bulk solids handling Volume 1, Number 2, May 1981

Belt Weighing Test Facility at Warren Spring Laboratory

J. A. Abbott, P. L. Bransby, R. Clark and W. T. Lee, England

Testeinrichtung für Bandwaagen im Warren Spring Laboratory
Installation d'essai de bascules courroies dans le Laboratoire de Warren Spring
Instalación de prueba para vásculas de correa en el Laboratorio Warren Spring
ワーレン・スプリング研究所におけるベルト秤量テスト設備
沃伦斯普林实验室带式称重检试设备
تسهيلات اختبار الوزن بالسير في مختبر ورين سبرينج

Summary

The economic and other advantages of belt weighers are reviewed and a history of research into belt weighing at Warren Spring Laboratory (WSL) is given. The paper then describes the aims and objectives of the present Belt Weighing Co-operative Project, which includes industrial sponsorship, and its mode of operation. A full description is given of the mechanical aspects of the industrial scale troughed belt test facility as well as the instrumentation and the computer system for collection, storage and analysis of data. Experimental data and a typical computer print-out are included to demonstrate typical results that can be achieved from the rig.

1. Introduction

Continuous weighing of granular material as it is carried along a conveyor belt can offer economic advantages to management in process control, stock control and in accounting, but only if accuracies can be guaranteed to fall within a specific tolerance, typically better than ± ½ % full scale deflection.

Apart from neglect of belt weigher manufacturers' recommended operating procedures, the more obvious sources of inaccuracy in commercial installations are:

- Poor calibration techniques.
- Poor installation.
- Misalignment of idler-sets on the weigh scale and of threshold idler-sets, so that the effective *weigh-length* varies according to the load on the belt.
- Poor belt tracking or lateral variation of belt position on idler-sets.
- Poor installation and positioning of belt speed sensors so that the measurement does not represent the belt speed over the actual weigher length.

2. WSL Involvement in Belt Weighing

The aim of the project at Warren Spring Laboratory (WSL) is to help industry to make full use of the economic and technical advantages of belt weighing; this necessitates:

a) The investigation and quantification of sources of inaccuracy in the performance of continuous conveyor weighing equipment.

b) The definition of design, operation and calibration procedures to enable specified weighing accuracies to be achieved consistently: following from this is the production of a Code of Practice for the guidance of users and manufacturers.

During the first stage of the project, valuable experience was gained from a test facility in which experiments were conducted on a horizontal flat belt conveyor 12 m long. To allow continuous running throughout experiments, a recycle system was used; this included a return conveyor and a bucket elevator. Material was fed from an 8 tonne feed hopper at 60 t/h on to the test conveyor, which discharged into two weigh hoppers, each of 2 tonne capacity. The weigh hoppers were used alternately so that there was a continuous record of the quantity of material conveyed. The simply-supported weigh-scale used 1 to 3 idlers of diameter between 75 mm and 125 mm at pitches from 0.5 m to 4 m. High accuracy measurements from numerous sources on the rig were stored on an Argus 500 computer.

Work done during the flat belt stage of the project forms the basis for a comprehensive report by Jones and Laws [1] on Speed Sensing in Belt Weighing. Recommendations are made regarding (a) the design and position of a speed sensing system and (b) the design and operation of the conveyor necessary to ensure high accuracy in the measurement of speed.

For the second stage of the project a sophisticated replacement test facility was built to incorporate troughed belts and increased accuracy of measurement from an increase in scale. To help sponsor the second stage as well as to give guidance and thus ensure the relevance of the WSL research to industrial needs, a co-operative project was set up with both users and manufacturers of belt weighers as members. A draft Code of Practice based on the work is planned for publication in 1983.

3. Description of Present WSL Rig

Table 1 shows some of the important items on the rig and gives details of their accuracy of construction or measurement.

