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Optimal Design of Silo System for Drying and Storage of Grains (I)
- Simulation Modeling with SLAMSYSTEM -

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ABSTRACT

A simulation modeling is necessary for the optimal design of a rice processing plant, which consists of a facility (a silo system) of rice drying and storage and a rice mill plant. In a rice processing plant, the production scheduling and the decision on capacity of each unit based on a queuing theory is very important and difficult. In this study a process-oriented simulation model was developed for the design of a rice drying and storage system with SLAMSYSTEM. The simulation model is capable of simulating virtually all the processing activities and provides work schedules which minimize total processing time, mean flow time and bottleneck of the plant system and estimate drying time for a batch in a drying silo. Model results were used for determining the size and capacity of each processing unit and for analyzing the performance of the plant. The developed model was actually applied to construct a grain silo system for rice drying and storage.

Key Word: Grain Silo System, Simulation, Design, SLAMSYSTEM

INTRODUCTION

Recently, Korean agriculture is in difficulties due to the opening of agricultural product market by Uruguay Round. Especially, Korean rice market is very threatened by the international rice market with low price. The opening of Korean rice market should be considerate bacause rice is a major agricultural crop as a source of main income of farms in Korea. Rice processing plants have being constructed with a rice mill plant and a facility of drying and storage to overcome problems caused by UR and to produce good quality of rice in Korea.

A simulation modeling was necessary for an optimal design of a silo (grain bin) system for rice drying and storage in Korea. The simulation modeling is an effective and proven computer-aid to decision making in industry and business. It is a powerful tool for designing and analyzing a facility of rice drying and storage. Especially today's rice processing plants are more complex in operation and construction than the plants of a few years ago. The rice processing industry is extremely competetive and capitally intensive in Korea. The shortage and high cost of agricultural labor and the requirement of high rice quality place a great emphasis on the development of rice drying and storage system in bulk. A simualtion was conducted for the efficient plan and optimal design of the rice processing plant using a simulation system, SLAMSYSTEM(Simulation Language for Alternative Modeling System, Pritsker, 1986, 1990).

SLAMSYSTEM was used as a simulation tool because it supports model building, analysis of models, and the presentation of simulation results. A simulation model using SLAMSYSTEM was developed to design a silo system for rice drying and storage and evaluated the performance of the rice silo system without building a pilot plant. The simulation model can be adapted to provide effective and

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efficient evaluation of various alternative models for scheduling and design improvements of the silo system. The model includes all the processing equipments and main operating parameters of the silo system from the input of rough rice to drying and storage. The model provided the system performance measures such as bottlenecks in processes, prediction of drying time, allocation and utilization of all the major equipments, mean flow time, total processing time, weekly production of dried rice.

The main purpose of this study was to develop a simulation model of a silo system for rice drying and storage as a part of a rice processing plant. The simulation model developed would be used to facilitate the design and performance analysis of the drying and storage system of silos.

BACKGROUND

In the recent years, considerable progress has been made in the areas of computer-aided design, operations research and system analysis. Simulation modeling has become an integral part of the systems approach to problem solving and decision making techniques. This simulation technique has been successfully applied in the major mordern industries. However, little attention has been given to design and evaluate the rice processing plants in Korea. Processors and system designers of rice plants need timely information on important decisions of designing systems and adding costly equipment to satisfy their throughput and efficient production scheduling.

There are considerable researches in this simulation field. Reklaitis(1982) has given an extensive overview of the role of scheduling within the overall production planning problem. Scheduling and design considerations have received a good deal of attention (Shah,1985). Shah et al.(1985) reported that simulation was one of the best ways to analyze scheduling problems of food processing plant, which consisted of a combination of serial and parallel production systems. They developed a simulation model of a sausage manufacturing plant. They studied and evaluated an existing sausage maufacturing plant by a simulation. The model was used to facilitate design and procedural analysis of the plant. They also reported on the development of a scheduling model of an existing bacon processing system. They investigated the role of scheduling and the effects of various heuristic scheduling rules on the operation of the plant. Elias and Habah (1986) developed a network-based simulation model to analyze a fishing processing facility. They represented a quick-freezing process in a typical fish processing plant in the model and performed sensitivity analysis on some of the major factors that could affect the efficiency of the system. The model provided a methodology of evaluating alternative production strategies for a fish processing facility, and provided the production manager with a tool to develop short-term production policies.

