

## New approach to silo weighing

The requirement by industries to accurately and reliably monitor the contents of silos, hoppers, tanks and bins is growing steadily worldwide.



The ability for any measuring system to be retrofitted to existing vessels is especially appealing, both from a cost and system disruption view point. There is also an added bonus if such systems can be fitted to new installations without vessel design changes.

The two main options open to the user are level control and weighing. There is no doubt that weighing provides the optimum solution in terms of accuracy and the majority of today's process weighing applications use strain gauge load cells as the primary measuring sensor for converting

load to electrical output. However, for a wide range of high capacity silo and vessel measuring applications, load cells are either too expensive or impractical and impossible to fit.

This leaves the user with the option of a range of level control solutions or retrofit sensors.

Although modern level control systems provide an acceptable solution for a wide range of applications, their accuracy is limited for bulk storage systems where materials are not free flowing and can leave voids or cling to the sides of the storage vessels. Such materials are typically not self-levelling and upper surfaces can be conical or sloping. Further inaccuracies arise from changes in bulk density and problems with dust, especially prevalent with materials such as flour, grain, fertilizers and cement. In these applications overall errors in large silos can be as large as 10-20% full scale, which is totally unsuitable for stock control purposes.



Retrofit sensors have, to date, met with mixed success, due in part to product shortcomings, the way they have been marketed and the inherent problems associated with this approach. In many

cases, systems are highly susceptible to drift and instability problems, resulting in very poor results.

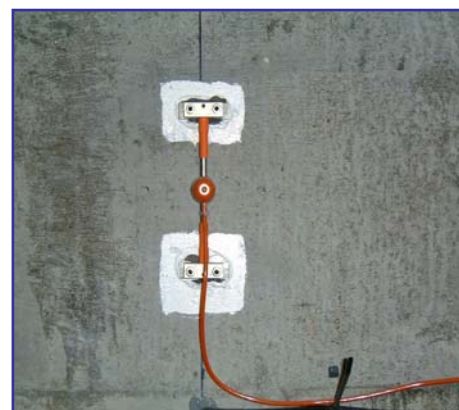
Retrofit sensors are used to measure the changes in strain levels of supporting legs or other support structures. Simplistically they convert this part of the structure into a giant load cell. However, conventional strain gauge load cells are designed to work over a given range or capacity and their dimensions are carefully selected so that the output is optimised over this full range giving a typical full scale strain level of 4000 microstrain (equivalent to 2mV/V).

Load cell performance is directly dependant on sensor design, material and build procedure. Units are compensated for the effects of temperature changes and great care is taken to ensure that the devices have minimum susceptibility to unwanted forces such as side and off-axis loads. To minimize these effects further, well designed mounting hardware and restraints are used to ensure that load cells only measure those forces relative to the change in load.

By comparison, silo supports are designed to meet the dual requirements of optimum strength and integrity versus cost. They are not designed to ensure optimum change in strain levels. Typical full scale strain changes in the support structures of a silo are in the order of 100-200 microstrain which represents a full scale change in length of just 2.5 microns over a common strain gauge length of 25 mm. To meet accuracy requirements of 1-2% means that such a gauge must be capable of measuring tiny changes of hundredths of a micron.

In order to do this effectively the system must be able to differentiate between signal output changes due to load change and those caused by changes in temperature or other influence factors. From their inception, strain gauges have been used to monitor stress changes in structures and building (The first units developed by Ruge in California in the late 1930's were used for investigating the effects of earthquakes on structures). However, strain gauge analysis is used to monitor all stresses, good and bad, whereas retrofit weighing systems are expected to measure load change without all the inherent errors associated with structure deformation.

