CONTINUOUS WEIGHING OF BAGASSE BY NUCLEAR WEIGHER

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ABSTRACT

A nuclear continuous bagasse weigher was installed at Felixton Sugar Mill towards the end of the 1973/74 crushing season and accuracy checks were performed on the weigher using an assized weighbridge as the reference standard. The average error was found to be 0,2% of full scale whilst the individual test errors were all well within 2% of full scale.

Introduction

Nuclear weighers have found applications in the South African sugar industry with varying degrees of success. Their use in the continuous weighing of bagasse has not previously achieved high accuracy. The reasons for this are many and include the use of machines not suited to the weighing of low density materials such as bagasse.

An Ohmart nuclear weigher, supplied by S.A. Philips and containing an Americium radiation source was installed on a belt conveyor at Felixton sugar mill towards the end of the 1973/74 crushing season and was calibrated and ran for approximately two months. A series of 27 accuracy check tests were conducted over a period of a month and the results of these tests are reported herein.

Principles of nuclear weighing

Continuous weighing of low density materials

To the process engineer the weighing of material in motion on a conveyor belt has always had great attraction but this has always been attended by problems originating from the mechanical operation of the belt. It is necessary with a conventional belt weigher to maintain a very high standard of condition of the belt. In particular, the belt idlers involved with the weigher and for a fair distance on either side of the weighing position require to be aligned in height and profile to a high degree of accuracy. In addition, where a steep troughing angle is employed on the conveyor (more than 20°), the results obtainable with a force sensing weigher are of severely restricted accuracy because of the high transverse stiffness of such a belt.

In the case of low-density materials such as bagasse, the problems with conventional weighing equipment are exceptionally severe, since even with the steepest obtainable troughing angle on the conveyor belt, the mass per unit run of the conveyor is still low in comparison with the mass of the belt. This leads (in conjunction with the already mentioned belt stiffness problems associated with a deeply-troughed belt), to unacceptably poor accuracy figures for a conventional belt weigher. The problem is very much reduced wito the non-contact type of weighing principle used with a nuclear radiation belt weigher.

A properly-applied and calibrated nuclear weigher is capable of giving accuracies of better than 0,5% of full scale value.

Physical principle of operation

It is found that the absorption of gamma radiation by materials follows the "Beer-Lambert Law". This can be expressed in the following form:

$I = I_o \exp(-a\rho x)$
where I = actual radiation intensity
I_o = radiation intensity without material
a = mass absorption coefficient
ρ = density
x = thickness of absorbing material

The mass absorption coefficient in the above equation is found to be essentially independent of the nature of the material and therefore the absorption of radiation is related to the mass of material placed in the radiation path. This means that a mass determination system can be based on measurement of the absorption.

Construction of the Ohmart belt weigher

A sketch of the layout of a nuclear weighing system for a conveyor belt is shown in Fig. 1. The source of radiation is enclosed in a sealed capsule mounted on the upper arm of the C-frame and the lower arm of the C-frame, which is placed underneath the belt, houses a radiation detector tube. The detector produces an electrical signal which is proportional to the total radiation impinging on it. This signal is passed to an amplifier and then to a computing unit which establishes the amount of material on the conveyor belt.

It will be apparent from the physical principles involved that the output signal from the radiation detector contains no information on the speed at which the belt is carrying material past the detecting unit so to account for this factor one of two approaches must be taken. The first approach is to regard the belt speed as being constant and this method is highly successful in the case where the belt speed does not vary appreciably. If the belt speed is liable to variation it becomes

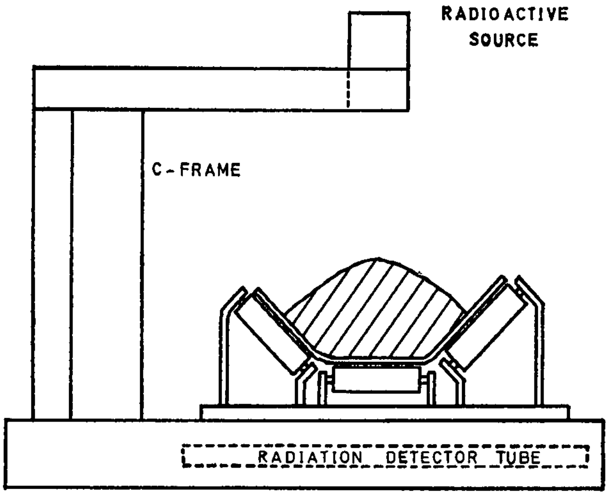

FIGURE 1 The nuclear weigher C-frame layout.

necessary to measure the exact speed and include this in the calculation of the flow rate. Belt speed is readily measured to the required degree of accuracy by means of a DC tacho-generator which is driven by the conveyor belt. To avoid problems of belt slippage it is necessary for the tacho-generator to be driven from an idler pulley on the belt and for this purpose the tail pulley is very frequently the most satisfactory point. A chain or gear drive is generally used to allow the tacho-generator to be run at the most suitable speed. The output of the tacho-generator is introduced into the computing unit at an appropriate point to make the necessary allowance for variations in belt speed.

