CHAPTER VI
IMPLEMENTATION AND EVALUATION

6.1 Implementation

The FMEA project of the studied factory has been implemented between May 2007 and September 2007. Prior to FMEA implementation, team members were called for meeting to explain the new documents and working procedures. The objective was to ensure that all of team members understand clearly the proposed FMEA. The improvement and control is already mentioned in Chapter 5.

6.2 Evaluation

6.2.1 Comparison of RPN before and after FMEA implementation

After FMEA project finished, the FMEA team analysed and revised the recommendation actions that mentioned in Chapter 4 (Table 4.12: Process FMEA according to the RPN score from the highest to the lowest RPN score). The severity, occurrence, and detection of each failure having previous RPN score higher than 100 are re-evaluated by using the team judgement. The RPN scores before and after implementation are compared and shown in Table 6.1.

Table 6.1: Comparison of RPN before and after FMEA implementation

Failure Mode and Effect Analysis (FMEA)

Workstation unit: Drying rooms
Process name: Drying process at drying rooms — Documented by: Pachara L.
Approved by: Factory Manager — Approved date: 9/3/07
Team members: Pachara L., Somsak T., Yupin K., Chainipat L., Manoch S., Noppadol K.

FMEA Date (Org.): 8/1/07
FMEA Date (Rev.):
Page: 1 of 4

Process Function & Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s)/ Mechanism(s) of Failure	O	Current Process Controls	D	RPN	Recommended Actions(s)	Resonsibility & Target Completion Date	Action result				
											S	O	D	RPN	%RPN reduction
Furnace	Heating system is not optimize	High energy cost, long drying time, Some dried maize sheaths are off-spec	5	No recycle of used hot air, no maintenace plan for bloweres, improper positions of blowers	10	No control	8	400	Modifying heating system	Process Eng. (13/5/07)	5	7	3	105	73.8
Maize drying	Non-uniform temp. in drying rooms	Some dried maize sheaths are off-spec	5	Position of blowers, efficiency of blowers	8	No control	8	320	Modify blowers set up preventive maintenance, install more temp. indicators	Process Eng. (13/5/07) Maintenance (10/5/07)	5	4	4	80	75.0
Maize drying	Poor hot air distribution	Some dried maize sheaths are off-spec, long drying time, high energy cost	5	Non-adjustable speed and low efficiency of blowers, improper positions of blowers, no baffles in drying rooms	8	No control	8	320	Reposition blowers modify blowers and drying rooms i.e. add baffles	Process Eng. (13/5/07)	5	4	4	80	75.0
Maize drying	Uncontrolled hot air direction	Some maize sheths have off-spec humidity	5	Improper positions of blowers, no baffles in drying rooms	8	No control	8	320	Modify blowers & drying room i.e. add baffles	Process Eng. (13/5/07)	5	4	4	80	75.0
Maize drying	Heat loss at drying rooms	Some dried maize sheaths are off-spec, long drying time, high energy cost	5	Old, inefficient, improper insulation,	8	No control	8	320	Set up work instruction	Production (15/5/07)	5	4	4	80	75.0

Failure Mode and Effect Analysis (FMEA)
Workstation unit: Drying rooms
Process name: Drying process at drying rooms
Approved by: Factory Manager
Team members: Pachara L., Somsak T., Yupin K., Chainipat L., Manoch S., Noppadol K.

Documented by: Pachara L.
Approved date: 9/3/07

FMEA Date (Org.): 8/1/07
FMEA Date (Rev.):
Page: 2 of 4

Process Function & Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s)/ Mechanism(s) of Failure	O	Current Process Controls	D	RPN	Recommended Actions(s)	Resonsibility & Target Completion Date	Action result				
											S	O	D	RPN	%RPN reduction
Furnace	Heat loss at furnace	Some dried maize sheaths are off-spec, long drying time, high energy cost	5	Old, inefficient insulation	8	No control	8	320	set up work instruction	Production (15/5/07)	5	4	4	80	75.0
Maize drying	Contaminates/ impurities in maize sheaths	Some dried maize sheaths are off-spec, long drying time, high energy cost	5	maize sheaths from different sources, poor visual inspection	9	Visual check by operators	7	315	Internal training, set up work instruction	QC (18/5/07)	3	4	4	48	84.8
Maize drying	Too hot in some areas of maize drying room	Some dried maize sheaths are off-spec	6	Non-worked blowers, poor visual inspection	8	Visual inspection by operators	6	288	Preventive maintenance, training	Maintenance (10/5/07)	6	4	4	96	66.7
Maize drying	Hot air blowing rate is not constant	Some dried maize sheaths are off-spec	5	Old and low quality blowers, no maintenance plan for blowers	7	No inspection but it is guaranteed by the supplier	8	280	set up preventive maintenance	Maintenance (10/5/07)	5	4	4	80	71.4
Maize drying	Humidity of maize sheaths varies batch by batch	High energy and fuel cost, long drying time Some dried maize sheaths are off-spec	5	Different sources of maize sheaths, season of harvesting, drying time unchnages with humidity of maize sheaths	8	No control for humidty of maize sheaths	6	240	set up work instruction to vary drying time according to inlet humidity, calibration drying time recorder	Process Eng. (13/5/07)	5	3	4	60	75.0

