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FINAL REPORT - SRDC PROJECT BS152S
CHOP-THROW - A POTENTIAL DRIVER FOR THE NEXT GENERATION OF PNEUMATIC CLEANING SYSTEMS

by

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SD00019

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EXECUTIVE SUMMARY

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This project investigated, from a sound theoretical basis, the potential for the design of an effective cleaning system for chop-throw harvesters, taking advantage of the high input velocity of billets into the cleaning chamber in a chop-throw harvester. The project included high-speed photography of the chopper and cleaning system in a prototype chop-throw harvester, and dilute and dense phase modelling of separation of cane components in the cleaning chamber.

The high-speed photography showed preferential orientation of billets parallel to the thrower vane for a significant distance after chopping and throwing. This means that billets are oriented parallel to any air stream introduced at right angles to the vertical motion of billets leaving the thrower. The drag on the billets is therefore reduced, allowing use of higher air velocities without risk of loss of billets during cleaning. However, the current extractor cleaning system used in the chop-throw prototype was shown to introduce severe swirl in the cleaning chamber, negating the benefit of billet orientation. This pointed to the potential benefit of using a well-designed blower system to produce laminar airflow in the cleaning system.

The dilute phase model studies utilised background information on terminal velocities and drag coefficients of cane components provided by previous SRI studies, data from Massey Ferguson R&D files and overseas studies. Whilst the dilute phase modelling indicated that there was potential for effective separation of leaves from billets in the conventional system, small changes in operating parameters produced billet trajectories which dramatically increased the potential for cane loss. In the dense phase relationships, which occur in a conventional cleaning system, the simplistic modelling of individual components will indicate dramatically enhanced performance. The potential usefulness of the dilute phase model is in the modelling of the chop-throw system where the particle interactions become somewhat less significant. The model indicates that the high velocity of injection of billets into the air stream allowed high cleaning air velocities, while minimising the deflection of the billet stream. The typical orientation of billets parallel to the airflow will clearly very significantly further reduce billet deflection, and therefore potential for cane loss.

The dense phase model, allowing modelling of the interaction of billets and leaves, was used to evaluate various options for cleaning system design. It was found that cane loss was generally minimised, and leaf removal maximised where a narrow, high velocity air stream rather than a wider, low velocity air stream was used. Cane loss increased in a non-linear fashion with height of the air stream above the billet injection point, primarily because of loss of vertical velocity and momentum of the billets. Billet loss became unacceptably high where the fan axis was located above 2 m. Cane loss was minimised by introducing the air stream below a height of 1.0 m, but cleaning efficiency was reduced at the standard air flow volumes used for the modelling. However, cleaning efficiency was improved significantly without significant cane loss by increasing the volume of airflow. The modelling studies indicated that a system injecting billets into the cleaning air stream at a higher velocity than conventional harvesters (such as the chop-throw harvester) gives greater potential for effective cleaning without significant cane loss.

1.0 BACKGROUND

Extraneous matter and cane loss are recognised as major problems for the sugar industry, both as direct losses (estimated as $40-50m/year) and because of the sugar quality and processing problems resulting from EM in the milled cane. The dramatic increase in throughput of current harvesters has added a new dimension to the EM/cane loss/pour-rate dilemma.

Current harvesters eject cane from choppers in a broad trajectory of approximately 45° upwards into cleaning chamber which has upward airflow. At the high pour-rates sought by the industry, dense phase interactions occur, and the performance of the cleaning systems deteriorates. Air velocities have to be limited to reduce cane loss, and EM becomes excessive. In addition to these problems, cane and trash is drawn through the fans, and wear rates and power consumption of the cleaning system are significant issues.

Although some improvements are possible by optimisation of the current design, it is widely believed that alternative concepts are needed to make major advances.

As part of the analysis of the current system, Hobson *et al.* (1996) developed a dense phase model of the interaction of cane billets and trash in pneumatic cleaning systems. This model allows the impact of the manipulation of various variables in current cleaning chambers to be studied.

A significant development from this research has been the development of alternative concepts for harvester cleaning systems, an example being the transverse airflow cleaning concepts. A consistent problem associated with the development of such alternative systems is the low velocity and highly variable trajectory characteristics and mass flow rates of material effluxing from the choppers.

Analysis of dynamics of cleaning mechanisms indicates that dramatic improvements can be achieved in the pneumatic separation of products by maximising the use of differences in aerodynamic properties and the kinetic energy of materials to be separated. Typically, much “finer” separation of materials can be achieved by increasing the kinetic energy and momentum of the material stream, and using high velocity transverse airstreams to achieve separation of materials by divergence of trajectories. With appropriate design, the capabilities of such concepts are such that chipped macadamia kernels can be separated from whole kernels (Young, *pers. com.*). Some high capacity grain harvesters (eg Deutz-Allis) use the concept to great advantage for the separation of grain from chaff.

The chop-throw concept as a key component in cane harvesters has been under investigation for over thirty years but has not, as yet, had a major impact on the development of commercial cane harvesters. Many of the claims for the system have not been realised.

From an engineering perspective, the chop-throw concept appears to have one outstanding advantage for the separation of materials on a cane harvester, which has not been exploited by the industry - the velocity (including directional control) and presentation of the billets leaving the thrower. Although some attempts have been made at optimising airflows on prototype chop-throw harvesters to date, the potential of the system has not been realised, as there has not been an understanding of the radically different dynamics of the chop-throw relative to traditional systems. Whereas typical extractor systems operate at air velocities of 10-20 m/sec, initial modelling indicates an optimised cleaning system for a chop-throw harvester may utilise air velocities of 25-45 m/sec. The power requirement for these higher air velocities would not be greater than existing systems because of the vastly improved efficiency of optimised blowers, better control of airflow, and elimination of the substantial losses associated with materials processing through extractors.

Photo 1 - Early Model Canavan Chop-Throw harvester

Photo 2 - Bonel Chop-Throw harvester prototype which was used in the investigation

Modelling of the chop-throw system using a simple dilute phase model, and the SRI dense phase model was seen as appropriate methods for determining the effectiveness of high velocity lateral air streams in separating cane from leaf and trash material. If the modelling was to verify the initial assumptions of this project, the chop-throw concept may well offer a very timely opportunity to change the EM/cane loss/pour rate equation. In addition, high-speed photography was seen to offer a method to determine orientation of billets leaving the thrower, and separation of billets from leaf and trash.