Rice drying involves a process of simultaneous heat and mass trasfers and balances. Prediction of drying time for a rice batch in a drying silo with stirring device is an important factor in the production scheduling and allocation of resources. The general theories of grain drying are conferred in Brooker' and Hall's (1980) books. Chung(1989) developed a simulation model using SLAM II to predict energy amount and drying time for a batch drying of rough rice in a drying silo.

GENERAL DESCRIPTION OF SILO SYSTEM

The total storage capacity of a grain silo system to be designed is 1,200 tons, which consists of four silos of 300 tons. The grain silo system is used for drying and storage of rice as a part of a rice processing plant. The layout and flowchart of a facility of grain drying and storage is shown in Fig. 1 and Fig. 2. The facility represents a continuous/semi-continuous system. The facility consists of a truck scale, a receiving hopper, bucket elevators, grain cleaners, a hopper scale, continuous moisture meters, a input drag conveyor, two drying silos, two storage silos, an unloading drag conveyor, monitoring and control systems and auxiliary equipments of silos. Most of the above processing equipments are designed in the basis of a treating capacity of 20 tons/hr.

The wet rough rice harvested by combines is delivered to a facility of drying and storage, a silo system. After a truck scaling, the rice is received and cleaned by a grain cleaner and is again weighed by a hopper scale. Then, it is dried in the form of a batch in a drying silo, and after scaling by the hopper scale is stored in a storage silo. Finally, the dried rough rice is delivered to a rice mill plant (4.5ton/hr) and is processed to milled rice in package. The characteristics of each process in the system are followings.

1) Weighing and Grading

Wet rough rice is harvested in the moisture contents of 20 - 24%(w.b.) after A.M. 10, and is delivered to a drying and storage facility of silos. The transported rice is weighed by an electronic truck scale installed in the facility. The weighing is accomplished with a 3.0 m by 18.3 m electronic, pitless, drivethrough motor truck scale. Its capacity is approximately 50 tons, and it is sized to weigh virtually any commercially available truck. The truck weights is read within a control room. The readout is digital with a ticket printer for recordkeeping. The grading of the grain from each truck is done in a small lab. A sample of the grain is taken from each truck for a quality test.

2) Intake Process

The unloading/receiving system consists of a receiving hopper/pit such that the facility can receive grain both in bags and in bulk simultaneously. The capacity of the receiving hopper/pit is total approximately 20 tons/hr. The rice is received through a receiving hopper. From a steel chain conveyor with a capacity of 20 tons/hr, the rice is lifted to be cleaned by a centrifugal bucket elevator with a capacity of 20 tons/hr. The elevator is drived in the power of a geared motor.

3) Cleaning Process

From the elevator, the rice is accumulated in a buffer tank to be cleaned by a rice cleaner. The capacity of the cleaner is about 20 tons/hr. It is equipped with sets of screens and a fan.

4) Hopper-Scaling Process

The cleaned rice is transported to a buffer tank for a hopper scale by a chain conveyor and a bucket elevator. The opening of the buffer tank is controlled with a pneumatic control gate with two step action of 90% feeding and 10% limit feeding. The hopper scale weighs rough rice by a batch of 500kg. The scaled rice is transported through a feeding tank and an elevator to a four-way distributor, which controls the direction of rice flow to a drying silo(or a storage silo or a mill plant or loadout tank).

5) Rice Drying Process

A batch of rice is dried in a drying silo with a stirring device. The drying silo with a diameter of 10.05 m and a height of 6.5 m has a capacity of 300 tons. The silo can be used for a storage silo after drying. The drying silo is equipped with a 15HP fan, a diesel oil heater with a thermostat and a humidistat, a 3-auger stirring device, air ways, an auto dry system with a moisture sensor, an aeration system and sweep and unloading augers. The silo may be insulated with uretan foams of 5 cm thickness for efficient batch-in-silo drying, if required.

The batch-in-silo drying process involves the following procedures: 1) Placing a 1m-layer of grain in the silo. 2) Forcing natural or heated air to temperature of about 30° C through the grain and using a stirring device for the uniform drying until the average moisture of the batch has reached the desirable final moisture(below 17%,w.b.). Typically, the drying silos have airflow rates of about 5 $\mathrm{cmm/m^3}$ (402 cmm), Koh et al.(1990). 3) Cooling the grain by runing the centrifugal fan with the heater off. 4) Moving the dried grain to the other storage silos for dryeration to get grain with the moisture below 15%,w.b.

