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Continuous Weighing of Solids in the Process Industries

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Kontinuierliches Wiegen von Feststoffen in der Verfahrenstechnik
Pesée continue de matières solides dans la technologie des procédés industriels
Pesaje continuo de sólidos en la técnica del procedimiento

加工工業における粉体の連続秤量

加工工业的固体连续称重

النقل المستمر للمواد الصلبة في صناعات العمليات المتعاقبة

Summary

With the advent of microprocessor technology about to revolutionalise the design and cost effectiveness of constant rate feeders and belt weighers this paper outlines the current status of the art of the design and application of constant rate feeders within the process industries.

1. Introduction

Continuous weigh feeders, feed rate indicators, belt weighers and check-on-stream feeders have been in use on continuous processes for many years. However, with modern improvements in accuracy and in design and control philosophy they are being applied more frequently to processes which were previously carried out by batch weighing systems.

There are various types of weigh feeders available with electrical, electronic or pneumatic control, with capacities ranging from a few kg/h to 2,000 t/h. Many suppliers have recently entered this important field of specialized weighing with machines which are inherently accurate but, unless they have considerable application engineering and materials handling experience, the overall system accuracy can often be inadequate.

Richard Simon & Sons Ltd., England, have been involved in the weighing industry for many decades and have as a result, built up considerable expertise in related materials handling, in order to get the best performance out of the weighers. This total capability ensures that dynamic accuracies can be guaranteed as opposed to just giving a static or dead-weight accuracy.

Since constant rate feeders with their feed forward control principle afford the best potential accuracy, a more detailed description is given in order to highlight the main features.

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2. Constant Rate Feeder

The constant rate feeder is shown schematically in Figs. 1 and 2.

The weigh section, comprising one or more idlers, is supported from a precision, strain gauge loadcell, usually of the tension type, but alternative designs have compression or beam loadcells (Fig. 3). A thyristor-controlled D.C. motor drives a tachogenerator which produces a voltage signal directly proportional to speed.

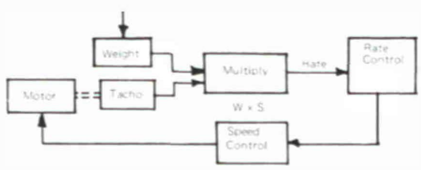

Fig. 2: Constant rate feeder block diagram

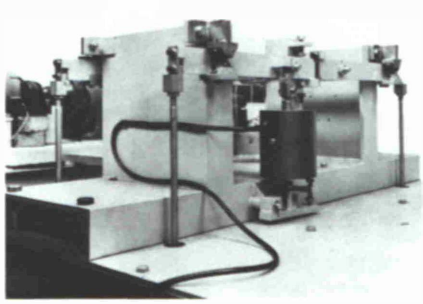

Fig. 3: Detail of transfer lever system and tension loadcell on constant rate feeder

The two signals are multiplied to produce an output directly proportional to the instantaneous feed rate. The signal conditioning equipment is all housed in a control panel (Fig. 4).

The actual rate is continuously compared with the desired rate setting, and the difference produces an inverse speed correction signal to the D.C. motor.

Because the bed depth on a constant rate feeder is fixed, there should not be any further speed corrections to the drive motor once the output rate matches the pre-set rate. However, in a practical situation it will be appreciated that the bulk density of the material can vary. For instance, the bulk density of iron ores can vary by as much as 3:1, but for most applications it is the moisture content which provides the main variable. Since the feeder is measuring the instantaneous weight per unit length, variations in bulk density are automatically regulated.

Short term errors of up to $\pm 1\,\%$ can be expected but over a 6 minute period accuracies of $\pm 0.3\,\%$ are achieved in practice over 10:1 turn down ratios, in desired rate, and including 3:1 changes in bulk density.

Totalising is carried out by means of a precision integrator and pulse generator; the output of which is suitably divided to provide pulses equal to decimal parts of a tonne or other convenient units.

The forward control principle of the constant rate feeder gives superior performance over constant weight feeders which are affected by transport lag problems, due to the distance between the bed depth regulator and the weighing idlers.