2.0 OBJECTIVES

The objective of this project was to determine if the chop-throw concept offered potential for high efficiency pneumatic cleaning systems, by virtue of the inherently high efflux velocities and billet presentation from the thrower mechanism.

The project only investigated attributes of the "chop-throw" concept, as related to potential enhancements to the cleaning of cane. Performance monitoring of the current design was not considered to be part of this project.

3.0 METHODOLOGY

The field measurement phase of this project was based on working with Bonel during their field evaluation program of the chop-throw harvester they had developed. The machine was a light weight conventional single row chopper harvester. The gathering and feeding components followed industry standard layout and design. The fundamental difference in the machine was the utilisation of a chop-throw mechanism in place of the conventional system of rotary pinch chop and elevator. The thrower had a diameter of 1.2 m and rotational speed of approximately 127 rpm giving the billets a velocity of approximately 8 m/sec, in a near vertical trajectory through the cleaning chamber. The material then followed a chute and was deposited on a transverse conveyor to transport it to the haulout.

The research program aimed to use this machine to facilitate an assessment of the chop-throw concept, rather than analyse the performance of this machine *per se*. The research program therefore included:

- High speed cine photography of the billeting mechanism and the trajectories of billets.
- Dilute phase modelling of particle trajectories to assess potential characteristics.
- Dense phase modelling of limited scenarios to assess probable performance and cane loss from potential machine configurations.

3.1 High speed cine photography

The cine camera used was a "Low-Cam 500" unit, on loan from the Agricultural engineering group within the Queensland Department of Primary Industries. The target area and camera settings such as aperture, focus etc are set "through the lens" before the film is loaded into the camera. The unit used 400 ft rolls of Eastman EXR200T colour negative film, with a maximum nominated film speed of 500 frames/second, giving a filming time of approximately 34 seconds. The film was transferred to video at 25 cine frames/second to maximise transfer of captured data, given the interlaced video format.

The high current 28 volt DC power supply for the unit was supplied by automotive type lead acid batteries and a voltage regulating circuit. Lighting for the filming was supplied by four 1000 watt 240 volt halogen lights, the power being supplied by a portable alternator mounted on the harvester.

Three positions of the high-speed cine camera were used on the chop-throw harvester. These were selected to investigate trajectories of billets and extraneous matter at various heights above the throwing mechanism, and orientation of billets relative to the direction of travel.

- The first camera position (Photo 3) viewed obliquely from the side of the machine through a viewing hole cut in the side of the machine, adjacent to the position of the rotary anvil and thrower. This position aimed to assess the first interaction between the cane stalk and the chop-throw components. The camera was fixed in position on a mounting frame attached to the guide bar in front of the harvester rear wheel.

Photo 3 - View of high-speed camera and viewing window adjacent to the thrower and rotary anvil.

Photo 4 - View of rear of harvester showing the position at the back of the machine from which filming occurred. The portable alternator is to supply power for supplementary lighting.

- The second camera position, from a fixed mounting with the camera axis perpendicular to the axis of the machine, facilitated a side view onto the machine (Figure 1). The viewing window was in the near vertical section of the chamber at the height of the extractor fan, approximately one third of the distance along the throw trajectory. This position aimed to record the presentation of the billets as they traversed the chamber. Potentially, the processes of trash removal by the fan would also be visible from this position.

- The third camera position (Photo 4) was from the back of the machine, viewing forward towards the extractor fan. The camera was hand held tor this phase of the process to allow scope to view billet and trash movement from different angles. For part of the time during this filming sequence, the extractor fans were turned off.

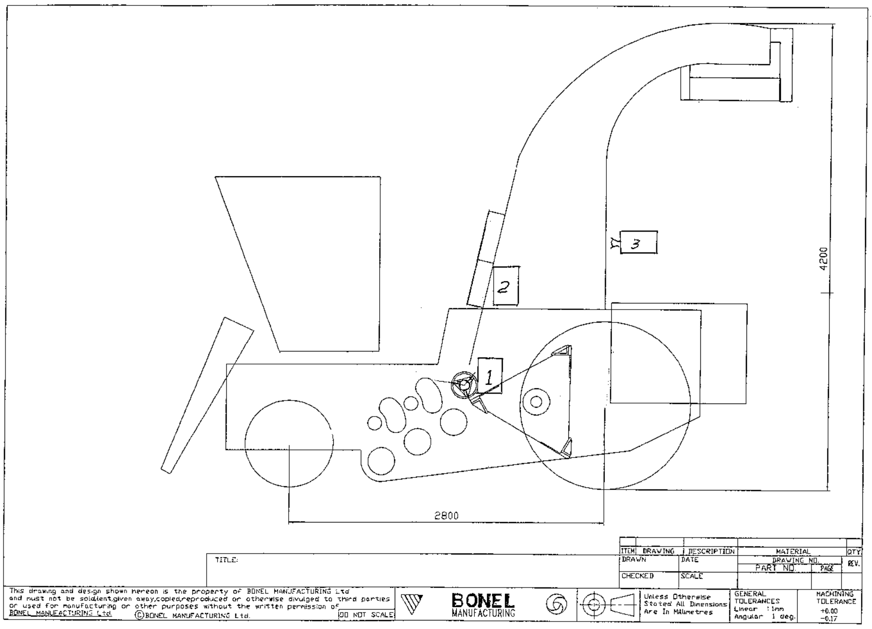

Figure 1 - Schematic showing a side view of the Bonel prototype chop-throw harvester and the viewing positions (1, 2 and 3) used for high speed cine photography

3.2 Dilute phase modelling of particle trajectories

Billet (small and large), top (cabbage), and leaf trajectories in a typical conventional harvester cleaning chamber were compared with those in a chop-throw harvester, using simple dilute phase modelling techniques. The simple dilute-phase model used had been developed in the "basic" programming language by the principal investigator to investigate separation of coffee cherries. Aerodynamic properties of billets, tops and leaves used in the dilute-phase model were derived from recent SRI research, data from MF R&D files and data published in the literature. The model was modified to allow operation within the program Excel, and facilitate plotting of trajectories.

