BUREAU OF SUGAR EXPERIMENT STATIONS

QUEENSLAND, AUSTRALIA

FINAL REPORT - SRDC PROJECT BSS156
PRODUCTION OF AN AUTOMATED CANE BILLET SAMPLER FOR RESEARCH TRIALS

by

B G Robotham

SD00001

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SUMMARY

An automated sugarcane billet sampler was designed, constructed and field-tested. The billet sampler combines the operations of weighing of the total material harvested from a plot, producing a representative sub-sample of this material, and unloading of excess bulk material to a cane haulout vehicle. Field-testing showed the sample taken with this billet sampling system is representative of the material harvested and accurately predicts the CCS determined at the sugar mill.

The sampler is mounted on a two wheel drive truck chassis which gave the unit sufficient mobility to test the concept of an automated billet sampler for testing purposes. Operation of the billet sampler is totally automated, and computer based software has been developed to control all phases of sampling. The sample size to be collected is pre-determined and samples are taken at evenly spaced intervals during discharge of the bulk harvested sample. The operator can easily alter sample size and other operational parameters stored in the controller, using the control switches. Construction of the prototype billet sampler was completed for testing during the 1998 sugarcane harvest season. The cane billet sampler has had limited field testing in the Bundaberg region. The ability to adjust the various parameters such as sample size, weight of material on an elevator slat, etc has resulted in a versatile sampler which can be altered to suit most harvesting situations. Once the parameters are set, there appears to be little need to adjust settings during a trial harvest.

The current machine can not reliably operate in cane with extremely high levels of extraneous matter or comprising of excessively long billets. In both cases, uniform feed of billets onto the slat elevator could not be maintained and bridging of the cane could occur. The researchers believe this deficiency can be corrected through redesign of the elevator boot area. The machine performed well when supplied with near uniform length billets and acceptable levels of extraneous material.

The concept has satisfied the initial design criteria and recommendations are given to improve operation of the billet sampler. An automated billet sampler could be used in the plant breeding program, in some agronomic trials and in sugarcane harvester testing trials.

1.0 BACKGROUND

Sugarcane breeding and research programs currently rely on hand-cut sound whole-stalk samples for determination of commercial cane sugar (CCS) and other quality components. These samples of sugarcane are free from extraneous material and inferior quality cane and, hence, a biased sample of the material is harvested for milling from experimental plots (Skinner, 1976). The whole-stalk samples must be obtained while mechanised equipment operates in the plots. Research staff are exposed to the risk of injury from harvesters and cane haulout vehicles. The BSES annual plant breeding program exceeds 250 individual trials along the Queensland coast. Billet samples are more compatible with current harvesting systems and this sampling method is more useful in predicting responses of commercial cane varieties to agronomic treatments. Collecting cane samples as billets is also more compatible with current harvesting systems. Dr T McRae initiated this need for an automated sugarcane billet sampler in 1994, and funding was obtained to determine design parameters for this machine. (McRae *et al.*, 1998).

2.0 OBJECTIVES

An objective of this project was to build and field-test an automated sugarcane billet sampler. This project continues the work of BS118S, which quantified the need for a billet sampler in sugarcane research trials.

3.0 PROJECT METHODOLOGY

3.1 Project planning workshop

A meeting was held in Bundaberg to ensure the design parameters were clearly defined and to brainstorm possible solutions. Attendance was limited to potential users from within BSES and the sugar industry and included:

Dr Tony McRae
Dr Jason Bull
Brian Robotham
Chris Norris
Dr Mike Cox
Ross Ridge
Rod Davis
Dirk Bakker (CSR).

Suggested design criteria for the billet sampler were:

- maximum weighing ability of 750 kgs (weighing bin capacity)
- potential storage capacity of 750 kgs
- high speed discharge system
- sampling site (to be decided)

- discharge bulk cane into most current haulouts
- on-board processing of samples to be considered only after billet sampling concept is proven.

A one-day workshop was held in Bundaberg to confirm the final design criteria and operational parameters of the billet sampler. The sampler design must minimise separation of billets and extraneous material and complete the sampling operation in the time available between harvesting of trial plots. Locations considered for the sampling operation were:

- before the harvester (ie sample the uncut face of the row to be harvested)
- between the harvester and haulout/weightruck
- on the current weightruck.

Workshop members worked in groups to brainstorm conceptual designs for an automated billet sampler. Common points from the groups included:

- the preferred sampling site was between the harvester and the haulout
- weigh and sample with one machine (hence the current BSES weigh trucks are not required)
- use of a separate vehicle for billet sampling independent of the harvester or haulout
- use of an elevator for discharging bulk material
- use of a sequential sampling system to 'build up' a representative sample of approximately 10–15 kgs.

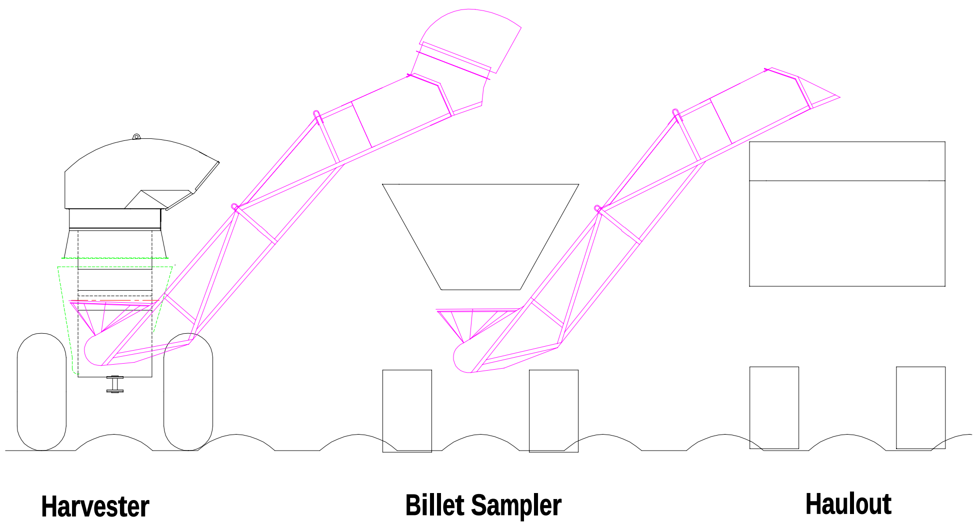

Figure 1: Proposed operational configuration for billet sampler

The proposed operational configuration for a billet sampler is shown in Figure 1. The concept of a separate billet sampling vehicle had the added advantage that the sampling component can be developed and, if required, sample processing added at a later time. The proposed billet sampling vehicle would be compatible with most commercial cane harvester and haulout operations.

3.2 Design of the automated billet sampler

3.2.1 Mechanical design

The concept of a billet sampler utilising the elevating cycle of the harvest operation was tested on a surplus Austoft 6000 harvester owned by BSES. A sampling door of dimensions similar to that proposed for the billet sampler was cut in the elevator floor of the harvester to determine elevator speeds and sampling times. Sampling during the elevating operation is ideal as the harvested cane sample is separated into sub-samples by the elevator slats during the unloading process. The billet sampler collects a billet sample that comprises a pre-determined number of sub-samples from the elevator slats.

The decision was made to base the sampling elevator on a commercial cane harvester elevator. The researchers believed this approach would save construction time and ensure spare parts would be available. A secondhand elevator from a Massey Ferguson 305 was selected in preference to an elevator from an Austoft 6000 or Austoft 7000. Although no longer commercially available, the MF elevator was deemed to be of lighter construction. The elevator purchased was, in fact, a poor copy of a MF elevator. The elevator frame was not square, heavier than anticipated, and in quite poor condition. The decision was made to persevere with this elevator and undertake repairs where required. Use of this elevator caused considerable extra work but resulted in a functional end product.

Tests were conducted on various harvesters to determine the mass of material conveyed on each elevator slat. The mass varied from 3 to 10 kilograms but was quite consistent within a crop. As this was a critical parameter for the billet sampler, slat mass would be a control variable that could be easily altered.