The output of the computing unit is used to actuate an electrical indicator which can be calibrated in terms of mass flow rate and also feeds a signal into an integrating unit which totalises in tons the material which has passed over the belt.

The mathematical functions implemented in the computing unit include the following:

(*a*) Suppression of the standing signal due to the radiation level with no material on the belt.

(*b*) Correction for the implicit non-linearity of the Beer-Lambert equation. This is an exponential function and consequently must be corrected by a non-linear curve-shaping technique.

(*c*) Correction for the fact that the geometrical configuration of source and load cause a non-linear deviation from the Beer-Lambert Law. This correction can in fact be combined with that outlined in section (*b*) above and in fact only a single "lineariser" unit is employed. The lineariser uses a series of 6 straight-line segments to represent any arbitrary curve.

(*d*) Multiplication of the computed load figure by the belt speed value to give an output in terms of mass rate of flow.

The use of modern solid-state circuitry has increased the reliability and has facilitated rapid fault-finding with the use of plug-in printed circuitry. Experience with this type of equipment has shown that when electrical faulting does occur, most of the difficulties are encountered in the first few days after commissioning and thereafter reliability is usually of a very high standard.

Choice of the radiation source

The radio-isotope which is used in an installation of this kind must satisfy a number of conditions. These are:

(*a*) A suitable energy of emitted radiation. This is a means of expressing the penetrating power of the radiation which must be correlated with the thickness of the material to be measured and its density.

(*b*) An acceptably long half-life. If the half-life of the isotope is too short, then a re-standardisation of the weigher will be required at excessively frequent intervals in order to maintain the accuracy of measurement.

(*c*) The isotope must be readily obtainable at a reasonable price.

For nuclear belt weighing three isotopes are in common use. For thick sections of heavy materials the high penetration obtained with radiation from Cobalt-60 is used. For most applications where moderate thicknesses of moderately heavy materials are involved the isotope Caesium-137 is used, whilst for light material such as bagasse the low-energy radiation from Americium-241 is necessary to obtain satisfactory measurement results.

For all of these isotopes the half-life is sufficiently long that re-standardisation of the weigher only requires to be done at relatively infrequent intervals. Actual half-life values are:

Cobalt-60	5,3 years
Caesium-137	30 years
Americium-241	458 years

The isotope is sintered into a ceramic pellet and further enclosed in a number of layers of inert material and this structure ensures that the radioactive material is not allowed to leak out and become a contamination hazard. The radiation itself produces no contamination of the product and this type of gauging is widely accepted in different parts of the food industry.

The radiation detector

A number of radiation detector systems are used in gamma ray gauging systems. Many of these involve an installation with high electrical potentials on the detector and possibly high frequency cabling from the detector to the electronic unit. A feature of the Ohmart equipment is the use of a special, patented, low-voltage ionisation chamber detector which involves the use of only low-frequency and low-voltage cabling. Consequently the electronic unit can be mounted at a considerable distance from the conveyor belt, thereby facilitating maintenance and calibration. A special multi-core electrical cable must be run from the C-frame to the instrument cabinet which may be sited up to 300 metres away.

Installation

A schematic diagram of the plant layout at Felixton is shown in Fig. 2. The nuclear weigher was placed on the second belt conveyor, after the transfer point, in order to smooth some of the fluctuations in the profile of the material which were observed on the first belt conveyor during normal operations. Considerations of belt width, belt loading and speed were also taken into account.

The mechanical installation of the weigher was simple, involving only the mounting of the C-frame on the belt conveyor support structure. The computing unit and weight totaliser were housed in an adjacent instrument display room.

