CHAPTER 4

DATA COLLECTION AND ANALYSIS

4.1 INTRODUCTION

In this chapter, a details explanations and figures are shown to explain the tasks done in Do phase (of PDSA cycle). This chapter also includes data collection framework which explain how the data are collected. The structure of FMS is briefly described. The data for before and after implementation of FMS are collected and written in tabular form. The collected data includes OEE, percentage of loss of material per hour, MTBF, monthly output and reworked material per month.

4.2 Do Phase

In do phase, the plan is carried out in the fertilizer plant. In other words, the GT cell is replaced by FMS. The data collection framework is defined in this phase. Data of before and after implementation of FMS are collected. To be specific, tasks done in do phase are:

- Framework for data collection
- Data collection before implementation
- Implementation of FMS.
- Data collection after implementation

4.2.1 Framework for data collection

The loss of material is calculated when the material pass by and weighed by the automated weighing machine and totalize weighing machine. There are 3 types of data collected, which are losses when material goes from stage 1 to stage 2, stage 2 go to stage 3 or the overall loss for the whole process. The weighing machines and totalize weighing machines record the data (weight) and send the data to computers for calculation in loss. The recorded data is in the form of:

- Percentage of loss of material per hour
- Weight (tons) per hour
- Daily production in tons

The Mean time between failures (MTBF) is the time between 2 failures. The MTBF is recorded by the technicians. With increment in MTBF, OEE of machine will increase. Reworked material per month is also recorded by the technicians. Other data such as monthly output of the plant is recorded.

Once raw data is obtained, it needs to be processed and analyzed so that data is comprehensible. Data analysis software tools used in this research is Microsoft Excel. This tool is used to create charts and graphs so that data appears to be understandable by the readers. Statistical process tools formulae are used for data analysis. Also, trends of data are easy to be observed with the aid of statistical tools.