3.2.1.1 Bulk bin and load cells

The bulk/weigh bin was made with horizontal dimensions of 2.5 metres by 2.5 metres. This was the maximum dimension allowable for a road legal vehicle, and ensured an adequate target for the harvester operator during sampling. The bin was suspended on four 250 kg electronic load cells to enable bulk sample weight to be measured. The load cells were mounted in a triangular configuration to reduce weighing error from transducer misalignment and twisting of the support frame. Cane is discharged through two hydraulically operated doors in the base of the bulk bin. The doors are of clam type design and when fully opened, the discharge hole measured 0.75 metres by 0.75 metres. These dimensions will be increased for future models of the billet sampler to prevent material bridging during discharge.

3.2.1.2 Sampling system

The sampling door is the key element of this type of billet sampler. The sampling door is a moveable floor panel that is mounted on pivoting parallelogram arms. Opening and closing action of the door is provided by a pitman arm system that is driven by a hydraulic motor (shown in Figure 2). A pilot operated pressure relief valve is used to brake the motor at the end of a cycle and is coupled directly to the hydraulic motor. The controller activating a hydraulic solenoid valve initiates movement of the sampling door. The solenoid valve is only activated for approximately 0.5 seconds after which an inductive proximity switch and cam arrangement assumes control of the door cycle. The adjustable metal cam is attached to a pitman arm and provides feedback to ensure the door always stops in the closed position.

Opening and closing cycle times of less than 0.5 of a second were possible but a cycle time of 2 - 3 seconds ensured all material conveyed by the selected slat has discharged through the open sampling door. Each billeted cane sample is collected in a bag mounted below the sampling door.

Figure 2: Sampling door and Pitman arm system

3.2.2 Hydraulic design

As current sugarcane harvester elevators are hydraulically powered, hydraulics were used for all major functions on the billet sampler. For ease of testing and setting up, two separate hydraulic systems were used. The slat conveyor and the sampling door were powered from a closed centre hydraulic circuit. This circuit used a variable displacement hydraulic pump driven by an 18.6 kW petrol engine. The circuit had two variable orifices to control oil flow to give the high and low elevator speeds. Oil flow for operation of the slat conveyor (on, off and high or low speed) was controlled by a spool valve (12 volt DC actuated). An additional spool valve (12 volt DC actuated) supplied oil to the sampling door motor (see Figure 2). Both spool valves could be controlled either by the electronic controller or from the manual controls (see Figure 6).

An open centre hydraulic circuit was used to control lift, lower and rotation of the elevator and lift and lower of the stabiliser arm. These functions could be controlled from the truck cabin using the joystick (see Figure 5) or by the manual controls. The hydraulic pump for this circuit was driven from a PTO shaft attached to the front of the diesel engine of the truck. The use of two separate hydraulic circuits is not the most efficient or cost effective method of driving these components but, in developing this prototype, it was considered the most practical.

3.2.3 Electronic design

A microprocessor based unit specifically designed for this task controls all functions of the billet sampler. Design of the electronic controller for the billet sampler was contracted to the Agricultural Engineering Group, QDPI, Toowoomba. The software design was sub-contracted to a consultant specialising in software for experimental applications. Discussions between Brian Robotham and Les Zeller, QDPI, determined specifications of the controller and software options.

The program for the controller was written in Forth language and has three modes selected on power-up:

- calibration mode
- run mode
- an option to clear the memory.

The *Run* mode is the default mode and is initiated when no button is depressed during power-up. The unit is identified during initialisation of the L.C.D. and the word “Ready” displayed. At this point, four options are available:

- Start
- Tare
- Dump
- Setup.

Pressing the *Start* button will initiate the sampling sequence as shown in the flow chart, Figure 3.

The *Dump* function enables downloading of data to a personal computer or other device, which accepts ASCII data. Pressing the *Setup* button allows the user to alter the nine variables used to control the operation of the sample door, bulk bin door and the speeds of the slat elevator. The time and date are also set in this option.

Two critical inputs to the controller program are the position of the elevator slats and the number of slats that have discharged material. Short lengths of 12 mm diameter rod were welded to the side of each slat. An inductive proximity switch is used to sense the rod and produces a signal each time a slat passes (see Figure 4). The proximity switch has a sensing distance of 8 mm. With a gap of 4 mm, the proximity switch can accept distance variations of up to ± 4 mm which could result from lateral movement of the slat. Lateral movement is minimised by increasing the tension on the elevator chain.

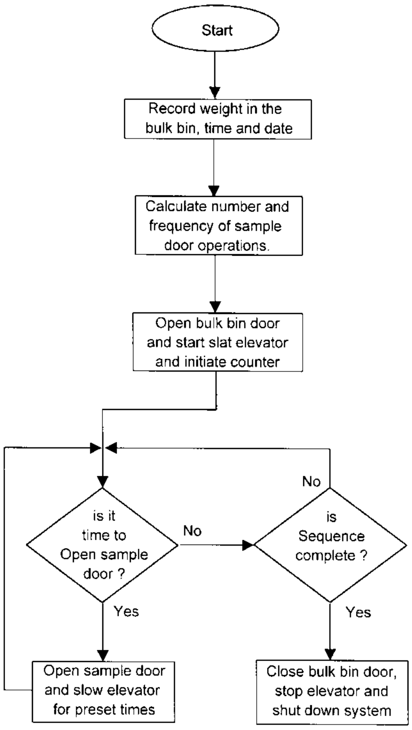

Figure 3: Flowchart of *Run* mode

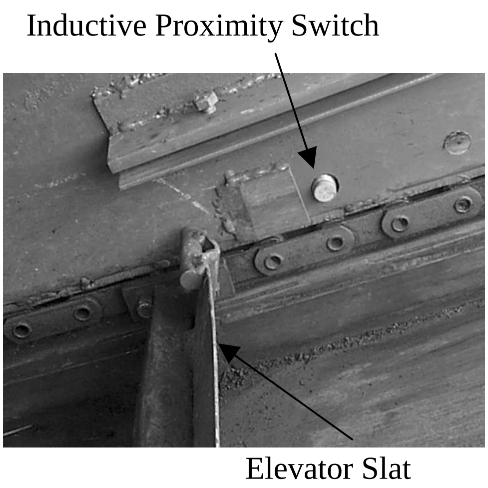

Figure 4: Slat sensor

All outputs are optically coupled and the controller power supply is isolated from the solenoid switching power supply to avoid transients affecting the micro-controller. In addition to the automatic control of the sampling functions, a joystick mounted in the cab of the truck gives the driver four-way control of the position of the elevator (up, down, slew out and slew in). An emergency stop button is mounted on the frame of the bulk bin which disables the automatic control of the sampler and allows manual control by the way of momentary push buttons for all hydraulic functions. Figure 6 shows the emergency button and manual controls.

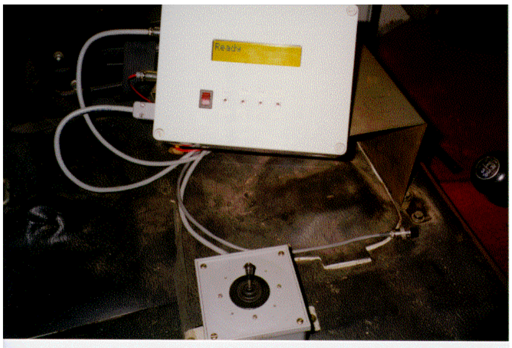

Figure 5: Controller and joystick

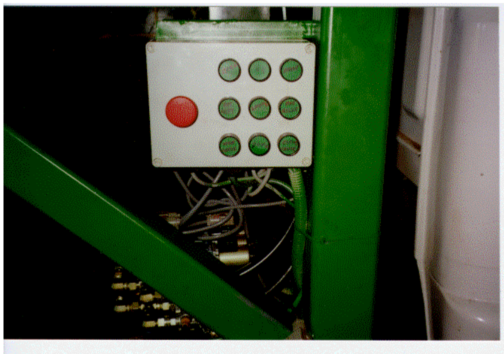

Figure 6: Emergency stop and manual controls

3.2.4 Set-up parameters

As the operation of the prototype billet sampler could not be accurately predicted prior to field testing, the ability to easily alter critical operational parameters was incorporated into the software. After the controller has been powered and the word ‘*Ready*’ appears on the screen, the set-up option can be selected by pressing the button marked ‘*Set-up*’. In this mode, the controller will sequentially step through the various parameters and changes made as required. Placing the cursor on the digit to be altered and increasing the value to the required level alters parameter values. Digits can be incremented through to 9 and then restart at 0. Once the value of a parameter is set, the next parameter is selected and the process repeated. The parameters, their roles and the adjustment range are listed below.