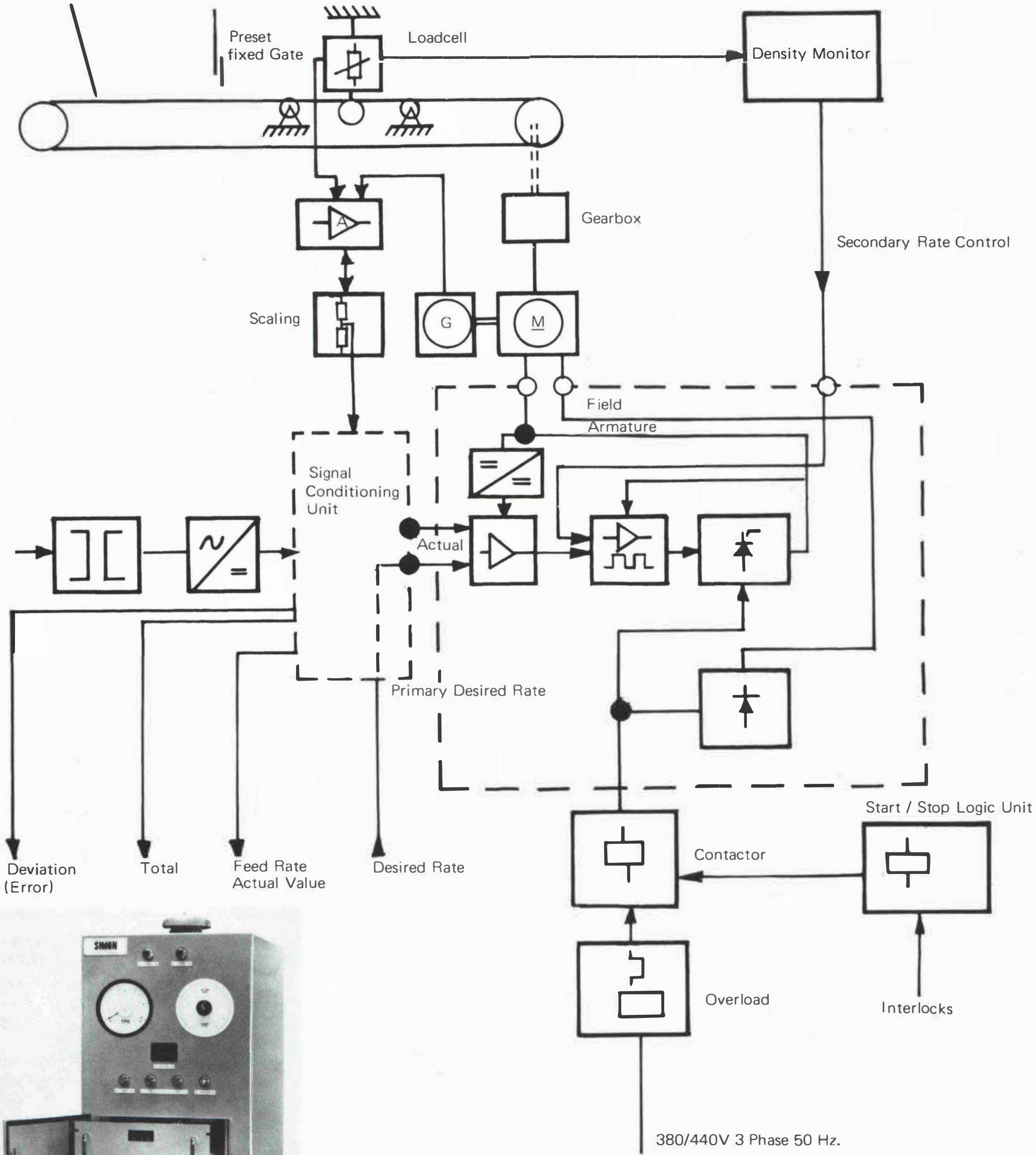

Fig. 1: Constant rate feeder schematic

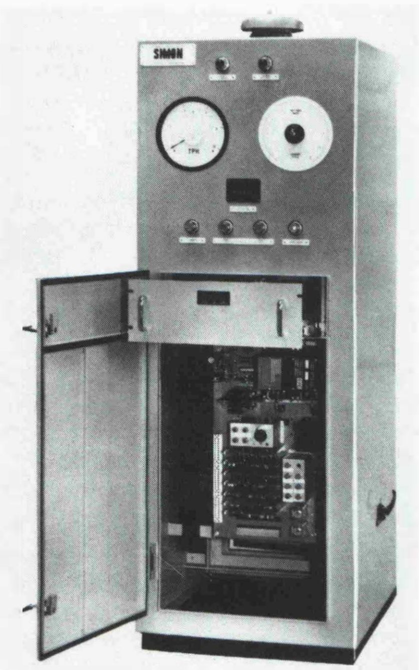

Fig. 4: Single unit C.R.F. controller with thyristor control

These transport lag problems can result in considerable instability in the feedback control system which is trying to maintain a constant weight per unit length on the feeder. This effect is more pronounced if the length of the feeder is increased when a de-fluidizing section is introduced between the feed inlet and the weigh section. For example when handling a product such as hot, very fine ground phosphate rock, which aerates very readily, it is essential to de-fluidize the powder.

Whereas in the constant rate feeder, as soon as an error is detected in the actual rate, the controller initiates the desired action to re-adjust the feed rate almost instantaneously.

