

ELECTRONIC WEIGHING IN THE SUGAR INDUSTRY

By B. L. TREHEARN

Summary

The paper describes the basic principles of measuring weight by means of electrical transducers and two applications of this weighing method in the Sugar Industry, namely, the weighing of molasses and the continuous weighing of cane and bagasse. The transducer, or load cell, produces an electrical output which has a direct relationship to the applied load. The usual expedients of mechanical weighers such as levers, fulcrums, knife-edges, etc., do not figure in electronic weighers.

There are two main advantages attributable to the load cell method of measurement:—

- (1) No moving parts.
- (2) The electrical output can be applied to indicating and control instruments.

Theory of the Load Cell

The load cell is basically a high quality steel billet mounted in a hermetically sealed die cast protective case. The law on which the action is based is as follows. When a material is subjected to a load it undergoes fractional deformation which is directly related to the load. The material reverts to its normal dimensions once the load is removed. If the elastic limits of the material are exceeded, the principle is no longer valid because the law is not linear. Fig. (1) shows a cross section of a load cell. Bonded to the circumference of the billet is a combination of wires known as strain gauges. The resistance of these wires changes as the cross-sectional area is varied by tension or compression. It follows therefore that the electrical resistance of the strain gauge will vary in direct proportion to the load applied to the billet. Such factors as hysteresis of the steel billet, bonding of the strain gauges and "zero creep" must be mentioned in passing since these are important design factors in the construction of a load cell. To consider them in detail is beyond the scope of this paper, but it will suffice to say that these factors decide the basic accuracy of the load cell. Four strain gauges are used to detect the deformation of the billet; two "active" and two temperature compensating types. The characteristics of the strain gauges are accurately matched and together form a simple temperature compensated Wheatstone Bridge. In the static state, (i.e. no load), the resistance of the four strain gauges is equal, and the bridge is electrically balanced. With the application of a load, the balance is disturbed and an electrical current flows around the Wheatstone Bridge in a direction determined by the applied load. Load cells of this nature have been made to accommodate up to 2,500 tons, but the usual ratings are from 2-50 tons. With careful manufacture, cells can be constructed to an accuracy of 0.1% of the full capacity.

Weights from 0-200 lbs. can be measured by means of a more sensitive type of load cell—the

"loadbeam"—which works on the same principle as the load cell. Fig. (2) shows a cross-section of a commercial product. Strain gauges are bonded to a "bending beam" and the load is transferred to the beam by the connecting bar. The unit is hermetically sealed and has an accuracy of 0.1% of full capacity. In order to measure tensile loads of up to 20 tons, the "dynamometer" can be used. This version of the load cell works on the same principle as the "load beam" and compression cell. It also has the same basic accuracy.

The Recorder Instrument

The alternating voltage output from the unbalanced Wheatstone Bridge (some 50 milli-volts) is applied to a self-balancing potentiometer, the principle of which is as follows. The voltage from the unbalanced Wheatstone Bridge is compared with an alternating voltage source generated within the instrument. The difference signal is amplified and applied to the single phase of a two-phase servo-motor, the other phase being fed from the common voltage source. Attached to the motor is the sliding contact of a high resolution potentiometer in the reference bridge circuit. The servo-motor is energised until the potentiometer pointer has reached a position whereby electrical balance is obtained between the unbalanced bridge output and the reference bridge output. It can be appreciated that the potentiometer pointer will therefore represent the applied load and a linear scale can be used to indicate directly the weight, level or volume of a quantity. With this type of circuit, it is possible to allow for tare weight so that only the nett weight is indicated. Almost any type of electrical indicator can be used in conjunction with the potentiometer, but industry in general favours the strip or circular chart recorder. Up to twelve pens, capable of recording twelve separate loads, can be incorporated in one indicator unit.

Before considering weighing applications suitable for the Sugar Industry, let us summarise the advantages attributable to this form of weighing system.

- (1) The instrument may indicate weight, or record and control a weighing function.
- (2) The indicator instrument may be mounted remote from the load cells.
- (3) Re-adjustment of tare and control limits is effected by dial control on the indicator instrument.
- (4) Static and varying loads can be weighed.
- (5) There are no moving parts in the load transducer.

Applications in the Sugar Industry

Electronic weighing is a fairly recent innovation in the Sugar Industry and to-date very few systems are used in the world exclusively for weighing or controlling in Sugar. One of the few can be found in the Union, and has been used for the automatic batch weighing of molasses over the last two years.

A Molasses Batch Weighing System

Fig. (3) illustrates the schematic layout of the system.

