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FERTILISER PACKAGING AND WEIGHING WITH PARTICULAR REFERENCE TO WEIGHING

by

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Introduction:

Advances in mechanical handling in the fertiliser industry during the post-war period have not been confined to raw material movement and manufacturing process, but have been extended to the packaging, weighing and despatch of products. For many years the normal method of bagging and weighing was to fill bags at catch weight from a hopper or chute and adjust manually to the correct weight on a dead weight scale. The bags were then hand-sewn. This method was extremely wasteful of man power, and it was of necessity common practice to employ a high proportion of casual labour during the spring delivery period.

Post-war conditions made it necessary for all industries to strive for increased productivity. The demand for fertilisers increased substantially and as labour was extremely scarce and expensive economies in man power had to be effected, In the fertiliser industry, mechanisation, which had been long overdue, was adopted on a large scale and both mechanical handling of raw materials and the granulation of compound fertilisers contributed to increased output and better utilisation of labour.

For some time, however, the old methods of hand weighing were retained, the product being bagged as it was made. This process had several disadvantages. There was at that time a tendency for the compounds to set and materials which had been bagged in the autumn and stored until the spring had frequently to be reconditioned to render them suitable for spring application. The appearance of the package often deteriorated during prolonged storage. Further, the process of bagging, sewing, stowing and reclaiming was expensive in terms of man power. As a result of early post-war experience it was decided that the most suitable method of handling fertilisers would be to store in bulk after garnulation and reclaim, bag, weigh and deliver as required. To meet the high rate of delivery in the spring of the year (some 50 -60% of the year's make being delivered in an 8 week period) rates of bagging and weighing substantially in excess of those previously practised were required. It was recognised that high speed automatic weighing was necessary and bagging plants were constructed incorporating automatic weighing machines, followed by packaging equipment for machine-sewn open-mouthed sacks of valve packers.

In this paper some experiences with the use of automatic weighing machines, operating on granular compound fertilisers, are to be discussed.

Legal Requirements.

There is in the United Kingdom a general civil requirement that the customer is in fact supplied with the weight of fertilis for which he is charged. Quite apart from the question of legal requirements the advantages of accurate and consistent weighing are apparent. The supply of short weight packages leads to bad customer relations, and the giving of over-weight to minimise the risk of supplying short weight packages can be very expensive. If the average weight of 1 cwt. bags is overweight by only 2 oz. (0.1% overweight) the loss on an output of 200,000 tons of typical fertilisers, can be in excess of £5,000. By accurate an consistent weighing the number of short weight packages supplied can be reduced while maintaining the average package weight at the required value.

There is no maximum permissible limit of variation specifie applying to individual sack weights. The Weights and Measures Regulations in the United Kingdom require that any weighing instrument used for the sale of goods shall be of a pattern approved by the Board of Trade, shall be stamped by the Weights and Measures Inspector and shall be capable of weighing to a specified degree of accuracy, the degree of accuracy varying with the quantity to be weighed and the nature of the material sold. In the case of fertilisers the accuracy required for packages in excess of 100 lb. weight (approximately 45 kilograms) is $\pm \frac{1}{2}\%$. As well as being initially stamped as capable of weighing to this degree of accuracy, the weighing instruments are subject to inspection at least once per annum to ensure that they are maintained at the required standard. The test specified for automatic machines is that a series of 20 consecutive bags should be all within the set limits.

Description of Plant.

The weighing instruments incorporated in the packaging plan at Ayr Fertiliser Works are typical of the equipment used for the high speed weighing in the fertiliser industry. Fertilisers are reclaimed from bulk storage (capacity 24,000 tons) by bulldozer and transferred by conveying and elevating plant to the packaging unit which consists of four bagging off points, each served by 2 automatic weighing machines. Each weighing machine has a rate capacity of 15 tons per hour (equivalent to 5 bags per minute for 1 cwt. packages) giving a total potential output from the plant of 120 tons per hour.