Number of Slats to Sample = (value range 0-10). This enables the elevating slats to be filled with cane before the sampling process is initiated and could be considered ‘priming’ of the system with cane. This parameter can be varied from 1 to 10 slats passing the sensor before sampling and a value of 5 was appropriate for most cane varieties in the testing trials.

Number of Slats to over-run = (value range 0-10). This will set the number of slats to run after the last sampling event has occurred. The purpose of this variable is to ensure all material is conveyed from the billet sampler and hence the value is always set in excess of that required.

Expected Slat Weight = (value range 0-9.99) The expected weight of cane, in kilograms, on each elevating slat will vary with cane variety, crop size etc and hence is estimated for each trial. As samples are taken this value can be adjusted to more accurately match the average cane weight in the elevator slats.

Sample Weight = (value range 0-99) This value defines the size of the billeted sample, in kilograms, to be collected. The controller divides this value by the *Expected Slat Weight* to determine the number of slats to sample to produce the desired *Sample Weight*. The total number of slats to empty the bulk bin (bin weight divided by *Expected Slat Weight*) is also calculated and slat sampling occurs at uniformly spaced intervals during emptying of the bulk bin.

Pre-Sample Slow Time = (value range 0-9.99) This is the time in seconds prior to the sampling when the low conveyor speed in initiated. The lower conveyor speed is essential to ensure all material from the selected slat is collected.

Sample Door Pulse = (value range 0-9.99) This triggering pulse initiates operation of the sampling door. A pulse of 0.5 second duration is appropriate for the prototype sampler.

Post Sample Slow Time = (value range 0-9.99) After a sampling cycle, the low conveyor speed is continued until all sampled material is conveyed to the collection bag. After this time, in seconds, has elapsed the conveyor speeds up to the normal conveying speed.

Bulk Open/Close Time = (value range 0-9.99) This sets the time that the bulk bin door remains open to ensure all material is emptied from the bin.

Time to Empty Bulk = (value range 0-99) This parameter sets the maximum time for a complete billet sampling cycle.

Date = **/**/** Current date.

Time = **:** Current time

A more detailed description of the control system and its operation is given in the paper by Zeller *et al*. (1998) that is reproduced in Appendix 2.

4.0 FIELD TESTING PROTOCOL AND RESULTS

It was intended to conduct field-testing in the Bundaberg and Gordonvale regions during the 1998 sugarcane harvest. Due to the extremely wet harvest conditions in the northern regions and the poor flotation of the billet sampler truck, the testing program was restricted to the Bundaberg region. The truck was only two-wheel drive and was equipped with conventional road tyres. The test program was further altered with all tests conducted in commercially grown sugarcane crops. Even under the drier harvesting conditions at Bundaberg, several testing opportunities could not be utilised due to flotation limitations of the sampler truck.

4.1 Trial methodology

The aims of the field trials were to:

- test the developed billet sampling mechanism under a range of field harvesting conditions
- test the operational concept of an automated in-field billet sampler for use in plant breeding selection and agronomy trials
- compare the CCS results produced from the automated billet sampler to those measured at the sugar mill for commercially harvested sugarcane from the same source. For a limited number of samples, an additional comparison with six whole-stalk samples (BSES current method of CCS determination) was conducted.

The test method involved using the billet sampler to obtain billet samples from sugarcane crops during commercial harvesting. The bulk sample was then taken to the tramway siding and a sub-sample taken while the bulk sample was unloaded into the rail bins. This operation is slightly different to the mode of operation proposed during the harvest of research trials but ensured thorough testing of the sampling system. During the harvesting of each selected rake of cane bins, representative billet samples were taken (between 5 and 10 samples) using the billet sampler. The researchers tried to maximise the number of billet samples taken for each rake of cane bins. As the billet sampling was taken during the filling of the rake of bins, the samples should be representative of the cane in that rake of bins. Whilst the frequency of in-field sampling could not be described as regular, it was repeated at intervals within the constraints of commercial harvesting operations. However, the harvesting contractors were extremely cooperative and regularly altered their harvesting routine to ensure the maximum number of samples was taken. The number of billet samples collected during a trial depended on:

- paddock size and crop yield
- number of rail bins in the rake
- interaction with the commercial harvester, haulout vehicles and the billet sampler
- haul distance crop and rail siding
- mechanical problems with the billet sampler, particularly in the initial testing phase.

The billet sampler truck was driven beside the harvester, and a cane sample with an estimated weight of between 150 and 350 kg collected (see Figure 7). The truck then travelled to the tramway siding and was positioned beside a rail bin. The sampler controller was activated and the bulk sample weighed and a billet sample taken while the cane was discharged into the rail bin (see Figure 8). As no attempt was made in this design to correct for weighing error caused by movement of the truck, all weight measurements had to be taken with the truck stationary. The bagged sample was removed and tagged for later analysis. The truck would then return to the paddock and another bulk sample obtained. Sampling often involved interacting with either two or three commercial haulouts and varying haul distances to the siding. A realistic sampling rate of 2–3 samples per hour was normally achieved.

Figure 7: Collecting sample in the field

Figure 8: Unloading bulk sample

The trial was completed when the rake of rail bins was filled. The bagged billet samples were taken to the BSES Southern Experiment Station for analysis. The sample was weighed and some samples were sorted to determine relative weights of billet, trash and tops, stool and soil. The sample sizes necessitated multiple operations of the cutter grinder to ensure the full billet sample was fibrated. Soil was removed prior to fibrating in an attempt to reduce wear on the cutter grinder. The soil was later returned to the fibrated organic matter and the material was thoroughly mixed in a concrete mixer. A sub-sample, of about 1 kilogram in weight, was removed and the juice extracted using the hydraulic press. The six whole-stalk samples were processed using the BSES small mill.

The extracted juice was analysed using standard BSES procedures and brix and pol readings obtained. The CCS for the cane was calculated using the same class fibre as used by the mill processing the commercially cut sugarcane.

The task of collecting and processing a batch of billet samples using the above technique was quite labour intensive and only one trial (field sampling, processing and analysis) could be completed per day.

4.2 Sampler operation

The automated controller for the billet sampling system required only minor fine-tuning in the field. The use of control parameters that could be altered via the controller input buttons enabled quick and easy fine tuning of sampler operation to suit field and crop conditions. During field testing, two minor software changes were made to the program used in the controller. Updated software was e-mailed to the researchers and downloaded in the controller thus saving considerable time and expense. Another significant adjustment required was reduction of the speed of the sampling door. Under field conditions, sampling door cycle times had to be increased to approximately 1 second (or greater) to ensure all cane, trash etc on a chosen slat was sampled. This greatly exceeded the 0.2 second cycle time determined under test conditions with cleaner cane samples. Altering of the sampling door speed only required the adjustment of a hydraulic flow control valve. A video camera was used to synchronise the opening of the sampling door with the position of the elevating slat. The sampling cycle of the billet sampler was recorded and viewed at slow speed to ensure that all material on the slat was discharged through the sampling door during the sampling cycle.

Problems occasionally occurred with unloading of the bulk bin and feeding of cane onto the elevator slats. Clean green cane or burnt cane had predictable flow characteristics and fed well, but high EM cane or long-billeted cane often caused blockages. This was the major problem encountered with particular harvesters or crops during field-testing. The researchers believe a positive displacement feeder (eg similar to a star feeder) or a powered agitator is essential to prevent cane blockages when handling canes of varying quality. Considerable information on the feeding of bulk cane to a conveyor has been acquired during development of the high-speed harvester elevator, BS210S. The feeding system required for the high speed elevator would ensure an even, blockage-free unloading of the billet sampler weigh bin. Use of this feed system would require some redesign of the doors of the weigh bin and the base of the elevator on the billet sampler.