3.3 Dense phase modelling

Using similar data for the aerodynamic properties of billets and leaves, the SRI dense-phase model was run to investigate various cleaning system options for the chop-throw harvester. These included narrow, high-speed air jets, and wider, lower velocity air jets. The different air-jets were compared with the same volume of air flow. Tests were also carried out with the air jets located at different heights above the thrower and with air jets at right angles to the trajectory of material, or angled 45 degrees downwards. The dense phase model projects trajectories of billets and leaves, and estimates cane loss and cleaning efficiency. The model runs were carried out under contract by Dr P Hobson of SRI.

From the information gathered as a result of this process, it was believed that the potential the chop-throw concept held for the enhanced cleaning of cane could be defined, if parameters associated with its design were optimised.

4.0 RESULTS AND DISCUSSION

4.1 High speed photography

Billeting process

The camera was located to allow access to cane as it was cut into billets by the thrower and anvil, and to observe the trajectories of billets. The photography of the thrower itself was carried out at 450 frames/sec, and quality of the resulting film was adversely affected by the extremely dusty conditions and problems with film breakage in the camera.

The most obvious observation, which could be drawn from the cine of the thrower zone, was significant visible juice loss as billets were cut and thrown, (Photo set 5) suggesting that this could be a major issue for the industry if the machine was commercialised. The evidence of significant juice loss is supported by the relatively low billet quality ratings achieved (only 16-22% sound billets, See Appendix 1). This level of damage is higher than for previous chop-throw tests (Ridge, *pers com*). It should be noted that there are often less than 50% sound billets in current drum chopper harvesters under commercial conditions.

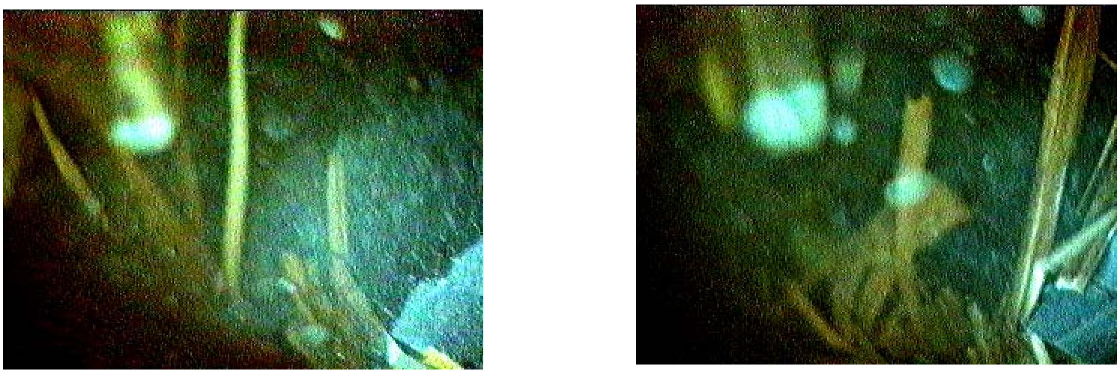

Photo set 5 - Scans of high-speed cine after the thrower mechanism has impacted on the cane. Numerous "globules" of juice (grey colouring) are visible indicating juice loss.

There may need to be improvements in the chopper blade/anvil of the chop-throw system to minimise losses during chopping.

Trajectories of billets

Subsequent filming of billet trajectories and the cleaning extractor was carried out at 300 frames/sec, to minimise the probability of film breakage. To observe billet trajectories and the effectiveness of the existing extractor cleaning system, footage taken from the rear of the machine (Photo sets 6 and 7) and through the window which had been cut into the thrower chute (Photo set 8), approximately level with the centre-line of the primary extractor fan was reviewed.

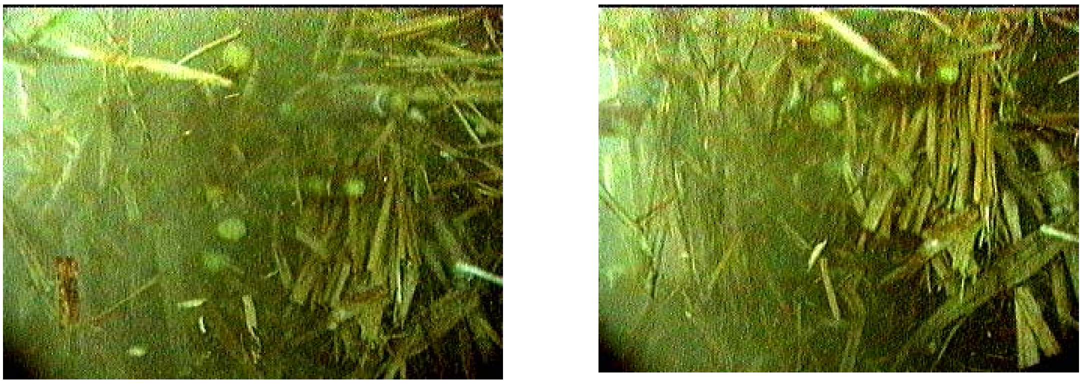

Photo set 6 - Scanned frames from the rear of the machine showing the typically near parallel orientation of billets. The interaction between billets and trash is also visible. In the second scan, one blade of the extractor fan is visible (above centre frame, LHS.)