The weighing instrument used is of the equal arm type and consists of a hopper counterbalanced by a weight box into which a placed weights to the required value. Fertiliser drops by gravity from a feed hopper above into the weigh hopper until the weigh hopper begins to move. The movement of the hopper operat a link mechanism which cuts off, by a gate, the main flow of fertiliser to the weigh hopper and permits only a restricted tric flow to continue. When the weigh hopper reaches the point of balance a second mechanism, also activated by the movement of the weigh hopper, cuts off the trickle feed. At this point a lamp lights in the bagging cabin below to indicate that the scale is ready for discharge. The operator places a sack to receive t charge and presses a foot pedal switch which releases the bottom door of the weight hopper by a solenoid device. After emptying, the movement of the weigh hopper from the point of balance closes the discharge gate and opens the gates controlling the flow of material from the feed hopper, so completing the weighing cycle.

A movable poise permits fine adjustment to the quantity of fertiliser delivered. The weigh hoppers and light boxes are fabricated of mild steel and suspended on hardened steel knife edges and bearings set in cast iron beams.

Check Weighing.

As large tonnages are handled in a relatively short period of time by automatic weighing equipment, undetected error could result in the delivery of large consignments of inaccurately weighed packages. It is therefore essential that a system of frequent check weighing be operated to provide a continuous and up-to-date record of the performance of each weighing machine in respect of both constancy and accuracy of weighing. Constancy of weighing may be defined as the ability of the weighing instrument to fill replicate sacks with the same quantity of material irrespective of the stipulated amount. The accuracy of weighing is the weighed amount in relation to the stipulated weight. The system adopted was that, twice daily, 5 consecutive packages from each automatic weighing machine were checked on a test scale and errors in weight recorded as ounces heavy or light. The test scale was maintained in a condition capable of weighing one hundred-weight to within ± 1 oz. by daily balancing. It is of the utmost importance to use only reliable standard weights examined and stamped annually by the Weights and Measures Inspector, for checking and adjusting the point of balance of the test scale. These weights are kept in a dust-tight box and reserved exclusively for this purpose. The test scale is examined and reset daily.

Operating Experience.

The initial performance of the automatic weighing machine on granular compound fertilisers was rather disturbing. Not only were erratic weights delivered but the machines did not always function correctly, the bottom doors of the weigh hoppers failing to engage properly and the gates on the feed hopper failing to close properly.

On investigation the troubles were found to be largely due to condensation caused by the high relative humidity of the atmosphere and further aggravated by the hygroscopicity of the product handled. The bagging plants were sited on the coast in areas where the relative humidity varies between 60% and 95% and stays for long periods between 80% and 90%. The normal changes in atmospheric temperature at these humidities frequently gave rise to conditions where the metal of the scale was below dew point. Condensation resulted and this caused sluggish action of the moving parts and incorrect operation.

To combat condensation the weighing machines were enclosed by canvas screens and temporary heating supplied by 12 kilowatt electric heaters later replaced by steam heaters. The building in which the weighing machines were sited was made as free from draughts as possible. Save in exceptional circumstances these changes had the desired result of maintaining the temperature above dew point.

The action of the machines was further hindered by the deposition of fertiliser dust on the working surfaces. This material was hygroscopic and tended to form a sticky film which in turn attracted more dust. The effect of this film on the knife edges was to reduce the accuracy of the weights, the range of such weights being considerably widened. Provision of heating did reduce this effect by eliminating condensation but the hygroscopic tendency remained and frequent cleaning was the solution found most practicable.

The effect of the hygroscopocity of the material deposited on the weigh hopper was still sufficient to make it necessary to clean the hopper frequently and to adjust the balance twice daily for the change in the tare of the weigh hopper.

Even after the atmospheric conditions around the weighing machine had been improved by the installation of heaters and a system of regular cleaning instituted, the constancy of weighing fell off over a period and we found it necessary to overhaul the machines regularly to restore accuracy. The overhaul consisted simply of stripping and cleaning the machines and cleaning and polishing the knife edges, linkages and other working parts, Results of check weighings for four machines have been collected and are shown below in Table I:-

Period since Overhaul	Average Range in 5 bag samples ozs.
Up to 1 week	4.0
Over 1 week up to 2 weeks	6.2
Over 2 weeks up to 3 weeks	5.5
Over 3 weeks up to 4 weeks	8.8
Over 4 weeks	15.0

It will be seen that the constancy of weighing, as measured by the average range in 5 bag samples, is quite accepta for the first three weeks, but falls off rapidly thereafter. In this case it was decided that each machine should be over-hauled in turn in its fourth week of operation. Obviously the duration of the period between overhauls, consistent with satisfactory performance, will vary with the conditions under which each machine is working, and the number of hours worked etc. but there seems to be an optimum period of operation and i this is exceeded constancy of weighing will fall off relatively rapidly.

