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National Centre for Engineering in Agriculture
A Joint Venture of University of Southern Queensland, and Queensland Department of Natural Resources

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FINAL REPORT

Project NCA 001

DEVELOPMENT OF AN IMPROVED METHOD OF HARVESTER PERFORMANCE TESTING – IN ASSOCIATION WITH THE JET-CLEAN SYSTEM PROJECT

Chief Investigator	Associate Professor Harry Harris
Objectives	To automated the measurement of harvester performance
Final Report	Due 30/6/01
Status	PROJECT COMPLETE

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Acknowledgments
This project was funded by the Sugar Research and Development Corporation. The authors would like to formally aknowledge the support of Gary Sandell from BSES as well as Stuart McCarthy and Damina Spinaze from the NCEA for his help in field trials and the numerous harvester operators and field personnel who have helped with the project over time. Mr Simon Zillman was primarily responsible for initiating all the investigations discussed within the report and used the equipment developed extensively in other projects.

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ABSTRACT

In seeking to evaluate the performance of some advanced cleaning system concepts such as the NCEA Jet Clean System (NCA 006) and the NCEA Clean Flow Fan the NCEA became aware of the lack of objective automated harvester performance assessment systems. On this basis the research team set out to apply some greater level of automation and objectivity to the assessment of Extraneous Matter and Cane Loss during field experimentation. As a result of these investigations an automated billet sampler was built and trailed successfully, a trash sampling mechanism was commissioned but not adopted due to field difficulties, an improved acoustic cane loss monitor based on billet/fan-blade impact recognition was successfully commissioned and trailed and a multi purpose CANBUS based on board data management system developed in conjunction with a commercial yield monitoring product. All of these tools were used in the assessment of the NCEA Cleaning system research projects and the Cane Loss monitor will be subjected to extensive laboratory and field evaluation by the BSES in the 2002 season.

NON TECHNICAL SUMMARY

As this project represents only a subset of the work undertaken in NCA 006 the non-technical report presented as a final report to that project provides an appropriate summary of outcomes and activities.

1.0 BACKGROUND AND OBJECTIVES

This original Jet Clean Project has been transferred to NCA 006 and is due for completion in December 2000.

This project is being undertaken using carryover funding from the original Jet Clean Project.

The main aim of this work is to support the testing program being undertaken on the Jet Clean System in the 2000 and 2001 season.

A range of automated harvester performance technologies have been developed and trialed as a result of this work.

The final work to be undertaken by the project team was outlined in the last milestone report as follows:

- Implementation of the acoustic cane loss meter;

- Commissioning of an integrated yield/performance monitoring device for a cane harvester which incorporates the following data recording systems:
- Instanteous pour rate;
- GPS positional information;
- Fan speeds (Primary and Pressure);
- Fan Pressure; and
- Ground Speed.

2.0 METHODOLOGY AND RESULTS

2.1 IMPLEMENTATION OF AN ACOUSTIC CANE LOSS MONITOR

The status of this work is best outlined in the attached paper by McCarthy, Billinsley and Harris to be presented at the 2002 ASSCT conference.

In summary:

- A robust acoustic device for the measurement of billet impacts on fan blades has been designed for retrofitting to Case Harvesters;

- Data analysis and management software have been developed which utilises the outputs of the acoustic device to count "Billet Impacts"; and

- Rough field trials have been undertaken which indicate a correlation between expected cane loss measurements and acoustic device outputs.

This represents a potential revolution in the measurement of cane loss through conventional harvesters. A proposal to subject the device to intensive laboratory and field testing by BSES is currently under review by SRDC.

2.2 COMMISSIONING AN INTEGRATED YIELD AND PERFORMANCE MONITORING SYSTEM

The research team combined the commercial yield monitor developed by the NCEA and now commercialised through CNH along with additional sensor inputs from the cane loss monitor, multiple fan speed sensors and fan pressure data to provide a robust performance monitoring platform.

This was made possible by constructing a CANBUS style communication protocol throughout the system making it possible to continue adding on further sensor inputs.

The attached installation documentation provides a detailed update on this systems capacity.

3.0 DISCUSSION and ASSESSMENT OF LIKELY BENEFITS

The key outputs of the project were:

a) The research team provided the necessary technical mechatronic and software support to Mr Simon Zillman in completing Project NCA 006;

b) The Cane Loss Monitor developed within the project in conjunction with Mr Stuart McCarthy may become one of the most important harvester performance analysis tools available to the industry.

   The existing cane loss monitoring equipment is not well regarded because of accuracy, repeatability and reliability problems inherent in its design. Despite these problems the industry is critically interested in a device which can provide real time feed back to the operator on cane loss.

