Technical Note TN-275 August 1998

A COMPARATIVE EVALUATION OF ONBOARD WEIGH SCALES

J. Michaelsen*

Abstract

In early 1997, FERIC performed an operational evaluation of five onboard weigh scales for semi-trailers. The purpose of the study was to assess the scales in the field under normal operating conditions and as used by the drivers. The scales were based on load cells, pneumatic devices, or combinations thereof, and were intended for use with either leaf-spring or air suspensions. Data were collected on the ease of use of the scales, their accuracies, and their short-term reliability, and were used to assess the suitability of the scales for in-woods use. The study found that four of the scales were consistently within the tolerance (1500 kg) accepted by the Ministère des Transports du Québec, which served as a reference.

Introduction

Study Context

In December 1996, a member company asked FERIC to perform an operational assessment of the various onboard weigh scales that were being used by its truckers on one of the company’s Quebec operations. The goal of this assessment was to evaluate the scales’ effectiveness during actual haul operations, as actually used by the drivers, so as to determine which systems were sufficiently accurate to justify their purchase. FERIC visited the haul operations in January 1997, and met with the driver of each truck involved in the study to explain the study's purpose and the data collection method.

Types of Scales

There are several brands of onboard weigh scales on the market, designed for use with either air or traditional mechanical suspensions. These scales may be based on a single technology or a combination of three technologies: load cells, load transducers, and pneumatic devices. This report applies only to scales manufactured by Cléral Electronic Scales for Trucks, SI Technologies, inc. and Stress-Tek, inc.

Scales designed to work with traditional mechanical suspensions (leaf-spring, rubber block or solid block) are based on either load cells or load transducers. Load cells are devices that support the weight of the load continuously, and are built from precisely machined steel bars to which a strain gauge is affixed. The cells are installed as an integral part of a load-bearing structure on the tractor or trailer. On tractors, two load cells typically replace the standard supports for the fifth wheel; if the fifth wheel has been modified, supports must be welded to the outside of the tractor's frame to support the load cells. On tridem semi-trailers, with or without an air-lift axle, four load cells are typically used, one between each center hanger and the trailer’s frame.

Load transducers do not support the weight of the load. Instead, they consist of a transducer welded to a load-bearing structure on the tractor or trailer frame. The transducers themselves consist of a strain gauge affixed to a small metal bar, which is in turn supported by blocks at its extremities. The transducer measures the bending of the metal bar created by the weight of the load on the load-bearing structure, and converts this into an estimate of the weight of the load. On tractors, a

* Jan Michaelsen is a Researcher, Transportation and Roads, Eastern Division
KEYWORDS: Load-weighing systems, On-board systems, Mechanical systems, Pneumatic systems, Hybrid systems, Logging trucks, Payload, Evaluation, Comparison.

load transducer is installed on each of the suspension's walking beams. On semi-trailers, one is installed on each fixed axle (e.g., three would be required for a four-axle trailer with a single lift axle). Systems of this type are not included in this report.

Pneumatic devices calculate the weight of the load based on the pressures generated by the load in the air chambers of the suspension. Typically, an air hose links the suspension's air bags with a pressure transducer or gauge in the tractor's cab. One device is usually used for each air suspension system. Thus, a tractor-trailer entirely equipped with air suspensions would require two transducers linked to the scale's central unit: one for the tractor’s air suspension system and another for the trailer’s air suspension. In the simplest case, an inexpensive dial gauge is used to display the air pressure, which the driver must convert into a weight. More sophisticated devices use more accurate transducers and convert the air pressure directly into a weight reading.

Methodology

Equipment Used

In all, FERIC studied five trucks equipped with onboard scales (Table 1). One of the systems was entirely mechanical (based on load cells), two were entirely pneumatic, and the remaining two were hybrid systems (i.e., mechanical on the tractor and pneumatic on the trailer).

Cléral Electronic Scales for Trucks: Cléral both manufactures and distributes its own scales and currently offers scales only for trucks equipped with air suspensions. However, the company plans to market a system for mechanical suspensions in 1998. The main distinguishing characteristic of their scale (Figure 1a) is that the entire device (pressure transducer, signal conditioner, electrical system, and display) is contained in a single box. This simplifies installation, since all that is required is mounting the box at an appropriate location within the cab and hooking it up to the air suspension. The disadvantage of this approach is that the box is too large to fit on most dashboards, and must typically be mounted on the floor between the seats or on the side of one seat. The unit simultaneously displays the tractor, trailer, and total weights. This facilitates reading the weight values.