The drying time for a batch of rough rice in the drying silo is predicted by a model based on a heat balance equation between sensible heat of drying air and latent heat of vaporization for grain drying. The heat balance equation for the drying process can be written as follows:

$$\frac{\mathrm{cmm} \times 60}{v} (C_a)(T_a - T_g)\ t\ E = h_{fg}\ DM\ (M_i - M_f), \qquad \text{Brooker et al.(1982)}$$

$$E = Q_{dry} / (Q_{in} - Q_{exit})$$

where, cmm: airflow rate, cmm

v: specific volume of air, kJ/kg° C (Koh et al. 1990)

C_a: heat capacity of air, KJ/kg° C

T_a: plenum air temperature, ° C

T_g: exit air temperature, ° C

h_{fg}: heat of vaporization, KJ/kg (2,742 kJ/kg)

DM: dry matter, kg

M_f: final moisture content, d.b., decimal

M_i: initial moisture content, d.b., decimal

t: drying time required for a batch drying of rice, hr

E: drying efficiency of drying silo

Q_{in}: heat input from a heater

Q_{exit}: heat loss from exhausted air

Q_{dry}: heat of vaporization in rice drying, $(Q_{in} - Q_{exit}) - Q_{loss}$

Q_{loss}: $Q_{wall} + Q_{bottom} + Q_{duct} + Q_{heater}$

6) Re-Scaling and Storaging Process

The dried rice is rescaled by the same hopper scale and is transported to a storage silo (or loadout tank, or paddy tanks(30 tons) of the mill plant) by the bucket elevator and the four-way distributor. The rice delivered is dryerated in the storage silo by the aeration system, and then is stored under the automatic aeration systems: a fan, a heater, airways, and a stirring device.

SLAMSYSTEM SIMULATION MODEL

The simulation model for a drying and storage facility of rough rice was developed using a combined network orientation of SLAMSYSTEM. The simulation model consists of a network model and an user-insert subprogram. The conceptual network of SLAMSYSTEM helps in formulating the model and it also aids in focusing attention on the elements and characteristics of a real system which must be modeled. The user-insert subprogram supports the limited flexibility of the network model. The network model is structured of some specialized symbols, called nodes, and branches which are combined to represent the system as queues, servers, batches, and logical decision points. The practical representation with nodes is automatically translated into an equivalent statement model for input to the SLAM processor. Standard programs are built within SLAM for automatic collection of operational statistics. For a detailed explanation of SLAMSYSTEM see Pritsker et al. (1990).

1) Network Model

The overall operation of the facility is modeled correctly with the network nodes. The model can determine the state of the system over time by processing various activities such as cleaning, scaling, drying, and conveying. The objects within the boundaries of a system are called entities. In this model an entity represents a batch of 250 kg rough rice. The network represents the semi-continuous flow of these entities through the system from intake to storage in silos. The capacity of each unit machine and equipment is not fixed in the model because it should be determined with the results of the simulation.

The SLAMSYSTEM network, as shown in Fig. 3, consists of three independent networks, resource blocks, and gate blocks. The first network starts with a CREATE node, which creates entities, the rough rice harvested and delivered to the facility from the field. The CREATE node can create only entities according to working time of the day using a GATE node as WORK, and do it with a specified time of 0.75 min. between creations. The time interval between creations means that rough rice is routed into the network on the speed of 20 ton/hr. The characteristics of entities are represented by a ASSIGN node using ATTRIBUTE variables. The intake hopper is represented by a GATE node as INTAKE, which is blocked when the hopper scale is used for discharging the dried rice from the drying silo to the storage silo, otherwise it is always often. The routed entities are delivered to a feeding tank for a paddy cleaner through a chain conveyor and a bucket elevator, which is represented to indicate the time delay by REGULAR ACTIVITY nodes. The feeding tank is expressed by a QUEUE node, and the operation of the paddy cleaner is done by a SERVICE ACTIVITY node. The cleaned rough rice is delivered through a chain conveyor and a bucket elevator to a feed tank for a hopper scale. The lower buffer tank of the bucket elevator is expressed by a QUEUE node and the elevating function is done by a SERVICE activity.