Two inclined return conveyors are incorporated along with the main 23 m long horizontal conveyor (TC1) on which the majority of the experiments are carried out. The schematic layout is shown in

J. A. Abbott, Higher Scientific Officer,
P. L. Bransby, Head of Division,
R. Clark, Higher Scientific Officer,
Materials Handling Division, Warren Spring Laboratory, Dept. of Industry, P.O. Box 20, Stevenage, Herts SGI 2BX, England

W. T. Lee, Managing Director, Lee Micromatics Ltd., 40 Stone Hills, Welwyn Garden City, Herts AL8 6PD, England

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Table 1: Brief specification of some important items of WSL belt weighing test rig

Item	Manufacturer	Description
Load cells on weigh-hoppers	Interface	6 tension cells for 2 hoppers Capacity of each cell 2270 kg_f Non-repeatability ± 0.01 % FSD
Weighbridge 1	Fisher	4 compression cells Capacity of each cell 125 kg_f Non-repeatability ± 0.05 % FSD
Load cells for belt tension on TC1 head-pulley	Fisher	2 compression cells Capacity of each cell 1130 kg Non-repeatability ± 0.05 % FSD
Load cells for belt tension on TC2 head-pulley	Bofors	2 beam-type cells Capacity of each cell 5000 kg_f Non-repeatability ± 0.01 % FSD
Belt-speed transducer (3 at different locations)	Baldwin	Optical incremental encoder 10^4 pulses/revolution of pickup wheel Accuracy 2 arc sec bit-to-bit
Belt-speed transducer (at weighbridge)	Rank	DC tachometer 100 mV/revolution of pickup wheel
Belt-speed transducer (at weighbridge)	Fisher	Optical encoder 1 pulse/cm of belt movement
LVDTs for recording lateral position of belt	RDP Electronics	4 are used to give lateral curvature of belt Working range ± 50 mm Linearity BSI Grade A Sensitivity 4 v RMS/25 mm
LVDTs for measurement of idler deflections under varying belt loadings	RDP Electronics	Working ranges ± 1 mm and ± 2.5 mm Linearity better than BSI Grade A Sensitivity 2 mV/V/0.025 mm
Pneumatically operated flap for diverting material into either weigh-hopper	WSL	Total transit time < 0.3sec Non-repeatability < ± 0.05sec
Idler-set optical alignment system	WSL and Rank, Taylor Hobson (telescope)	Setting up of pattern: Accuracy ± 0.4 mm lateral ± 0.2 mm vertical

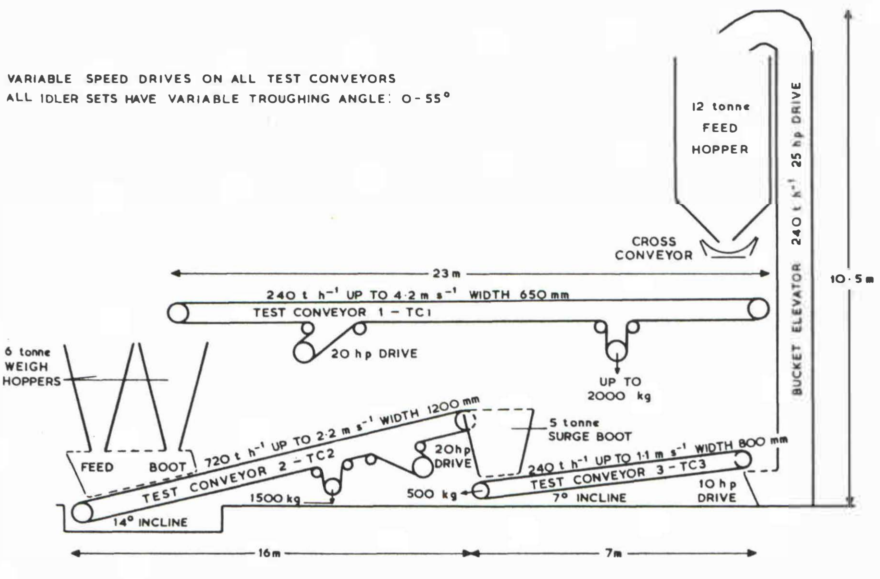

Fig. 1: Basic components of troughed belt test rig

Fig. 1. The two inclined conveyors (TC2 and TC3) use standard commercial idler-sets, one conveyor having 4-roll idler-sets and the other, 3-roll idler-sets. An impression of the overall scale of the rig can be gained quickly from Figs. 1 and 2.