5.0 RESULTS AND DISCUSSIONS

The operational concept of a billet sampler interfacing between the harvester and a commercial haulout was shown to be extremely workable in the field. As the automated billet sampler had the ability to measure and record trial plot yields, the current weigh truck used by BSES would no longer be required. The billet sampler has the added advantage of a fully automated (microprocessor controlled) sampling sequence. Within BSES research and breeding programs, this is the first application of an automated system utilising microprocessor and hydraulic control to reduce labour, improve accuracy and improve safety under field conditions. All harvesting contractors found the height, position and size of the bulk bin acceptable for filling. As previously stated, the current truck was not always acceptable as an infield vehicle due to trafficability limitations.

Eight trial sites were sampled with the cooperation of two harvesting contractors and six canegrowers. A summary of trial data is shown in Table 1 and more complete data attached as Appendix 1. Due to the method used, CCS is determined from brix and pol with an assumed fibre only. The author was initially concerned about the correlation between the press obtained CCS and mill CCS. Recent work by Mr S Staunton and Dr D Mackintosh of BSES has shown a strong correlation between the Carver press obtained CCS and small mill CCS ($r^2 = 0.9501$). The press obtained CCS was slightly greater than the mill CCS and the appropriate correction based on their recommendations was applied. Even with this correction, the correlation between billet sampled CCS and rake (mill measured) CCS is more important in the trials than the matching of absolute values.

The billet sampling field trials showed very good correlation between the averaged billet sampler derived CCS figures and the averaged mill measured CCS for that rake of sugarcane bins ($r^2 = 0.93$ and $P < 0.00001$). There was, however, no significant correlation between either the averaged billet sampler derived CCS and the six whole-stalk derived CCS or the averaged mill measured CCS and the six whole-stalk derived CCS ($P = 0.22$ and $P = 0.23$ respectively). However, only one six whole-stalk sample was taken per field, compared with 4-10 billet samples, so that the whole-stalk sample was less representative of the field being sampled. Clearly, a composite sample of billets from across the full area to be sampled has the potential to predict mill CCS more accurately than whole-stalk samples, and this sampling can be done with a high degree of safety. Average error for all trials, between the averaged CCS as determined from the billet samples and the averaged mill estimate was only 0.35 of one CCS unit. Six whole-stick samples (the current method of sampling for crop CCS) were not undertaken for every trial. The whole-stalk samples taken ranged from good to very poor predictors of harvested crop CCS, even after the BSES correction factor of 1.5 was subtracted from the calculated CCS figure. At best, the whole-stalk sample produced a result 0.33 of a CCS unit different to both the mill and the billet sampler, while the greatest error was 3.12 CCS units. These results compare favourably with the crop sugar balance studies of Crook *et al*. (1999), that showed errors from a minimum of 2 to a maximum of 7 CCS units between sound whole-stalks of cane and the mechanically harvested cane.

Table 1: Field test results

Trial No.	Average billet sampler CCS*	Average mill measured CCS	Six whole-stalk measured CCS**
1	11.1	11.2	
2	10.8	11.1	
3a	13.3	13.4	
3b	13.1	13.2	
4	13.4	13.1	
5	11.3	11.5	11.8
6	11.4	10.9	9.9
7	12.5	12.0	15.1
8a	14.6	13.9	
8b	14.2	13.9	14.8

* calculated using class fibre and corrected using Staunton and Mackintosh recommendations
** lab mill and corrected using BSES method of calculated CCS – 1.5

Of initial concern was the variation of the CCS within individual billet sampled trials. Examples of these can be seen in the full data for individual trials (see Appendix 1). However, the billet samples are taken from across the entire field, not just a single plot. The variation in CCS may be a reflection of actual crop variation rather than sampling error. Kingston and Hyde (1995) showed that variation for CCS in the field can be significant, particularly with some varieties. Cox *et al*. (1996) showed large variations in crop yield also occurs. They produced yield maps with mean yield variations of 75 t/ha using a prototype harvester yield monitor. McRae *et al*. (1998) showed very clearly that billet samples can be highly variable however their manual sampling method comprised of a single 'grab' sample (maximum mass of 20 kg). The automated billet sampler method of using sub-samples from the elevator slats to produce the composite sample should result in a more representative cane sample than manual sampling. The composite sample is made up of sub-samples uniformly taken from all the cane in the bulk weighing bin (up to 400 kg). McRae *et al* also found that 'billet samples provide a far more accurate estimate of commercial CCS'. They argued that billet samples 'are preferable for predicting the true responses of commercial varieties to various agronomic treatments'.

Billet samples would be expected to be subject to some sampling error, as they will have variable amounts of extraneous matter and damaged cane due to interaction of the harvester. An additional advantage of the billeted sample is that it is possible to sub-sample this material to produce a random sample of sound cane. This random sample of sound cane will indicate the genetic potential of the cane, under those growing conditions, as well or better than the current six sound stalk sample. A billet sample can produce a CCS figure that predicts the mill measured CCS and by sub-sampling can also produce a CCS similar to that from the current sound stalk sampling system.

With assistance from Mr C Norris, the author accessed the raw data from the Mulgrave Mill sugar balance trials of Crooke *et al*. (1999). Forty-two data sets detailed in-field cane sampling were used. In each set of six adjacent rows, cane from randomly selected 2 metre lengths of row was removed. The cane was sampled and a sub-sample of sound stalks used for CCS determination. The total sampled area was then machine harvested. This rake of cane was sampled at the mill and a CCS of the harvested material determined. Comparison of the mean CCS values from the 6 x 2 m samples and from the mill gives an indication of in-field sampling variability (see Figure 9). The data from the billet sampled trial are presented in a similar form in Figure 10. The CCS values of the four six whole-stick samples from the billet sampling trials are included in Figure 10 but not included in the analysis.

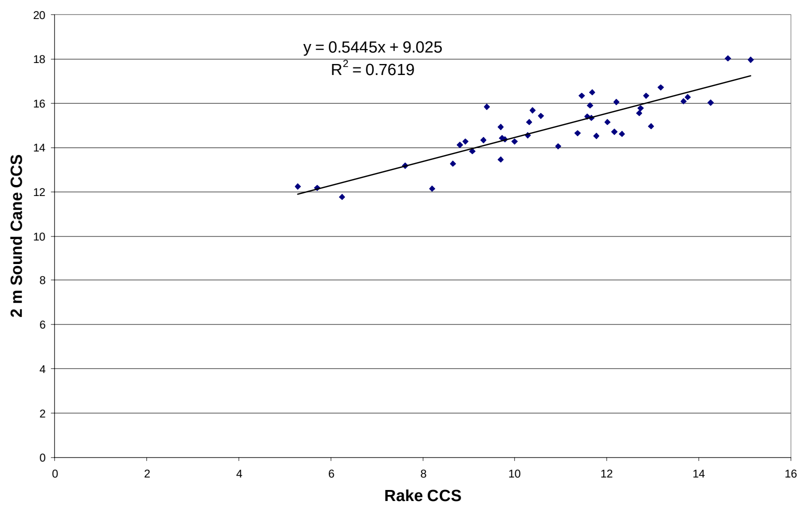

Figure 9: Mean CCS from 2 m sound cane sample versus rake CCS

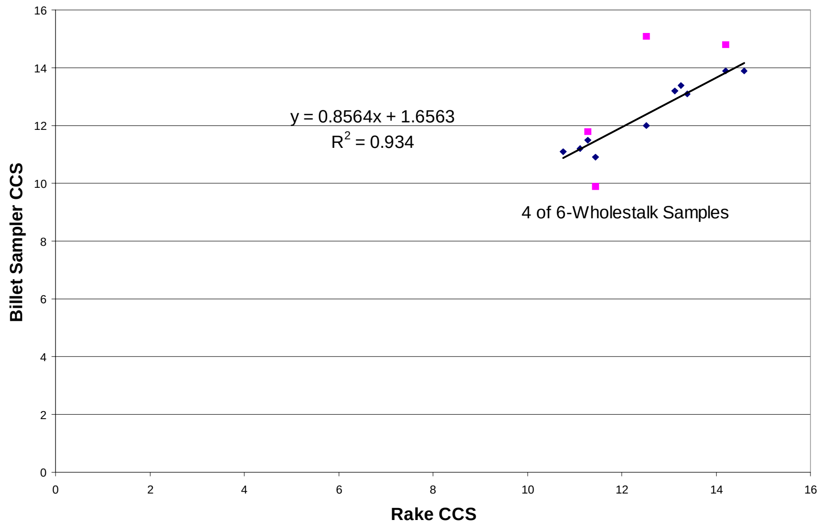

Figure 10: Mean CCS from billet sampled cane versus rake CCS

Whilst both sampling methods show good correlation, the billet sampler based CCS is the better predictor of mill CCS ($r^2 = 0.93$ for billet sampler and $r^2 = 0.76$ for the 2 m row samples). The slope of the fitted line in Figure 10 is closer to unity (0.8564) than for the 2 m row samples (0.5445 on Figure 9). The y-axis intercepts are also smaller for billet sampler CCS than for the 2 m row values (1.656 versus 0.934).