Failure Mode and Effect Analysis (FMEA)

Workstation unit: Drying rooms
Process name: Drying process at drying rooms
Approved by: Factory Manager
Team members: Pachara L., Somsak T., Yupin K., Chainipat L., Manoch S., Noppadol K.

Documented by: Pachara L.
Approved date: 9/3/07

FMEA Date (Org.): 8/1/07
FMEA Date (Rev.):
Page: 3 of 4

Process Function & Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s)/ Mechanism(s) of Failure	O	Current Process Controls	D	RPN	Recommended Actions(s)	Resonsibility & Target Completion Date	Action result S	Action result O	Action result D	Action result RPN	Action result %RPN reduction
Maize drying	High humidity of maize sheaths	High energy and fuel cost, long drying time Some dried maize sheaths are off-spec	5	Harvest maize in raining season, maize sheaths from different sources	8	No control for humidty of maize sheaths	6	240	set up work instruction i.e. sun drying	Production (15/5/07)	5	2	4	40	83.3
Maize drying	Weak hot air blowing	Some dried maize sheaths are off-spec, long drying time, high energy cost	5	Old, low efficient blowers No maintenance plan for blowers	5	No control	8	200	set up preventive maintenance	Maintenance (10/5/07)	5	4	4	80	60.0
Furnace	Insufficient heat generation	Some dried maize sheaths are off-spec, long drying time, high energy cost	5	Not good quality of fuel, variation of fuel	5	No control	8	200	develop methods to evaluate fuel quality	Process Eng. (13/5/07)	5	2	4	40	80.0
Maize drying	Inaccurate temp. in drying rooms	Some dried maize sheaths are off-spec, long drying time, high energy cost	5	Temp. indicator false, poor maintenance	5	Random check of temp. indicator	7	175	set up work instruction for calibration	Maintenance (10/5/07)	5	2	4	40	77.1
Furnace	Insufficient supply of fuel	Some dried maize sheaths are off-spec, long drying time	5	Poor management and purchasing systems, operators do not follow work instruction	5	Plan of fuel in advance	7	175	Set up work instruction	Inventory (11/5/07)	5	2	4	40	77.1

Failure Mode and Effect Analysis (FMEA)

Workstation unit: Drying rooms
Process name: Drying process at drying rooms
Approved by: Factory Manager
Team members: Pachara L., Somsak T., Yupin K., Chainipat L., Manoch S., Noppadol K.

Documented by: Pachara L.
Approved date: 9/3/07

FMEA Date (Org.): 8/1/07
FMEA Date (Rev.):
Page: 4 of 4

Process Function & Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s)/ Mechanism(s) of Failure	O	Current Process Controls	D	RPN	Recommended Actions(s)	Resonsibility & Target Completion Date	Action result				
											S	O	D	RPN	%RPN reduction
Maize drying	Packing of maize sheath varies batch by batch	Some dried maize sheaths are off-spec, long drying time, high energy cost	5	Production operators do not follow manuals, poor visual inspection	7	Visual inspection by shift engineers	5	175	Training operators, set up work instruction	Production (15/5/07)	5	2	4	40	77.1
Furnace	Inaccurate temp. at furnace	Some dried maize sheaths are off-spec, long drying time, high energy cost	5	Temp. indicator false Poor maintenance	4	Temp. check every shift	7	140	set up work instruction for calibration	Maintenance (10/5/07)	5	2	4	40	71.4
Furnace	Insufficient heat generation	Some dried maize sheaths are off-spec, long drying time	5	Fuel feed is not enough, feeding is inconsistent	4	manual feed of fuel	7	140	Set up work instruction, training	Production (15/5/07)	5	2	4	40	71.4
Maize drying	Improper packing of maize sheath	Some dried maize sheaths are off-spec, long drying time, high energy cost	5	Production operators do not follow manuals, poor visual inspection	5	Visual inspection by shift engineers	5	125	Training operators, set up work instruction	Production (15/5/07)	5	2	4	40	68.0