The calibration process is more complicated than with the other scales, particularly for users with poor math skills. However it does make the relationship between pressure readings and weights clear. In addition, it permits "post-calibration" of the loaded values even after unloading the trailer by simply adjusting the calibration parameters (with the manufacturer's help, if necessary) rather than the weight displayed. Since the tests were run in the winter of 1997, Cléral has made two modifications to their scale. They have reduced the size of the display box so it can fit on the dashboard, and they have improved the calibration procedure by simplifying it and by displaying help messages in one of the windows to guide the driver through the calibration process.

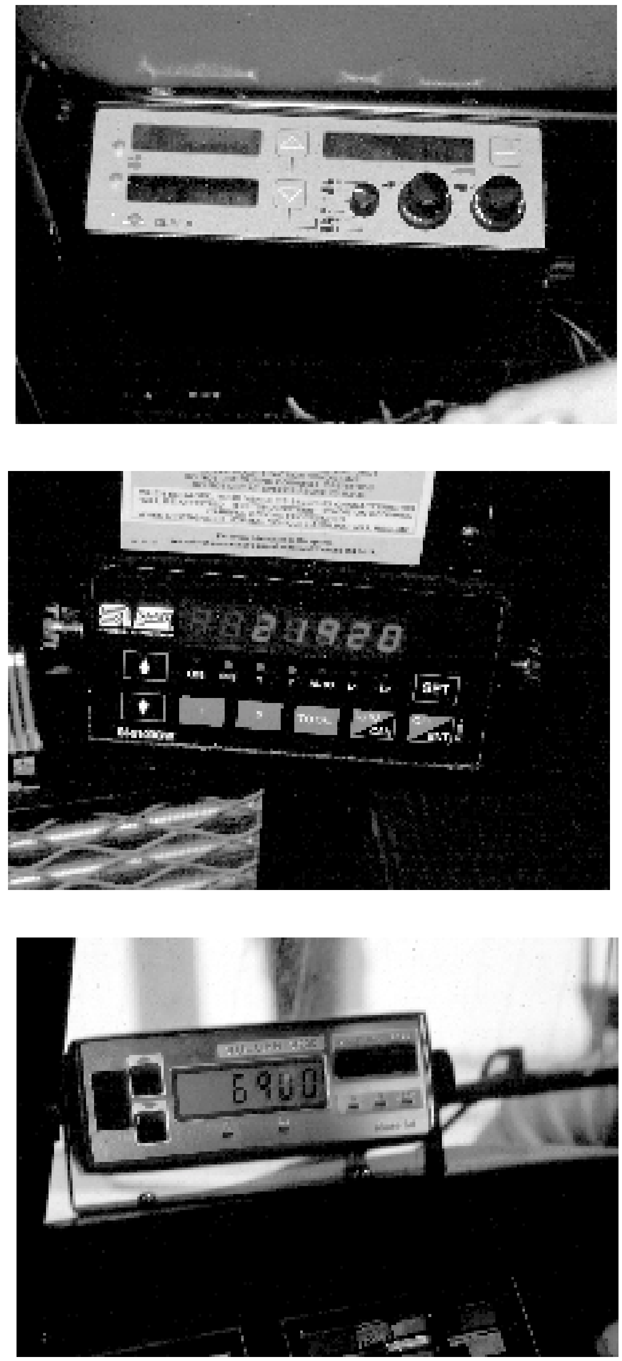

Figure 1. The three scale displays: (a) Cléral, (b) SI, and (c) Vulcan.

Table 1. The five scales that were evaluated in FERIC's study

		Type of scale		Cost ($)[a]	
	Manufacturer	Tractor	Trailer	System	Installation
Mechanical system	Vulcan	Load cell	Load cell	n.a.[b]	n.a.
Pneumatic systems	Vulcan	Pneumatic	Pneumatic	2366	400
	Cléral	Pneumatic	Pneumatic	2345	67.50 to 450
Hybrid systems	SI	Load cell	Pneumatic	5125[c]	800 to 1000
	Vulcan	Load cell	Pneumatic	4424	800

[a] The system cost represents the manufacturer's suggested retail price, and does not include shipping. Prices may vary by region and vendor. The installation cost depends on many factors, including the type of tractor, semi-trailer, and suspension system.