Having determined the most suitable machine and pre-feeder for a particular application, the most important function is to determine the power requirements to drive the machine. The formulae for these calculations are already well established and present few problems. However, there are certain constants which have to be determined and which have a significant bearing on the results. The main ones concern the shear characteristics of the material to be transported and the effective load on the belt at the feed inlet, particularly at the start-up on full load. The load on the belt is influenced by feed hopper discharge characteristics, the material of construction, the size and especially the shape of the inlet.

In order to apply the correct constants, the manufacturer must have considerable experience and access to the results obtained from a wide range of practical installations handling products, with the appropriate flow characteristics.

A typical set of calculations is shown below:

3. Power Calculations

In order to calculate the total power requirements of the feeder, it is first necessary to calculate the total effective belt tension T_E (see Appendix 1).

As previously stated, these calculations follow standard belt conveyor design criteria but are suitably modified according to the specific application. For example, angle Θ which determined the height of pyramid in Fig. 5 has a significant effect on belt tension for material extraction.

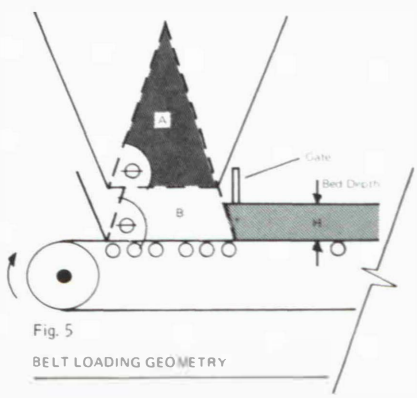

Fig. 5: Belt loading geometry

4. Check-on-Stream

Many installations are based on a number of constant rate feeders having group control in order to maintain desired ratios for pre-blending as well as the total demand.

These installations present difficulties associated with periodic calibration. Obviously, if it is desired to check the calibration of a single machine, this must be isolated from the feed hopper in order to empty the system for a tare check before weights can be applied. This means that group control cannot be maintained and all machines must stop. A neat solution to this is to incorporate a *check-on-stream* function (Fig. 6).

The whole weigher, including the intermediate hopper, is mounted on precision tension load cells. In normal operation, the level in the hopper is maintained to provide a suitable head of material. When a check routine is initiated, the primary feeder rate is increased in order to fill the hopper until level HL is reached and then is stopped. The level then starts to fall until level CH is reached. The level continues to fall until CL is operated. The integrated total passed by the weigh feeder in this time is displayed and compared with the known weight difference between the pre-set levels CH and CL.

If any correction (within set limits) is required, a feedback signal will automatically compensate for the error. During the whole of this procedure the weigh feeder continues to operate normally under the control of the enclosed loop system.

5. Coal and Refuse Overload Limiter Feeders

A particular variation of the constant rate feeder has been developed for use in coal preparation plants, where usable coal is washed and separated from shale and other refuse. These machines, developed by the National Coal Board, England, function as coal and refuse overload limiters; hence the designation CAROL feeder. The overall capacity of the feeder is designed to suit the requirements of the plant such that coal is washed and floated off, while the refuse sinks to the bottom and is extracted. The rate at which refuse can be extracted is a limiting factor.

