ISSN 0111-4743

LOGGING INDUSTRY RESEARCH ASSOCIATION

NEW ZEALAND

TECHNICAL RELEASE

Vol. 10 No. 7 1988

THE INDEXATOR WEIGHING SYSTEM

A Report by R. Wingate-Hill and I.J. MacArthur (CSIRO Division of Forest Research) and R.B. Cunningham (Australian National University), Australia.

ABSTRACT

The Indexator MV3 Weighing System has been developed for mounting on knuckleboom cranes to measure grapple loads and to keep a running total of successive loads.

Five different types of tests were carried out on the Indexator to measure various aspects of its performance. These tests ranged from static measurements of its accuracy using calibrated weights[1], to an assessment of its usefulness in measuring loads of logs on trucks.

The Indexator cannot be regarded as an accurate measuring instrument, indeed with an unskilled operator it could be simply misleading. With regular calibration, however, it can be a useful device, with an acceptable level of accuracy, for tasks such as measuring output from logging operations and loading log trucks to their legal limits.

ACKNOWLEDGEMENTS

LIRA thanks the CSIRO Division of Forest Research for permission to publish this Report. The project is part of the Young Eucalypt Programme which aims to increase the productivity of the regrowth eucalypt forest and quantify the properties and values of young eucalypt wood. The results presented and conclusions drawn are interim and may be subject to revision.

----

1. *In this Technical Release the word "weight" is used in place of "mass".*

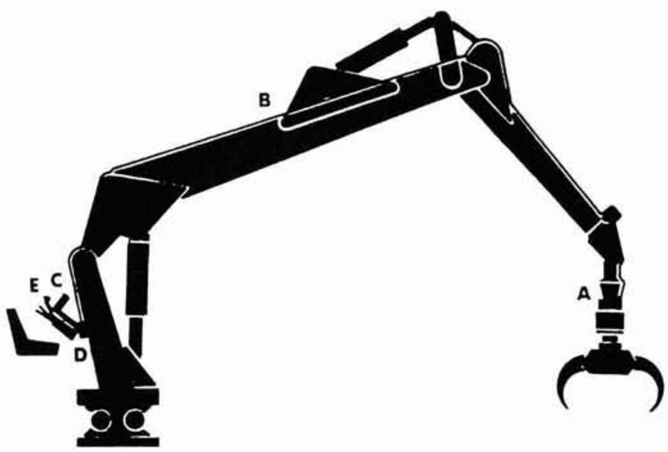

Figure 1.

Example of system configuration: A) Weighing unit with oscillation damper; B) Signal cable runs along top of boom where it is well protected; C) Cassette-type mounting bracket and MV3 instrument; D) Junction box; E) ENTRY button.

INTRODUCTION

The Indexator MV3 Weighing System is designed for mounting on hydraulic cranes to weigh individual grapple loads. In the forest industry it would most probably be mounted on a forwarder or truck crane for keeping a running total of grapple loads. This would allow the loading of log trucks to their legal axle loadings so exploiting their full capacity yet avoiding fines for overloading. It could also be used to improve production control in logging operations.

A weighing system of this type, mounted on a loader, can service a number of trucks. The Indexator system which is fitted to a truck can service only that one truck.