[b] Balances canadienne Bourbeau no longer recommends this type of system because of its high cost and the complexity of the installation. Instead, they recommend that the trailer suspension be converted to a pneumatic system. (n.a. = not available)

[c] Prices will vary depending upon the type of fifth wheel. The price listed here is for a load cell for Holland's fixed fifth wheel.

SI Technologies, Inc.: SI scales, which include load cells, load transducers, and pneumatic systems, are distributed in Quebec and the Atlantic provinces by Les balances Trans-Québec Ltée. Each system comprises a minimum of two load cells, two strain gauges, or two pneumatic gauges, combined with two signal conditioners and a display. Only a hybrid system based on two load cells on the tractor and a pneumatic gauge on the trailer was included in the present study. In contrast with the Cléral system, the SI display used in the study (the 9100-LD) had only a single display window (Figure 1b); thus, the three weights must be displayed sequentially during calibration, and this complicates the procedure. However, the three weights automatically display in sequence during loading. The calibration procedure is more involved than with the other scales that FERIC studied, and uses a series of sequential menus that require passing through several menu levels for recalibration. However, the scale permits post-calibration without requiring any manual calculations; the user need only record the displayed weight and the actual loaded weight. SI also offers the 100-M display, which has fewer features but is simpler to calibrate and costs $200 less.

Stress-Tek, inc.: Vulcan scales are manufactured by Stress-Tek and distributed in Quebec by Balances canadienne Bourbeau et frères inc. They offer two types of scales (pneumatic and load cells), in several models. Each system comprises a minimum of two load cells or pneumatic gauges, two signal conditioners, and a display. For pneumatic scales, the gauges and conditioners are generally installed in the cab, and the small size of the unit permits installation on the dashboard. The Vulcan display (Figure 1c) used during the study was the model V200. As with the SI display, this display has only a single window; however, the user must hold down one button while making adjustments via a second button. In addition, the numbers displayed during calibration represent calibration data, not actual weights, and to see the corrected weight, the user must release all buttons. Finally, the system does not permit post-calibration. In late 1996, Stress-Tek introduced a new display system (the V500) that, among other improvements, permits one-button calibration and tare adjustments, as well as post-calibrations.

NOTE: The purely mechanical system that FERIC studied (load cells only) was not a regular Vulcan product or installation. This custom installation was performed by Bourbeau solely to solve a particular problem. Bourbeau no longer recommends this type of installation due to its high cost and complexity.

Measurements

Drivers were provided with record books in which to record the date, time, delivery location, road conditions, distance traveled, and weights hauled for each trip; for weights, both the onboard scale's reading and the mill's scale reading were recorded. Tractor and trailer weights were recorded using the onboard scale at the point of loading, as well as at the mill, to permit a comparison of the scale's readings under field and ideal (i.e., mill) conditions; recording the onboard scale's readings at the mill compensated for any accumulation of snow or ice during the haul. Mill readings corresponded to the gross vehicle weight (GVW). The total weight reported by the onboard scale was calculated from the sum of the tractor and trailer weights. The results presented within this report are based on FERIC's analysis of the data as furnished by the drivers.

Location of Measurements

The operators of the SI hybrid system, the Vulcan pneumatic system, and the Vulcan hybrid system generally recorded their in-field measurements at the point of loading; when the road was particularly steep, they advanced to a more level stretch of road. The user of the Vulcan load-cell scale reported advancing his truck to more level ground in only about 10% of the cases, whereas the user of the Cléral pneumatic scale always took his measurements at the point of loading.

Results

It is important to note that the results presented in this Technical Note represent values recorded during a relatively short-term study of a single unit of each scale, operating under specific conditions, and that results elsewhere can be expected to vary depending on the habits of the operator and the characteristics of the operation.