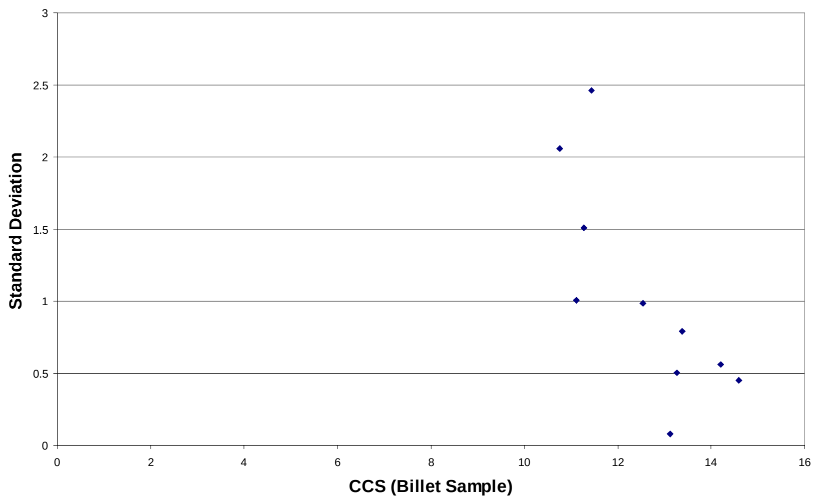

Figure 11: Standard deviation of billet sampled cane versus billet sampled CCS

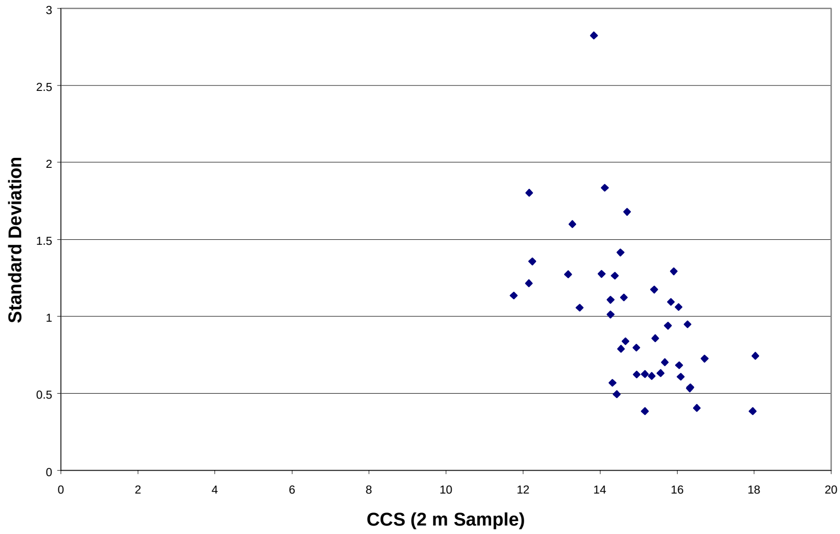

Figure 12: Standard deviation of 2 m sampled cane versus 2 m sampled CCS

It is reasonable to assume that a sound cane sample from 2 metres of row would be as representative, if not more so, than the six whole-stalk sample. Thus, as the billet sampler derived CCS is a better predictor of mill CCS than the 2 metre row sample, the billet sampler derived CCS would also be a better predictor than the current six whole-stalk sample. However, for the billet sampler to provide a good prediction of mill CCS, it is essential to use the average CCS from a number of samples. Individual samples would not provide good estimates of mill CCS but are most likely a good estimate of the CCS of the area the cane was taken from (cane and harvester interaction). The variability of the data in Appendix 1 is the cumulative result of in-field crop variability and variation in sugarcane harvester performance. The variability of CCS measured from the billet sampler is similar to that measured by Crook *et al* (see Figures 11 and 12). Standard variations ranged from 0.077 to 2.461 for the billet sampler and 0.384 to 2.824 for the 2 metre sound stalk samples. This further supports the value of the automated billet sampler.

The composition of samples collected by the automated billet sampler clearly illustrates why the billet sampling system is a more accurate measure of the CCS of commercially harvested sugarcane crops. The sample from the billet sampler accurately reflects the composition of material sent to a sugar mill. An automated billet sample (mass 18.5 kg) of harvested burnt sugarcane was reduced to its components of 13.3 kg of cane billets, 1.5 kg of trash and tops, 2.2 kg of roots and 1.3 kg of soil (see Figure 13). The current six whole-stalk sampling method does not include soil or roots and has little or no trash and top. Hence, this sampling method does not produce a sample as representative of the cane supplied to the sugar mill.

Figure 13: Components of billet cane sample

The billet sampler developed is an important step towards automation of trial harvests. However, the existing sampler and sample processing system are too slow for routine use in the plant breeding program. This sampler would be very useful in strip trials of advanced varieties in which it is desired to obtain a prediction of the mill CCS of the varieties when grown commercially. The method of processing samples used in these trials was extremely slow and labour intensive. The high degree of variability between billet samples is also a problem for routine plant breeding use, and this was discussed by McRae *et al*. (1998) who pointed out that genetic gain from using sound whole-stalks for estimating CCS was likely to be as good as gain from using billet samples. This is despite the variable estimate of mill CCS provided by whole-stalk samples. However, if the billet sampler can be automated further, so that it produces a shredded sample for analysis, its increased safety is likely to make it worthwhile for routine use. It is envisaged that the shredded samples would be processed using NIR technology.

6.0 CONCLUSIONS AND RECOMMENDATIONS

A fully automated billet sampler was designed and built by the BSES Engineering Group. An early model truck was provided by BSES as a platform for the billet sampler. This vehicle was of two-wheel drive configuration and hence only suitable for operation under dry, firm field conditions. It was also considerably underpowered with a maximum highway speed of 65 kmh^{-1} making travel to and from test sites slow and sometimes dangerous. The age of the truck made future mechanical reliability questionable. The truck also lacked operator comforts such as air-conditioning which are considered essential for continued field operation. Vehicle track width of 1.75 m front and 2.0 m rear was not compatible with current crop row widths. However, it was an available and convenient platform for testing the prototype billet sampler.

The developed billet sampler is considered a proof of concept machine and as such a number of improvements or modifications have been identified for future versions of billet sampler. This machine utilises an innovative but simple sampling technique and an innovative electronic control system to achieve a desired outcome. The automated billet sampler enables a representative sample of harvested material to be collected under both commercial and research harvesting conditions. This sample, when analysed, accurately predicts the CCS produced by that cane at the sugar mill. The recommendations listed below are of an engineering nature and based on the results of the 1998 test program. An internal review of BSES sugarcane trial methodology was proposed for 1999. The outcomes of this or a similar review should determine future utilisation, by BSES, of the billet sampling concept. The researchers believe the design, construction and field testing of this billet sampler has shown the concept to be an essential step towards a safe and reliable method of in-field sugarcane sampling. Additional field testing is required to further quantify sampling variations.