Prior to the installation of electronic weighing, the molasses tank was supported by three steel legs. To convert the tank and supports into a form suitable for load cell mounting, a few modifications were found necessary. A steel beam was welded along the circumference of the tank and mounting platforms were welded to the top of the supports for the load cells. Three load cells were used, each of two tons weighing capacity. The maximum weight of the tank was calculated at 6 tons. A recorder instrument similar to the one previously described was built into a cabinet, (15), together with the manual/auto controls and power supplies. To obtain a complete weighing cycle, two simple circuits which control the high and low levels of the molasses in the tank were built into the recorder. The setting of these levels is effected by two dials conveniently mounted in the instrument. When a pre-set value is reached a relay is made in the control cabinet, and air pressure at approximately 17 lbs. p.s.i. is passed through a solenoid valve (13 or 17) to the inlet or outlet valve.

The automatic cycle is summarised as follows:—

- (a) Outlet valve closed, inlet valve open.
- (b) Molasses run into tank until the pre-set upper level is reached.
- (c) Inlet valve is automatically closed and outlet valve automatically opened.
- (d) Molasses run from the tank until the lower level is reached.
- (e) The lower valve is closed and the cycle is repeated.

From the diagram it can be seen that two load cells are solidly fixed to the support legs, whilst the third has a cylindrical base which rests on a support leg. The tank weight is transmitted to the load cells by three ball bearings. It is by these means that possible errors due to the expansion of the tank and supports with temperature are minimised. Tolerances are taken up by fractional movements of the cylindrically based transducer accompanied by slight re-orientation of the load on the ball bearings about the axes. Wind forces on large tanks produce lifting and bending movements on the support legs which would prevent the tank from sitting vertically on the load cells. Obviously this would lead to errors in the weighing function and it is advisable to shield the tank from the elements. Expansion of connection pipes also produce the same results and in this case flexible couplers or "U" bends reduce the errors to negligible proportions. The automatic process was found to be reproducible to within $\frac{1}{2}\%$, and the accuracy in weighing to 0.1%. These facts are impressive when considering the arduous conditions under which equipment is worked in the sugar season. Also, the system has been in operation for 24 hours a day during two whole sugar seasons, and only routine maintenance and calibration have been found necessary once a year.

Proposed Continuous Bagasse or Cane Weigher

The second form of weigher uses the "loadbeam" and is suitable for adaption to belt conveyors. The uses to which the continuous weigher can be put are many, perhaps the most readily to mind are the weighing of bagasse or cane. It must be remembered that the output from the loadbeam can also be used to control the speed of the belt. In other words, to regulate the flow of material to a specific point. Fig. (4) depicts a possible set-up, with a requirement for a tons-per-hour indicator and a totaliser. To instal a belt-weigher, a number of the existing idler arms are removed. The factors determining this number are discussed later. The drawing shows a section of three idlers mounted on a common steel framework. One end of the framework rests on fixed supports, whilst the other end is placed on two loadbeams solidly bolted to the floor on either side of the frame. Material on the belt loads the platform which tilts on the fixed supports and bears down on the loadbeam bar. The output voltage from the loadbeam is derived in exactly the same way as the load cell weigher described. The cable connections and recording instrument are also similar.

Practical Aspects of Belt Weighers

- (1) The drawing shows a horizontal conveyor, but there is no objection to the application of this principle to inclined conveyors. Angles of up to 30° can be accommodated, but above this figure, shear forces are likely to introduce errors.
- (2) In a system where the tare weight has been electrically suppressed, varying belt tension is manifest by an unstable zero reading. This is never desirable and the provision of extra idlers either side of the measuring section or a continuous belt stretcher are sufficient to remove the cause of zero fluctuation.
- (3) If a loadbeam were mounted beneath one idler, the combined weight of belt and idler would be too large in comparison with the normal load passing over that point to obtain a workable output from the loadbeam. The ratio of tare weight to total weight can be improved by measuring the load over a specific length of the belt. This length is calculated with the knowledge of the tare weight per foot, speed of the belt and the weight of the load per cubic foot.

Should the weight of cane entering the factory per hour be required, it could be readily obtained by the installation of an electronic weigher in the carrier after the knives. On this belt the weight of cane might be 20 lbs. per cubic foot, and a section of three idlers might be required to effect the necessary ratio of tare to total weight. The voltage indicating weight could also be used to regulate the speed of the knives, and hence a constant input of sugar cane to the factory. Likewise, if the total output of bagasse be required, it could be obtained from a continuous weigher installed on a conveyor system which is used to remove the bagasse from the factory area. Since the weight of bagasse per cubic foot is less than that of cane, it

would be necessary to use a longer section of the belt for weighing.