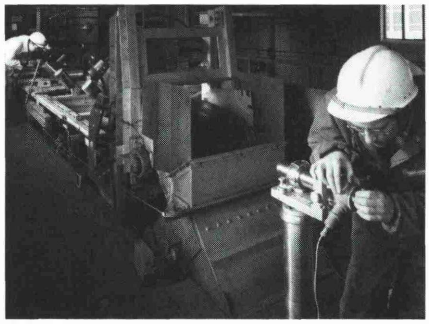

Fig. 2: Telescope mounting on test conveyor 1

The horizontal conveyor has WSL designed and manufactured idler-sets of 3-idler construction (all idlers are precision machined to diameter 127 ± 0.125 mm). On the transom which supports the three idlers, each centre-idler can be raised or lowered independently of the wing-idlers: this allows the geometry of each idler-set to be adjusted according to a rigid pattern of any specified shape. The pattern which incorporates lateral and longitudinal spirit levels, is located positively astride the idler-set, after the belt has been lifted from the idler-sets by overhead pneumatic jacks. By means of a transparent optical grid which is mounted on the pattern, each idler-set in turn can be optically aligned with the centre-line of the conveyor; a telescope mounted at one end of the conveyor and an illuminated target at the other end of the conveyor are used in conjunction with the optical grid on the pattern. The principle of the alignment system is shown in Fig. 5, and Fig. 2 shows the actual telescope mounting.

On each conveyor belt tension is measured by load cells registering those forces, parallel to the conveyor, which are applied to the head-pulley support bearings. A record also is kept of the load on the gravity take-up units by means of load cells built into the weight-hangers.

Fig. 3 is a photograph taken from alongside the weigh hoppers and looking along TC2 which takes material to the surge boot: In the foreground is the vertical post (C) which has at its upper end the base (D) for the telescope used in aligning the idler-sets. The small illuminated circular target (E) for the telescope can be seen in Fig. 3 con-

Fig. 3: Test conveyor 2

trasted with the darkness at the far end of the conveyor. By means of the overhead jacks, the belt has been lifted away from the idlers in order to show more detail of the Fisher single idler-set weighbridge installation (F) which can be seen clearly in Fig. 4, along with one of the four load cells (G) supporting the

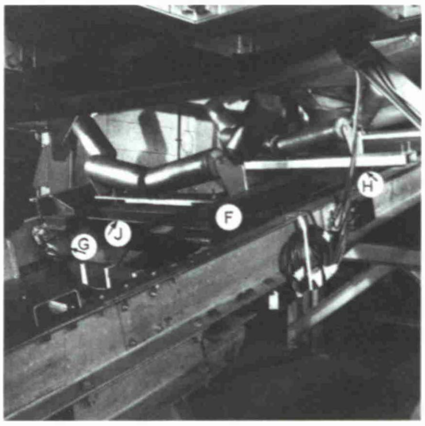

Fig. 4: Weighbridge mounting on test conveyor 2

weighbridge. The load normal to the top face of each load cell is transmitted via an almost frictionless ball table of WSL design and manufacture: this eliminates side-loads on the cell. The weighbridge is positively located on the conveyor by means of pin-jointed longitudinal (H) and lateral (J) tie-rods, which can be seen in Fig. 4. The Fisher single-idler weighbridge also can be installed on the horizontal conveyor along with two other weighbridges: one manufactured by Rank is supported by four beam-type load cells and has two idler-sets: the other, manufactured by Pye Unicam, is a multi-idler weighbridge which can carry as many as six idler-sets, according to the required spacing, and which is supported by a beam-type load cell (Fig. 5).

Linear variable deflection transducers are used to measure deflections of the idler-sets so that there can be a continuous record of the deflections and their variation under different belt loadings and tensions. Similar transducers are used to record the lateral position of the belt on the conveyor and preparations are being made to install several of these transducers so that variations in lateral curvature of the belt can be measured and recorded.