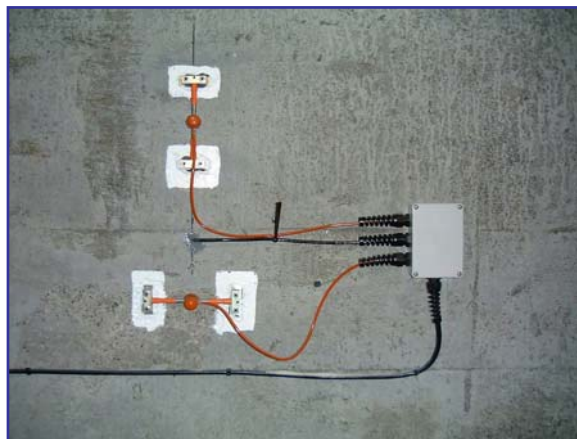
Stockport based AV Technology have brought a fresh approach to high capacity silo weighing emanating from their extensive experience in stress analysis and condition monitoring. Unlike most weighing companies, they have a detailed understanding of the behaviour of structures, based on over 15 years experience. While most current retrofit sensors are based on electrical resistance strain gauges which struggle to provide sufficient stability and accuracy, AVT's Silo-weigh system uses specially developed 'low strain' vibrating wire strain gauges (VWG's). These devices are inherently waterproof and are insensitive to moisture, long cable runs and low signal levels. Further more, these gauges are recognised to offer the best attainable long term stability of any strain sensor,



demonstrating excellent results over periods of up to 25 years.

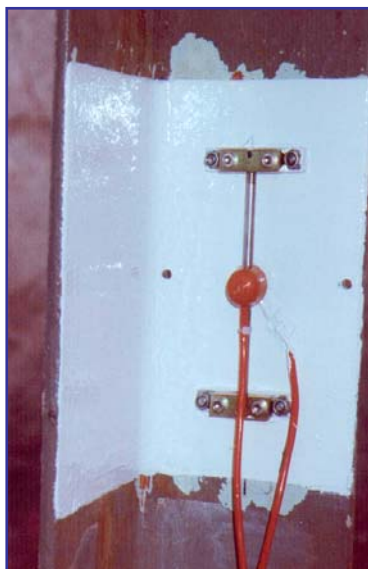
Although VWG's have been used successfully for civil engineering applications for more than 25 years, they are comparatively unknown to engineers from other disciplines and AVT are now demonstrating that these gauges are ideally suited to high capacity silo weighing. Although their system was initially developed for the huge retrofit market, the same technology is being successfully used for new installations and the most exciting aspect of this new technology is that it can be applied to all common support structures including not only steel legs but also metal skirted silos, concrete legs and concrete skirts. The system can be fitted to most existing silos within one or two days on site without disruption to normal operations.

The operating principle of VWG's is very simple. The units comprise a taut steel wire tensioned between two steel mounting blocks which are in turn attached to the surface of the structure. An electromagnetic coil is used to 'excite' the wire at its natural resonant frequency and to measure the changes in vibration frequency as the strain in the wire changes. The conversion from frequency to wire strain (and hence load change) is derived from;



$$\text{Strain in wire} = \text{gauge factor} \times (\text{wire frequency})^2$$

Following installation, the change in strain in the structure will be equal to the change in strain in the wire and can be easily calibrated against silo weight.



AVT are quick to point out that they have no magic solution for dealing with the low and irregular strain changes in structures. However their practical and logical approach is effective in minimizing inherent system anomalies and it is in the handling and analysis of data where AVT have been so successfully. The main sources of error in retrofit systems are temperature, differential support deflection and structure interaction (cross talk). Temperature changes in different parts of the structure will affect the sensors to different extents and the magnitude of these errors is usually significantly greater than the required system accuracy. Differences in deflections from one support to another as load distribution varies and interference from adjacent structures will introduce significant errors.

To overcome this, AVT have developed compensation techniques which are effective in reducing these errors to acceptable levels. Rather than try to adopt standard weighing instrumentation, the company utilize a multi channel data logging system and standard read out unit. This provides

capabilities for enabling:

- Non-linear calibration factors
- Individual calibration factors for each silo support
- Measurement of temperatures and on-line thermal compensation
- Intelligent data validation and signal conditioning
- Data storage for weight trending
- Remote modem interrogation
- Single data logging system for multiple silos

A prime example of the effectiveness of the new Silo-weigh system is illustrated at Cerestar UK at Trafford Park Manchester. Here the customer was having difficulty in achieving a reliable measurement of the contents of two 250 tonne steel silos. These share a common concrete plinth supported on eight 600mmx600mm concrete legs and therefore any change in weight in either silo can affect all eight common supports to varying degrees.