Future versions of the cane billet sampler will:

1. utilise a vehicle with improved flotation and four-wheel drive configuration as the platform for the billet sampler. The in-field mobility of the billet sampler must closely match that of the harvester.
2. use an elevating conveyor of lighter construction. A lighter weight conveyor should be designed to replace the elevator on the current billet sampler machine. The current commercial unit has adequately fulfilled the requirements but the conveyor is excessively heavy for the task required and affects the stability and hence the function of the billet sampler in the field.
3. improved feed system from the bulk bin into the elevator. The current discharge of harvested material from the bulk bin to elevating conveyor is considered inadequate. A more controllable feed system is required.
4. with due consideration to the role of the billet sampler in the BSES trial program, the method of collecting samples in bags should be reviewed. The current bagging system requires an operator to fit empty bags, remove filled bags and tag samples for later identification. During the testing program, this system was considered adequate but a less labour intensive process may be required for larger sampling trials.
5. be supported by appropriate sample analysis systems. Due consideration must be given to the downstream handling and processing of billeted cane samples. The current system of fibrating the cane sample, mixing, sub-sampling and pressing to extract the juice sample for analysis is very labour intensive and time consuming. Emerging technologies such as NIR appear to offer significant benefits in this area.

The author believes considerable knowledge could be gained by trialing the automated billet sampler in the plant breeding program, in certain agronomic trials and in some harvester testing trials.

7.0 HUMAN RESOURCE ISSUES

The chief investigator, Dr Tony McRae, resigned from BSES on 31 July 1998. Dr J Bull who was an investigator in BSS118S and a collaborator on this project also resigned from BSES on 8 June 1998. This greatly increased the input required from Mr B Robotham. Dr Nils Berding had assumed the position vacated by Dr T McRae but due to his location at Meringa, could offer little assistance. Due to these staff changes, Mr B Robotham, Mr W Chappell and BSES Engineering staff conducted all field-testing and analysis.

8.0 ACKNOWLEDGMENTS

The author thanks Mr Winston Chappell for his assistance during construction, set-up and field testing of the billet sampler. The efforts of Mr Peter Hockings were also much appreciated during the construction phase of this project. Mr Chris Norris offered considerable assistance during the analysis of the data. His suggestion of the comparison between the billet sampled results and raw data from the Mulgrave Mill sugar balance trials has greatly enhanced understanding of the sampling accuracy and variation. The staffs of Redtrail Harvesting and Heidke Harvesting are thanked for their assistance during the field testing. Both harvesting crews were extremely cooperative and their efforts enabled the collection of billet samples under often trying circumstances.

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APPENDIX 1

BILLET SAMPLER
FIELD TEST RESULTS

Trial 1 – Variety Q151: harvested green

Sample	Total weight (kg)	Sample weight (kg)	Billet sampler CCS*	Mill measured CCS
1	222	12	10.35	
2	212	13	11.99	
3	192	20	11.93	
4	182	16	11.11	
5	199	17	9.14	
6	201	12	11.85	
7	150	15	10.77	
8	167	9	11.81	
Average	190.6	14.3	11.1	
Rake				11.4
Rake				11
Average				11.2

* calculated using class fibre and corrected using Staunton and Mackintosh recommendations

Billet Sampled Standard Deviation = 1.0041

Comments:

- High levels of extraneous matter and dirt

Trial 2 – Variety Q154: harvested green

Sample	Total weight (kg)	Sample weight (kg)	Billet sampler CCS*	Mill measured CCS
1	146	5	8.48	
2	124	12	10.5	
3	141	7	10.58	
4	235	5	13.48	
Average	161.5	7.3	10.8	
Rake				11.1
Rake				11.1
Rake				11.1
Average				11.1

* calculated using class fibre and corrected using Staunton and Mackintosh recommendations

Billet Sampled Standard Deviation = 2.0572

Trial 3 – Variety Q135 and Q124: harvested green

Sample	Total weight (kg)	Sample weight (kg)	Billet sampler CCS*	Mill measured CCS
Q135				
1	222	15	13.52	
2	257	15	12.82	
3	276	18	12.87	
4	315	19	13.85	
5	300	11	13.81	
Average	274.0	15.6	13.4	
Rake				13.4
Q124				
6	321	14	13.17	
7	265	23	13.06	
Average	293.0	18.5	13.1	
Rake				13.2

* calculated using class fibre and corrected using Staunton and Mackintosh recommendations

Billet Sampled Standard Deviation 3a = 0.5037
3b = 0.0778

Trial 4 – Variety Q135: harvested burnt

Sample	Total weight (kg)	Sample weight (kg)	Billet Sampler CCS*	Mill measured CCS
1	240	21	12.78	
2	252	20	14.01	
3	246	17	13.31	
4	248	27	13.99	
5	287	10	11.87	
6	231	13	12.7	
7	216	30	13.09	
8	237	23	13.75	
9	280	22	13.74	
10	291	10	14.56	
Average	252.8	19.3	13.4	
Rake				13.0
Rake				13.2
Average				13.1

* calculated using class fibre and corrected using Staunton and Mackintosh recommendations

Billet Sampled Standard Deviation = 0.7902

Trial 5 – Variety Q155: harvested green

Sample	Total weight (kg)	Sample weight (kg)	Billet Sampler CCS*	Mill measured CCS
1	246	15	9.14	11.9
2	201	14	12.87	11.0
3	190	7	12.95	
4	167	24	10.08	
5	171	16	11.25	
6	218	15	11.47	
Average	198.8	15.2	11.3	
Rake				11.5

* calculated using class fibre and corrected using Staunton and Mackintosh recommendations

Billet Sampled Standard Deviation = 1.5093

Comments:

- Sample 7 comprised of six whole-stick samples
  Measured CCS = 13.33 : Corrected CCS (BSES method of -1.5) = 11.83

Trial 6 – Variety Q124 mixed: harvested burnt

Sample	Total weight (kg)	Sample weight (kg)	Billet Sampler CCS*	Mill measured CCS
1	341	7	16.28	
2	287	29	6.72	
3	300	26	10.55	
4	212	20	11.23	
5	253	27	11.57	
6	263	18	11.57	
7	263	24	11.02	
8	258	14	12.74	
9	287	25	11.28	
Average	273.8	21.1	11.4	
Rake				10.2
Rake				11.0
Rake				11.6
Average				10.9

* calculated using class fibre and corrected using Staunton and Mackintosh recommendations

Billet Sampled Standard Deviation = 2.4613

Comments:

- Sample 10 comprised of six whole-stick samples
  Sample weight = 5.1 : Measured CCS = 11.39 : Corrected CCS (BSES method of -1.5) = 9.89

Trial 7 – Variety Q155: harvested green

Sample	Total weight (kg)	Sample weight (kg)	Billet Sampler CCS*	Mill measured CCS
1	231	23	12.24	
2	236	25	13.24	
3	239	13	11.96	
4	239	26	13.54	
5	239	21	10.97	
6	275	28	13.23	
Average	243.2	22.7	12.5	
Rake				12.0

* calculated using class fibre and corrected using Staunton and Mackintosh recommendations

Billet Sampled Standard Deviation = 0.9856

Comments:

- Sample 18 comprised of six whole-stick samples
  Measured CCS = 16.62 : Corrected CCS (BSES method of -1.5) = 15.12
- Large number of suckers

Trial 8 – Variety Q135 and Q154: harvested burnt

Sample	Total weight (kg)	Sample weight (kg)	Billet Sampler CCS*	Mill measured CCS
Q135				
1	270	12	14.22	
2	221	17	15.25	
3	278	26	14.43	
4	217	18	14.46	
Average	246.5	18.25	14.6	
Rake				13.7
Rake				13.8
Rake				14.3
Average				13.9
Q154				
5	282	24	14.75	
6	207	21	13.73	
7	260	23	14.88	
8	202	25	13.77	
9	175	19	13.9	
Average	225.2	22.4	14.2	
Rake				14.0
Rake				13.8
Average				13.9

* calculated using class fibre and corrected using Staunton and Mackintosh recommendations

Billet Sampled Standard Deviation 8a = 0.4528
8b = 0.5614

Comments:

- Sample 10 comprised of six whole-stick samples (Q154)
  Sample weight = 4.25: Measured CCS = 16.29 : Corrected CCS (BSES method of -1.5) = 14.79
- High dirt levels

APPENDIX 2

Paper No SEAg 98/034

An Automated Controller for Sampling Sugarcane Trials.