Ease of Use

On the whole, the truckers were satisfied with the onboard scales, but varied in their assessment of the ease of calibration. The truckers' assessment was based on their experience since installing the scales, including calibrations performed before, during, or after the data collection period. The SI hybrid scale was only calibrated twice, once by following instructions over the telephone and the second time by a regional representative of the vendor. The Cléral pneumatic scale was transferred to a new truck prior to the study, and was recalibrated at that time by a representative of the vendor; thereafter, the operator calibrated the system once by himself with telephone support from Cléral. Calibration of all the Vulcan scales was simple enough to be done by the operators themselves; the load-cell scale was calibrated roughly twice per year, versus "occasional" calibrations for the hybrid system and calibration at least once per month for the pneumatic system.

Reliability

The scales were generally quite reliable, and experienced few problems. The SI scale's plastic display casing broke once during the study period. The display of the Vulcan hybrid system was broken for a time because the operator neglected to inform the company to request a repair. The Cléral pneumatic, Vulcan pneumatic, and Vulcan load-cell systems experienced no breakage over the course of the study; however, several bolts retaining one of the latter system's load cells had to be tightened.

Accuracy

Tables 2 and 3 summarize the differences between the GVW weights recorded by the onboard scales and the mill scales. Analysis revealed that for a given truck, weight differences remained relatively constant irrespective of which mill was visited. The accuracy of each scale was thus assessed by assuming that the mill scale represented the correct value. The *mean* differences presented are not a true reflection of a scale's accuracy since the values could also be influenced by the scale's calibration bias. However, the *standard deviation* (SD) of the differences provides a good indication of the accuracy of a scale, since it represents the variation with respect to a fixed reference (the mill scale). The 95% confidence interval (equal to roughly twice the standard deviation) provides a good indication of the potential error (kg) of each scale, since measurements will fall within this range 95% of the time. The percentage error of each scale equals its 95% confidence interval divided by the mean total loaded weight as measured by the mill scale; for example, if a scale has an error of 2%, its reading will be within 2% of the mill scale's reading 95% of the time, assuming the onboard scale is properly calibrated.

Table 2 summarizes the in-woods results, whereas Table 3 summarizes the results recorded at the mill. The scales are ranked in each table so that scales whose variances were not statistically different received the same ranking.

Table 2 indicates that none of the systems had a high mean difference, which suggests that the calibrations were relatively accurate. Four scales had an error of less than 3%, which represents an error of about 1500 kg (the tolerance accepted by the Ministère des Transports du Québec) for a GVW of 55 500 kg. The SI scale performed exceptionally well, with an in-woods error of only 1.15%. Since the operator of the truck that used the Cléral air-based scale indicated that he always performed his measurements at the point of loading, the error rate for this scale probably overestimates the values that would have been obtained if the readings had consistently been taken on level ground.

Table 2. Difference between the mill scale's reading and the onboard scale's in-woods reading

	Ranking	No. of readings	Difference (kg)[a]		95% confidence interval	Error (%)[b]
			Mean	SD		
Scale						
SI hybrid	1	91	138	330	656	1.15
Vulcan hybrid	2	42	211	588	1188	2.08
Vulcan air	2	62	294	603	1206	2.13
Cléral air	2	43	139	723	1459	2.63
Vulcan load cell	5	70	100	902	1800	3.17

[a] The difference represents the mill scale reading minus the onboard scale's reading.
[b] The error equals the 95% confidence interval divided by the mean GVW recorded by the mill's scale.

Table 3. Difference between the mill scale's reading and the onboard scale's reading at the mill

	Ranking	No. of readings	Difference (kg)[a]		95% confidence interval	Error (%)[b]
			Mean	SD		
Scale						
SI hybrid	1	88	113	265	527	0.93
Vulcan hybrid	2	38	69	356	721	1.26
Cléral air	2	43	96	356	718	1.30
Vulcan air	4	61	80	554	1109	1.96
Vulcan load cell	5	63	175	698	1396	2.46

[a] The difference represents the mill scale reading minus the onboard scale's reading.
[b] The error equals the 95% confidence interval divided by the mean GVW recorded by the mill's scale.

As was the case for Table 2, the mean data in Table 3 suggest that none of the balances exhibited a serious calibration bias. The accuracy of all the onboard scales when used at the mill was improved compared with the in-woods measurements, though the improvement was relatively minor with the SI hybrid scale and the Vulcan pneumatic scale. This can be explained by the fact that most of the scales were affected by the in-woods operating conditions; however, it is possible that the drivers of the trucks with the SI and Vulcan air-based scales more commonly moved their trucks to level ground before taking measurements. Table 3 also indicates that four of the scales had an error of less than 2%, which is exceptional; the fifth scale had an error of less than 2.5%, which is acceptable.