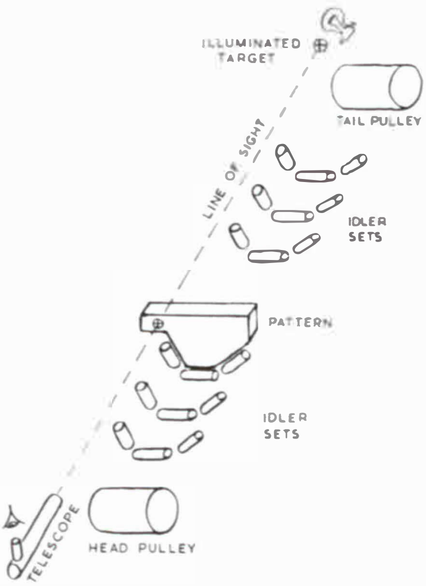

Fig. 5: Principle of idler alignment system

4. Instrumentation

A high precision Digital Voltmeter is used to monitor the 10 V load cell power supply unit. The DVM output is linked directly to a digital multiplexed Argus computer input. DVM accuracy on a 20 V range is ± 0.004 % of reading ± 0.001 % FSD ± 1 μV.

A Mycalex series 5 Data Logger is dedicated to monitoring conveyor belt tensions and weigh-hopper loads. The accuracy is ± 0.01 % of reading ± 1 μV.

WSL High Accuracy Signal Transmission Equipment (HASTE) was developed to fill a precision requirement not apparently available commercially. The HASTE system provides high accuracy measurement of analogue voltages at high sampling rates. The resolution is better than 0.01 % of FSD at the maximum sampling rate of 50 Hz. HASTE was designed for monitoring low level signals such as those from strain gauges. Each HASTE system is a portable unit with built-in temperature control for added stability and is placed alongside the transducer (e.g. load cell) to minimise signal loss and noise problems. The system is essentially a voltage to frequency converter and provides a 5 V pulse train which is transmitted approximately 100 m to the Argus computer using a matched transmission line.

In order to monitor the speed encoders and HASTE system outputs, WSL designed and built Scalers which are 20 bit binary counters with a 20 bit latch to allow sampling of the count at intervals of 100 milliseconds. WSL also constructed the clock circuit necessary for such a sampling rate. A 1 kHz crystal is the basis from which a 10 Hz square wave is obtained and monostable multivibrators are used to produce the 3 synchronised 10 Hz (100 millisecond) signals of different pulse widths which are necessary for (i) execution of the SAFE software programme every 100 milliseconds, (ii) collection of the data from the Scalers and (iii) the provision of a reset pulse for the Scalers.

5. Computation and Software

Responsibility for the development and application of a comprehensive computer software package to support experiments was assigned to consultants Lee Micromatics Ltd. They worked closely with WSL staff in this activity.

5.1 The Process Computer

It was intended that existing computer equipment should be used for the project. Warren Spring Laboratory's Argus 500 process computer provided a service for several divisions requiring online computer support of experiments. With 32K core memory, two disc storage units, line printer and paper tape equipment, software packages were normally produced in the Fortran language. The computer had high speed multiplexers for interfacing analogue, contact-sense, and pulse-rate signals from process measuring instruments.

5.2 Feasibility Study

The consultants began with a feasibility study to establish requirements. Computer support of experiments required acquisition of key measurement data 10 times every second, with extensive and precise data processing for statistics and integrations in real-time; programs were to be driven automatically by rig process operations involving quite complex sequencing and logic; sets of experiments would involve various numbers and combinations of various types of weighbridge, yet it had to be quick and easy to change the software to suit, and transparently easy to operate during experimental runs.

The consultants considered that the conventional software approaches would be much too slow and inflexible. They proposed instead a data driven software package allowing a high level building-block approach to application programming, with on-line and interactive VDU programming and operation, a technique with which they had previous experience in process control applications.

The software package proposed was named SAFE (Software for Automatic Flowchart Execution). It incorporated a building-block algorithmic 'language' which allowed programs to be defined as application flowcharts and entered directly into the system block by block, via the VDU, without any requirement for the conventional computer activities of coding and compiling, so making it easy for engineers unskilled in computer technology to use the system's powerful facilities.

5.3 System Software Development

Following a further detailed proving study, development began in earnest. The software system was designed in detail, coded, developed and checked out during the second half of 1978. A standard operating system called Small Machine Organiser was used as the master executive program of the core-only real-time system, with all SAFE system software implemented in Assembler language, to achieve the required operating speed. Programs amounted eventually to 10K 24-bit words, with a further 10K words required for the system database and text library.