From Table 6.1, the percentage of reduction of RPN before and after implementation of FMEA technique is varied between 60.0-84.8%. It is important to note that the occurrence score (the possibility that potential causes of failure happen) and the detection score have been significantly decreased while severity score has been maintained because:

- New work instructions and some modification in drying rooms and furnace workstation units are created to control the potential failure mode. They have also increased the capability to detect both of potential causes of failures and subsequent failure modes.
- People are the key factor for project implementation. Therefore training these people involved in both drying room and furnace workstation units for new work instruction and preventive maintenance plan could lead to a significant reduction of occurrence score.

From Table 6.1, the formula and two examples in calculation of the percentage of reduction for RPN before and after implementation of FMEA technique are shown below.

(RPN before - RPN after) / RPN before * 100 = % RPN Reduction

1) For Potential Failure Mode: Heating system is not optimized
   RPN before implementation FMEA = 400
   RPN after implementation FMEA = 105
   Calculation of %RPN reduction:
   (400-105)/400 * 100 = 73.8% Reduction

2) For Potential Failure Mode: Contaminates/ impurities in maize sheaths
   RPN before implementation FMEA =315
   RPN after implementation FMEA = 48
   Calculation of %RPN reduction:
   (315-48)/315 * 100 = 84.8% Reduction

6.2.2 The way to revise the score of occurrence and detection of each failure in drying room and furnace workstation units

After implementing of FMEA, the FMEA team revised the score of occurrence and detection of each process having the RPN score higher than 100 in drying room and furnace workstation units as shown in Table 6.1. The severity scores are always constant (compared between and after implementation of FMEA) due to that the process does not change. As can be seen from Table 6.1, all 19 high-risk areas are revised. However only one of them will be explained in detail to show how occurrence and detection scores are revised as following:

As previously mentioned in section 4.1.4.1, one of the main critical failure modes in the maize sheath drying process is that the temperature in the drying room is not uniform. After revise the score, it was that the severity is ranked at the same level as before FMEA implementation because the process does not change. This failure does not endanger operators or machines or process without warning and maize sheaths that do not pass the humidity specification can be recycled to the drying process and dried again (no product scraped). Therefore the severity score of 5 is assigned according to the criteria presented in Table 4.2. In term of detection, the score of 4 is given because the assigned process engineering team has installed more numbers of temperature indicators inside the drying rooms in order to measure the temperature in several positions in the rooms which will suggest how well the heat distributed inside the rooms, leading to a new design of more proper positions of blowers. These temperature indicators are daily checked and calibrated in order to report temperature distribution in the drying rooms precisely and regularly according to a new work instruction. In addition, the process engineers have calculated the current efficiency of the blowers and modify by replacing some components of the blowers to make them more efficient. Some blowers are also replaced with adjustable-speed blowers in order to make the air distribution in the rooms better. Positions of blowers are somewhat changed. Finally the drying rooms are modified by adding baffles to improve circulation of the hot air in drying room and prevent hot air blowing to the corners of the rooms to improve energy loss. These work instruction and controls are applicable and effective. They are trained to users, but sometimes the operators do not follow instruction strictly. According to the criteria given in Table 4.3, the detection score of 4 is given.

For the occurrence score, it was found that after all recommended actions were performed, the temperature in drying rooms is more uniform than before. Based on the statistical data collected from temperature indicators in drying rooms, the failure occurs slightly (only 1 batch out of 448 batches (0.22%) that temperatures in drying rooms was not uniform). Based on the criteria given in Table 4.4, therefore the occurrence score of 4 is given. To calculate the RPN score after FMEA implementation, multiplying 5 by 4 by 4, the RPN score of 80 is obtained according to the agreement of the FMEA team.