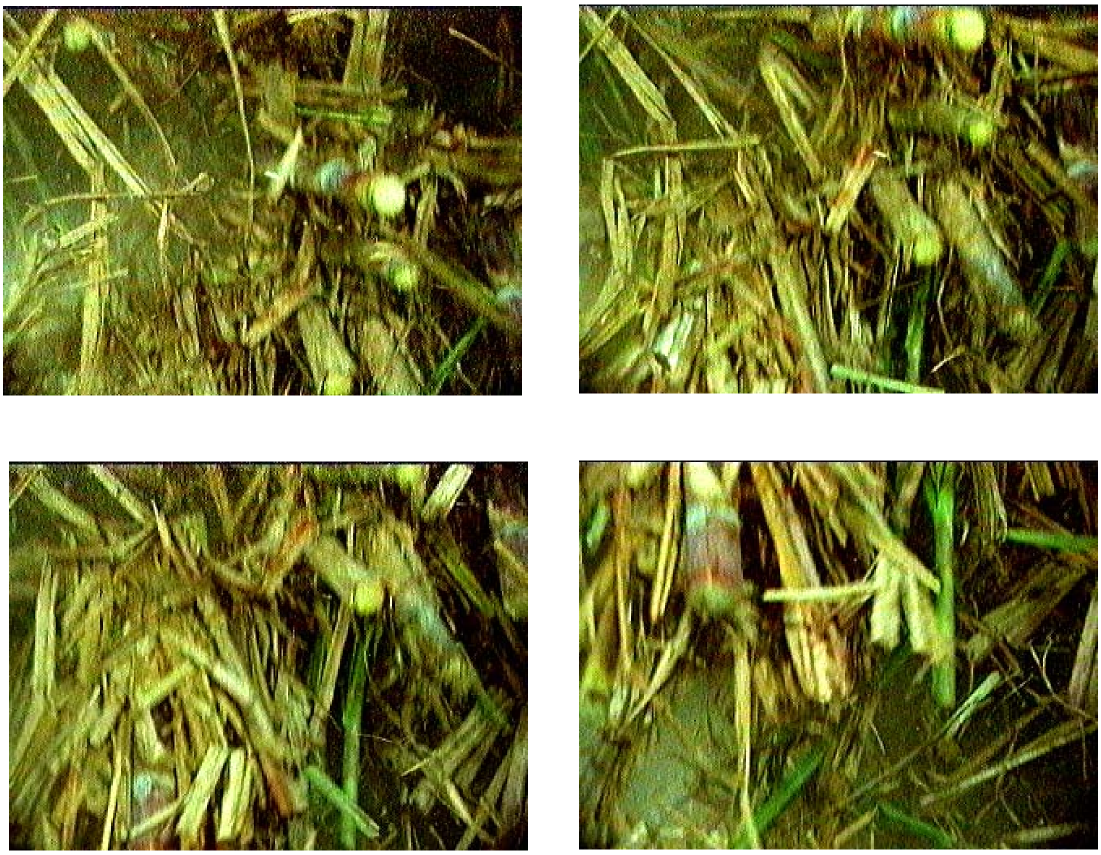

Photo set 7 - A series of scans as the billets pass in front of the extractor fan. The sequence illustrates the relative ineffectiveness of the extractor fan, as well as the necessity to use airflow parallel to the axis of the billets if cleaning is to be optimised.

Photo set 8 - A series of scans from the side of the machine showing the parallel movement of billets vertically upward. The location of the viewing window was approximately 1.4 m above the thrower.

The key observations from the high-speed photography of the thrower/extractor chamber were:

- Billets remained parallel to the direction of flow of cane into the chopper for some distance above thrower, with a large percentage still being in this orientation as they reached the extractor fan. The swirl of the air as the billets passed the extractor fan appeared to induce some rotation of the billets.
- The "space" between the cane billets tended to increase as the billets increased their distance from the thrower.
- A degree of separation of the trash occurred from the billets during the throwing process. In footage taken with the extractor off, the trash appeared to be somewhat controlled by induced airflows, which moved the trash towards the rear of the machine.
- Photography of the extractor fan inlet from the rear of the thrower chamber indicated that the highly visible swirl induced by the extractor caused considerable differences in the interaction between the trash, the billets and the airstream from one side of the chamber to the other.
- The combined effect of the placement of the extractor fan and its induced swirl can pull trash through the path of the billets, with events where billets were encased in trash and drawn into the fan being observed on film

From the above observations, the following implications can be drawn:

- The initial parallel movement of billets would allow the use of a higher velocity air-stream to separate leaf and trash and smaller tops from billets, provided the air flow was introduced close to the thrower, and the air-flow was parallel to billet orientation.
- The compromise not considered by later model studies was the increasing separation between the billets as they move away from the thrower.
- The present extractor system is unsuitable for optimum separation of extraneous matter from billets, due to the unconfined fan entry conditions and induced swirl in the air flow. It is likely that a well designed blower system producing linear air flow would dramatically enhance trash removal, as it would capitalise on the parallel orientation, and near perpendicular presentation of the billets relative to their trajectory.

The most significant outcome of the observations of the cine photography is the tendency of billets to remain parallel for a significant time as they traverse the trajectory. This effect significantly enhances the fundamental advantage of the chop-throw concept for cleaning of cane.

4.2 Parameters used in model studies

Data derived from Joyce and Edwards (1994) and Clayton *et al.* (1975) was used in the dilute phase model to plot trajectories of the different cane components. The dilute phase model uses calculations of velocity relative to the prevailing airflow to predict the drag force on cane components at successive small time intervals. This information is then used to determine resolved forces on the component and subsequent acceleration. The equation on which the model is based is:

$$F= M*G= K*A*V^2$$

where M = mass of cane component
G = gravitational acceleration
K = frictional coefficient of component
A = surface area of component
V = terminal velocity of component

Typical model inputs and calculated K values for cane components in an air-stream are given in Table 1. Background information for these model inputs is given in Appendix 2.

TABLE 1
Typical terminal velocities and friction coefficients for cane components used in dilute phase model

Component	Nominal diameter (mm)	X sect area sq M	Bulk density kg/cc	Mass kG	Friction coefficient	Terminal velocity estimated	Terminal velocity measured Leon	Terminal velocity measured Joyce	Terminal velocity assumed
Large billet: perpendicular	35	0.007	1.05	0.202	0.400	27	27	23	25
Large billet: parallel	35	0.001	1.05	0.202	1.200	41	NA	NA	
Small billet: perpendicular	20	0.004	0.8	0.050	0.400	18	17	13.5	15
Small billet: parallel	20	0.000	0.8	0.050	1.200	36	NA	NA	
Cabbage: perpendicular	25	0.005	0.65	0.064	0.500	16	8..13	12…17	13
Cabbage: parallel	25	0.000	0.65	0.064	1.600	28	NA	NA	
Leaf	10	0.002	0.3	0.005	2.500	3	.5..2.5	1….4	3

4.3 Dilute phase modelling

4.3.1 Conventional harvester

Modelling of the conventional harvester cleaning system was carried out assuming that billet trajectory in the cleaning system as set by the position of the deflector plate above the chopper was 30° from the horizontal. The injection velocity from the chopper was calculated as 3.2 m/s, giving vertical and horizontal velocity components of 1.6 and 2.77 m/s, respectively. Vertical air velocity in the cleaning chamber was assumed to be 16 m/s.