L.C. Zeller[1], B.G. Robotham[2], G. Freshwater[3]
1. National Centre for Engineering in Agriculture, Department of Primary Industries, Queensland
2. Bureau of Sugar Experiment Stations, Bundaberg.
3. Software consultant, Wallangarra.

1. INTRODUCTION

Sugarcane breeding and research programs currently rely on hand-cut sound whole-stalk samples for determination of commercial cane sugar (CCS) and other quality components. As whole stalks are free from extraneous material and inferior quality cane, a biased sample of the material is harvested for milling from experimental plots (Skinner, 1976). The whole-stalk samples must be obtained while mechanised equipment operates in the plots, thus exposing field staff to the risk of injury from harvesters and cane haulout vehicles. Billet samples have been shown to give a more representative estimation of CCS and are more useful in predicting responses of commercial cane varieties to agronomic treatments. Collecting cane samples as billets is also more compatible with current harvesting systems. An automated sugarcane billet sampler will enable cane samples that more accurately represent the canes commercial performance to be obtained in a safe and repeatable manner (McRae *et al*., 1998).

2. MACHINE DESCRIPTION

The sugarcane billet cane sampler is mounted on a truck and consists of a bulk weighing bin, a slat elevator and a hydraulic power unit. The bulk weighing bin is mounted on four 250 kg load cells for measuring trial yields and has hydraulically operated doors for emptying. A hydraulic motor drives the slat elevator and the oil circuit is switchable to produce two material discharge rates. An inductive proximity switch is used to sense the movement of slats when the elevator is operated. The sampling chute is mounted in the floor of the elevator and is operated by a hydraulic motor and pitman arm system.

3. THE CONTROLLER

The sampler controller composes of a micro-controller circuit board, an interface circuit board and relay switching circuit boards. The micro-controller circuit has a real time clock, battery backed RAM, an LCD interface, a power supply and an RS232 interface. Signals from the load cells

are amplified by the interface circuit board and converted to frequencies proportional to the load. As signal period is measured, a resolution of ± 0.1% of the total weight is achieved. The interface circuit consists of a power supply, high input impedance differential amplifiers, voltage to frequency converters and optical isolation for relay switching. The relay switching circuit boards actuate the hydraulic solenoids when signals are received from either the controller, the joy stick or the manual over-ride switches.

4. OPERATION

During the harvesting operation, the sampling truck travels beside the sugarcane harvester which discharges all cane billets into the bulk weighing bin. At completion of a trial plot, the truck driver initiates the sampling sequence. The electronic controller initially weighs the material in the bulk bin and records the date, time and yield. It then calculates the number of slats to convey the harvested cane billets and the desired frequency of sampling chute operation to produce a sample of the required mass. The bulk bin door is opened and cane billets are supplied to the slat elevator. The slat elevator is started and continues until all harvested cane billets are conveyed. After the pre-determined number of slats, the controller initiates operation of the sampling chute. The controller also operates the oil flow solenoid and reduces the elevator speed. This lower elevator speed is necessary to ensure all billets on a selected slat pass into the sampling chute. This process continues until all cane in the bulk bin is cleared. During operation, the controller displays the sample weight and the percentage of the unloading operation completed.

The controller has the following modes of operation:

- run mode;
- load cell calibration mode;
- solenoid timing parameters mode;
- data retrieval mode; and
- clear memory option.

The controller includes manual over-ride controls and an emergency stop button to ensure the safety of the operators.

5. CONCLUSION

The automated cane billet sampler reduces sampling bias from sugarcane research trials and provides a safer environment for field staff.

6. REFERENCES

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An Automated Controller for Sampling Sugarcane Trials

L.C. Zeller, National Centre for Engineering in Agriculture, Department of Primary Industries, Toowoomba.
B.G. Robotham, Bureau of Sugar Experiment Stations, Bundaberg.
G. Freshwater, Software consultant, Wallangarra.

Summary

An automated sugarcane billet sampler was developed to improve the quality of cane samples used for the determination of commercial cane sugar (CCS) and to reduce the risk of injury to research staff.

The sugarcane billet sampler uses an electronic controller to measure the yield of trial plots and control hydraulic motors and rams to automatically obtain a representative sample from the cane harvested for each trial replicate. This paper describes the components and operation of the billet sampler. It includes a description of the controller program and the electronic hardware.

To date the cane billet sampler has had limited field testing, but has satisfied the initial design criteria and further trials will determine the correlation between automated billet sampled and commercially harvested sugarcane.

Introduction

Sugarcane breeding and research programs currently rely on hand-cut sound whole-stalk samples for determination of commercial cane sugar (CCS) and other quality components. These stalks of sugarcane are free from extraneous material and inferior quality cane and hence a biased sample of the material is harvested for milling from experimental plots (Skinner, 1976). The whole-stalk samples must be obtained while mechanised equipment operates in the plots. Research staff is exposed to the risk of injury from harvesters and cane haulout vehicles. BSES annual plant breeding program exceeds 250 individual trials that are repeated at five sites along the Queensland coast. Billet samples have been shown to give a more representative estimation of CCS and therefore are more useful in predicting responses of commercial cane varieties to agronomic treatments. Collecting cane samples as billets is also more compatible with current harvesting systems. Dr Tony McRae identified the need for an automated sugarcane billet sampler in 1994 and funding was obtained to determine design parameters for this machine. (McRae *et al*., 1998).

Operation of billet sampler

Most experimental sugarcane trials are harvested using commercial sugarcane harvesters and haulage equipment. During the harvesting operation, the billet sampling truck travels beside the sugarcane harvester which discharges all harvested cane billets into the bulk weighing bin. At completion of a trial plot, the truck driver initiates the sampling sequence. The electronic controller initially weighs the material in the bulk bin and records the date, time and yield. It then determines the desired frequency of sampling operation to produce a sample of the required mass. The bulk bin door is opened and cane billets are supplied to the slat elevator. The elevator is started and the slats convey harvested material to a cane haulout vehicle parked alongside.

The billet sampler relies on the elevating slat conveyor to reduce the bulk harvested material into a large number of similar sized units for conveying to the cane transport vehicle. The operating principle of the automated billet sampler is the selectively removal of the pre-determined number of elevator slats of harvested material. The representative plot sample of a required mass can be obtained during the unloading cycle after each plot is harvested.
Control of a task such as this is ideally suited to a micro-computer based system.

The controller continuously records the number of slats conveying the harvested cane billets. After recording the pre-determined number of slats, the controller initiates operation of the sampling door. The controller also activates solenoid operated hydraulic spool valves to reduce the elevator speed. This momentary operation at a lower speed ensures all material on the selected slat drops through the sampling door. This process continues until the predetermined number of sub-samples has been collected and all cane in the bulk bin is cleared. During operation, the controller displays the sample weight and the percentage of the unloading operation completed.

The System

The controller is required to control hydraulic motors and rams to automatically obtain a representative sample from the cane harvested from each trial replicate. The sample is not obtained during the harvest operation, as consistency of harvested material, in either quality or quantity, cannot be guaranteed. Therefore, the trial plot fully harvested and a measure of the yield recorded. The mass of the sub-sample can then be calculated as a proportion of the total plot yield. A mechanism was needed to extract sub-samples periodically as the cane was transferred to a haul-out vehicle, thus providing a truly representative sample from the harvested plot.

Figure 1 shows the automated cane billet sampler mounted on a truck.

Figure 1 - Automated Cane Billet Sampler

Controller Program

The program for the controller was written in Forth language and has three modes selected on power-up:

- calibration mode;
- run mode; and
- an option to clear the memory.

The calibration mode is selected when the *Dump* button is depressed during power-up of the unit. This mode enables testing and, if necessary, recalibration of the weighing systems to be undertaken.

The *Run* mode is the default mode and is initiated when no button is depressed during power-up. The unit is identified during initialisation of the L.C.D. and the word “Ready” displayed. At this point, four options are available:

- Start
- Tare
- Dump
- Setup

Pressing the *Start* button will initiate the sampling sequence as shown in the flow chart, Figure 2.