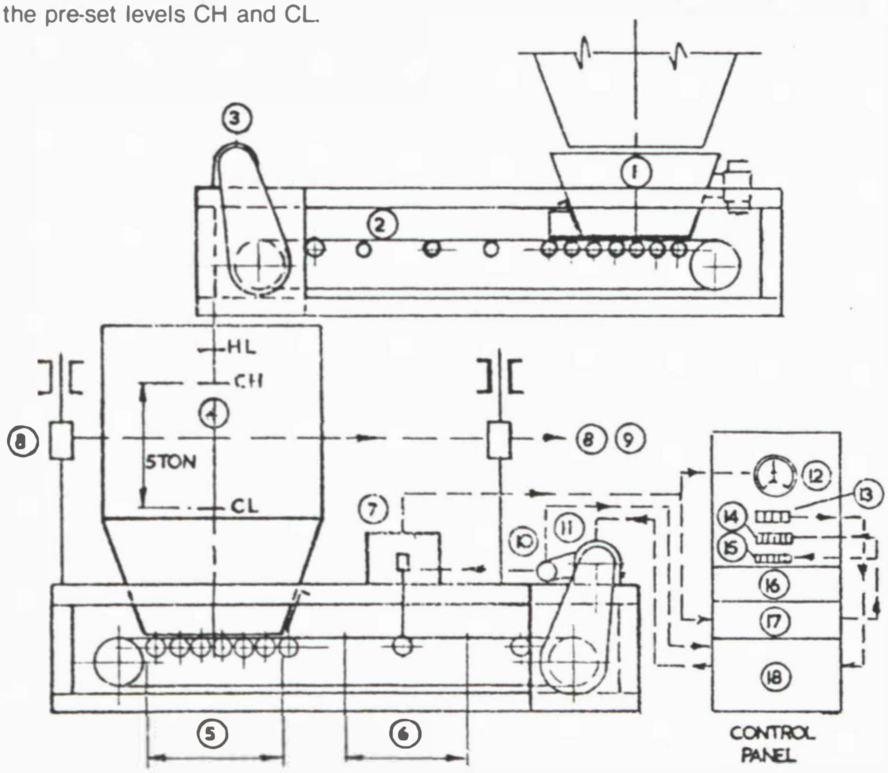

Fig. 6: Check-on-stream weigh feeder with strain gauge load cells

1. VIBRATORY HOPPER
2. BELT EXTRACTOR
3. B.E. DRIVE
4. INTERMEDIATE HOPPER
5. EXTRACTOR SECTION
6. WEIGHED SECTION
7. LOAD CELL WEIGH HEAD
8. BATCH LOAD CELLS
9. TRIP LEVELS
10. TACHOGENERATOR
11. D.C. MOTOR
12. RATE INDICATOR
13. RATE PRESETTER
14. TOTALISER CONTINUOUS
15. TOTALISER BATCH CHECK
16. POWER SUPPLIES
17. INTEGRATOR
18. THYRISTOR

Since the feeder has a fixed gate inlet, giving a fixed bed depth over the weigh length, the weight per unit length can be used to determine the density of the product. Usable coal has a lighter density than shale, e.g.

Coal : $0.8 \, t/m^3$
Shale : $1.4 \, t/m^3$

If the maximum extraction rate of shale

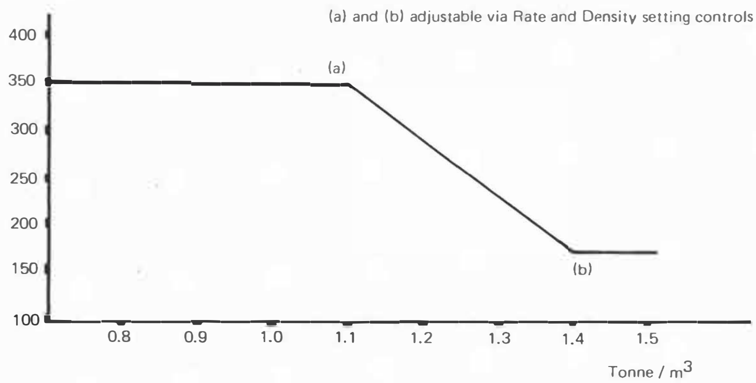

Fig. 7: CAROL feeder

is 175 t/h and the maximum feed rate is established at say 350 t/h (Fig. 7), the density measurement has no effect on the set rate until a density of $1.1 \, t/m^3$ is registered. At this point the intake of shale is equal to the extraction rate. As the density increases, a feedback signal progressively reduces the total feed rate, thus ensuring that the maximum permissible quantity of coal is washed. In the extreme case of all shale, the density will be $1.4 \, t/m^3$ and the feeder will limit at 175 t/h input.

Current microprocessor development work which is taking place should lead to more cost effectiveness and improved performance in constant rate feeders and belt weighers in the near future, thus keeping pace with the demands of industry.

Appendix 1:
Total Effective Tension and Total Power Requirement

The total effective tension is calculated utilising the following basic formulae and steps:

1) Total effective tension T_E
$= T_1 + T_2 + T_3 + T_4$

2) Extract $T_1 = 9.81 \, W\mu$ (Newtons)
where μ = coefficient of shear

3) Weight on belt at inlet, W (Fig. 5)
$= \varrho$ (Volume A + Volume B) (kg)
where ϱ = density of material

4) Tension empty conveyor drive, T_2
$= G(F_B \times L \times L_A) \, 9.81$ (Newtons)
G = Weight of moving parts (kg/m)
F_B = Friction factor empty belt
L = Conveyor length
L_A = Length adjustment factor

5) Skirt friction T_3
$= (F_M H^2 + F_S) \, L_S \, 9.81$ (Newtons)
H = Bed depth (m)
F_M = Factor to overcome material friction
L_S = Skirt length (m)
F_S = Constant to overcome belt friction

6) Tension to convey material T_4
$= \frac{R}{S} (F_B \times L \times L_A) \, 9.81$ (Newtons)
R = Rate (kg/s)
S = Belt speed (m/s)
F_B = Friction factor empty belt
L = Conveyor length
L_A = Length adjustment factor

7) Total power requirement P
$= \frac{T_E S}{1000}$ (kW)
where S = Belt speed (m/s)

The head drum will normally be driven through a gearbox and D.C. motor. Therefore, the installed power required will take these factors and drive efficiency into account and will be somewhat higher than total power requirement (P).