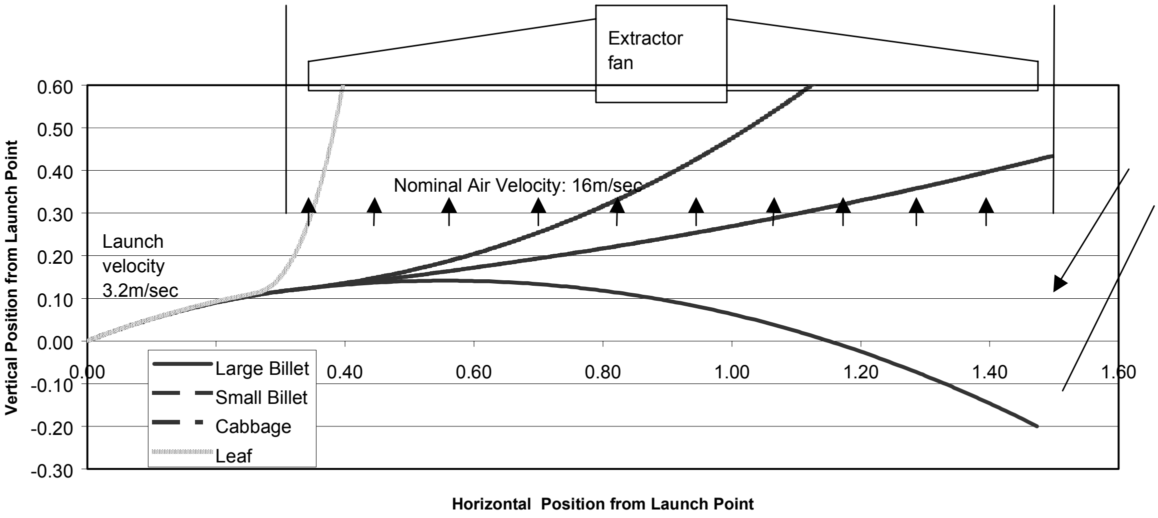

Figure 2 - Dilute phase trajectories of cane components in a typical conventional harvester cleaning chamber

Model predictions of typical trajectories of different cane components in the cleaning chamber are shown in Figure 2. These indicate that in an idealised dilute phase system leaves can be readily separated from other components, but there will be difficulty in separating tops (cabbage) from smaller billets. In practice, other studies indicate difficulties in separating components in the dense phase flow associated with high pour rates. This is a result of swirl in air flow, random orientation of billets, and mechanical impedance to trash flow caused by the thick mat of material in the cleaning chamber. It is evident also that there will be significant cane loss with a cleaning extractor located just above the flow of cane in order to limit the height of the harvester, and losses will increase as air velocity is increased.

4.3.2 Chop-throw harvester

Two modelling inputs for the chop-throw harvester were investigated. For the first, the assumptions were:

- a vertical billet velocity from the thrower of 8 m/s;
- a vertical air flow of 6 m/s created by the thrower vanes;
- a wide, low velocity parallel airstream of 15 m/sec over a vertical distance of 1000 mm. (Nominally similar profile to that achieved with low pressure axial flow fan with flow straightening.)

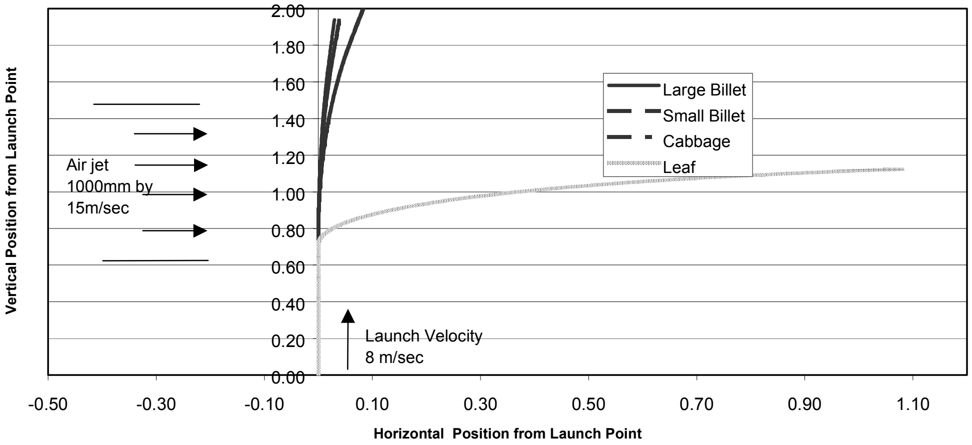

Figure 3 - Predicted trajectories of components subjected to a launch velocity of 8 m/sec and a transverse airflow of 15m/sec. Billets are assumed to be "end on" to the airflow.

Model predictions of trajectories of the different cane components after leaving the thrower are shown in Figure 3. The trajectories show clear separation of leaves from other components, with minimal deflection of the billets. Clearly, the higher air velocities possible in the chop-throw system with higher velocity of billets leaving the chopper offer the possibility of improved cleaning efficiency without significant cane loss.

The second option investigated was the use of a higher velocity air jet of 40 m/s at right angles to the vertical between 0.95 and 1.25 m above the thrower (approximately the position of the bottom section of the current extractor fan).

The results of this simulation are given in Figure 4. Again, this option indicated potential for significant cleaning and minimal impact on the trajectory of billets but with additional potential to remove some tops and cabbage.