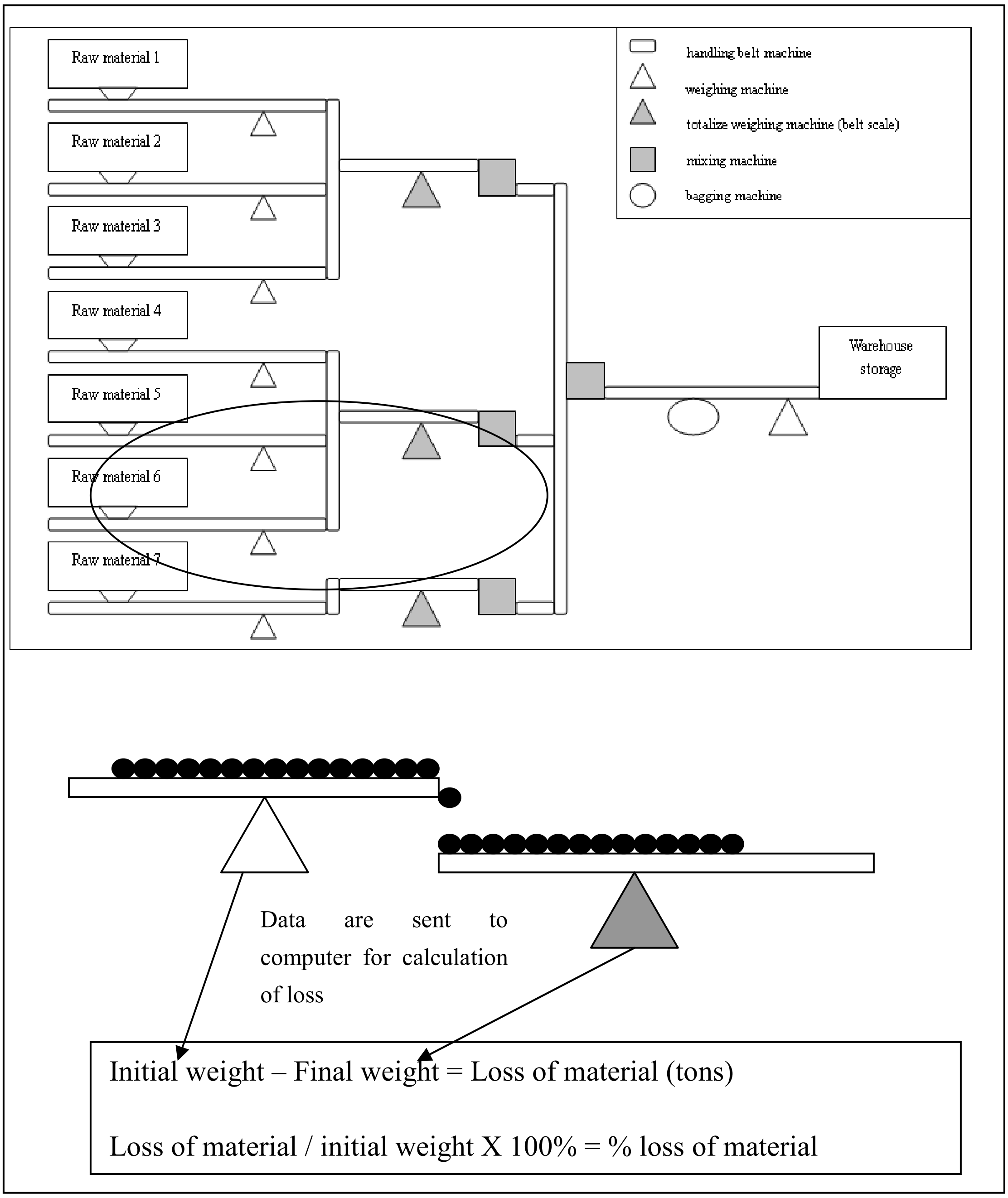

Figure 4.1Schematic diagram showing framework of data collection and how the loss of material is calculated

4.2.2 Data Collection before Implementation

The implementation of FMS is done at July. Before the implementation of FMS, data collected are:

- ♦ OEE: To evaluate machine utilization.
- ♦ Monthly output: To estimate production capability of the plant.

- ♦ Percentage of loss of material per hour: Loss of material affects productivity and induces other sub-problems.
- ♦ MTBF: Failure causes idle time, so it is important to know the rate of occurrence of failures.
- ♦ Reworked material per month: In this study, reworked material represents inventory level. This is because high quantity of reworked material means high quantity of WIP material, and results in high inventory level.

Overall Equipment Effectiveness (OEE)

Every problems and issues happened in the plant are directly affecting the OEE of machines. Data related to the problems are explained in chapter 3, and these data are quantified and summarized in the following form. Each and every problems and issues occurred can be transformed into losses or waste of a plant. In additions, the data are summarized in the following form so that overall equipment effectiveness (OEE) can be presented is an understandable way.

In **March**, working conditions are single shift, 8 hours per shift, 7 days per week. Planned throughput is 44 tons per hour. Actual output is 1657.04 tons per week. List of losses:

1. Poor setup of machines and causing the powder materials were dispersed in the air. This happened every hour, with 14.41 tons per hour of materials were lost.
2. Dusty environment caused blur vision to the operators. The processes of picking up stones from the conveyors were interrupted.

- ♦ Stones caused breakdown on the rotating valve. This happened 3 times per week, took 16 minutes to repair.
- ♦ Stones caused wear on the rotating valve. The replacement of rotating valve happened 1 time every 2 weeks, and took 1.4 hour to replace.

3. Dusty environment caused difficulty in breathing. Operators went outside of the shop floor to get fresh air. This happened every 2 hours, and took 5 minutes.
4. At the start of each shift, cleaners removed part of the soil accumulated on the machines and floor. It took 20 minutes.
5. To prevent premature wear and overheating of the weighing machines and totalize weighing machines, operator sprayed lubricants at the start of each shift, and took 8 minutes each time.
6. The accumulation of the soil on the conveyor increases the total weight of the conveyor. New setup on weighing machines and totalize weighing machines were adjusted to nullified the deviation cause by the soil. This happened every 4 hours and took 18 minutes to set up.
7. The speed sensors of totalize weighing machine wore and had to be replaced. This happened once every month, and took 25 minutes.
8. The speed sensors were overheated and needed to cool down for 12 minutes after running of 5 hours. This happened once in a day.
9. The soil was stuck between the gap of the conveyor belts and the speed sensors. The repairs took 6 minutes to clear the soil. This happened 3 times per day.
10. The materials were mixed with impurities (salt). The fertilizer had to be reworked or scrapped. For every week average of 38.28 tons of materials had to be reworked,

12.66 tons of material had to be scrapped and it took 3.5 hours for the processes.