Conclusions

Because the study was of short duration, the results are not necessarily an indication of the long-term accuracy or reliability of the scales. In addition, it is important to emphasize that some manufacturers offer a range of products and that it is not appropriate to generalize the study's conclusions and apply them to other products by the same manufacturer. Finally, because operators differed in their measurement practices (e.g., how often they advanced to level ground before taking a measurement, how often they calibrated their scales), the data are not entirely comparable for different scales, but serve as an indicator of relative performance.

The results in Table 2 suggest that only four scales (the SI hybrid, the Vulcan air-based and hybrid scales, and the Cléral scale) produced an error within the Ministère's acceptable limits under actual in-woods conditions. The results in Table 3 (measurements at the mill) supported this finding. The Vulcan load cell system demonstrated marginal performance (i.e., slightly over the specified limit under in-woods conditions) and at a much higher price. Additional trials would be warranted to determine whether the in-woods results were due to the operating conditions in the forest or the driver's method of using the scale.

Many truckers use a simple dial gauge to read the air pressure in their suspensions and manually convert this to a weight. For example, drivers know that when the pressure reading for the semi-trailer suspension reaches 75 psi, they have reached their legal load for that axle group. This is much more economical than using a specialized system but offers lower accuracy in most cases because of the low accuracy of most dial gauges and the need to manually calibrate the pressure reading. Results from an unpublished FERIC study showed that for a multipurpose truck (chips and tree-length logs) going from a sawmill to a pulp mill (i.e., not under forest conditions), a truck equipped with two dial gauges for the tractor suspension and one for the trailer suspension achieved an error level of 3.4% of GVW. This is roughly one percentage point more than the average for the two fully pneumatic systems examined in this study; this represents 550 kg more per trip, or a payback of between $3000 and $4000 per year in a typical forestry trucking operation. Therefore, the scale systems would pay for themselves in roughly 1 year.

Recommendations

All scales in this report proved suitable for use with air suspensions. However, the study did not identify an inexpensive scale suitable for use with a trailer equipped with a leaf-spring suspension. The Bourbeau/Vulcan system for mechanical suspensions is expensive, and this suggests the need for further development efforts to meet the needs of users of leaf-spring suspensions.

Drivers should also be trained to use their scales more effectively. For example, drivers of vehicles with tri-axle semi-trailers in Quebec should load their vehicles until the scale displays a total weight of 55.5 tonnes. The error levels observed in this study suggest that respecting this limit will lead to a minimal risk of overloads that exceed the 57.0-tonne GVW limit permitted by government regulations. As well, drivers should be instructed to conduct all measurements on level ground, where possible, until they learn the effects of *small* slopes on the scale reading and to regularly verify the calibration of their scales.

Finally, even though dial gauges are economically attractive, they do not appear to offer the same accuracy as the more sophisticated systems and end up costing more in lost payload.

Disclaimer

For further information, please contact:

Cléral Electronic Scales for Trucks
450, 3e Ave., Suite 202A
Val D'Or, Que. J9P 1S2
Tel.: (819) 825-5553
Fax: (819) 825-5556
E-mail: cleral1@sympatico.ca

Balances canadienne Bourbeau et frères inc.
(Distributor for Stress-Tek Scales)
6190 Vanden Abeele
Ville Saint-Laurent, Que. H4S 1R9
Tel.: (514) 337-2260
Fax: (514) 337-3811
E-mail: bcbf@total.net

Les Balances Trans-Québec ltée.
(Distributor for SI Scales)
8230, Ave. De L'Industrie
Ville d'Anjou, Que. H1J 1S7
Tel.: (514) 353-0928
Fax: (514) 354-4556
E-mail: transqc@dsuper.net

Canadian Stress-Tek, inc.
1642 Langan Avenue, Number 11
Port Coquitlan, B.C. V3C 1K5
Tel.: (604) 944-1481
Fax: (604) 944-1482

SI Technologies, inc.
Canadian Operations
1765 Springfield Road, Unit 106
Kelowna, B.C. V1Y 5V5
Tel.: (250) 860-8450 or 1-800-989-1499
Fax: (250) 762-9811
E-mail: siscales@netchop.net