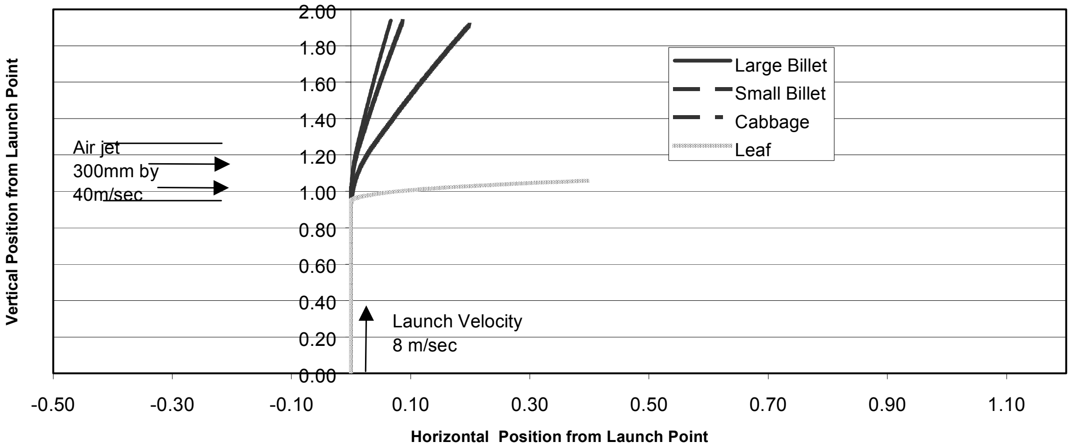

Figure 4 - Predicted trajectories of components subjected to a launch velocity of 8 m/sec and a transverse airflow of 40 m/sec. Billets are assumed to be "end on" to the airflow.

The indications from the dilute phase modelling are that:

- A broad low speed airflow similar to that achieved from an axial flow fan and a high velocity airflow both appear to give very good potential for cleaning.
- The poor performance observed for the extractor system fitted to the harvester can in part be explained by the non-parallel airflow and high degree of swirl in the airflow. These effects would have maximised interactions between the billets and the trash.

The totally different separation characteristics are evident from the high relative velocity system versus the "diffusion" approach of the conventional extractor system.

4.4 Dense phase modelling

The dense phase modelling was used as a guide to the most efficient cleaning system for the chop-throw harvester in terms of maximising cleaning efficiency, and minimising cane loss. Several cleaning system options were evaluated as outlined below:

(1) Horizontal air velocities of 15 and 40 m/s with the simulated fan axis at 2 m above the chopper were tested in the model. A total air flow in each case of approximately 15 m^3/s was measured. Average leaf linear densities representative of those measured for the variety Q124, and an initial extraneous matter level of 20% were assumed. The predicted average cane loss and final extraneous matter levels for the two fan speed settings are given in Table 2.

TABLE 2
Predicted cane loss and final extraneous matter levels for the variety Q124 with a fan height of 2 m and horizontal air velocities of 15 and 40 m/s

Air velocity m/s	Cane loss %	Final EM %
40	0.2	4.4
15	1.4	4.8

The model predicts a significant reduction in cane loss and a small, non significant reduction in extraneous matter levels with the narrower, higher velocity air stream.

Typical trajectories for billets predicted by the model are shown in Figures 5 and 6. Predicted trajectories for leaves have been excluded from these figures.

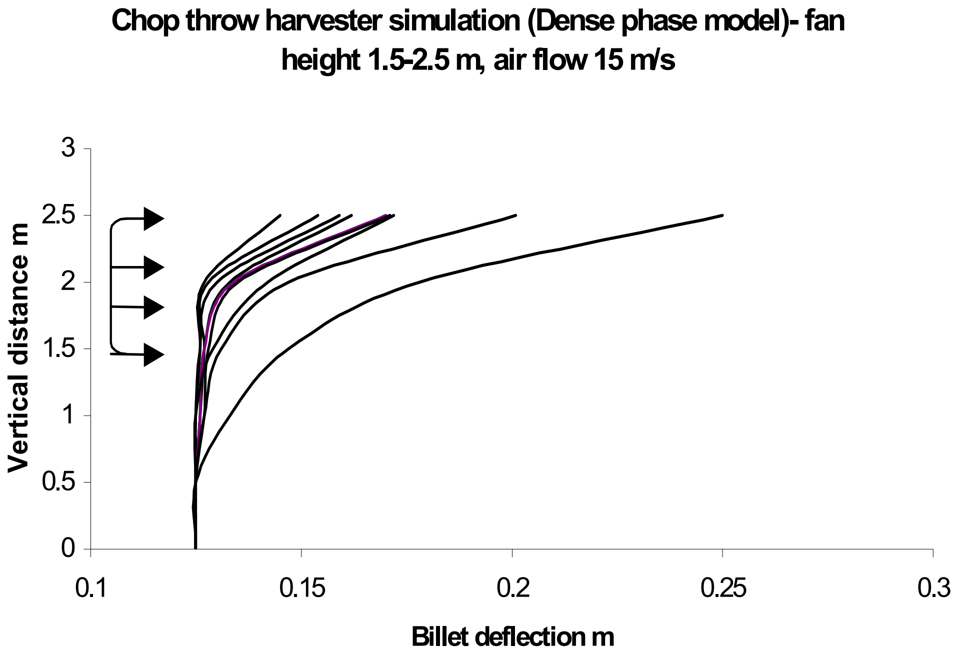

Figure 5 - Predicted billet trajectories for the 15 m/s air stream at right angles to the flow of billets, with the fan axis at a height of 2 m

The figures show significantly more deflection of billets in the wider, lower velocity air stream than in the narrower, higher velocity air stream. This is thought to be due to the longer residence time of billets in the wider air stream, increasing direct aerodynamic drag on the billets and the effect of leaf impacts on the billets.