The machines are rated at 5 loads per minute and in fact the machines as adjusted and used can deliver up to between 6 a 7 loads per minute with the degree of accuracy quoted later in this paper. If any attempt is made to increase the capacity beyond this point, however, accuracy falls off rapidly. The reason for this will be readily seen. The accuracy depends to a great extent on the length of time for which the trickle feed is passing and if this is restricted then the accuracy will fal off.

A further occasional error was found occurring when the storage hoppers were emptied. Each hopper serves four machine and it was found that when the level of product in the hopper fell to within a few feet above the level of the weighing machi gate, erratic sack weights were delivered. This phenomenon wa checked and it was found that in fact the consistency of weighing deteriorated when the level fell as described above an was restored when the hopper was refilled. The explanation of this would appear to be that when the storage hoppers are reasonably full the rate of flow of material through the weighi machine feed gate is controlled by the pressure of the head of material in the hopper. When the pressure is removed the flow becomes irregular and this leads to irregular weighing. The extent of the effect is such that the range of weights in five bag samples can increase from around 4 to 8 ozs. to as much as 15 to 40 ozs. Following this discovery the fertiliser in the hoppers was maintained at a consistently high level and the hopper was allowed to empty only when a change was made in the grade of material being packaged.

Conclusions.

Automatic weighing machines are capable of giving much better performance in respect of both consistency and accuracy of weighing than was previously obtained with hand weighing. To achieve this result it is necessary to control the working conditions of the machine quite closely. The requirements found necessary were as follows:-

(1) The plant must be designed to deliver at the maximum rate required and the weighing machines must not be speeded up beyond the limits of accuracy.

(2) The machine must be kept at a temperature above dew point to prevent condensation.

(3) Accumulation of dust on the working parts must be avoided.

(4) Frequent routine check weighing and balancing of the scales must be observed.

(5) There is a minimum level of product in the storage hopper below which erratic weighing occurs and it is necessary to ensure that during normal working the product is kept above this level.

(6) Routine plant maintenance is necessary as there is an optimum period of operation between overhauls after which the consistency of weighing rapidly deteriorates.

Much of the tendency to inaccuracy is due to adhesion of a skin of fertiliser dust to the weigh hoppers and to the effect of fertiliser dust on the knife edge and bearings. At present these effects are counteracted by regular cleaning and maintenan but it seems likely that a careful choice of materials of construction might greatly reduce the amount of cleaning and maintenance necessary. The use of plastic or plastic coated metal for the weigh hopper and weight box would greatly reduce the adhesion of dust and formation of scale. Knife edges and bearings which are at present subject to corrosion might be constructed in non-corrosive alloys. A machine so constructed would require less frequent maintenance and might reasonably be expected to give even more constant and accurate performance.

Acknowledgements.

In conclusion I wish to express by thanks to the Directors of Scottish Agricultural Industries for permission to present this paper and to those of my colleagues who have assisted in its preparation.

SUMMARY

As a result of post-war conditions large-scale mechanisatio took place throughout the fertiliser industry. Granulation of compounds became accepted practice in the United Kingdom and experiences led to the view that bulk storage, followed by high speed bagging at the time of delivery, was the best method of handling granular fertiliser both from the point of view of delivering a good product and for economies in manpower. Automatic weighing methods became necessary with the increased rate of packaging and this paper deals with experience with thei use.

Comparison of Results of Package Weights produced by Automatic Weighing and Hand Weighing.