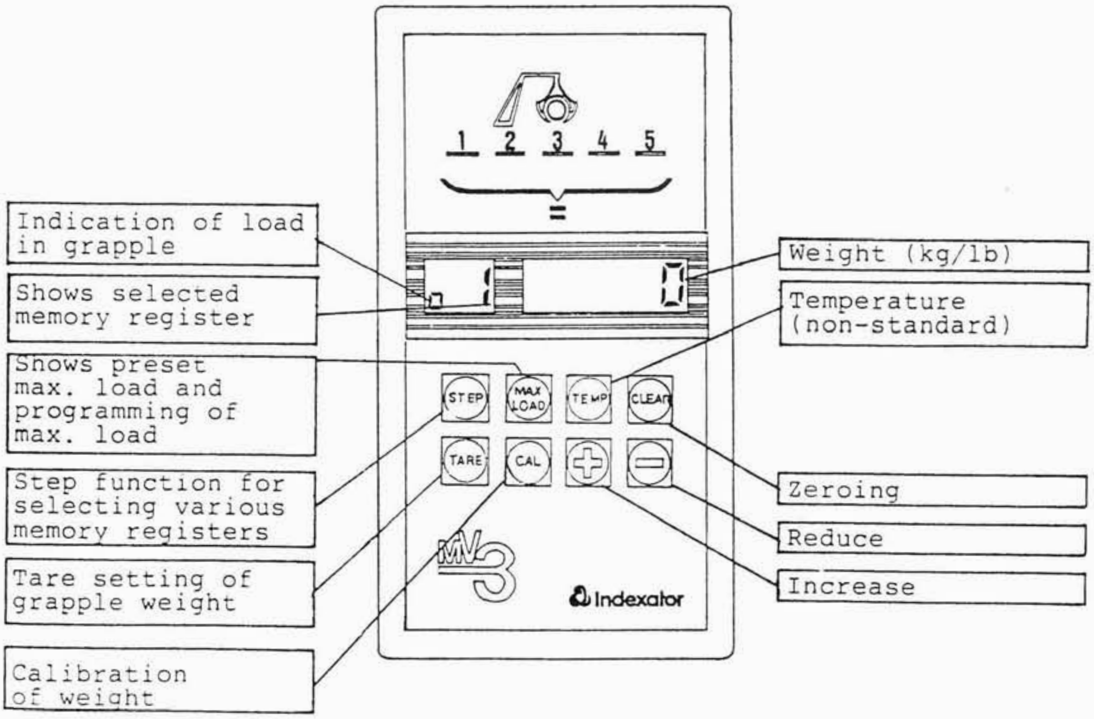

Figure 2 : Indexator weighing instrument display panels and operating keys

DESCRIPTION OF INDEXATOR SYSTEM

There are four main assemblies in the system (Figure 1): a weighing unit (A), weighing instrument (C), a cable joining the two (B) and a load entry button (E).

The weighing unit is mounted between the top of the rotator on the grapple and the outer end of the crane boom. It consists of two parts which can slide relative to each other. Between these is a hydraulic load cell. At the base of the weighing unit there is a device to damp oscillations of the grapple, similar in principle to a disc brake.

The other parts of the Indexator are a mounting bracket, intended to be permanently attached to the crane close to the crane controls, and the micro-computer-based, programmable weighing instrument which can be easily removed from the mounting bracket for safe storage (Figure 2). The weighing instrument is about the size of an ordinary video cassette (110 x 195 x 30 mm). Its temperature range for reliable operation is -40° to 60° celsius.

Operation

The display panels, operating keys and their functions are shown in Figure 2. The numbers 1 to 5 refer to the memory registers, for use when there are a number of bunks on a truck and the load in each bunk is required separately. The "=" sign refers to the register which contains the aggregate load for all the memories 1 to 5.

Calibration

The empty grapple is raised, CAL is depressed and held down at the same time as TARE is depressed. A known weight, eg 1000 kg is then raised in the grapple and CAL and + or - are depressed until the correct weight is displayed.

It is recommended that a series of ten lifts is carried out using the same weight and the error readings are averaged. The average error is then used as a basis for completing the calibration, ie the average error is added to or subtracted from the Indexator reading, as necessary. No further calibration is claimed to be required unless the battery in the instrument goes flat (but see testing).

Selection and Zeroing Memory Registers

By depressing the STEP key it is possible to shift from one memory to another. If STEP is depressed and held down the reading in the current memory is displayed.

The memory registers used in the previous loading operation are usually zeroed before loading commences. All memories can be zeroed by selecting the aggregate memory register with STEP and depressing CLEAR. Alternatively, individual memories can be zeroed separately by the same method, in which case the aggregate memory total will be correspondingly reduced.

Programming Maximum Load

The operation is carried out by depressing the MAX LOAD and + or - keys until the desired weight is displayed for the memory being programmed. The programmed maximum load can be checked by pressing the MAX LOAD key. Maximum load for all memories is 99,999 kg.