The company had already spent considerable time and money on level control equipment and as automation support coordinator, Graham Beswick, explains: "We thought we had run out of options for monitoring the contents of these silos. The properties of the product stored in them caused the product to bridge or cling to the sides of the silos. This, combined with the irregular shape of the surface and high levels of dust, renders level measurement totally ineffective. The design of the silos precludes the fitting of conventional load cells without major redesign and downtime. "

AVT convinced Cerestar that they could provide an accurate weighing system without any disruption and at a realistic cost. Their solution comprised the fitting of opposite pairs of surface mount VWG's on to each support. All



16 gauges were then connected into a Campbell Scientific CR10X data logger located in an adjacent switch room together with a local weight display. As expected the silo measurement system initially suffered from 'cross talk' effects, where any change in weight in the adjacent silo affected the weight indications. This was resolved by using multi-variant calibration techniques. Using data from all 16 gauges, it was possible to compute 16 term calibration equations for each silo which were then successfully implemented to perform on line cross talk compensation.



To overcome drift problems the system was fitted with an 'easy zero' feature. By pressing both the Silo A (or B) button, together with the confirmation button and holding for five seconds, the easy zero control interrupts the system control unit and stores the currently displayed weight. This weight is then subtracted from subsequent weight indicators.

Two years on and Cerestar are very pleased with the Silo-weigh system. Graham Beswick is delighted with the results. *"At first,"* he points out, *"we were very sceptical of the solution offered by AVT, but their attention to detail and technical understanding of the problems involved have resulted in a system which is providing the data we need, consistently and reliably, under all operating conditions."*

As a result, they recently commissioned AVT to install similar systems to four new 3000 tonne concrete storage silos. Each massive silo is supported on 12 concrete legs and instead of waiting until the silos were built before fitting the sensors, embedded type VWG's have been cast directly inside each leg. The permanent nature of this installation emphasizes the confidence AVT have in their system and the sensors. The VWG's were pre-installed onto the re-enforcing bar cages, mounted onto steel supports bars to locate them centrally within the column. Expanded metal protection was attached directly above each gauge to protect it from falling concrete during casting and from the vibrating pokers used to de-aerate the concrete.

Each leg has one VWG fitted exactly half way up and as with the earlier installation at Cerestar, all the sensors are connected into a central data logging system. In addition to a local display in the control room, an independent 4-20 mA signal is generated for each silo which is connected to the customer's DCS control system.

Initially the readings from the silos exhibited significant thermal errors of around 20% full scale for just 5°C ambient temperature variation from day to night. These errors were successfully removed



using the thermal compensation techniques developed by AVT and the system is providing extremely stable results with weight readings within 3%FS.

As AVT's Technical Director, Neil Parkinson, concludes: *"Unfortunately retrofit sensors are often sold as a cheap and quick solution for high capacity weighing applications. This approach has led to retrofit products getting a poor reputation and customers ending up with little or no after sales support when things go wrong or malfunction. Our approach is that we are selling a complete system and take full responsibility for the design, installation and calibration. Although the strain levels involved are relatively small and the possible sources of error relatively large, by employing the correct strain measurement and compensation techniques, it is possible to compute accurate silo weights based on strain measurements. The Silo-weigh solution provides a cost effective weighing system for applications where alternative technologies do not offer sufficient accuracy and the ability to monitor contents of concrete silos, opens up exciting opportunities for new and retrofit installations."*

Silo-weigh is successfully monitoring contents of huge 500 tonne silos at Pilkington Glass in St Helens, Lancs



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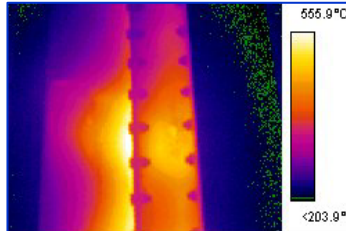
- Condition Monitoring
- Facilities
- Maintenance
- Noise & Vibration
- Structural Integrity
- Training

**Services:**

- Condition Monitoring
- Lubrication Management
- Maintenance Solutions
- Noise & Vibration
- Strain Gauging
- Structural Monitoring
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**Products:**

- Acoustic Emission Sensors
- Condition Monitoring Systems
- Lubrication & Filtration
- Silo Weigh
- Structural Monitoring Systems
- Vision Systems



AV Technology Limited  
 AVTECH House  
 Birdhall Lane  
 Cheadle Heath, Stockport  
 Cheshire  
 SK3 0XX

Tel: 0161 491 2222  
 Fax: 0161 428 0127  
[enquiries@avtechnology.co.uk](mailto:enquiries@avtechnology.co.uk)  
[www.avtechnology.co.uk](http://www.avtechnology.co.uk)



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