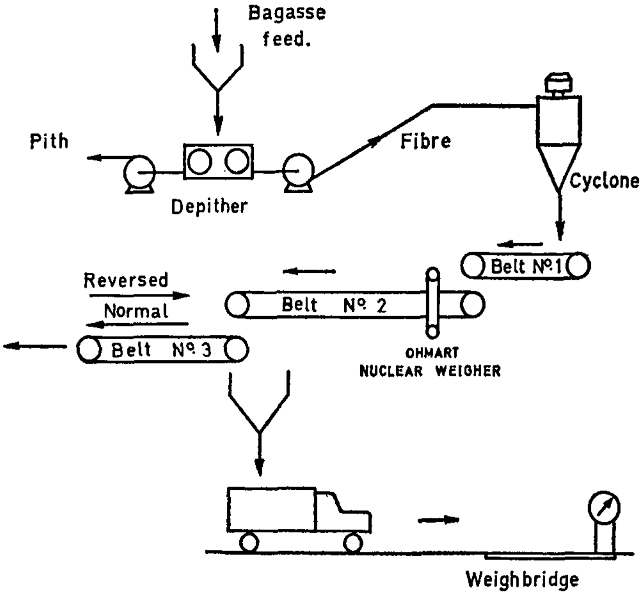

FIGURE 2 Schematic plant layout.

Calibration

Calibration involves setting the instrument zero and setting the computing unit to linearise the radiation detector output.

Physically this is done on a static, empty belt. After adjusting the zero, a load of actual process material is placed on the belt between the arms of the C-frame. The material is placed over a length of belt between 0,3 and 0,6 m and profiled in cross-section to match the profile of the material under normal operation. The amount of material placed on the belt is calculated to be equivalent to the weight per unit belt length under full load conditions. The computing unit is then adjusted to give a reading of 100% of full scale and the procedure is repeated using belt loadings corresponding to a series of lower belt loadings ranging between 0% and 100% of full scale.

A final adjustment to the zero is made under dynamic conditions by running the conveyor for several revolutions of the belt and observing the integrated reading for a complete number of revolutions. For this purpose the counting unit is capable of integrating negative and positive deviations and the zero is adjusted to give a net integrated total of zero. The positive and negative deviations are due to fluctuations in belt thickness including the belt joint.

Calibration checking

For subsequent calibration checking it is simpler to check the instrument zero and a single standard load at approximately 80% of full scale. This is achieved by using a steel or light alloy plate of thickness chosen to provide this equivalent absorption when placed in a standard position between the arms of the C-frame with the belt running empty.

A standard equivalent absorption plate is selected and the actual reading corresponding to the plate is found immediately after the initial calibration of the instrument. This reading is recorded for reference purposes in subsequent calibration checks. If the plate reading is subsequently found to be in error, the instrument must be re-standardised, a simple operation which occupies less than 15 minutes.

The frequency of calibration checking should be determined experimentally when the weigher has been installed. It will generally be found that a check twice a year will be sufficient.

Application in the sugar industry

In the sugar mill context, calibration and calibration checking presents no difficulties with regard to the requirement of an empty belt for the purpose. The weekend shut-down periods provide the opportunity, and calibration checks could be timed to be performed at start-up or shut-down when cane is not being processed.

For calibration checking on the run, it is necessary to provide a material by-pass around the weigher.

Weighing accuracy

Test procedure

The accuracy of the nuclear weigher was checked on a relative basis using an assized weighbridge as the reference. Figure 2 serves to illustrate the schematic layout of the relevant plant at Felixton.

Bagasse fibre was separated from whole bagasse in the depither and passed through the system to storage. During each test period, the full stream of bagasse fibre was diverted into a trailer where it was collected and subsequently weighed on the weighbridge. The weight of material passing the nuclear weigher during the same test period was then compared with the weighbridge value.

In detail, the test procedure involved stopping the bagasse feed and conveyor belt No. 1 (see Fig. 2), in order to check the nuclear weigher zero with conveyor belt No. 2 running and to establish the tare reading on the instrument's weight integrator. Conveyor belt No. 3 was then reversed in its direction of travel.

Conveyor belt No. 1 and the bagasse feed were then restarted and the test period commenced when the first material reached the nuclear weigher. When the collecting trailer was nearly full, the bagasse feed was again stopped and the test period ended when the last material passed the nuclear weigher. The trailer was then driven to the weighbridge and weighed immediately. Spillage of bagasse during the tests was negligible.

Weighbridge accuracy

The weighbridge used as a reference standard was an Avery 100-ton rail-weighbridge. The chart range was 20 tons in 50 kg divisions with printing to the nearest 50 kg. The assized tolerance allowance on the weighbridge is ± 0,625 divisions or approximately ± 31 kg.