Load

When the above steps, or as many as necessary, have been completed the instrument is ready for the loading operation. When a load is picked up in the grapple, the grapple load indicator lights up and the load weight is displayed. This reading may be entered in the selected memory by pressing the ENTRY button. Immediately the grapple load indicator light is extinguished and the total weight entered in the chosen memory register is displayed for about four seconds.

If the display numerals start to blink when an entry is made and the signal bar lights up this indicates that the maximum load value programmed into the current active memory will be exceeded by the weight shown on the display. One remedy is to move the current grapple load to another bunk on the log truck which is not fully loaded. When all three signal bars light up it means that the maximum load in the aggregate memory is about to be exceeded. If the operator wants to enter the grapple load reading regardless of the warnings the ENTRY button must be pressed twice.

TESTING

Five tests were carried out to measure different aspects of the Indexators' performance.

1. Type of lift
2. Drift
3. Three-part loading cycle
4. Continuous loading cycle
5. Log loading

Tests 1 to 4 were carried out using the equipment shown in Figure 1, that is, an Indexator system attached to an hydraulic crane mounted on a prime mover. Calibrated weights and baskets were used as the loads. Prior to the first lift of each load in each test the grapple weight was tared off.

Tests 1 to 4 were carried out with the crane stabilizer legs down, on a flat horizontal area with minimum air movement. By contrast, in Test 5 the performance of an Indexator system attached to a forwarder was measured in a log loading operation. The forwarder was not stabilized, the surface was not flat, there were some wind effects and the log loads varied in size and shape.

Test 1 — Type of Lift

The object of this test was to measure any effects on the accuracy of weighing caused by 'jerky' lifts compared with smooth lifts, that is what effect the rate of load application had on the accuracy of the load cell.

Method

Five different loads were used, 100, 250, 500, 750, 1000 kg. The loads were lifted about 2 m from the ground as smoothly as possible or as fast as possible (jerk) and held suspended. The Indexator reading was taken 10 seconds after the start of the lift when the load had stopped swinging. The order in which the loads were lifted and the methods of lift were chosen at random and four replications were carried out.

Results and discussion

There was a significant difference ($P < 0.05$) between the errors for the two lifting methods. The mean error for the jerk was +3.70 kg and for the smooth lift +1.25 kg (standard error of the difference between these means was 0.871 kg). Hence to minimise weighing errors loads should be lifted smoothly.

The mean errors for each of the weights, averaged for both methods of lifting, were :

Weight (kg)	Mean error (%)
100	+2.50
250	+0.55
500	+0.30
750	+0.50
1000	+0.33

The differences between the means were not significant.

Test 2 — Drift

The aim here was to find out the change with time in the load registered by the Indexator. This is one of the routine measurements carried out by testing authorities to determine the performance of load cells.

Method

Loads of 100, 250, 500, 750 and 1000 kg were gently lifted from the ground and held suspended. Indexator readings were taken every 10 seconds for 2 minutes. Loads were selected at random and three replications carried out.

Results and discussion

The mean errors over the three replications for the five different weights during the 2 minute suspension periods were :

Weight (kg)	Mean error (%)
100	1.78
250	-0.01
500	-0.24
750	0.04
1000	0.03

The standard error of the difference between these coefficients was 0.182.

These results indicate that there was a tendency for errors to be initially small for weights 100 and 250 kg and increase with time to positive values; whereas for the 750 and 1000 kg weights the reverse was the case. Errors associated with the 500 kg weight were quite small and did not vary much with time. No reason could be found for these trends in the weighing errors with increasing suspension time.

Test 3 — Three-part Loading Cycle

There are an almost infinite number of situations under which a load may be measured with the Indexator. Broadly these involve various combinations of vertical and horizontal movement (including rotation) and acceleration or deceleration of the load, or measuring when the load is stationary.

The last situation was covered in tests 1 and 2. In this test and test 4, two of the measuring situations most likely to be employed in practice were used, viz in this test vertical lift, slew, vertical lower and in test 4 a smooth combination of lift and slew flowing into slew and lower.

Essentially in this test the calibration operation, described earlier, was carried out with each load, but extended to include three phases, and the loads were moved so as to simulate a log loading operation. Appropriate corrections were applied after the first and second phases of the calibration in the manner recommended by the suppliers. Three phases were included because preliminary trials indicated that the accuracy of the total load after the ten lifts in each phase depended a good deal on the operator and how quickly he settled into the task.