6.2.3 Improvement of the average fuel cost, the drying time and quantity of maize seeds rejected by QC

Prior to project starting, the average fuel cost was 94.7 thousand baht per month, drying time was 7150 minutes per month and the average quantity of maize seeds rejected by QC was 615 kg/month as shown in Table 3.2. After FMEA implementation, there are significant improvements in terms of a reduction in monthly fuel cost and the drying time but slightly decrease in the quantity of maize seeds rejected by QC as shown in Table 6.2. The average fuel cost per month is reduced by 10% (from 94.7 to 84.9 thousand baht), drying time 8% (from 7150 to 6580 minutes), and quantity of maize seeds that do not pass QC by 2% (from 615 to 602 kg). Comparison month by month of average fuel cost, drying time, and quantity of maize sheaths rejected by QC is shown in Figures 6.1-6.3 respectively.

Table 6.2: The average fuel cost, the drying time and quantity of maize seeds reject by QC in year 2007 after FMEA implementation

Month	Average fuel cost (thousand Baht)	Average Drying time per batch (minutes)	Quantity of maize seeds that do not pass QC (kg)
May	91	6850	587
June	91.5	6530	593
July	82.3	6300	635
August	80.2	7030	584
September	79.3	6900	610
Average	**84.9**	**6580**	**602**

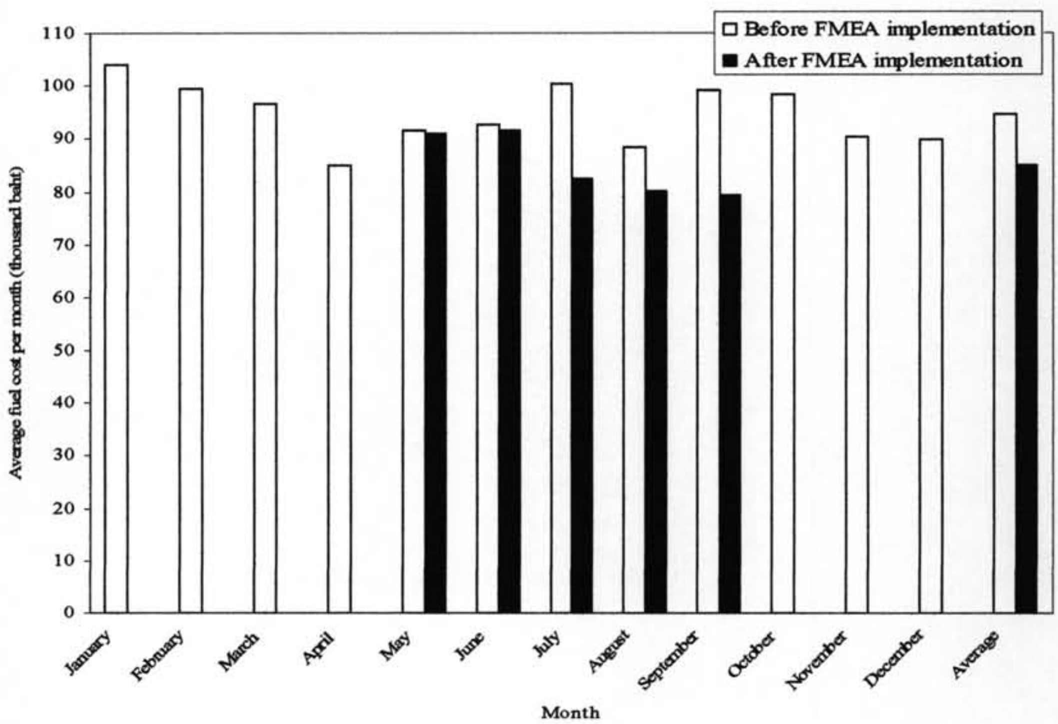

Figure 6.1: Average fuel cost (thousand Baht) before and after FMEA implementation