   Effective utilisation of such an instrument will allow continuous optimisation of fan speed with pour rate. Plans are already underway to link the sensor output via a closed loop control system with a fan speed controller. This type of integration will become necessary particularly with the potential adoption of new cleaning chamber designs and/or fans such as the NCEA Clean Flow Fan which have a much finer margin of error in relation to over extraction and cane loss.

c) The co-development with Satellog and CNH of a CANBUS data management platform within the commercially available Yield Monitor.

This means that any harvester fitted with a Satellog/CNH yield monitor can easily link additional sensor units into the system without the need for any hardware changes and only minimal software alterations.

This means that any Yield Monitor Equipped harvester can link the Cane Loss Monitor in automatically as well as any additional sensor inputs. We believe that this capability will be an essential part of the utilisaiton of the cane yield monitoring system in optimising field logistics and harvester utilisation parameters. Early indications are that harvesting contractors can se this type of data being extremely useful in maintaining a continuous log of harvester activity.

4.0 DESCRIPTION AND INTELLECTUAL PROPERTY

The Yield Monitoring equipment discussed above is the subject of a number of existing patents held by the NCEA and supported by CNH.

The NCEA has not chosen to patent the Cane Loss System given the nature of the device and the commercial opportunities available at this time.

If the SRDC wishes to go down this track we would need to halt publication of the attached ASSCT article.

5.0 TECHNOLOGY TRANSFER

The Cane Loss System has been trialled by BSES this season and they will be continuing laboratory and field trials in the 2002 season. CNH have been aware of the trials and interested in making the device a OEM installation if trial work is successful.

The fact that the Yield Monitor has been developed by Satellog on a CANBUS interface will allow other researchers and growers to utilise the basic platform for data capture and management on the harvester in future.

6.0 CONFIDENTIALITY

No aspect of this report is considered confidential as far as the NCEA is concerned.

7.0 TECHNICAL SUMMARY

The documents attached within the report appendices provide a detailed desription of the technical aspects of the key components of the project.

7.1 ADVANCED CANE LOSS MONITORINGS.

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7.2 CANE YIELD MONITOR SPECIFICATIONS AND INSTALLATION MANUAL

8.0 RECOMMENDATIONS

Again it must be stated that this report represents a subset of the activities essentially carried out within NCA 006. The key recommendations of the overall project are set out within its final report.

Specific recommendations associated with this portion of the work are as follows:

- The Assessment of Harvester Performance is still a very vexed issue with little concensus on the best approach and very few objective tools available to the researcher or commercial producer – on this basis the industry needs to continue to debate this issue;

- The Advance Cane Loss Monitoring System developed within this project should be subjected to further independent assessment by BSES in the 2002 year;

- The Satellog/CNH Cane Yield Monitor represents an industry standard data collection and management device which can be used researchers and producers generally as a harvester performance enhancement tool. The industry should support this device by ensuring that further sensor developments is compatible with its data management architecture. As this device gets used more widely within the industry the developers will continue to improve its performance, reliability and capacity thus benefiting all within the industry.

9.0 APPENDICES

Appendix 1: ADVANCED CANE LOSS MONITORINGS.

ADVANCED CANE LOSS MONITORING

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Keywords

billet, cane loss, extractor fan, acoustic transducer, impact

Abstract

The loss of billets during the harvesting process is estimated to cost the industry fifty million dollars per year. Careful control of the extractor fan speed is required to achieve a balance between excessive trash in the cane supply, and the ejection of cane billets.

To achieve this control, cane loss must be measured in real time. This can be achieved by detecting the vibrations produced by billet impacts on the blades of the primary extractor fan. This approach makes use of an acoustic transducer coupled from the moving blades to the stationary frame. These signals are collected and analysed on-line to give a measurement of cane loss.

Field trials of this detection process have been successfully conducted on a cane harvester in Mackay. Samples of the raw and of the conditioned recorded signals are presented here, and the relationship between fan speed and cane loss is demonstrated.

Introduction

Loss of billets through the extractor fan is estimated to cost the sugar industry fifty million dollars per year.

The objective of the sugar cane harvester is to provide 100% clean cane to the sugar mill for refining. The efficiency of the harvester's cleaning system is gauged by how satisfactorily cane billets are separated from trash during the harvesting process. The fan speed requires adjustment to obtain a compromise between excessive residual trash in the harvest, and a substantial quantity of cane being lost.

Cane loss caused by the extractor fan of a cane harvester can currently be measured by the traditional “blue-tarp” method or the “mass-balance” cane loss method. Both of these techniques only provide information after the harvest has been completed.

Existing cane loss monitors (Dick and Grevis-James, 1992) have relied on detection of the impact of ejected cane billets on the hood of the primary extractor fan. However many lost billets fail to hit this hood rendering this method unreliable. Furthermore, plastic hoods have largely superseded metal shrouds and this method of impact detection has been made more difficult.