There are 3 types of losses when considering OEE, which are Availability losses, Performance losses and Quality losses. The losses above are identified and categorized as below:

1. Quality loss: The loss of materials is considered as quality loss.
2. Availability loss: Breakdown and replacement of rotating valves are considered as availability losses because the machines and the system are not operating during this period.
3. Performance loss: The machines are still running, but the performances of the operators are affected, so this is considered as performance loss.
4. Performance loss: The performances of the machines are affected by the soil, so this is considered as performance loss.
5. Performance loss: In order to preserve the performance of the machines, the maintaining tasks (lubricating) are essential. Therefore, lubrication is considered as performance loss.
6. Availability loss: The machines are not operating because of setup and adjustment, so this is considered as availability loss.
7. Availability loss: Replacement of speed sensors are considered as availability losses because the machines and the system are not operating during this period.
8. Performance loss: The production is interrupted by a temporary malfunction, so this is considered as performance loss.
9. Availability loss: Repair is considered as availability loss because the machines are

not operating during this period.

10. Quality loss: The reworked and scrapped materials are considered as quality loss.

Performance loss: The processes of reworking and scrapping are considered as performance loss.

Total availability losses

= 3 x 16 + 0.5 x 1.4 x 60 + 18 x 2 x 7 + 25 x 0.25 + 3 x 6 x 7

= 474.25 minutes per week

Total performance losses

= 5 x 4 x 7 + 20 x 7 + 8 x 7 + 12 x 7 + 3.5 x 60

= 630 minutes per week

Total quality losses

= 14.41 x 8 x 7 + 38.38 + 12.66

= 857.9 tons per week

Production time (planned)

= 8 hours per day x 7 days per week x 60 minutes per hour

= 3360 minutes per week

Loading time

= Planned production time – breaks – planned maintenance time

= 3360 minutes per week – 474.25 minutes per week

= 2885.75 minutes per week

Percent Availability (A%)

= 100 x [Planned production time – breakdown & setup loss time] / Planned production time

$$= \frac{2885.75}{3360} \times 100\%$$

= 85.89%

Percent Performance (P%)

= 100 x quantity produced / {time run x capacity of given time}

$$= \frac{1657.04}{2885.75 \times \frac{44}{60}} \times 100\%$$

= 78.30%

Percent Quality (Q%)

= 100 x [Quantity produced – quantity losses] / quantity produced

$$= \frac{1657.04 - 857.9}{1657.04} \times 100\ \%$$

= 48.23%

Overall Equipment Effectiveness (OEE)