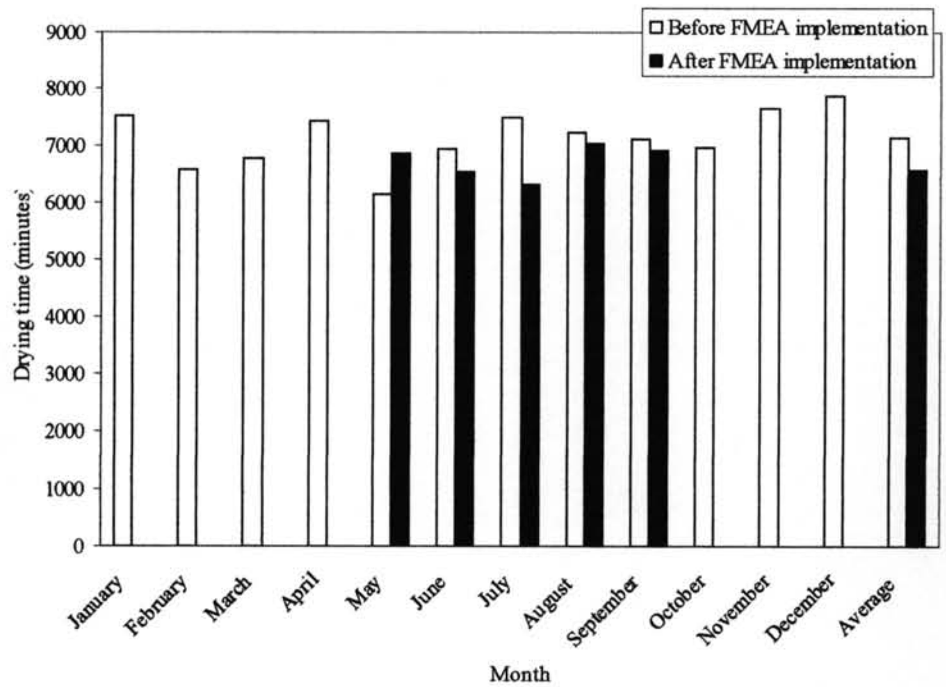

Figure 6.2: Average drying time (minutes) before and after FMEA implementation

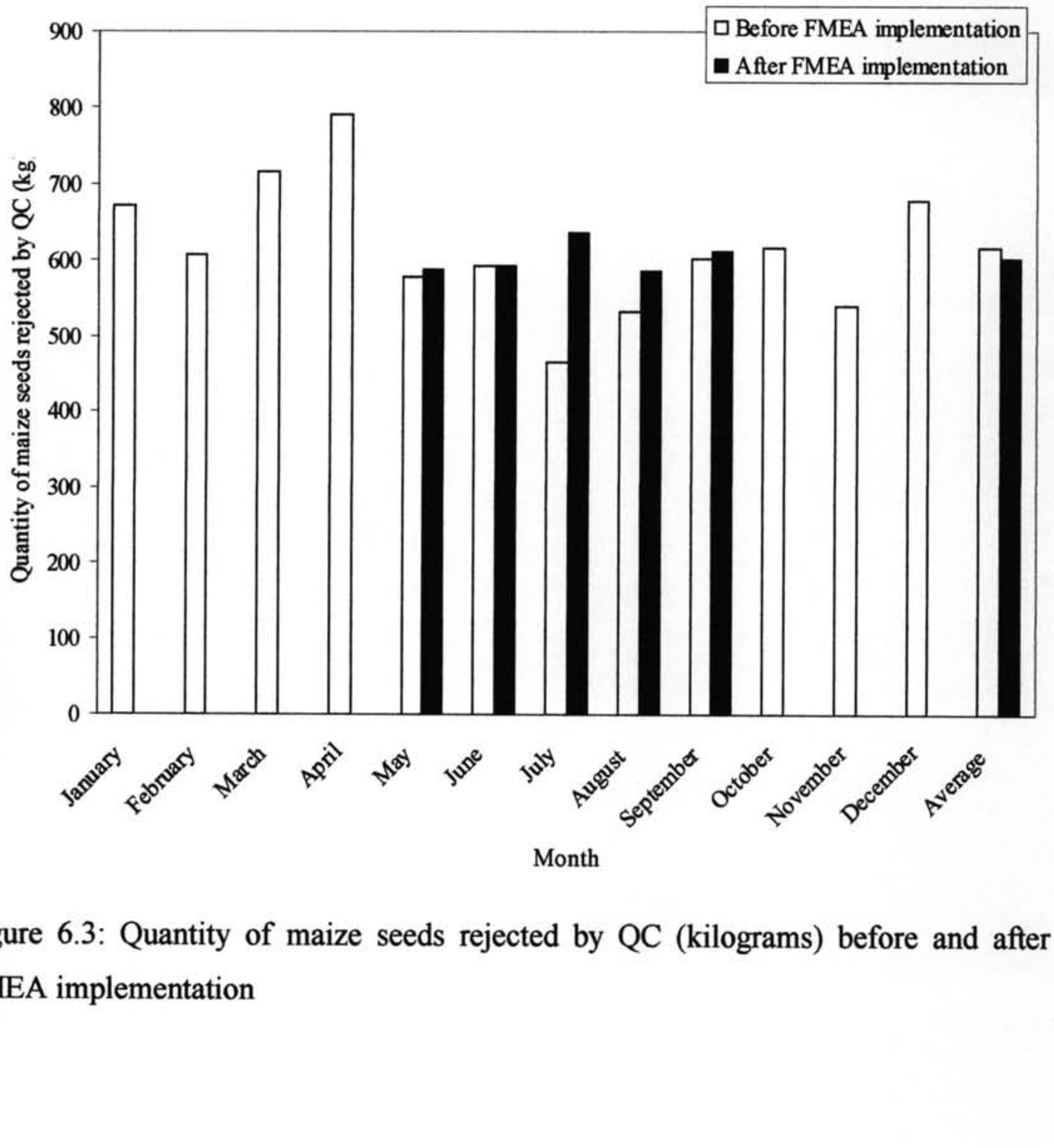

Figure 6.3: Quantity of maize seeds rejected by QC (kilograms) before and after FMEA implementation

6.3 Summary of what have been improved in drying room workstation unit

6.3.1 Uniform temperature in drying rooms

The temperature in each drying room needs to be homogeneous, particularly temperature of maize sheath which directly affect the quality of final product and energy consumption. The procedure for control temperature in drying rooms is set up as shown in Document 1 in Appendix III. In addition, temperature indicators in drying rooms needs to be regularly checked, calibrated, maintenanced according to the new work instruction. Temperature indicators need to be replaced after use for a specific time and the new type of temperature indicators that have higher efficiency should be sought out. Positions of blowers are re-designed and some baffles are added into the drying rooms to improve circulation of the hot air in drying rooms and prevent hot air blowing to the corners of the rooms to reduce energy loss.

6.3.2 Blowers in drying rooms

Preventive maintenance plan is set up for the control of blowers in drying rooms (Appendix IV). After FMEA implementation, all blowers have been checked for their efficiency, modified, and some parts of them have been replaced in order to improve its efficiency. Thereafter the created preventive maintenance plan is followed by the operators in order to regularly inspect the blowers, clean the blowers, checking the air flow rate, and cleaning the ventilation system in the drying rooms.

6.3.3 Control of drying time of varied humidity of maize sheaths