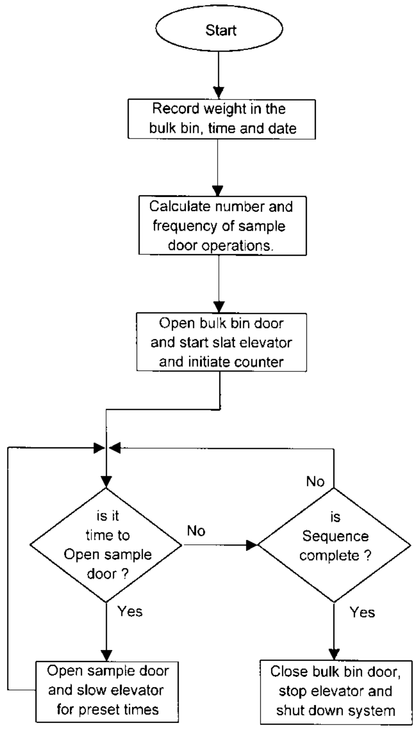


Figure 2 - Flowchart of *Run* mode.

Pressing the *Tare* button causes a measurement of the current bin weight and this value is recorded as the new offset. The weight calibration settings remain unchanged. Upon completion, the program returns the start and displays “Ready” on the LCD.

The *Dump* function enables downloading of data to a personal computer or other device which accepts ASCII data.

Pressing the *Setup* button allows the user to alter the nine variables used to control the operation of the sample door, bulk bin door and the speeds of the slat elevator. The time and date are also set in this option.

Clearing the memory is achieved by simultaneously pressing the *tare* and *setup* buttons at power-up.

Measurement of plot yield

The yield of the plot is measured by weighing the harvested cane from that plot in the bulk bin. Harvested material is weighed using four 250 kg load cells connected in parallel and produce a signal proportional to the total mass. The signal from this configuration is amplified by the high impedance differential amplifier circuit shown in Figure 3.

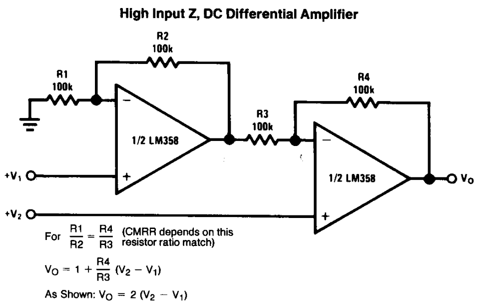


Figure 3

The output of the amplifier is then fed to a voltage to frequency converter (AD537K) to produce a digital signal with a frequency in the range of 50 to 300 Hz. The period of this signal is measured by the micro-controller to a resolution of 500 nS, which corresponds to a minimum resolution of 1/6000 or 0.02%. The combined error of the load cells and instrumentation give an accuracy of ±0.1% for the weighing system. This circuit is duplicated on the interface circuit board allowing for a future modification when minor software changes would allow for feedback to the system incorporating weighing of the sample bin during sampling. Testing to date has shown these changes to be unnecessary.

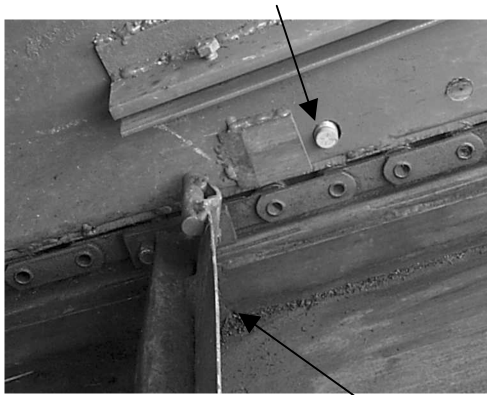
Input/Output

Port A of the micro-controller is used for signal inputs and outputs. Port A bits 1 and 2 are used for measuring bin weights and bit 0 is used for sensing slat movement. Bits 3 to 7 are outputs, which operate hydraulic solenoids to control the high and low speed of the slat elevator and operation of the sample door and bulk bin door.

Slat Movement Sensing

Short lengths of 12 mm rod were welded to the side of each slat. An inductive proximity switch is used to sense the rod and produces a signal each time a slat passes (see Figure 4). The proximity switch has a sensing distance of 8 mm. With a gap of 4 mm the proximity switch can accept distance variations of up to ± 4 mm which could result from lateral movement of the slat. Lateral movement is minimised by increasing the tension on the elevator chain.

Inductive proximity switch



Slat

Figure 4 - Slat sensor

Hydraulic Solenoid Switching

All outputs are optically coupled and the controller power supply is isolated from the solenoid switching power supply to avoid transients affecting the micro-controller. In addition to the automatic control, a joystick is mounted in the cab of the truck that allows four-way control of the position of the elevator (up, down, slew out and slew in). An emergency stop button is mounted on the frame of the bulk bin which disables the automatic control of the sampler and allows manual control by the way of momentary push buttons for all hydraulic functions. Figure 5 shows the emergency button and manual controls.

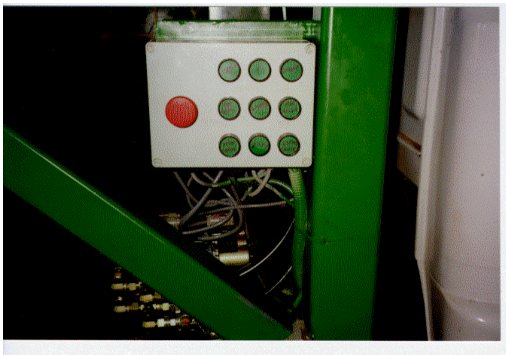


Figure 5 - Emergency stop and manual controls

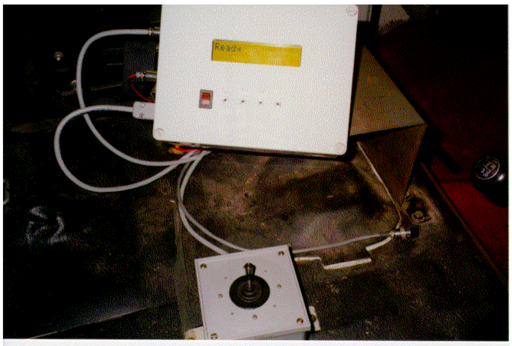


Figure 6 - Controller and joystick

Operation of sampling door

The sampling door is a moveable floor panel that is mounted on parallelogram arms. Opening and closing action of the door is provided by a pitman arm system that is driven by a hydraulic motor (shown in Figure 7). A pilot operated pressure relief valve is used to brake the motor at the end of a cycle and is coupled directly to the hydraulic motor. Movement of the sampling door is initiated by the controller activating a hydraulic solenoid valve. The solenoid valve is only activated for approximately 0.5 seconds after which an inductive proximity switch and cam arrangement assumes control of the door cycle. The adjustable metal cam is attached to a pitman arm and provides feedback to ensure the door always stops in the closed position.

Opening and closing cycle times of less than second were possible but a cycle time of second ensured all material conveyed by the selected slat has discharged through the open sampling door. Each billeted cane sample is collected in a bag mounted below the sampling door.

Figure 7 - Pitman arm system

Discussion and Conclusion

The automated cane billet sampler has been manufactured with limited field testing undertaken. The concept has satisfied the initial design criteria and a large number of trials shall determine the correlation between the quality measurements of automated billet sampled sugarcane and commercially harvested sugarcane.

The ability to adjust the various parameters such as sample size, weight of material on an elevator slat, etc has resulted in a versatile sampler which can be altered to suit most harvesting situations. Once the parameters are set there appears to be little need to alter settings with a trial plot.

The current machine cannot successfully sample from cane with extremely high levels of extraneous matter or excessively long billets. In both cases, uniform feed of billets onto the slat elevator could not be maintained and bridging of the cane can occur. This deficiency is not considered as significant, as harvesters used on all BSES trial plots are set up to produce near uniform length billets and acceptable levels of extraneous material.

As the machine has not been used extensively, reliability and robustness of the sampling system has not been accessed.

Acknowledgments
The authors thanks Messrs McRae and Bull for their assistance in developing this concept of an automated billet sampler. Thanks also to Mr Win Chappell for his assistance with the construction and testing of the billet sampler. This work was funded by the Sugar Research and Development Corporation and the authors thank them for their support and desire to improve current practices.

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