= Percent availability x Percentage performance x Percentage quality

= A x P x Q

= 0.8589 x 0.783 x 0.4823

= 0.3244

= 32.44%

Loading time per month

= 8 hours per day x 7 days per week

= 56 hours / month

Net profit to each kg

= RM 0.90 per kg

= RM 900 per ton

Theoretical earning capacity

= 56 hours per month x 44 tons per hour x RM900 per ton

= RM 2,217,600 per month

True earning capacity

= RM2,217,600 per month x 32.44%

= RM 719,389 per month

Cost of losses

= RM2,217,600 per month x (100 – 32.44)%

= RM 1,498,211 per month

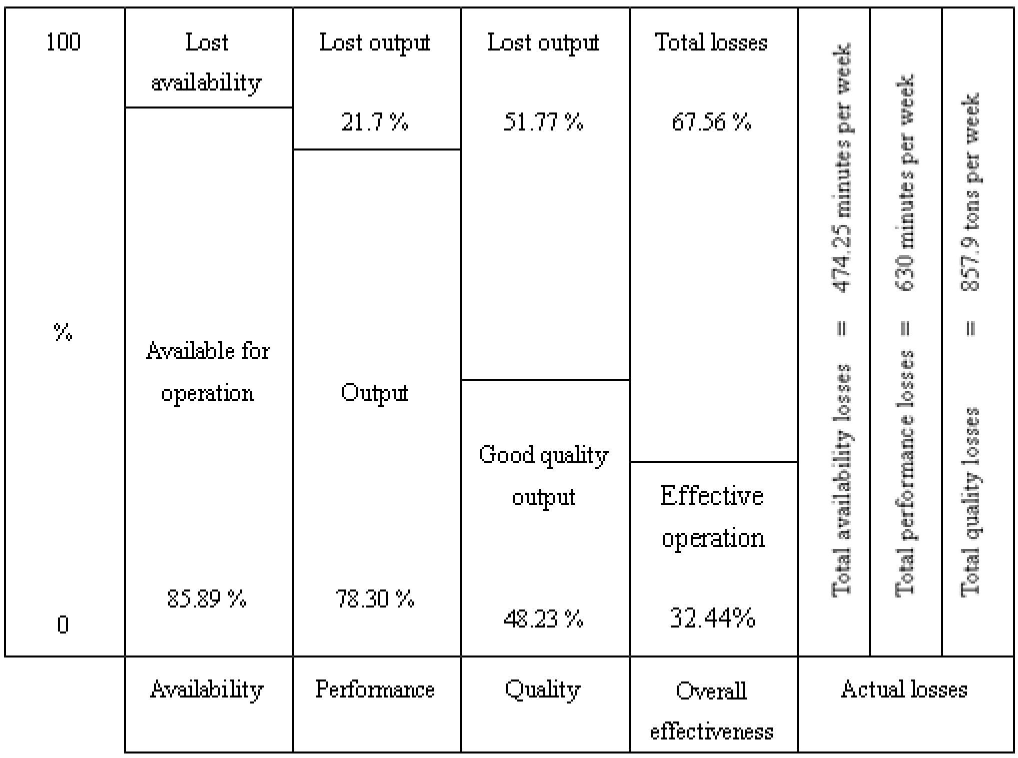

Figure 4.2 Effectogram for March

The OEE of the plant is 32.44 percent only and the main reason is because of the high percentage of quality loss. These results are not satisfactory. Immediate actions need to be taken to solve the root cause of this problem.

The details of raw data for month April, May and June could not be shown like month March to avoid infringement. However, the management of the plant is willing to provide the final calculated OEE values for those 3 months. The OEE of the machines for March, April, May and June are shown in tabular forms:

Table 4.1 OEE of the machines for March, April, May and June

Month	OEE (%)
March	32.44
April	31.08
May	36.84
June	35.21

Monthly Output, Percentage of Loss of Material per hour, Reworked Material per Month and MTBF

Again, the details of raw data for month March, April, May and June of these 4 categories could not be shown to avoid infringement. However the final calculated values for these 4 categories are provided. Therefore, monthly output, percentage of loss of material per hour, reworked material per month and MTBF for month March, April, May and June are:

Table 4.2 Monthly output, percentage of loss of material per hour, reworked material per month and MTBF for March, April, May and June

Month	Monthly output (tons)	loss of material (% per hour)	Rework material per month (tons)	MTBF (minutes per month)
March	6628.16	32.76	153.12	214
April	6574.33	31.03	144.78	237
May	6495.57	30.89	150.66	225
June	6852.12	34.55	156.97	229

4.2.3 Implementation of Flexible Manufacturing System

As stated in the previous chapter, the loss of material is caused by constant moving speed of conveyor belts and uneven weight distribution of material. In order to solve these two problems at one time, a FMS is implemented. The new FMS can control and vary the moving speed of conveyor belts regard to the instantaneous weight on the conveyor belts. This reduces the loss of material effectively, and results in better OEE of the machines.

Before implementation of FMS, the layout of the shop floor and machines are considered as automated GT layout. The conveyor belts of GT cell are running at constant speed, regardless of the weight of material on them. GT cell does not have any non-processing workstation (such as coordinate measuring machines) that support production but does not directly participate in it. Moreover, GT cell does not have sophisticated computer and feedback system that involve complete diagnostics and tool monitoring.

To ensure high utilization of machines, the project team decided to upgrade the GT cell to FMS. This upgrade was done at July 2010. The implemented FMS added new features such as sophisticated computer control systems and feedback systems. The computer control systems and feedback systems were installed at the weighing machines and totalize weighing machines. The details are explained in the following sections.

FMS on Weighing Machines

New features such as computer control systems and feedback systems were integrated into the weighing machines. The weighing machines are now named as weight feeder. Weight feeders can improve the accuracy of processing, blend consistencies, accountability, and record keeping. The weigh feeders come standard with a belt weigh bridge and speed sensor. An integrator is required to complete the system. The weight feeder is used to deliver an accurate mass flow rate of material. The feed rate is maintained and adjusted by varying the speed of the belt, regards to the weight on the conveyor belt.

The system consists of three components: weight and speed sensing, integration and control, and the mechanical conveying system. Using the belt load and the belt speed signals, small incremental totals of weight per time are measured by the integrator and then the flow rate is calculated. The measured flow rate is compared against the desired flow rate and the on-board PID controller makes necessary corrections to the belt speed.