Although the humidity of maize sheaths during transportation and storing can be controlled, the sources of maize sheaths cannot be controlled. Therefore the humidity of raw maize sheaths is varied batch by batch. To cope with this problem, the work instruction for quality control of drying time according to inlet humidity of maize sheaths has been created as shown in Document 2 in Appendix III. Moreover calibration procedure and calibration schedule of all equipments used for checking drying time such as drying time recorder, etc are created in order to ensure the precision of the equipments as shown in Document 3 in Appendix III.

6.3.4 Control quality of raw material

The maize sheath raw material needs to be controlled in terms of their humidity and contaminates. The work instruction for controlling the quality of raw material is shown in Document 4 in Appendix III. The work instruction includes the handling system of maize sheaths from loading workstation unit up to drying room workstation unit and the systematic inspection of contaminates. In addition, work instruction for sun drying of maize sheaths are set up in order to partly reduce the humidity of raw materials and help reducing energy cost as shown in Document 5 in Appendix III.

6.3.5 Control quality of fuel

The quality of fuel fed to the furnaces which certainly affect the heat generation and the drying time needs to be controlled according to its types and specifications. A method to evaluate the quality of fuel and develop appropriate formulation of fuel composition is presented in Document 6 in Appendix III.

6.3.6 Packing of maize sheaths in drying rooms

The method of packing maize sheaths in drying rooms also needs to be controlled by setting up a work instruction describing how to pack maize sheaths, how to place maize sheaths in the drying containers and how to organize the containers in drying rooms. The work instruction is shown in Document 7 in Appendix III. In addition, training about packing is put into compulsory for all new operators working in the drying rooms.

6.3.7 Insulation at drying rooms

The work instruction to cope with insulation at drying rooms is proposed is shown in Document 8 in Appendix III. The work instruction suggests the procedure to regular check insulation, how to evaluate the efficiency of insulation, the time period to replace old insulation.