The totaliser in the proposed system is of a very simple construction. Based on the operation of a kilo-watt hour meter, a current proportional to the rate of weight is fed from the indicator instrument to the current coil of the totaliser. The voltage coil is connected to a constant alternating current source if the belt speed is constant. If the belt speed is variable, a voltage proportional to the speed is derived by a tachometer connected to the belt.

Conclusions

The installation accuracy of an electronic weigher is of the order 0.1% to 0.5% and as such does not meet the approval of the Assize Department in this country. However, large sums of money are being spent on research and development for the commercial use of electronic weighing and a few years hence will see the majority of all weighing functions performed electronically. Most of the applications to-day are therefore found in heavy industry where process control, external checking and safety monitoring are required outside the jurisdiction of the local assize authority. Weighbridges for road and rail

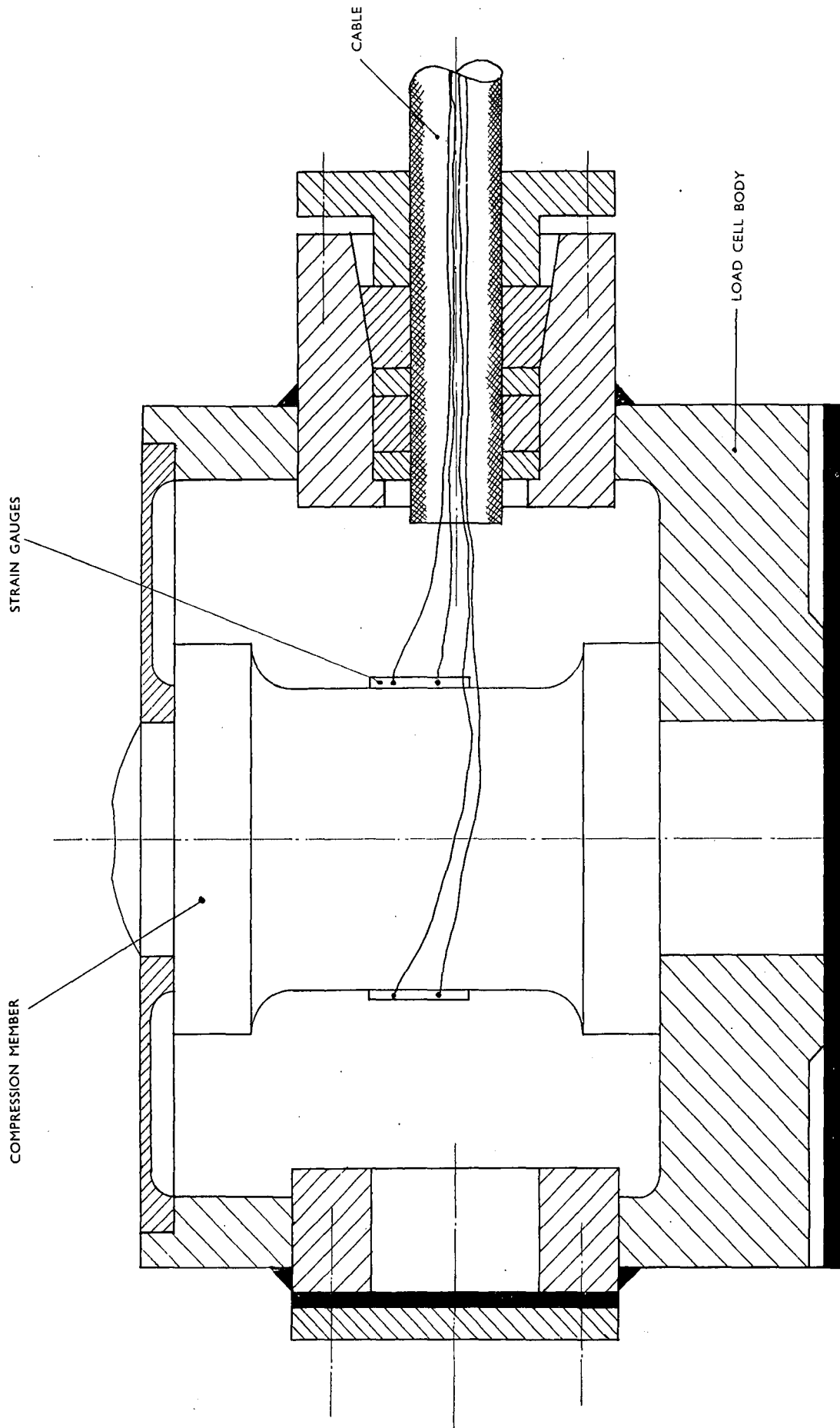
transport, the weighing of smelting furnaces, the automatic dosing and mixing of concrete in bunkers and even the weighing of missiles on the launching pad are a few of the many applications to be found. It can be said that many uses have been found in the industrial world for the advantages of electronic weighing, together with some of the most extreme working conditions possible.