Then, the rice is accumulated for a batch of 500 kg to be weighed by the hopper scale. An ACCUMULATE node is used to indicate a batch of rice to be weighed, and a AWAIT node with the RESOURCE of the hopper scale is used for weighing a batch of rice. After weighing the batch, the batched rice is unbatched into an entity of 250 kg by the UNBATCH node. The weighed rice is distributed by a four-way distributor to drying silos or storage silos. The wet rice is batched into a 20 ton entity by the BATCH node. The batched rice is dried in the drying silo during the drying time of USERF(1). The drying time is estimated by a user-insert subprogram, a USERF function. The subprogram provides a drying time required for a batch of rice according to the drying conditions. If the waiting entity, batched wet rice, exceeds a queuing capacity of the AWAIT node with 2 RESOURCEs of drying silos, the batched rice is balked and routed to the AWAIT node waiting for the RESOURCEs of the storage silo.

As the rice is dried in the drying silo during the drying time of USERF(1), the drying silo is freed by the FREE node in case the dried rice is completely discharged, otherwise the drying silo is not freed until the drying silo is empty. The dried rice is unbatched by the UNBATCH node and is discharged to the storage silo through the chain conveyor and the hopper scale. The weight of a dried entity is reduced against original weight of the wet entity and the dried rice is separated from the wet entity using the ASSIGN node with the variable of ATRIB(3). When the dried rice is moved to the storage silo through the hopper scale, the intake hopper is blocked by closing the GATE node of INTAKE. After the drying silo is completely empty, the intake hopper is opened by the open GATE node of INTAKE. The total weight of the dried entities is summed up by assigning the total weight to the XX(1) at the ASSIGN node and is collected by the COLLECT node with SLAM variable of XX(1). The total time in the system from intake to storage is also collected by the COLLECT node with the variable of INT(1) and is terminated by the TERMINATE node. The terminated entity indicates being stored in the storage silos.

The wet entity balked at the AWAIT node for drying silos is also dried at the storage silo during the drying time of USERF(2). The time interval between balked entities is collected by the COLLECT node. The total weight of balked entities is summed up by the ASSIGN node and is collected by the COLLECT node with the SLAM variable of XX(2). Then, the balked entites are terminated by the TERMINATE node, which indicates being storing in the storage silo.

The second network starting a CREATE node indicates off-time and working time to generate entities harvested in the field during a day. As the working time is set like 120 minutes, the CREATE node can only create entities during the working time with the time interval of 0.75 minutes and generate total amount of 40 tons. It means that the total amount of rough rice harvested during a day is 40 tons and that the time interval of 0.75 indicates the intake speed of 20 tons/hr. The gate of WORK is normally open at the GATE BLOCK. However, if the GATE node of WORK is closed by the closed GATE node, the CREATE node can not generate entities at the CREATE node of the first network.

The third network represents a breakdown of the hopper scale. The breakdown of the scale is expressed by the PREEMPT node. The breakdown is assumed to be occurred at a time interval of 10,000 minutes with a repair time of 10 minutes. If the scale is out of order, the entity to be scaled can pass by the scale without weighing or should wait for a repair time of 10 minutes. In this model it is assumed to pass by the scale. The hopper scale, drying silos and storage silos are defined by RESOURCE BLOCKs, and the gates of WORK and INTAKE are expressed by GATE BLOCKs.

2) FORTRAN User-Insert Model

The drying process of rough rice is modeled by a FORTRAN language. The User-Insert Model is programmed in dialogue and is linked to the network model of the SLAMSYSTEM. The model can determine total heat required for a batch drying, heater capacity, drying time, heat loss during drying, and effect of insulation. The input parameters of the model are drying air temperature, ambient air temperature, exhausted air temperature, airflow rate, initial moisture content, final moisture content, thermal properties of air, weight of grain, dimension of silo, drying efficiency, coefficients of heat conductivity of concrete, corrugated steel, and insulation material, etc.

RESULTS AND DISCUSSION

The grain silo system was modeled with SLAMSYSTEM as shown in Fig. 3. The developed simulation model was executed at the following conditions: total simulation time of 6 days, daily intake amount of 40 tons, initial moisture content of 22% - 24% (w.b.), final moisture of 17%(w.b.), use of a 15 HP centurifugal fan with 127 mmAq and 402 cmm, drying air temperature of 30° C, daily average temperature of 13.8° C and daily average relative humidity of 73% of ambient air during October at Namwon city in south Korea. The results of some simulations on the system were shown with the two variables of the initial moisture content of rice and drying efficiency of silos in the table 1.