The method presented here involves detecting the impact of cane billets on the blades of the primary extractor fan. This method is potentially superior to any existing cane loss monitoring technique because examination of the trash blanket reveals that almost all billets lost through the primary extractor have struck the fan’s blades and have either been damaged or disintegrated. Practically no billets appear to pass undamaged through the fan and strike only the hood.

The objective of this project is to develop a monitoring device that can continuously detect and provide a measure of the number of billets passing through the primary extractor fan. It is envisaged that this device will provide relevant information to the harvester operator in “real-time” so that the primary extractor fan speed can be adjusted to minimise loss.

Method

Primary extractor fan blades are held in position on the hub flange by four bolts. When cleaning, the trash and some cane billets exit the harvester via the extractor fan chamber and a vast majority of this material strikes the fan blades. This can be appreciated by visually inspecting the wear on the blades, and the damage caused to the discarded billets in the trash blanket.

In this application the fan blades become the sensors for cane billets extracted. When a billet hits the fan blade there is a differential movement between the hub flange and the blade. An acoustic device that is embedded in the flange detects this tiny vibration. It is simply a pick-off similar to that of an electric guitar, and it provides the electrical signal that correlates to a mechanical vibration event.

This system has evolved from an early prototype whose objective was to prove the initial data collection concept (McCarthy et al., 2000).

Figure 1: Acoustic transducer in extractor fan hub

Figure 1 shows the acoustic transducer that has been mounted into one of the three blade mounts of a standard fan hub. This novel transducer requires no external power source, and it generates an electrical signal from the impact vibration from the trash and billets on the fan blades. Trash impacts are not as coherent and hence not as identifiable as the more abrupt impacts, such as that of a billet.

The acoustic transducer was inserted into the blade mount so as not to hamper installation of new blades, as well as to make the system as robust as possible considering the abrasiveness of the extraction chamber environment. The leads carrying the signal generated by the transducer are fed internally through the hub, also for robustness.

In order to transfer the signal across the gap between the rotating fan and the stationary frame, a passively induced rotating transformer was installed. Previous monitors (Dick and Grevis-James, 1992) have used piezoelectric devices to detect vibration. These devices are not suitable in this application because of their very high output impedance, which is not suitable to drive a transformer of this type.

The transformer is made of two halves, and is installed inside the primary extractor fan drive shaft. The terminals from the transducer signal are coupled to the transformer primary coil that is clamped to the internal spline shaft of the drive mechanism, and hence forms the rotating member of the transformer. The transformer secondary winding is stationary, and acts as an inductive pick-off from the primary coil. The leads are then fed out of the top of the fan motor, and returned to the cabin of the harvester.

In the past (McCarthy et al., 2000) the data returned from the transducer mounted in the fan hub has been collected as raw audio files. By playing back the collected data, it was possible to visually and aurally discriminate billet impacts from trash and ambient noise. However, a suitable signal-conditioning unit needed to be implemented to give a raw "billet-count" output to interface with existing data collection hardware.

Signal Conditioning

From earlier field trials (McCarthy et al., 2000), various signal processing algorithms were attempted. Many algorithms, both digital and analogue, have been attempted and comparisons were made for the performance in real-time. The ability of any conditioning system to perform well on the correct time sequence is very important. For optimum performance, a high level of discrimination is required between billets and trash on the large amount of data returned in real-time.

Another major consideration was the interface between the improved system and the data logging hardware. For simplicity, and also so that the data can be sampled at a much lower frequency, it was decided that merely a count of impacts was required for data collection. An analogue signal-conditioning box was designed to suit, and a sample of the raw and conditioned data is illustrated below.

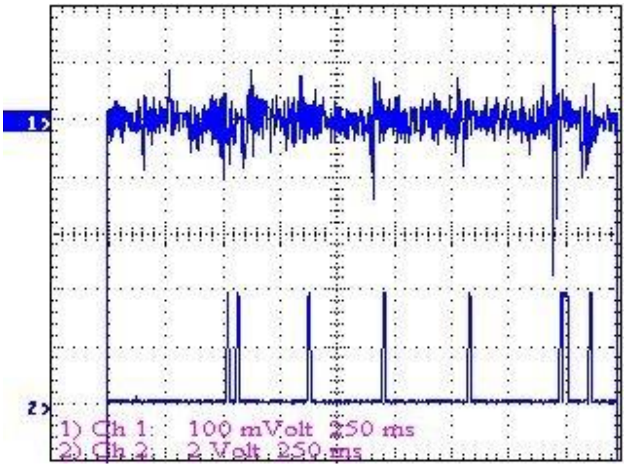


Figure 2: Raw data (above) and conditioned data ready for data collection

Figure 2 represents 2.5 seconds of data recorded during green cane harvesting. The upper trace represents the raw data that is a noisy signal that consists primarily of ambient noise, and the random intense events that are attributed to being billet impacts, and this can be verified aurally. The lower trace is the conditioned data that discriminates the billets from noise and gives a logic output that can be recorded on the pre-existing data logger.