Mr. J. Mc. D. Dick: What would be the comparison in price between a mechanical weigher and electronic weigher to perform the same function?

Mr. Trehearn: To perform automatic batch weighing of molasses, an electronic weigher would be hundreds of rand cheaper. It would also be far simpler to instal and maintain.

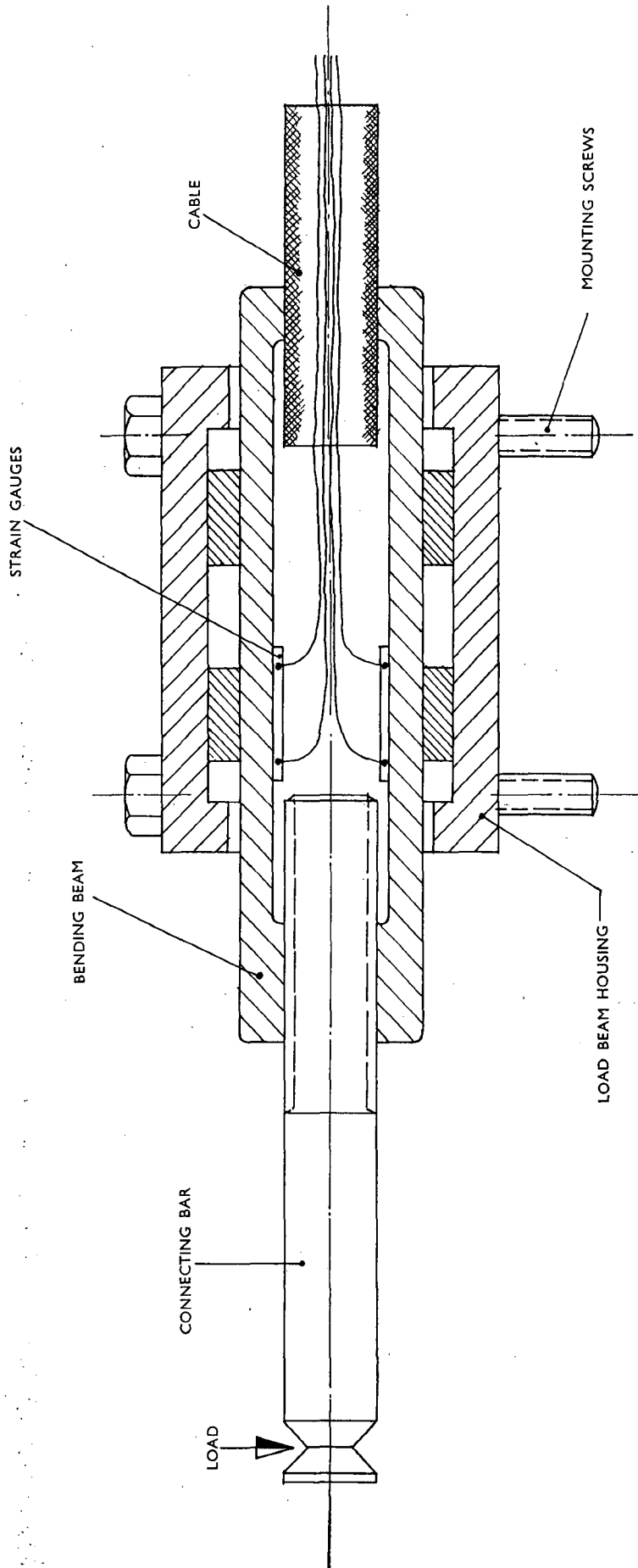
Mr. J. B. Grant: Would a continuous belt weigher perform satisfactorily at the lower ranges of its capacity?

Mr. Trehearne: There is no reason to assume that the lower range is any less sensitive than the upper range. The law of the basic system is a linear one.