To assess the performance of high speed automatic weighing in comparison with hand weighing, approximately 500 test weighings for each method have been considered. The results are summarised in Table II:-

	Automatic Ozs.	Hand Ozs.
Average of all bags weighed	+3.6	+2.2
Lowest weight found	- 28	-112
Highest weight found	+ 28	+112
Standard deviation (calculated from average range of groups of 5)	3.2	21.0
50% Confidence limits of a single bag	±2.2	± 14.1
∴50% of bags lie between	+3.6 ±2.2	+2.2 ±14.1
i.e. between	+1.4 & +5.8	-11.9 & +16.3
Average range of groups of 5	7.5	48.8

Statistical examination of the mean errors in weighing by the two methods leads to the conclusion that the mean weight of the bags weighed by hand is not significantly nearer the stipulated value than the mean weight of bags weighed automatically. The highest and lowest recorded weight would seem to indicate that automatic weighing greatly reduces the variation in package weights and this conclusion is borne out by the relatively low standard deviation of the package weights in respect of the automatic machines.

Calculation of the 50% confidence limits showed that one might expect half of the automatically weighed packages to lie in the range between 1.4 oz. to 5.8 oz. over the stipulated rate. When compared with the corresponding range of +11.9 oz. below the stipulated weight to 16.3 oz. above the stipulated weight for hand weighing the advantage of the automatic method is strikingly obvious.

The scales were adjusted during the test period to deliver amounts slightly in excess of the nominal weight to minimise the number of underweight packages. There is a tendency for the bags to become slightly, but significantly lighter in the interval between the twice daily balancing of the machines by the moving poise. From the experience gained it has been possible to reduce the overweight setting and so reduce the average overweight figure, at the same time limiting the range of package weights to an acceptable degree. The most recent figures show an average of +0.14 ozs. for all bags checked compared with +3.6 ozs. in Table II.

The results quoted in Table II were obtained some five years ago shortly after the installation of the weighing machines when an intensive check on their performance was made. Since then routine, twice daily checks have been continued. It is of interest to note that after five years and after around 200,000 tons of fertiliser have been packaged, there has been little if any deterioration in the constancy of weighing as measured by the range of five bag samples.

The procedure of check weighing was adopted whereby a sequence of five bags was checked from each machine twice daily. Examination of the results of these checks showed whether the machine was performing satisfactorily as regards consistency of weighing, (this was indicated by the range of the five bag sequence), and in terms of accuracy of setting, (this was indicated by the average weight of the five bag sequence).

On initial installation trouble was experienced with inaccurate and erratic weighing and faulty operation of machines. This trouble was found, however, to be due to condensation from the high relative humidity combined with the hygroscopicity of the product handled. To combat this, the weighing machines were enclosed so far as possible and the air surrounding them heated to well above the dew point. This, together with frequent cleaning, resulted in maintaining the machines in a condition in which the mechanism worked freely and accurately. Deposits of fertiliser dust on the inside of the weigh hopper still occurred and it was necessary to balance the machine twice daily to minimise the effect of this.

It was also found necessary to maintain the machines by stripping and cleaning the knife edges and linkages every three to four weeks otherwise the accuracy of weighing fell off substantially.

Examination of a series of regular check weighings against check weighings of hand-weighed fertiliser, showed that the automatic machines gave packaging weights which were more constant then hand-weighed packages.

Automatic weighing machines are capable of giving much better performance in respect of both consistency and accuracy of weighing than was previously obtained with hand weighing. To achieve this result it is necessary to control the working conditions of the machines quite closely. The requirements found necessary were as follows:-

(1) The plant must be designed to deliver at the maximum rate required and the weighing machines must not be speeded up beyond the limits of accuracy.

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Much of the tendency to inaccuracy is due to adhesion of a skin of fertiliser dust to the weigh hoppers and to the effect of fertiliser dust on the knife edge and bearings. At present these effects are counteracted by regular cleaning and maintenance, but it seems likely that a careful choice of materials of construction might greatly reduce the amount of cleaning and maintenance necessary. The use of plastic or plastic coated metal for the weigh hopper and weight box would greatly reduce the adhesion of dust and formation of scale. Knife edges and bearings which are at present subject to corrosion might be constructed in non-corrosive alloys. A machine so constructed would require lessfrequent maintenance and might reasonably be expected to give even more constant and accurate performance.