1) Power of Fan and Heater

The power and capacity of a fan and a heater mainly affected the performance measures of the silo system. The power, static pressure drop, and airflow rate of the fan was determined in the basis of optimal airflow rate of about 5 cmm/m^3, which was based on the removal rate of water from grain (about 0.3%/hr). The power of a heater was determined by the drying air temperature as shown in Fig. 4. The rated power of the heater required for heating average ambient air of 13.8° C to 18, 24, and 30° C was ranged from 31 kw to 82 kw and 132 kw at the drying efficiency of 0.9, respectively.

2) Drying Time

The drying time was, respectively, ranged from 15 hrs to 22 hrs and 29 hrs for a batch drying of 20 tons, 30 tons, and 40 tons at the drying air temperature of 30° C, 402 cmm airflow rate, drying efficiency of 0.9, initial moisture content of 24% and final moisture content of 17%. The drying time was ranged from 11 hrs to 13 hrs and 15 hrs with different initial rice moisture content of 22%, 23%, and 24% (w.b) at the drying of 20 tons/batch and drying efficiency of 0.9. The drying efficieny of silos also affected the drying time from 13 hrs to 15, 17, 19, 22 and 27 hrs, corresponding to the drying efficiency of 1.0, 0.9, 0.8, 0.7, 0.6 and 0.5 at the drying of 20 tons/batch, respectively.

3) Performance of System

The performance measures of the system were percentage of time open of intake hopper, average and maximum waiting entities (length) and average waiting time at the INTAKE GATE, average utilization of resources such as hopper scale, drying silo, storage silo, average utilization of service activities such as rice cleaner, elevators, and unloading auger, time in the system from intake to storage, total weight of dried grain through each silo, average waiting entities and time for drying silos, and average waiting length and time for other processes, as shown in the Table 1. The performance measures were analyzed with the drying efficiency. The silo system has no bottleneck and no problems at the drying efficiency of more than 0.6. The minimum value of the time in the system from intake to storage of grain is shown in Fig. 7 with the drying efficiency at the initial moisture content of 24%, airflow rate of 402 cmm, batch drying of 20 tons. The main time, 15 hours, among the minimum time in the system of 16 hrs was the drying time at the drying efficiency of 0.9 in Fig. 5 and Fig. 7. The status of INTAKE GATE, which is closed in case of discharging the dried rice from the drying silos, is shown in Fig. 8. The INTAKE GATE is closed during 11 percentage of the total simulation time for discharging the dried rice from the drying silos to the storage silos or the loadout tank or the rice mill plant. However, unloading of the stored rice from storage silos to the loadout tank or the rice mill plant can be carried out at any time except the intake time and the time discharging from drying silos. The average waiting time and entities for each processing unit are shown in Fig. 10 and Fig. 11. The values obtained at drying temperature of 30° C, drying efficiency of 0.9, intake of 40 tons/day, a batch drying of 20 tons did not indicate bottleneck or any problems in the silo system. The size and capacity of all equipments in the silo system could be determined with the such data through much simulations. The simulations of the system at different conditions were required with alternative models.

CONCLUSIONS

The conclusions of this study are as follows.

1. A simulation model to design a grain silo system was developed with SLAMSYSTEM.
2. The silo system at intake amount of 40 tons/day was analyzed by the simulation model. The system had no bottleneck in material flow at intake amount of 40 tons/day and a batch drying of 20 tons. The size and capacity of all eqiupments such as buffer tanks, hopper scale, bucket elevators, conveyors, paddy cleaner, etc could be determined by the simulation data.
3. A hopper scale and a main bucket elevator to the 4 way distributor could be enough used for loading wet rice to the drying silos and for unloading dried rice to the storage silos or a rice mill plant or a loadout tank, not requiring an additional hopper scale and discharging elevator.
4. The drying silo required a diesel oil burner of 132 kw (about 120,000 Kcal/hr) for heating average ambient air of 13.8° C to drying air of 30° C at airflow rate of 402 cmm. The drying time was, respectively, 15, 22, and 29 hrs with 20, 30, and 40 tons/batch of drying at drying air temerature of 30° C, airflow rate of 402 cmm, initial and final moisture content of 24% and 17%(w.b), and drying efficiency of 0.9.

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Table 1. Performance measures of 1,200 ton silo system at intake amount of 40 ton/days, 20 ton/batch of drying, initial moisture of 24%, final moisture of 17%, airflow rate of 402 cmm, drying air temperature of 30 ℃ with different drying efficiency.