6.4 Summary of what have been improved in fuel burner workstation unit

6.4.1 Optimizing heating system

Modification of heating system at fuel burner workstation unit is carried out by developing a heat exchanger to transfer the heat from hot air to recycled water before mixing with fresh water (temperature about 25-30 °C). After modifying the heating system, the recycled water after passing heat exchanger has a temperature increase about 8-12 °C, and after mixing with fresh water, the temperature of the mixed water feed to boiler increases about 5-7 °C as shown in Table 6.3. As a result of this modification, energy is significantly saved.

In addition, setting up a new blower underneath the fire (F3) in the furnace reduces power consumed by the old blowers (F1 and F2) as shown in Figure 5.1. Now the blowers F1 and F2 which consume 22 kw are not used as often as before. Instead blower F3 which consumes energy only 2 kW is often used. This significantly reduces energy cost at the furnace workstation unit.

Furthermore, after the factory has the modification of heating system at fuel burner workstation unit is carried out by developing a heat exchanger. The team can observe the improvement of productivity by evaluation of the decreasing time of drying compared with the increasing temperature that operators can record a shorter time. However, the calculation of improvement is shown below. The strokes of fans are major concern that have to be started up when temperature down. This is one reason to focus and compare of major energy saving on the new system.

1) The original system (Before new heating system): the fans had to start running up average 10 strokes per day

   (24 rooms * 5.5 Kilowatts of 1 blower * 30 days) + (22 Kilowatts * 10 strokes * 30 days)

   = 10,560 Kilowatts-hour

2) The new system (after new heating system): the fans had to start running up average 5 strokes per day

(24 rooms * 5.5 Kilowatts of 1 blower * 30 days) + (22 Kilowatts * 5 strokes * 30 days)

= 7,260 Kilowatts-hour

The results of comparison of energy saving will be calculated as based on the fact as there are average 7 tons of finished dried maize seeds per room with 24 identical drying rooms that normally have 7 batches per month.

Then, the average finished dried maize seeds per month will be equal to

= 7 * 24 * 7 = 1,176 tons per month

Therefore, the new system can save energy by compare ton/Kilowatts-hour as followings:

Before new system: 1,176 tons per month / 10,560 Kilowatts-hour

This is equal to 0.11 ton of dried seeds per Kilowatts-hour

After new system: 1,176 tons per month / 7,260 Kilowatts-hour

This is equal to 0.16 ton of dried seeds per Kilowatts-hour

After the calculation we found that the new system resulted in improving of productivity which is shown as

= 0.16 – 0.11 = 0.05 ton increasing of dried seeds per Kilowatts-hour

In addition, temperature is more stable that can control the drying maize sheathes for a shorter drying time, the operator do not need to adjust temperature several times that can run the smooth process for a longer period. Normally, the temperatures of drying maize sheaths in the factory are set at 40 degrees Celsius. But after the modification the team can increase temperature between 42 and 43 degrees Celsius. The results caused of decreasing average drying time at 6,580 minutes from 7,150 minutes per batch.

6.4.2 Insulation at fuel burners and connections between fuel burners and drying rooms

The work instruction to cope with insulation at furnaces and connections between furnaces and drying rooms is also shown in Document 8 in Appendix III. This work instruction is the same as that used at drying rooms suggesting the procedure to regular check insulation, how to evaluate the efficiency of insulation, the time period to replace old insulation.

6.4.3 Control feeding of fuel

The work instruction for controlling the quality of fuel feed is already mentioned in Document 6 in Appendix III. The work instruction also includes the method of feeding of fuel at the furnaces and the controlling system.

6.4.4 Control stock of fuel feed

A proper stock of fuel is necessary for providing enough heat to drying rooms. This requires cooperation with Stock and Purchasing department of the factory and good management. The revised work instruction for fuel supply control is proposed as shown in Document 9 in Appendix III. The request for the fuel supply from the production (furnace workstation unit) will be sent back to Stock and Purchasing department by internal networking in order to recalculate the stock and acquire fuel if necessary.

Table 6.3: Comparison in temperatures before and after modifying heating system at furnace workstation unit according to Figure 5.1

Before modifying heating system			After modifying heating system		
Month	Temp of recycled water from heat exchanger (°C)	Temp of mixed water feed to boiler (°C)	Month	Temp of recycled water from heat exchanger (°C)	Temp of mixed water feed to boiler (°C)
May 06	40	31	May 07	48	36
June 06	38	30	June 07	47	35
July 06	39	31	July 07	50	38
August 06	38	29	August 07	50	36
September 06	41	32	September 07	52	39
Average	*39*	*31*	*Average*	*49*	*37*