5.4 Development and Commissioning of Application Software

The next phase was the design, implementation and commissioning of full application software packages to meet WSL detailed specifications for support of the research programme. The work took a further six months.

Two packages were produced. The first was to support experiments with one weighbridge installed in the rig, while the second was a fully comprehensive package able to support a range of experiments with up to four weighbridges installed in various situations. This package incorporated almost 1000 flowchart functions, divided among some 20 concurrent real-time tasks. Project staff are able to amend and extend system functions themselves.

5.5 System Operation

Data processing specific to each experimental equipment configuration may be set up quickly and conveniently. After the entry of data defining options and parameters via the VDU, data processing proceeds automatically in response to rig sequential and cyclic operation.

All operator commands for the control of data processing during the preparation and undertaking of experimental runs are made by operating key switches, whose functions are defined by the SAFE applications software. Reports on rig preparation activities, and summarising the integrations and statistics generated for each experiment, are produced on the Line Printer.

6. Conclusion

Contractual agreements prevent the presentation of any results in detail other than the typical data given in Table 2, the typical computer print-out shown in Fig. 6 and the typical Influence Function curve shown in Fig. 7 (An I/F curve is obtained by putting incremental loads on a static conveyor belt at positions away from the weighbridge and measuring the output from

Table 2: Typical short term belt weigher performance*

Time	Weigh Hopper No.	Belt Speed m/s	Weighbridge Loading kg/m	Error %	Tare Weight kg/m
11:26		1.1744			70.5368
11:38	2	1.1733	42.9749	—0.13	
11:40	1	1.1724	49.6958		
11:41	2	1.1720	50.4000	—0.13	
11:43	1	1.1720	52.9135		
11:44	2	1.1722	52.7271	—0.13	
11:46	1	1.1719	53.3476		
11:47	2	1.1717	52.7718	—0.12	
11:48	1	1.1711	53.7973		
11:55		1.1750			70.5395
11:59	1	1.1728	52.3535	—0.17	
12:00	2	1.1731	53.9940		
12:02	1	1.1740	48.5422	—0.13	
12:04	2	1.1744	43.3755		
12:05	1	1.1741	43.1840	—0.12	
12:07	2	1.1742	43.0327		
12:09	1	1.1744	43.3023	—0.09	
12:11	2	1.1740	43.0438		
12:15		1.1766			70.5428
12:20	1	1.1754	42.8301	—0.09	
12:21	2	1.1756	42.1231		
12:23	1	1.1757	43.4274	—0.15	
12:25	2	1.1751	43.0172		
12:27	1	1.1752	43.1700	—0.14	
12:28	2	1.1749	43.0787		
12:30	1	1.1747	43.2732	—0.09	
12:32	2	1.1743	43.1035		
12:35		1.1771			70.5499
12:47	2	1.1728	42.7949	—0.09	
12:49	1	1.1727	42.8505		
13:34		1.1755			70.5487

*See Appendix 1

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                    BELT WEIGHER PROJECT - RUN NO. 2 0001

         001  WEIGH HOPPER FULL LOG CONVEYOR       0001  CYCLE        0007

                    DATE       2 09 80          TIME      1615

                                                MAXIMUM     MINIMUM     MEAN

APPLIED TENSION         0001                        9010        8883        8951

HEAD TENSION            0001                      1 1032      1 0571      1 0718

WEIGH BRIDGE            0001 LOAD                30 6705     26 6785     28 6132

WEIGH BRIDGE            0002 LOAD                31 8547     26 9427     29 3038

BELT SPEED              0001                      1 1905      1 1702      1 1796

BELT SPEED              0002                      1 1953      1 1675      1 1783

WEIGH HOPPER            0002 WEIGHT FULL          7 1910      7 1890      7 1897

WEIGH HOPPER            0002 WEIGHT EMPTY         1 8740      1 8730      1 8730

         VREF                                    10 0684     10 0674     10 0678

         SAMPLES                                    1579

TOTALISED LOAD WEIGH BRIDGE        0001      SPEED        0001                5 3297

TOTALISED LOAD WEIGH BRIDGE        0001      SPEED        0002                5 3239

TOTALISED LOAD WEIGH BRIDGE        0002      SPEED        0001                5 4584

TOTALISED LOAD WEIGH BRIDGE        0002      SPEED        0002                5 4524

TOTALISED LOAD WEIGH HOPPER                                                   5 3167
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Note

The comparison of totalised weights, approximately 5.4 tonnes, measured by the weighbridges, with different speed sensors, and the weigh hoppers is shown in the bottom right corner of the print-out.