It is important to note that the developed system is a “relative” system because of the large number of variables involved in the harvesting process. The acoustic transducer produces a signal representing events occurring on the blades of the fan, and variables such as billet length and diameter that change both within a field as well as between fields will affect the level signal levels.

Results and Discussion

The system described earlier was installed on a BSES harvester in the Mackay district. The trials were conducted over a few days, and once the system was calibrated some data was collected.

Figure 3 indicates the correlation between cane loss and primary extractor fan speed identified by the advanced cane loss monitor. For this trial, the fan speed was kept low for a majority of the time, and it is only at the initial period that the speed was increased (twice). It is clear that once the fan speed is increased, the cane loss also increased. These results were verified with blue-tarp tests that were conducted on the two fan speeds.

From the figure it can be seen that the system indicates only the extremes of cane loss, i.e. no loss or significant loss. It is assumed that these extremities occurred as a result of an over-sensitive signal-conditioning unit, as well as perhaps an inaccurate calibration of the unit in the field. It is anticipated that future trials will not have this same problem.

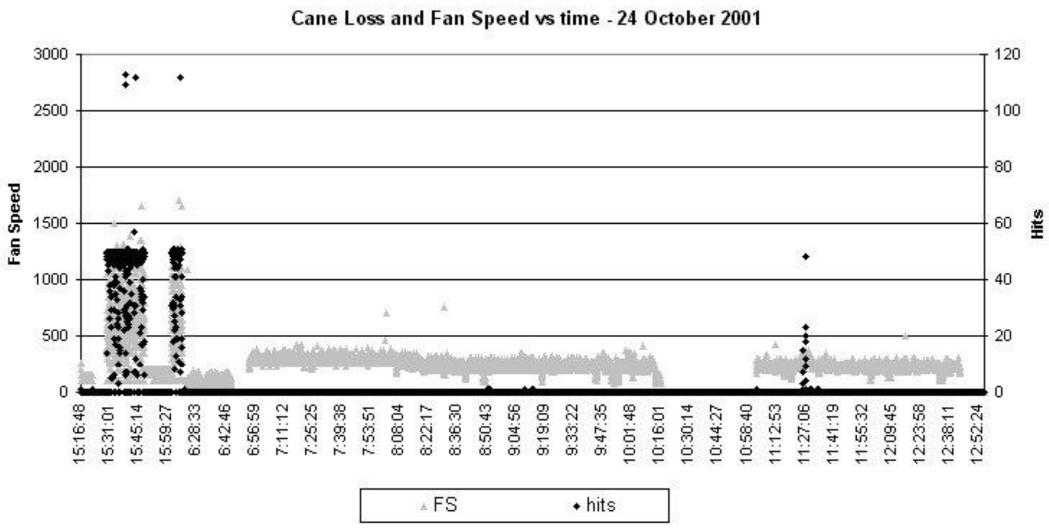


Figure 3: Fan speed and estimated cane loss versus time

At this stage the system is purely a qualitative measure of cane loss, but it is hoped with more development of the signal conditioning hardware that the values recorded will be more absolute.

Conclusions

An improved method of assessing cane loss has been described in which cane billet impacts on the primary extractor fan blades are detected by an audio transducer. The signals from this transducer are coupled from the moving blades to the stationary frame, where these signals are collected.

Field trials of this detection process have been conducted with BSES on a cane harvester in Bundaberg. A sample of the raw and processed signals has been presented here, and the correlation between fan speed and cane loss has been established.

The methods described here show promise of providing an accurate real time assessment of cane loss.

Acknowledgments

The authors are grateful for the efforts of Damian Spinaze and the cooperation of BSES Mackay. The work was undertaken with the financial support of the Sugar Research and Development Corporation.

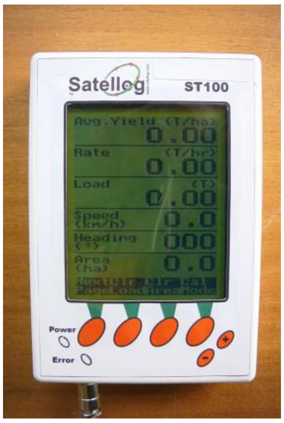
References

Dick, R.G. and Grevis-James, I.W. (1992). The electronic cane loss monitor. Proceedings of the Australian Society of Sugar Cane Technologists, 14: 150-155.

McCarthy, S.G., Billingsley, J. and Harris, H. (2000). Listening for Cane Loss. Paper presented at the 7th Annual Conference on Mechatronics and Machine Vision in Practice (M^2VIP), September 19-21 2000, Hervey Bay, Queensland, Australia.