Milltronics Weighfeeder (MW) 600 Series was chosen to be installed in the FMS. The benefits of this weight feeder are:

- High accuracy
- Ideal for low- to medium-capacity loads
- Fast installation, easy to clean and maintain
- Flexible, rugged design allows configurations to suit many applications

♦ Quick delivery on custom units

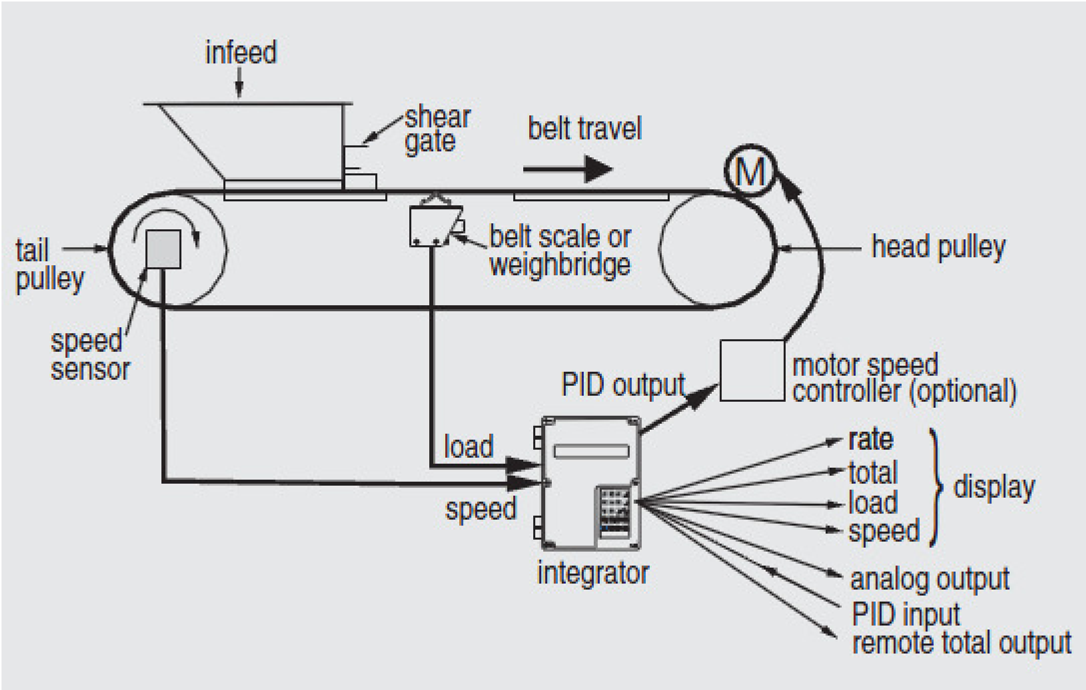

Figure 4.3 Installation of feedback and control system (PID) in a weight feeder and how it functions

As stated, the feed rate is maintained or adjusted by varying the speed of the belt, regards to the weight on the conveyor belt. For ideal case, the feed rate is maintained at 2 km/h for 85 kg of material on the belts. The feed rate is increased by 0.02353 km/h for every reduction of 1 kg on the belt, and vice versa. In other words, after computer control systems and feedback systems were integrated into the weighing machines, the moving speed of the conveyor belts is dependable on the weight on the conveyor belts. So, for every instantaneous change (increase or decrease) in 1 kg of powder material, feed rate is affected (decrease or increase) by 0.02353 km/h in proportional.

Figure 4.4 Installing PID on weight feeder and how the PIDs are arranged in a rack

FMS on Totalize Weighing Machines

The same computer control systems and feedback systems were also integrated into totalize weighing machines. The FMS totalize weighing machine has a weigh bridge structure supported on load cells, an electronic integrator, and a belt speed sensor. The load cells measure the material weight on the belt, and send a signal to the integrator. The integrator also receives input in the form of electrical pulses from a belt speed sensor connected to a tail or bend pulley. Using these two sources of data, the integrator calculates the rate of material transferred along the belt using the equation weight x speed = rate. The system helps maximize the use of raw materials, control inventories, and aid in the manufacturing of a consistent product. This system is easy to install, and require little maintenance. They produce repeatable, accurate results.

The system show minimal hysteresis and superior linearity, and ignore side loading. Load cell overload protection is a feature of the belt scale design. With use of approved intrinsically safe barrier strips, all belt scales can be used in hazardous locations.

The system measures the vertical component of the applied force. As material moves down the conveyor belt and travels over the belt scale, it exerts a force proportional to the material load through the suspended idler directly to the load cells. The resulting force applied in each load cell is sensed by its strain gauges. When the strain gauges are excited by voltage from the electronic integrator, they produce an electrical signal proportional to belt loading, which is then applied to the integrator. The vertical movement of the load cells is limited by the positive overload stop incorporated into the design of the belt scale or load cells. The stops protect the load cells from failure in the event of extreme overload forces.