Method

Weights of 250, 500 and 750 kg were used. The crane did not have sufficient capacity to lift and

Table 1 : Mean absolute error (10) values* in Test 3

Operator	*Mass*	*Phase 1*	*Phase 2*	*Phase 3*
	250	*42*	*29*	*22*
1	*500*	*9*	*13*	*9*
	750	*21*	*26*	*4*
	250	*22*	*40*	*12*
2	*500*	*28*	*44*	*13*
	750	*7*	*6*	*26*
	250	*7*	*4*	*5*
3	*500*	*9*	*11*	*2*
	750	*12*	*4*	*3*

* %

slew 1000 kg. Three operators were employed. They were asked to enter the load and shout out the current total to the recording person at about the mid point of the slewing element, when there was no vertical acceleration and horizontal acceleration was minimal.

Ten readings were taken, lifting the load from one side of the truck to the other and back again. Then a correction was applied according to the method described under 'Calibration'. This process was called a 'phase' and carried out three times for each load within each of the two replications.

Results and discussion

Indexator owners could lose financially if the instrument readings are above or below the true values. Hence the weighing errors recorded in this test and Test 4 were analysed by taking absolute error values, that is, the +ve or -ve signs were ignored.

The same types of analyses were applied to these data as to those in Test 2. In phase 1 operator 3 had significantly smaller errors with less variability than the other two. However, there was no significant differences between mean absolute errors due to operators or weights in phases 2 and 3.

Error readings at the end of each phase (error 10), (Table 1) were analysed separately. Again in phase 1 operator 3 had significantly lower errors ($P < 0.01$) than operators 1 and 2 but none of the differences between operators or weights was significant in phases 2 and 3. This is not surprising considering the large variability in the errors and the small size of the test.

In nine cases of the eighteen sets of measurements with different operators, weights and replications, the smallest absolute (error 10) values were recorded at the end of phase 3 and over the whole of Test 3 the smallest mean absolute error was again at the end of phase 3. Therefore, it is advantageous to go through three phases in the calibration procedure with corrections at the end of phases 1 and 2.

The magnitude of nearly all the errors was disappointingly large but they diminished as testing proceeded.

Test 4 — Continuous Loading Cycle

Here the loading cycle consisted of lifting and slewing the load followed by lowering and slewing as one smooth operation. It requires considerable skill from the operator but is a preferred method of loading logs because it is so quick.

Method

Three weights, 250, 500 and 750 kg were used with two operators and the same procedure as in Test 3.

Table 2 : Mean absolute error (10) values* in Test 4

Operator	*Mass*	*Phase 1*	*Phase 2*	*Phase 3*
	250	*15*	*22*	*9*
1	*500*	*1*	*4*	*3*
	750	*6*	*1*	*5*
	250	*19*	*17*	*6*
2	*500*	*23*	*16*	*6*
	750	*12*	*12*	*22*

* %

In this case, however, the operators were asked to enter the load reading, and shout out the current total, when the crane was lifting and slewing. The object was to measure the load when it was not bouncing or swinging to-and-fro. Vertical acceleration was relatively high at this point but as long as operator skill was good enough to ensure that it was fairly constant its effect on the load readings could be compensated in the calibration procedure.

Results and Discussion

There were no significant differences in mean absolute errors between operators or weights in phase 1, although the analysis of mean cycle times showed a significant operator weight interaction ($P < 0.05$) mainly due to operator 2 taking a much greater time to move the 250 kg weight than operator 1. This interaction disappeared in phases 2 and 3 and there were no other significant cycle time differences. In phase 2 the mean absolute errors associated with the three weights changed significantly ($P < 0.05$) but when adjusted for cycle time differences by co-variance techniques the differences ceased to be significant. There was no significant differences in absolute errors related to operators or weights in phase 3.

The mean error readings at the end of each phase (error 10) are shown in Table 2. Again the smallest mean error occurred at the end of phase 3 so that is was worthwhile working through three phases during calibration rather than only two or one.