Appendix 2: YIELD MONITOR

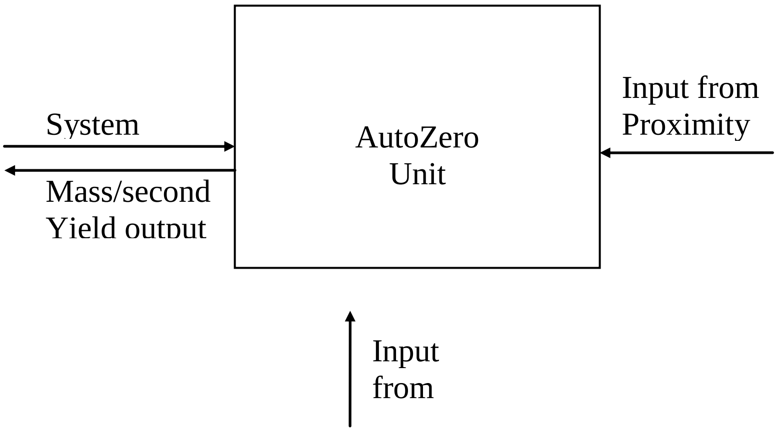
SATELLOG / AUSTOFT
SUGAR CANE YIELD MONITOR



Display developed by Satellog,
cane yield measurement system developed by NCEA in conjunction with Pivot Ltd, measurement system developed in conjunction with and sold and serviced by CNH Austoft
Specifications in this document are subject to change without notice

1. Overview

The NCEA Auto-zeroing Sugar Cane Conveyor Weighpad consists of a load cell weighing platform (Weighpad), an inductive proximity sensor (Proximity Sensor), and an electronic measurement and calibration unit (AutoZero Unit).
The Weighpad is mounted in the floor of the conveyor near the top where the cane is expelled. As cane passes over the Weighpad this weight is measured and electronically processed.
The Proximity Sensor is mounted on the side of the conveyor just after the Weighpad and detects each of the conveyor flights as it passes the sensor.
The AutoZero Unit processes the signals from both the Weighpad and the Proximity Sensor to determine the mass per second of cane flowing through the conveyor.
The output from the AutoZero Unit can be fed into a commercial yield monitoring device (such as a MicroTrak Yield Monitor) for recording the ongoing cane yield information.



2. Theory of Operation

The Weighpad is constantly measuring the weight resting upon it. The AutoZero Unit accumulates these readings for the duration of a single flight passing the Weighpad.
This accumulated mass is then divided by the time it took for the flight to pass the Weighpad, and the result is the mass per second of cane flowing through the conveyor.
The Proximity Sensor is used to determine when each flight passes the Weighpad, and thereby calculate the flight duration.
Due to the possibility of mud and debris building up on the Weighpad and contributing to a false reading, the system provides an autocalibration mechanism.
Autocalibration is achieved by having one of the conveyor flights removed during installation. This creates a gap in the cane so that there is a period when the no-load reading of the Weighpad can be measured, which is subsequently used as an offset to ensure the mass readings remain accurate.

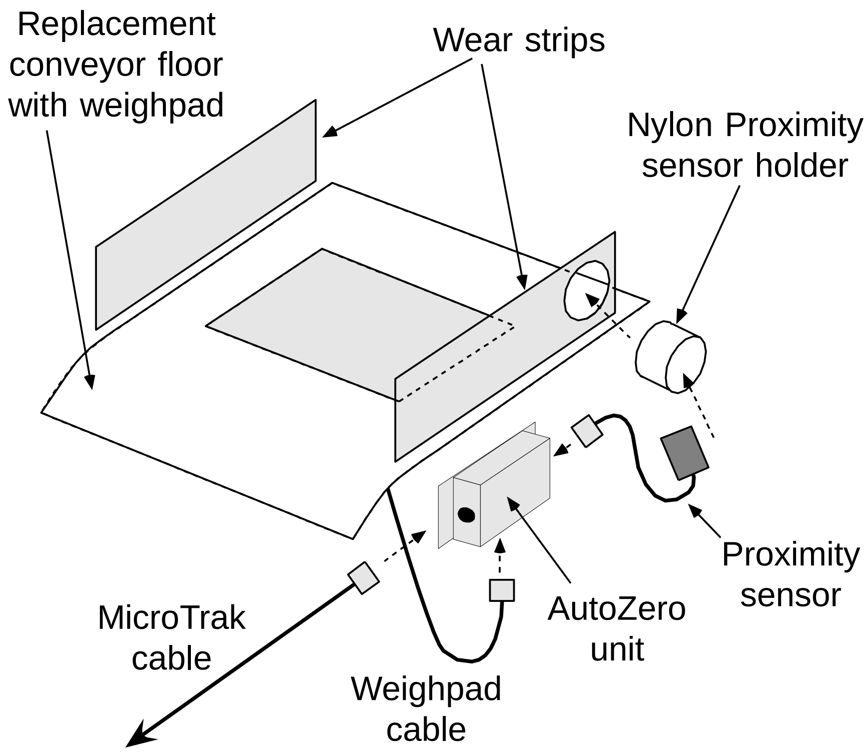
The Proximity Sensor is also used to determine which flight is missing so the measurement unit knows when to take the no-load reading.