As stated, the equation used in the system is weight x speed = rate. Considered rate = constant, so weight x speed = constant. Therefore, speed = constant / weight. In ideal case, weight = 85 kg, speed = 2 km/h, so constant = 170 kg.km/h. Finally, in adjusting the speed due to the varying weight, the relationships of moving speed to instantaneous weight on the belts are: speed = 170 / weight.

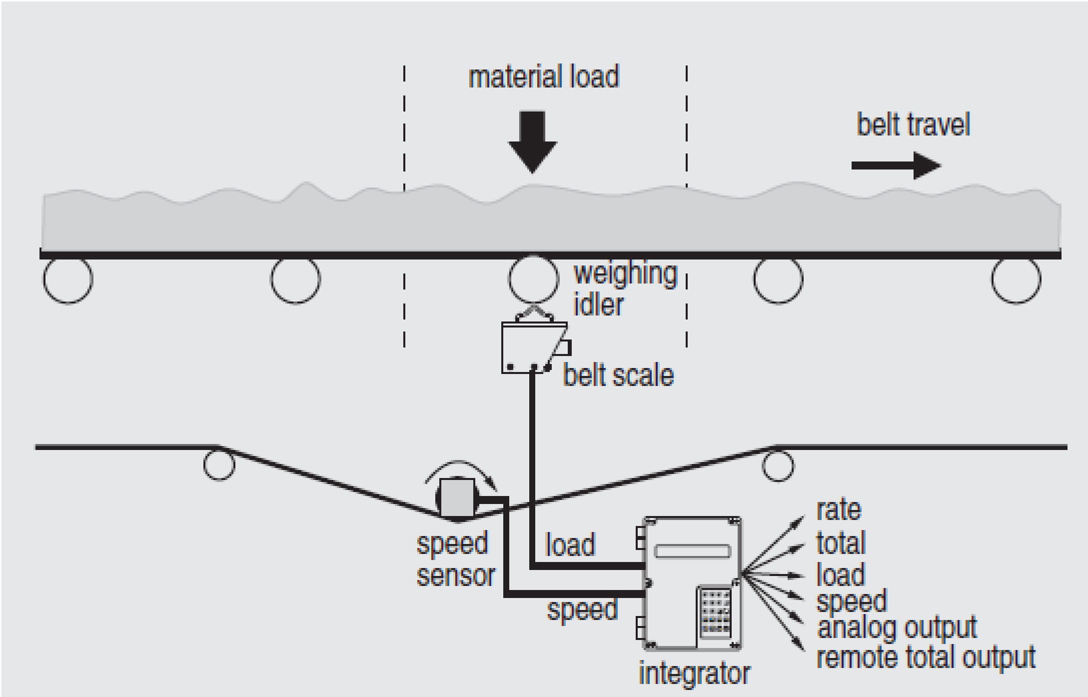

Figure 4.5 Improved totalize weighing machine with PID and how it functions


Figure 4.6 Installing PID on totalize weighing machine and how the PIDs are arranged

4.2.4 Data Collection after Implementation

Overall Equipment Effectiveness

The implementation of FMS is done at July. Again, the details of raw data for month July, August, September, October and November could not be shown to avoid infringement. After implementation of FMS, the OEE of the machines for July, August, September, October and November are summarizes and shown in tabular forms:

Table 4.3 OEE of the machines for July, August, September, October and November

Month	OEE (%)
July	56.75
Aug	67.56
Sept	73.18
Oct	68.29
Nov	69.01

Monthly Output, Percentage of Loss of Material per hour, Reworked Material per Month and MTBF

Again, the details of raw data for these 4 categories could not be shown to avoid infringement. After implementation of FMS, monthly output, percentage of loss of material per hour, reworked material per month and MTBF are collected and shown in tabular form:

Table 4.4 Monthly Output, percentage of loss of material per hour, reworked material per month and MTBF for July, August, September, October and November

Month	Monthly output (tons)	Loss of material (% per hour)	Reworked material per month (tons)	MTBF (minutes per month)
July	7377.65	18.28	86.49	328
Aug	8089.58	15.87	80.11	346
Sept	8944.55	10.58	77.52	401
Oct	8967.06	13.68	78.05	370
Nov	8731.48	12.33	77.89	379