In order to improve the accuracy of the check weighing, the printing facility was not used but instead, the weight-indicating pointer was read directly to the nearest 10 kg. This eliminated rounding up and down errors which would otherwise have been introduced by the printing device.

The precision of the weighbridge was determined by repeated checks of the tare weight of the collecting trailer. These checks were conducted by physically loading and unloading the trailer on to the weighbridge on a number of different occasions. The precision obtained was excellent and the accuracy of repeat weighings was within the accuracy of reading the indicated weight on the weighbridge.

Effect of bagasse moisture loss

The loss of moisture from the bagasse fibre between the position of the nuclear weigher and the weighbridge was not investigated thoroughly. However, a trailer load of moist bagasse was weighed once and then again after an hour and the weight loss amounted to 1 per cent of the load.

It would not be correct to assume that the losses during the individual test periods were proportionally lower since the physical circumstances of evaporation losses on the conveyor belt and from the trailer are not comparable. No corrections, therefore, have been made for moisture losses during the test periods.

Test results and discussion

The results obtained during a series of 27 tests over a period of a month at the end of the 1973/74 season are shown in Tables 1 and 2. The results have also been expressed graphically in Fig. 3.

The agreement between the nuclear weigher and the weighbridge was very good as can be seen from Fig. 3. Statistical analysis of the data shows a high degree of correlation (correlation coefficient = 0,9979 with t value of 77,7). Statistically the slope and intercept of the fitted line are not significantly different from unity and zero respectively.

Maintenance of a consistent profile of material on the conveyor belt is usually a pre-requisite for accuracy with nuclear weighers. The selection of a suitable installation site at Felixton was strongly influenced by this consideration. However, due to low milling rates at the end of the crushing season, it was impossible to maintain steady flow conditions throughout each test period. In fact, during some of the tests the belt loading fell to zero for short periods and this could be expected to have had an adverse effect on the Ohmart weigher readings.

TABLE 1

Test data

Test No.	Test duration S	Test supervised by	Test weight		Belt loading	
			Ohmart tons	Weighbridge tons	kg/m	% full scale
1	313	S.A. Philips	3,13	3,10	5,49	71
2	346	S.A. Philips	3,15	3,20	5,13	67
3	282	S.A. Philips	2,84	2,80	5,51	67
4	600	Felixton staff	2,25	2,25	2,08	27
5	600	Felixton staff	4,02	4,00	3,70	48
6	600	Felixton staff	3,30	3,37	3,12	40
7	660	Felixton staff	3,38	3,42	2,87	37
8	342	Felixton staff	3,12	3,05	4,95	64
9	343	Felixton staff	3,07	3,10	5,01	65
10	312	Felixton staff	3,02	3,00	5,33	69
11	355	Felixton staff	3,26	3,30	5,15	67
12	354	Felixton staff	2,60	2,65	4,15	54
13	340	Felixton staff	3,13	3,05	4,97	65
14	355	Felixton staff	2,99	3,00	4,69	61
15	407	S.A. Philips	2,97	2,95	4,02	52
16	469	S.A. Philips	3,05	3,06	3,62	47
17	466	S.A. Philips	3,23	3,12	3,71	48
18	466	S.A. Philips	3,41	3,38	4,02	52
19	468	S.A. Philips	3,43	3,33	3,95	51
20	449	S.A. Philips	3,18	3,12	3,85	50
21	461	S.A. Philips	2,85	2,86	3,44	45
22	480	S.A. Philips	2,91	2,87	3,32	43
23	491	S.A. Philips	3,23	3,15	3,56	46
24	483	S.A. Philips	3,00	3,00	3,44	45
25	783	S.A. Philips	2,98	3,02	2,14	28
26	584	S.A. Philips	3,01	3,06	2,91	38
27	547	S.A. Philips	2,92	2,98	3,02	39

A statistical analysis of the errors found in the check tests has been performed. Correlation of the errors with belt loadings was poor and the hypothesis that the errors were unrelated to belt loading could not be rejected with high confidence. This would seem to indicate that the Ohmart weigher was insensitive to low belt loadings and the associated problems of changing material profiles on the belt.

Conclusions

The application of a nuclear weighing device to the continuous weighing of moist bagasse fibre at Felixton has given highly satisfactory results. It is apparent that the Americium radiation source was well suited to bagasse weighing.