It is noticeable that the magnitude of absolute errors was generally reduced in Test 4 compared with Test 3 in spite of the fact that the continuous loading cycle demanded greater skill and concentration than the three-part loading cycle. Test 4 was carried out after Test 3 and a likely explanation for the reduction in mean absolute errors is that operators 1 and 2 were still in the learning phase and their performance was improving. Nevertheless the errors were, in most cases, unacceptably high and this was partly the reason why the following Test 5 was carried out.

Test 5 — Log Loading

The purpose of this test was to determine the accuracy of the Indexator MV3 system in a commercial operation as opposed to the idealised conditions used in the previous tests. An effort was made to minimise any adverse operator effects by choosing a person skilled in using a boom loader and with substantial experience in operating the Indexator.

An Indexator system fitted on a Kockums 84-35 forwarder equipped with a Cranab 6010 crane belonging to a logging contractor in Morwell, Victoria was studied. The owner had been using the instrument for about 18 months prior to this study.

Method

Performance of the instrument was assessed over two days in loading logs from the forwarder and from stockpiles onto trucks. Two methods were used in measuring the accuracy of the unit.

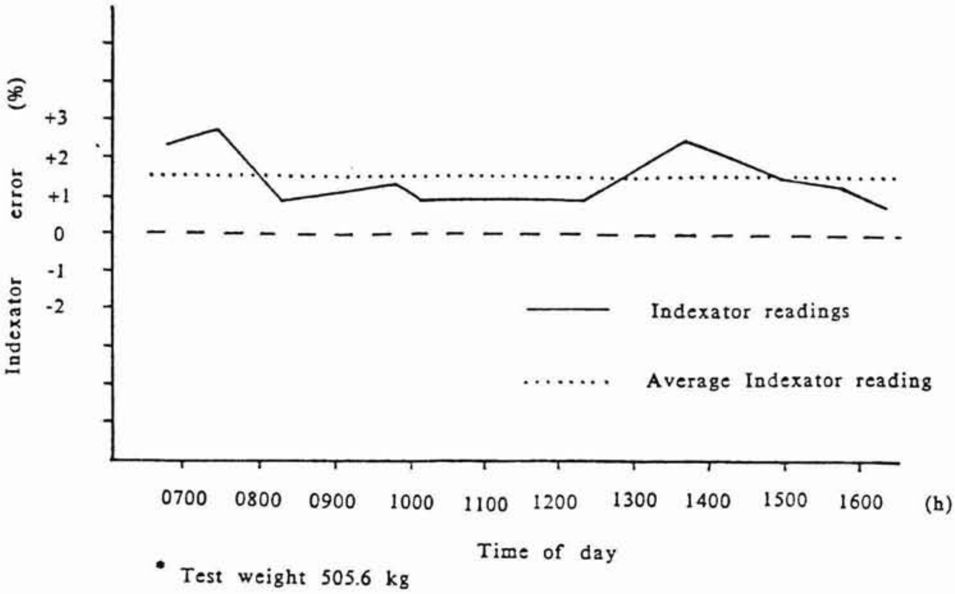

Figure 3 : Test 5 - changes in Indexator readings during the day (Test weight 505.6 kg)