The AutoZero Unit also contains a combined inclinometer and accelerometer which is used to compensate for the adjustable incline of the conveyor, and compensate for moderate bouncing of the conveyor and vehicle which may otherwise affect the measured mass reading.

3. Installation

3.1 Parts Supplied

	Item	Quantity Required	Quantity Supplied	Quantity Received
1	AutoZero Unit	1		
2	Proximity Sensor	1		
3	AutoZero to MicroTrak Yield Monitor Cable	1		
4	Weighpad elevator floor assembly complete with Weighpad to AutoZero cable	1		
5	Nylon Proximity Sensor holder	1		
6	Wear Strip	1		
7	Wear Strip with hole for nylon Proximity Sensor holder	1		

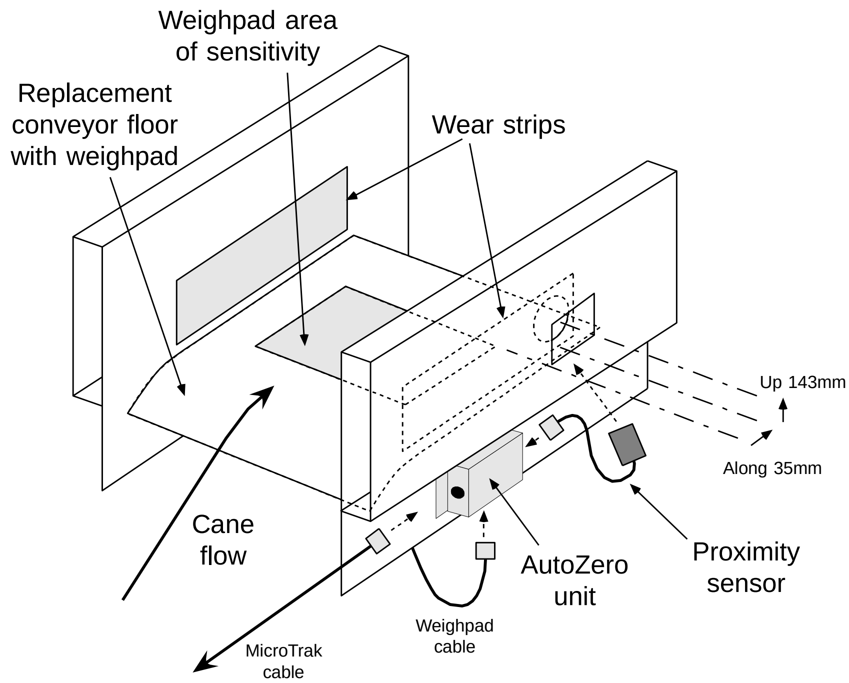


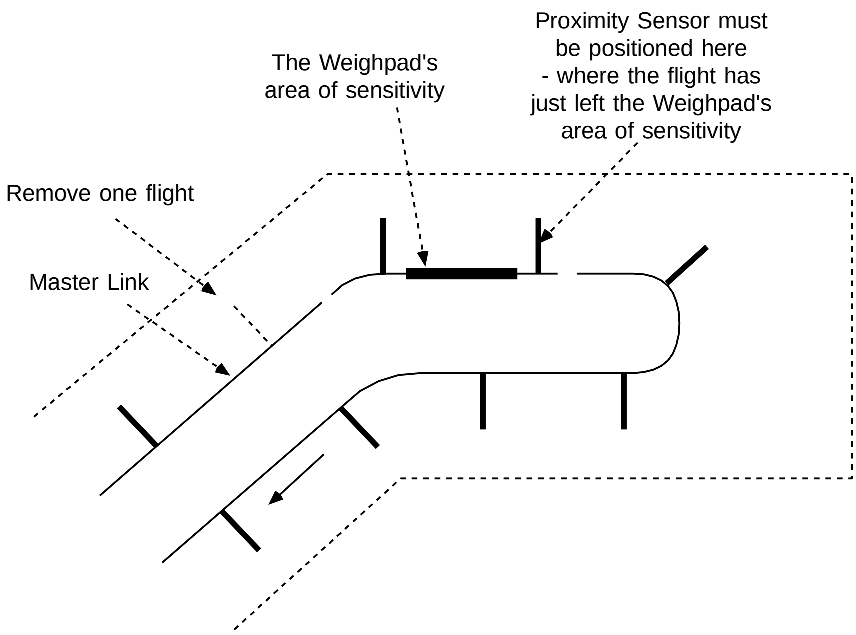
3.2 The Weighpad

The Weighpad needs to be mounted at the top of the conveyor as shown, replacing the standard upper section of elevator floor.