In a series of 27 check tests the nuclear weigher was found to have a mean error of 0,2 per cent of full scale and the errors of individual tests were well within 2,0 per cent of full scale. These figures include all errors arising from the test procedure used for checking the weigher and no attempt has been made to separate the errors due to the two sources.

The accuracy of the nuclear weigher appeared to be maintained even in situations of low loadings. It is significant that in the application at Felixton, the Ohmart weigher accuracy was apparently insensitive to fluctuations in the conveyor belt loading and to the profile of the material on the conveyor.

TABLE 2

Derived data

Test No.	Equivalent rate Ohmart tons/h	 Weigh-bridge tons/h	Error 1* tons/h	Error 2* %	Error 3* %
1	36,00	35,65	+ 0,35	+ 0,97	+ 0,69
2	32,77	33,29	− 0,52	− 1,56	− 1,04
3	36,26	35,75	+ 0,51	+ 1,43	+ 1,02
4	13,50	13,50	0,00	0,00	0,00
5	24,12	24,00	+ 0,12	+ 0,50	+ 0,24
6	19,80	20,22	− 0,42	− 2,08	− 0,84
7	18,44	18,66	− 0,22	− 1,17	− 0,44
8	32,84	32,11	+ 0,73	+ 2,30	+ 1,47
9	32,22	32,54	− 0,32	− 0,97	− 0,63
10	34,85	34,62	+ 0,23	+ 0,67	+ 0,46
11	33,06	33,46	− 0,40	− 1,21	− 0,81
12	26,44	26,95	− 0,51	− 1,89	− 1,02
13	33,14	32,29	+ 0,85	+ 2,62	+ 1,69
14	30,32	30,42	− 0,10	− 0,33	− 0,20
15	26,27	26,09	+ 0,18	+ 0,68	+ 0,35
16	23,41	23,49	− 0,08	− 0,33	− 0,15
17	24,95	24,10	+ 0,85	+ 3,53	+ 1,70
18	26,34	26,11	+ 0,23	+ 0,89	+ 0,46
19	26,38	25,62	+ 0,76	+ 3,00	+ 1,54
20	25,50	25,02	+ 0,48	+ 1,92	+ 0,96
21	22,26	22,33	− 0,07	− 0,35	− 0,16
22	21,83	21,53	+ 0,30	+ 1,39	+ 0,60
23	23,68	23,10	+ 0,58	+ 2,54	+ 1,17
24	22,36	22,36	0,00	0,00	0,00
25	13,70	13,89	− 0,19	− 1,32	− 0,37
26	18,55	18,86	− 0,31	− 1,63	− 0,62
27	19,22	19,61	− 0,39	− 2,01	− 0,79
	Mean ..	.. ..	+ 0,998	+ 0,28	+ 0,20

* Error 1 = (Ohmart — Weighbridge) tons/h

$$\text{Error 2} = \left\{\frac{\text{Ohmart — Weighbridge}}{\text{Weighbridge}}\right\} \times 100 \quad \%$$

$$\text{Error 3} = \left\{\frac{\text{Ohmart — Weighbridge}}{\text{50 ton/h (full scale)}}\right\} \times 100 \quad \%$$

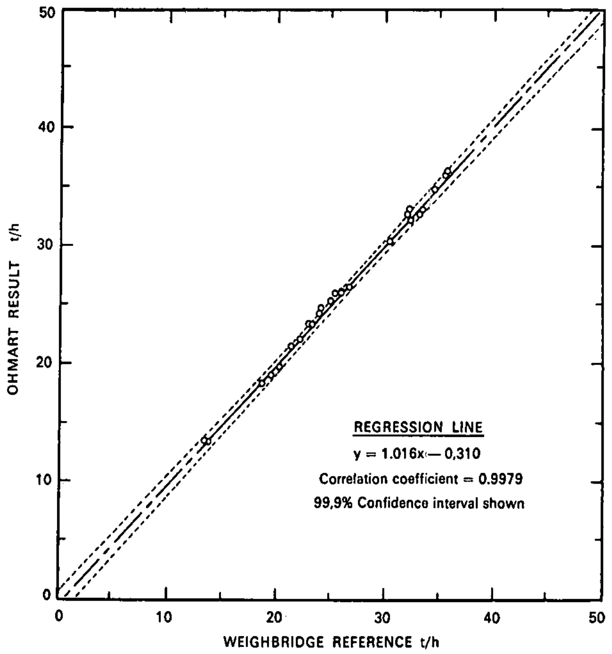

FIGURE 3 Correlation between nuclear weigher result and weighbridge reference standard.

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