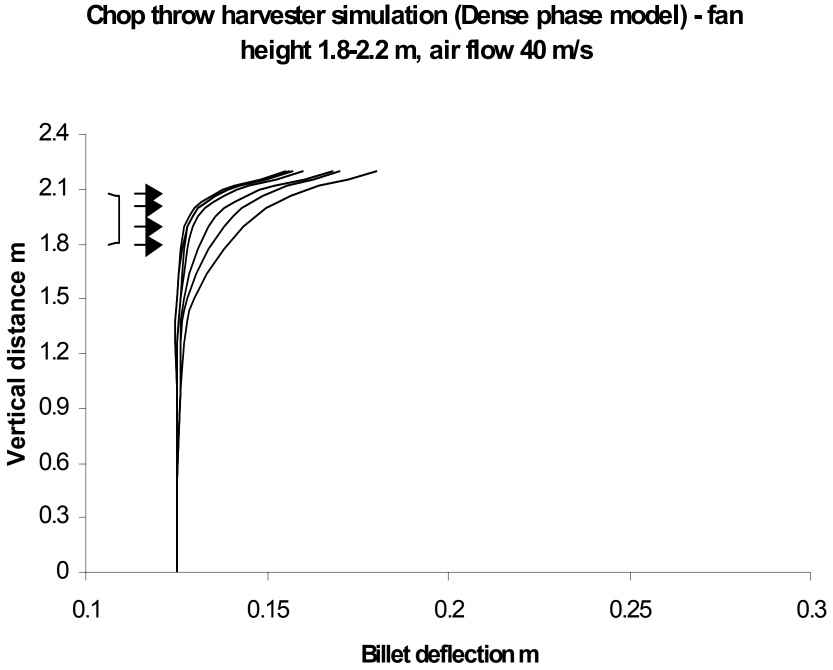

Figure 6 - Predicted billet trajectories with an air velocity of 40 m/s at right angles to the flow of billets, and the fan axis at a height of 2 m

(2) The second set of simulations investigated the effect of the fan height on cleaning efficiency and cane loss. The fan axis was located at 0.5 m and 2.0 m, with simulated air speeds of 15 and 40 m/s at each fan height. The duct width was adjusted to maintain a constant volume flow as previously. Results are summarised in Table 3. With the fan axis at 2.5 m cane loss was again higher with the wider, lower velocity air jet than for the narrower, high velocity air jet, and was much higher than predicted previously for the fan axis at 2.0 m. The higher predicted cane loss at 2.5 m fan height probably reflects the loss in vertical momentum of billets with increasing height above the thrower. Cleaning efficiency was similar to that predicted with the fans at 2.0 m.

TABLE 3
Predicted cane loss and extraneous matter levels with the fan heights of 0.5 and 2.5 m, and air velocities of 15 and 40 m/s

Fan height m	Velocity 15 m/s		Velocity 40 m/s	
	Cane loss %	EM %	Cane loss %	EM %
2.5 m	49.7	5.5	17.7	4.3
0.5 m	0	14.6	0.1	7.8

Location of either type of fan at a height of 0.5 m reduced cane loss significantly to very low levels, but cleaning efficiency was also reduced significantly, particularly with the lower velocity, wider air jet.

(3) The third model runs involved increasing the velocity of the wider air jet in case 2 from 15 m/s to 25 m/s with the fan axis at 0.5 m, with similar air jet dimensions; and, repeating the low air velocity test in case 1 with the air jet angled 45 degrees below the horizontal. These model runs are summarised in Table 4.

TABLE 4
Predicted cane loss and extraneous matter with a wider, 25 m/s air jet at 0.5 m, and a 15 m/s air jet at 2.0 m, directed at an angle of 45 degrees below the horizontal

Fan angle 45 degrees downwards, velocity 15 m/s, height 2 m		Horizontal fan, velocity 25 m/s, height 0.5 m	
Cane loss %	EM %	Cane loss %	EM %
5.5	4.1	0	4.0

The increase in the air velocity of the wide air jet at 0.5 m from 15 to 25 m/s resulted in a significant improvement in cleaning efficiency without any increase in predicted cane loss. This suggests that applying an air jet very close to the launch point gives minimal deflection of billets, but can be very effective in removing leaves. The predicted trajectories of billets in this test run (Figure 7) suggest that the air velocity can be increased further without significant cane loss.

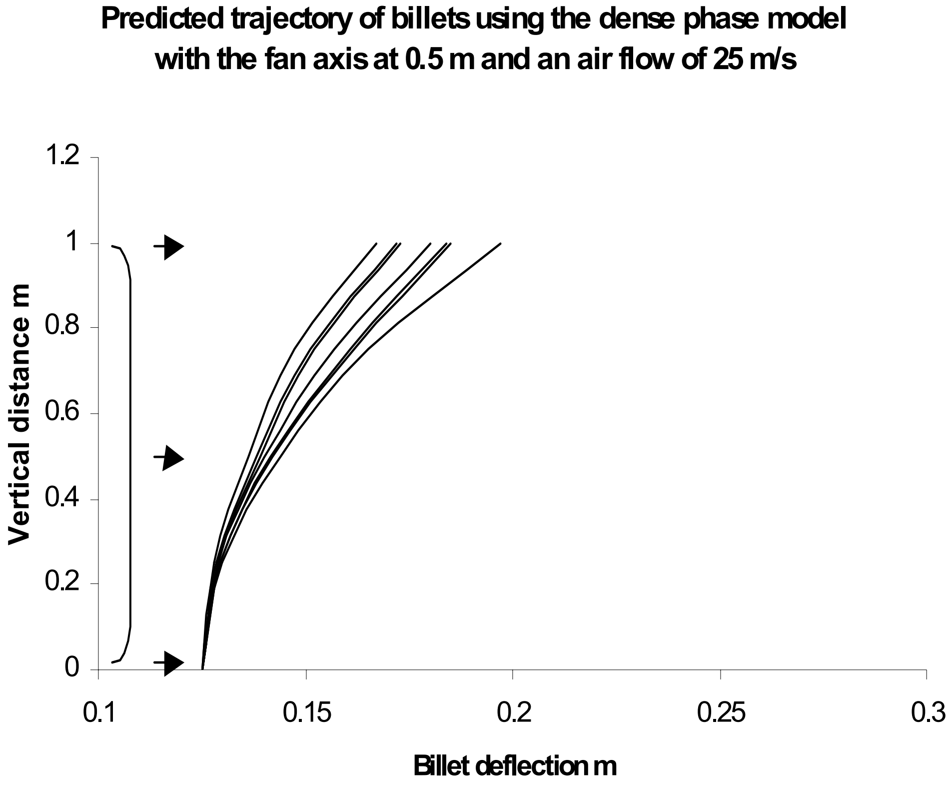

Figure 7 - Predicted chop-throw billet trajectory using the dense phase model, with the fan axis at 0.5 m and an air speed of 25 m/s

The angling down of the air jet at 2.0 m gave similar cleaning efficiency to a horizontal air jet, but increased predicted cane loss. This can be explained in terms of increased residence time of billets in the air jet.