Be careful when routing the wiring from the Weighpad to the AutoZero unit to ensure that there is no possibility of mud or a stray cane billet catching the cable and damaging it.

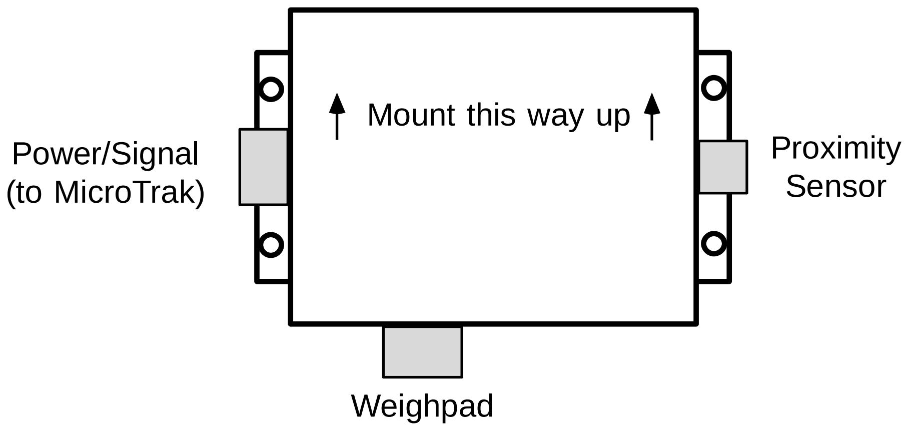
When selecting the elevator flight to remove, it is best to remove the flight nearest the master link. This means that if links are removed in future to tighten the conveyor chains then only the large gap (where the flight is missing) will be affected.

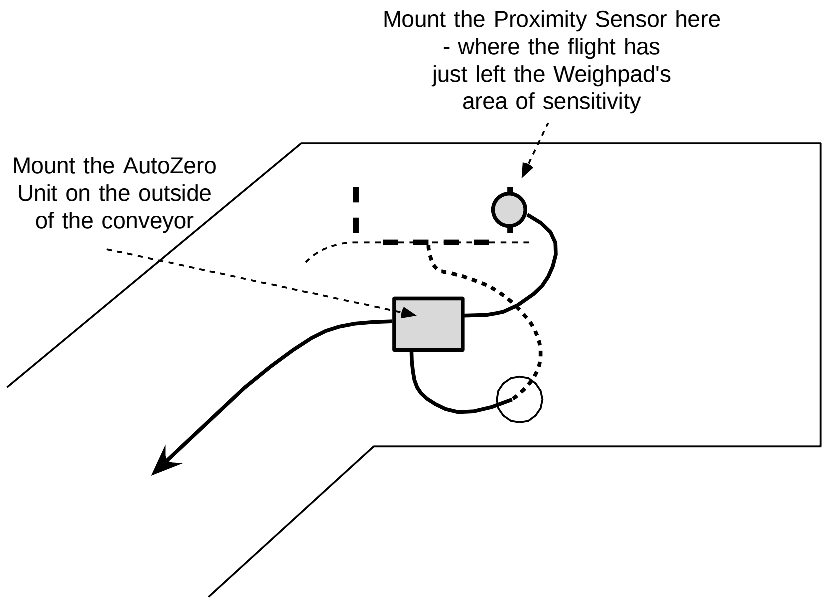

Weighpad area
of sensitivity
Replacement
conveyor floor
with weighpad
Wear strips
Up 143mm
Along 35mm
Cane
flow
AutoZero
unit
Proximity
sensor
Weighpad
cable
MicroTrak
cable


Proximity Sensor must
be positioned here
- where the flight has
just left the Weighpad's
area of sensitivity
The Weighpad's
area of sensitivity
Remove one flight
Master Link

