level of filtering of the basecutter rpm and engine rpm signals. Lower values result in greater filtering (and a slower response to
sudden changes in the input signal) and higher values result in less filtering, with 100 representing no filtering.

**Settling Period (Ctl P)**

Default: 6  Minimum: 1  Maximum: 100  Units: 32ms

This parameter sets the minimum time between adjustments to the cutting height.

**Gain (Ctl g)**

Default: 100  Minimum: 0  Maximum: 255  Units: rpm

This parameter sets the basecutter rpm error value at which the basecutters will move the maximum distance set by the CTL U and CTL D calibration variables described above. For instance, if this parameter is 100 and CTL U and CTL D have been set to adjust height by 25 mm, then the controller will adjust the basecutter height by 25 mm if the basecutter speed is 100 rpm or more different from the set point. It will adjust the basecutter height proportionally less if the error in rpm is less than 100 rpm.

This parameter in effect sets the gain of the controller, with lower values of the parameter reflecting a higher gain and higher values reflecting a lower gain.

**Set Point Averaging Interval (Ctl I)**

Default: 30  Minimum: 1  Maximum: 255  Units: 32ms

This parameter sets the period over which the basecutter rpm is averaged when the SET button is pressed to determine the set point. With the default value of 30, the rpm will be averaged for about one second after the SET button is pressed and the average value will be used as the set point.

While the set point is being calculated, the first digit of the right side display will show a dash (-).

**Ground Speed Adjustment (Ctl A)**

Default: 10  Minimum: 0  Maximum: 255  Units: rpm/kph
This parameter sets the amount by which the basecutter set point is adjusted by changing ground speeds. This adjustment value is required because basecutter rpm varies with changing ground speed as well as changing cutting height. The only method for calculating the correct value for this variable is to measure the average basecutter rpm at various ground speeds, and calculate the change in rpm/kph. All test done to date show that a value of 10 rpm/kph is reasonable.

**Minimum Ground Speed (CtL L)**

Default: 40 Minimum: 0 Maximum: 255 Units: 0.1 kph

This parameter sets the minimum ground speed at which the controller will operate. The units are in tenths of a kilometre per hour so that a value of 40 represents 4.0 kilometres per hour.

If the controller is activated, and the ground speed falls to less than this value, then the right display will show an L in its first position and no adjustments will be made to the basecutter height until the speed rises above the set value.

**Engine RPM Control ON/OFF (CtL E)**

Default: 1 Minimum: 0 Maximum: 1 Units: none

This parameter sets whether the basecutter rpm set point is adjusted for varying engine rpm. With the parameter set to 1 (on), the set point is adjusted as engine rpm varies. With the parameter set to 0 (off), no adjustment is made for varying engine rpm.

**SETTING DEFAULT CALIBRATION AND CONTROL VALUES**

All calibration variables and control parameters can be reset to their default values by entering the calibration mode (switch power on whilst pressing the CAL button so that the left display shows CAL?) then pressing and holding the UP button and momentarily pressing the CAL button. This procedure should restart the controller with all variables set to their default values.

**TEST MODE**

The controller has a test mode where the basecutters can be driven up and down directly by the up and down switches on the front panel. To enter test mode, first enter calibration mode
(press and hold CAL while switching on the power), then press the SET button. The left hand side display should read TEST when in test mode.

Pressing the UP button will cause the basecutters to be lifted, and pressing the DOWN button will cause the basecutters to be lowered. To exit test mode, press the CAL button.

NORMAL OPERATION

When first switched on, the controller should display 8.8.8.8. in both displays for one second, then display the basecutter rpm in the left hand side display and the ground speed in the right hand side display.

The normal method of operation is to begin cutting a field using a manual method to set the correct cutting height. Once it has been established that the basecutters are cutting at the correct height, the SET button should be pressed. The controller will then ensure that the correct cutting height is maintained.

If for any reason (eg changing bins) the ground speed falls below the minimum set in the calibration procedure (eg 4.0 kph) the controller will be disabled. The controller will automatically re-engage when the ground speed rises above the minimum value.

At the end of each row the sight glass should be checked for the current cutting height, and the basecutters lifted as with normal manual operation. At the start of the next row, the basecutters should be lowered manually to the correct height, then the RESUME button pressed.

Note that the current set point is not saved when the power is switched off. This means that when the power is switched back on, the set point will require resetting with the SET button. The controller will ignore the RESUME button if it is pressed before a set point has been entered.