In summary, the dense phase modelling showed the following findings:

- For the same volume flow rate, in most cases a narrow, high velocity jet has better cleaning characteristics than a broad, lower velocity air jet.

- Directing the air jet higher up in the extraction chamber increases cane loss. This effect is not linear, and cane loss increases rapidly between 2 and 3 m near the apogee of the cane billet trajectory. At this location, the momentum "advantage" has been minimised and the billets react to the airflow in a similar manner to a current system where low billet velocities are used.

- Trash removal is relatively insensitive to changes in the vertical positioning of the air jet, except close to the launch point where the trash removal characteristics deteriorate for a fixed flow rate of air.

- For a jet positioned adjacent to the cane launch point, an increase in trash removal rate can be achieved without significant increases in cane loss by increasing the volume flow rate of the air jet, eg increasing the air velocity of the wider air jet used in the test runs. The effectiveness of an air jet located close to the launch point is likely to be increased by the parallel orientation of cane billets to air flow noted in high speed photography. In addition it is important that air flow is laminar to take maximum advantage of billet orientation. Hobson(1995) concluded that the greatest potential for improvement in cane cleaning lies in controlling the motion of particles as they emerge from the chopper into the cleaning chamber.

5.0 DIFFICULTIES ENCOUNTERED DURING THE PROJECT

The main difficulty encountered during the project was in the high speed photography of existing chop-throw systems.

- Access for photography was restricted by the design of the prototype harvester used for photography.
- The extremely dusty conditions meant that definition on the cine footage was poor. Under less dusty conditions, the footage would have been visually much more informative. The poor visibility was particularly unfortunate with respect to the information, which could have potentially been gained from the footage of the billeting process.

It was not possible to test the cleaning system designs identified by modelling within the budget allowed for the project, and the limited budget available to the commercial manufacturer.

6.0 RECOMMENDATIONS FOR FURTHER RESEARCH

The commercial development of chop-throw harvesters has ceased due to limited availability of finance for refining the chop-throw system, and the cleaning system. Commercial cane quality from the prototype harvesters was relatively poor due to billet damage during chopping (associated with damage to the chopper under commercial conditions), and limited design work on the cleaning system. This limited the acceptance of the chop-throw harvester as a commercial option.

However, the advantages given by imparting a higher velocity to material entering the cleaning chamber, and orientation of billets parallel to the air stream, are clearly evident from this study. Further research is warranted in these two fields.

7.0 APPLICATION OF RESULTS TO THE INDUSTRY

The research in this project has potential value for the sugar industry through the insights it gives into alternative cleaning system concepts.

Potential uses of the concepts explored in this report could include alternative secondary cleaning systems for current harvesters and cleaning systems for cane at sugar mills.

8.0 PUBLICATIONS ARISING FROM THE PROJECT

There were no publications arising from this project.

9.0 REFERENCES

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APPENDIX 1

BILLET DAMAGE DATA

Billet quality data for the chop-throw harvester from the same field in which the high-speed cine runs were undertaken is given in the table below.

Billet length mm	**Good billets kg**	**Damaged billets kg**	**Mutilated billets kg**	**Total billets kg**
Sprawled cane				
<100	0.31	0.28	0.72	1.31 (3.5 %)
100-150	1.23	1.53	0.56	3.32 (8.9%)
150-200	2.64	5.50	2.66	10.80 (28.8 %)
200-250	3.6	13.16	3.00	19.76 (52.7 %)
250-300	0.55	0.90	0.88	2.33 (6.2 %)
Total	8.33	21.37	7.82	37.52
%	**22.2**	**57.0**	**20.8**	
Lodged cane				
<100	0	0	1.29	1.29 (4.0 %)
100-150	0.31	0.96	1.08	2.35 (7.2 %)
150-200	0.93	1.75	3.60	6.28 (19.3 %)
200-250	3.27	7.07	6.52	16.86 (51.7 %)
250-300	0.67	0.92	4.24	5.83 (17.9 %)
Total	5.18	10.70	16.73	32.61
%	**15.9**	**32.8**	**51.3**	

The data in the sprawled cane indicates that significant damage was being done to the cane in the billeting process. Being a prototype machine under close scrutiny by the manufacturers, settings of the chop-throw mechanism could be assumed to be optimal. By comparison, commercial A7000 type harvesters typically operate at % sound billet levels of 40-50%. This indicates that significant damage is being done in the billeting process.

The data in the lodged cane is substantially worse than in the sprawled cane. This indicates substantial damage is being done in the gathering and feeding process. The fact that billet length distribution for both cane classes was similar indicates the gathering and feeding system was sufficiently aggressive to achieve reliable feed, but that the cane was damaged in the process.

APPENDIX 2

DATA USED IN MODELLING STUDIES

Densities of various canes measured at Bundaberg (MF R&D documents) used in calculating billet and top mass are given below:

Variety	Top	Middle	Bottom
Q111	0.8	1.0	1.04
Q108	0.86	1.07	1.10
Q87	0.87	1.02	1.08
CP44-101	0.74	1.06	1.08
Mean	0.82	1.04	1.07

Cane component dimensions used in calculating billet mass and surface area are also given below:

Large billet-

length	200 mm
nominal diameter	35 mm
nominal weight (@1.07 g/cc)	0.206 kg (F=2.02N)

Small billet-

length	200 mm
nominal diameter	15 mm
nominal weight (@0.82 g/cc)	0.029 kg (F=0.28N)

Large tops

length	200 mm
nominal diameter	22 mm
nominal weight (@0.65 g/cc)	0.049 kg (F=0.48N)

Small tops

length	200 mm
nominal diameter	13 mm
nominal weight (@0.65 g/cc)	0.017 kg (F=0.17)

Leaf

length	200 mm
nominal thickness	1 mm
nominal width	30 mm
nominal weight (@0.9 g/cc)	0.005 kg (F=0.05)

APPENDIX 3

DENSE PHASE MODEL OUTPUTS