3.3 The AutoZero Unit

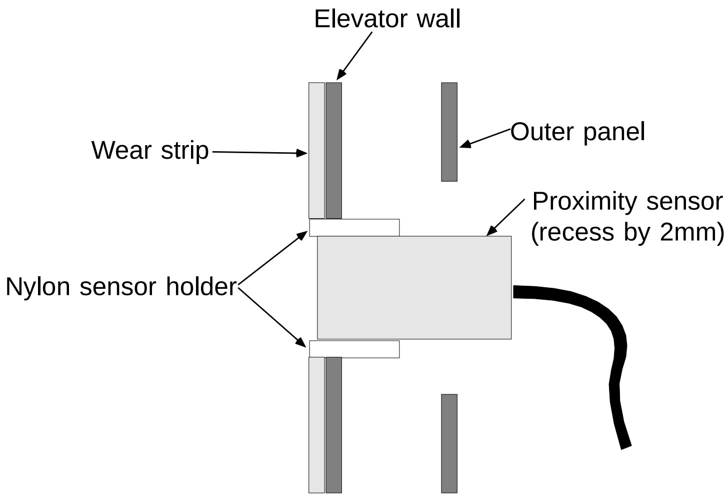
The AutoZero unit needs to be mounted as shown, with the Proximity Sensor connector facing to the right, the power and signal cable facing to the left, and the Weighpad connector facing down.
It is important that the unit be mounted like this since it contains an inclinometer which is orientation dependant.





3.4 The Proximity Sensor

The Proximity Sensor needs to be mounted so that it will detect each flight when it is about 35 mm past the edge of the Weighpad's area of sensitivity. Mount the sensor so that it is 143mm above the floor of the conveyor, which will ensure that the flights are correctly detected.
Two additional wear strips need to be installed in the top section of the elevator. The left hand side wear strip has a hole cut in it to hold the nylon proximity sensor holder. Two matching holes need to be cut in the elevator wall to install the proximity sensor. The first, a rectangular hole is in the outer paneling of the elevator and needs to be sufficiently large enough to allow access to the inner elevator wall. The second hole needs to be 50mm diameter. The location of the holes can be determined from the inside of the elevator after the installation of the wear strips and while the top elevator floor section is removed.
When the proximity sensor is mounted into the nylon holder, recess it by approximately 2mm and the nylon holder should not protrude into the elevator past the new wear strips.



4. Wiring (for diagnostics)

WeighPad Cable

	Box Internal			Exterior Cable			Load Cell Cable	
	Molex 5 pin Female Plug	individual	MilSpec 5 pin Female Socket	MilSpec 5 pin Male Plug	4 core + shield (1.5 metres)	W-Pak 5 pin Male Socket	W-Pak 5 pin Female Plug	4 core + shield (as supplied)
Signal	Pin	Wire Colour	Pin	Pin	Wire Colour	Pin	Pin	Wire Colour
+ Supply	4	Red	A	A	Red	A	A	Red
- Supply	1	Blue	B	B	Black	B	B	Blue
+ Signal	3	Green	C	C	Green	C	C	Green
- Signal	2	White	D	D	White	D	D	White
Shield	5	Black	E	E	Shield	E	E	Shield

Proximity Sensor Cable

	Box Internal			Proximity Sensor Cable	
	Molex 4 pin Female Plug	individual	MilSpec 3 pin Female Socket	MilSpec 3 pin Male Plug	3 core (as supplied)
Signal	Pin	Wire Colour	Pin	Pin	Wire Colour
+12V	1	Red	A	A	Brown
GND	3	Black	B	B	Blue
Signal	2	Yellow	C	C	Black

Power & Signal Return Cable (3 wire for MicroTrak systems)

	Box Internal			Exterior Cable		
	Molex 5 pin Female Plug	individual	MilSpec 6 pin Male Socket	MilSpec 6 pin Female Plug	3 core + shield (14 metres)	W-Pak 3 pin Male Socket
Signal	Pin	Wire Colour	Pin	Pin	Wire Colour	Pin
+12V	1	Red	A	A	Red	B
GND	2	Black	B	B	Green	C
				B	Shield	
Frequency	3	Yellow	C	C	Blue	A
Serial Rx	4	Green	D	D		
Serial Tx	5	Blue	E	E		
			F	F		
Load Test Signal Voltage	8					

Power & Signal Return Cable (5 wire for serial PC systems)

	Box Internal			Exterior Cable		
	Molex 8 pin Female Plug	individual	MilSpec 6 pin Male Socket	MilSpec 6 pin Female Plug	3 core + shield (14 metres)	MilSpec 6 pin Male Plug
Signal	Pin	Wire Colour	Pin	Pin	Wire Colour	Pin
+12V	1	Red	A	A	Red	A
GND	2	Black	B	B	Black	B
				B	Shield	B
Frequency	3	Yellow	C	C	Yellow	C
Serial	4	Green	D	D	Green	D

	Box Internal			Exterior Cable		
	Molex 8 pin Female Plug	individual	MilSpec 6 pin Male Socket	MilSpec 6 pin Female Plug	3 core + shield (14 metres)	MilSpec 6 pin Male Plug
Rx						
Serial Tx	5	Blue	E	E	Blue	E
			F	F		
Load Test Signal Voltage	8					

5. Compliance

While efforts have been made to minimise EMC effects, the NCEA Auto-zeroing Cane Conveyor Weighpad has not been tested to comply with EMC regulations at this time.