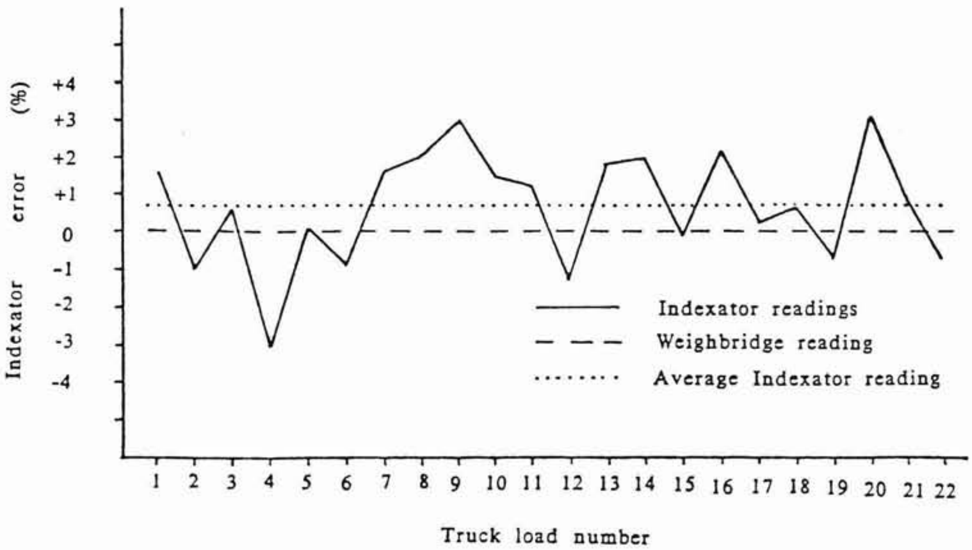

Figure 4 : Test 5 - changes in Indexator cumulative load readings

(i) Ten lifts were recorded at various times over the two-day period using a weight of 505.6 kg in an attempt to measure any inaccuracies occurring due to temperature changes or other factors.

(ii) Twenty-two Indexator truck payload readings were compared with corresponding payloads from the weighbridge at the local pulp mill.

A comparison was made of truck loading times and Indexator weight readings when loading from stockpiles and from the forwarder. The loading cycle elements timed were : time to grapple, lift and slew, place grapple load of logs and return. Number of grapple loads and number of logs per grapple load were also recorded.

Results and Discussion

The errors associated with lifting the 505.6 kg test weight are shown in Figure 3. The Indexator errors ranged from +0.9 to +2.7%, with an average of +1.5%.

The differences between the Indexator truck load readings and

Table 3 : Log loading performance - mean values of measured factors

Recorded quantity	*Grapple*			*Truck*
	From Stock	*From Forwarder*	*Per Grapple*	*Per Truck*
No. grapple loads	*20.9*	*17.5*		*38.4*
No. logs/load	*116.0*	*100.8*	*5.6*	*216.8*
Mean weight/load (kg)	*577*	*599*	*587*	*22.536t*
*Cycle time**	*53*	*39*	*47*	*17.87min*

** Time to grapple, lift and slew, place load and return (in 1/100th minute)*

the weighbridge readings, expressed as a percentage of the weighbridge readings, are shown in Figure 4. Indexator 'errors' ranged from -3.1% to + 3.2%, with an average of +0.7%. The higher accuracies achieved by the operator in this Test, compared with those in Tests 3 and 4, were probably due to his smooth, skilful loading technique. Comparison with the results from Tests 3 and 4 emphasizes the need for an operator of this calibre for successful use of the Indexator.

The truck loading times and Indexator weight readings when loading from stockpile and from a forwarder are shown in Table 3. No notable changes to the overall weighing performance could be attributed to the shorter cycle recorded when loading from the forwarder (slew angle about 90 degrees) compared with the longer cycle when loading from stock (slew angle about 180 degrees).

CONCLUSIONS

Five tests were carried out on the Indexator MV3 Portable Scale to access various aspects of its performance. The conclusions from these tests were :

1. To minimise weighing errors, rapid accelerations should be avoided, ie loads should be lifted as smoothly as possible.
2. When loads were suspended from the Indexator for up to two minutes the errors (drift) changed in different ways with different sized loads during the suspension period. No explanation for this behaviour could be found.
3. It was advantageous to use three phases in the Indexator calibration procedure, because this led to a reduction in the magnitude of the mean absolute weighing errors.
4. There was a trend to reduced errors as operator skill increased. In the log loading test involving a skilled operator, the errors recorded in total truck load weights, relative to a certified weighbridge, ranged from +0.9% to +2.7% with a mean of +1.5% over 22 loads.
5. The Indexator cannot be expected to achieve the levels of accuracy obtainable with a weighbridge and with an unskilled operator it could be misleading. With a skilled operator and regular calibration, however, it is a useful device for tasks such as weighing logs as they are loaded on to trucks to ensure that the trucks are loaded to their legal limits or for monitoring the output of different logging operations.

For further information, contact:

N.Z. LOGGING INDUSTRY RESEARCH ASSOC. INC.
P.O. Box 147,
ROTORUA, NEW ZEALAND.

Telephone: (073) 87-168