Fig. 6: Typical computer print-out

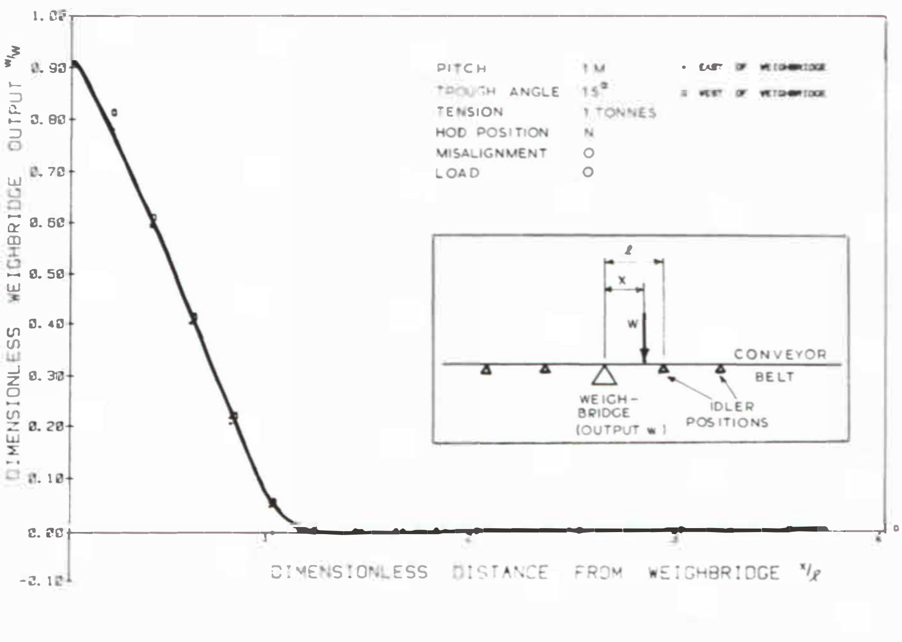

Fig. 7: Influence Function curve

the weigh-scale). Repeatability of results is evident from Table 2. It can be concluded that the troughed belt facility is capable of testing belt weighers with an accuracy of ± 0.05 % and of investigating the following factors affecting the accuracy of belt weighers.

a) Geometry of the weighing system: pitch, misalignment, troughing angle, angle of conveyor inclination, relative positions of rolls in a troughed idler set, idler diameter, eccentricity of idlers.

b) Geometry of the speed pickup: angle of wrap, misalignment, position on troughing curve, position relative to conveyor idlers/pulleys, diameter of pickup, displacement of pickup under load.

c) Conveyor operating parameters: load, loading variations, tension, tension variation, velocity, velocity variations.

d) Weigher and speed pickup locations on the conveyor.

e) Bulk material properties: cohesion, internal friction, adhesion, moisture content, particle or lump size, density.

f) Disturbances such as skirting friction, vibration, jammed idler, belt cleaners.

g) Integration method.

References

[1] Jones, R.J. and Laws, K.G. (1979) "Speed Sensing in Belt Weighing", Warren Spring Laboratory Report No. LR 267 (MH)

Appendix 1: Notes to Table 2

The data was obtained from test conveyor 1 on 22.04.80 using a single idler weighbridge simply supported by 4 compression load cells. The idler pitch was 2 m, the troughing angle 45°, idler misalignment 0 ± 0.2 mm and the belt tension 1.1 tonnes.

The percentage error is the difference between measurements of weight by the belt weigher and the weigh hoppers (the true weight) expressed as a percentage of the weight of material measured. The belt weigher calibration factor used was a theoretical factor based on independent calibrations of the weighscale and speed sensor, and on the measured geometry of the weighscale idlers. The error was calculated from measurements of approximately 10 tonne loads of material.