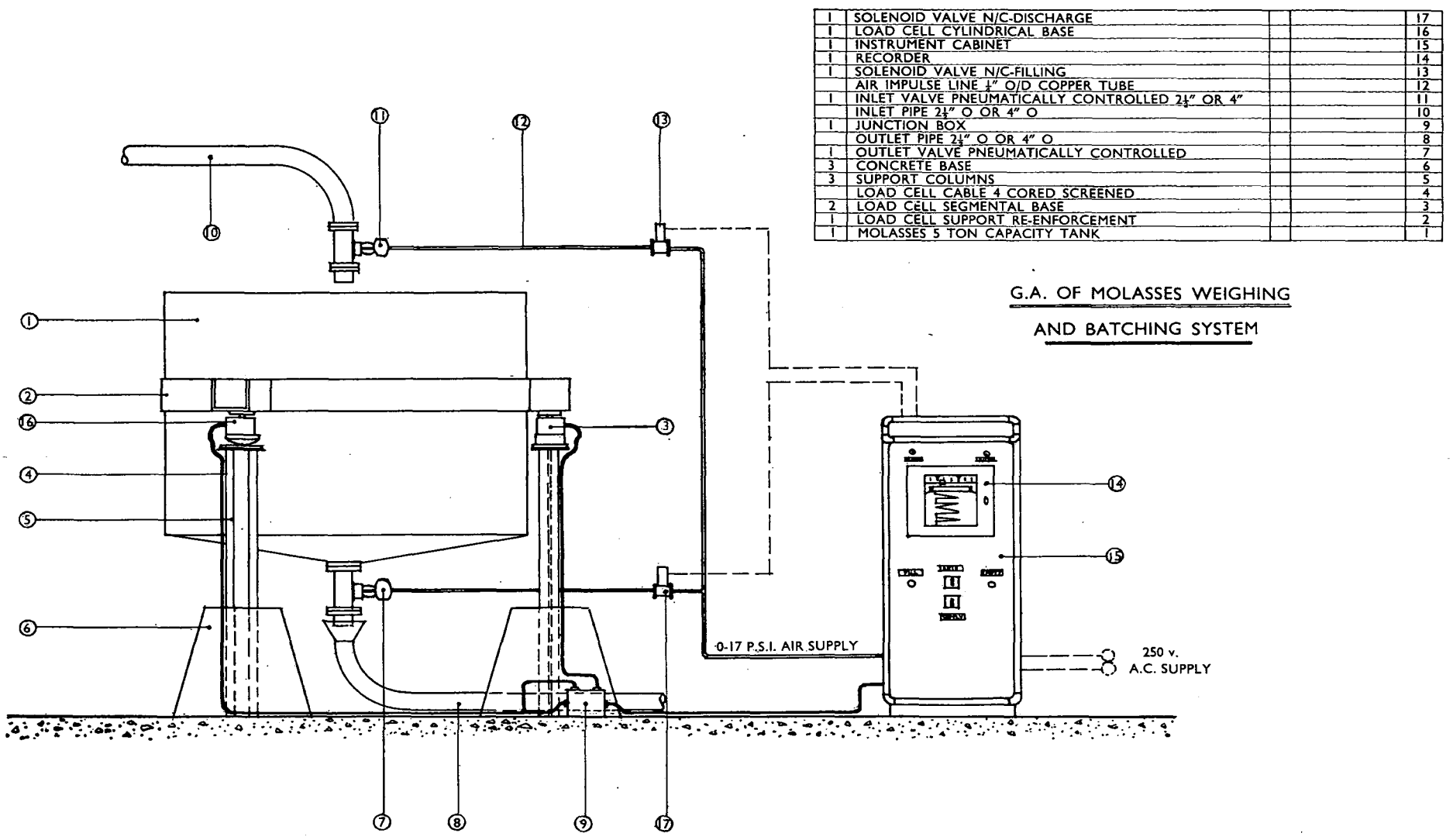
CROSS SECTION OF A LOAD CELL FOR ELECTRONIC WEIGHING

FIG. 1



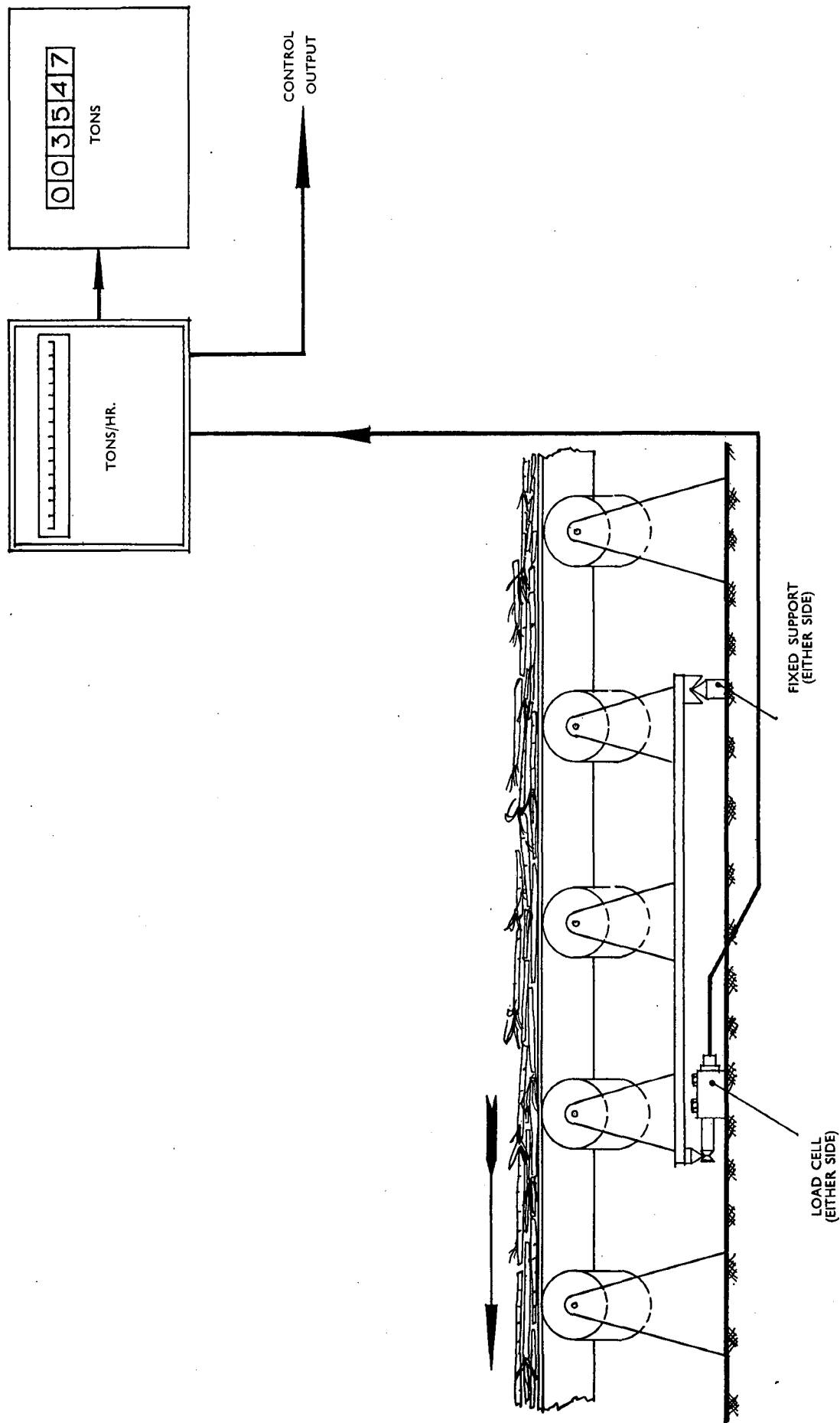
CROSS SECTION OF A LOAD BEAM

FIG. 2



1	SOLENOID VALVE N/C-DISCHARGE	17
1	LOAD CELL CYLINDRICAL BASE	16
1	INSTRUMENT CABINET	15
1	RECORDER	14
1	SOLENOID VALVE N/C-FILLING	13
	AIR IMPULSE LINE 1" O/D COPPER TUBE	12
1	INLET VALVE PNEUMATICALLY CONTROLLED 2 1/2" OR 4"	11
	INLET PIPE 2 1/2" O OR 4" O	10
1	JUNCTION BOX	9
	OUTLET PIPE 2 1/2" O OR 4" O	8
1	OUTLET VALVE PNEUMATICALLY CONTROLLED	7
3	CONCRETE BASE	6
3	SUPPORT COLUMNS	5
	LOAD CELL CABLE 4 CORED SCREENED	4
2	LOAD CELL SEGMENTAL BASE	3
1	LOAD CELL SUPPORT RE-ENFORCEMENT	2
1	MOLASSES 5 TON CAPACITY TANK	1

FIG. 3



SCHEMATIC DIAGRAM OF BELT WEIGHER SYSTEM

FIG. 4