ITEM		Drying Efficiency					
		1.0	0.9	0.8	0.7	0.6	0.5
Drying Time (hr)		13	15	17	19	22	27
Time open of Intake Hopper (%)		93.4	93.4	93.4	93.4	94.5	95.6
INTAKE GATE	Ave./Max. Length	0	0	0	0	0.8/63	0
	Ave.wait Time(min)	0	0	0	0	7.6	0
Ave. Utilization (%) of Resources	Drying Silo	60	62	70	80	92	82
	Storage Silo	0	0	0	0	0	26
	Hopper Scale	0.03	0.03	0.03	0.03	0.03	0.02
Ave. Utilization(%) of Service Activity	Rice Cleaner	0.08	0.08	0.08	0.08	0.08	0.08
	Elevator for Scale	0.17	0.17	0.17	0.17	0.15	0.14
	El. for Distributor	0.17	0.17	0.17	0.17	0.15	0.14
	Unloading Auger	0.07	0.07	0.07	0.07	0.06	0.04
Time in the Silo System	Mean (hr)	15	16	18	20	25	30
	Minimum (hr)	15	16	18	20	24	28
Total weight of Dried Grain (ton)	Drying Silo	220	220	220	220	183	147
	Storage Silo	0	0	0	0	0	37
Length and time for Drying Silo	Ave. Length	0	0	0	0	0	0.12
	Ave.wait Time(min)	0	0	0	0	1.8	118
Elevator for Hopper Scale	Ave./Max. Length	0.7/17	0.7/17	0.7/17	0.7/17	3.7/99	0.5/17
	Ave.wait Time(min)	3.1	3.1	3.1	3.1	18.2	2.6

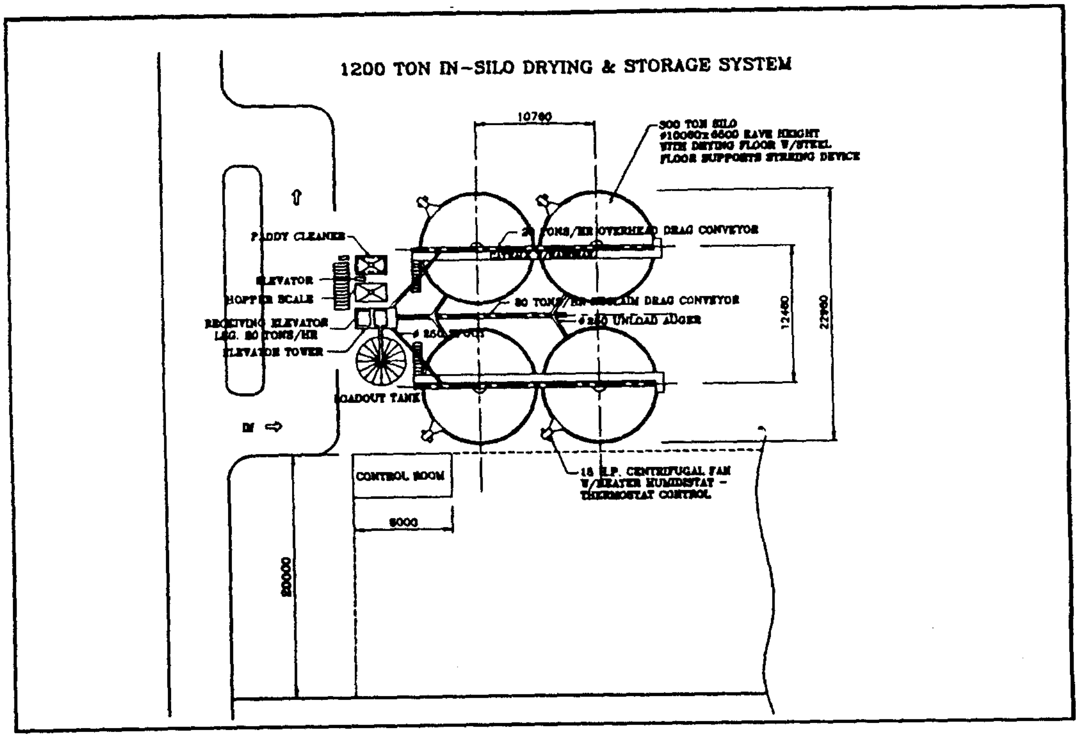
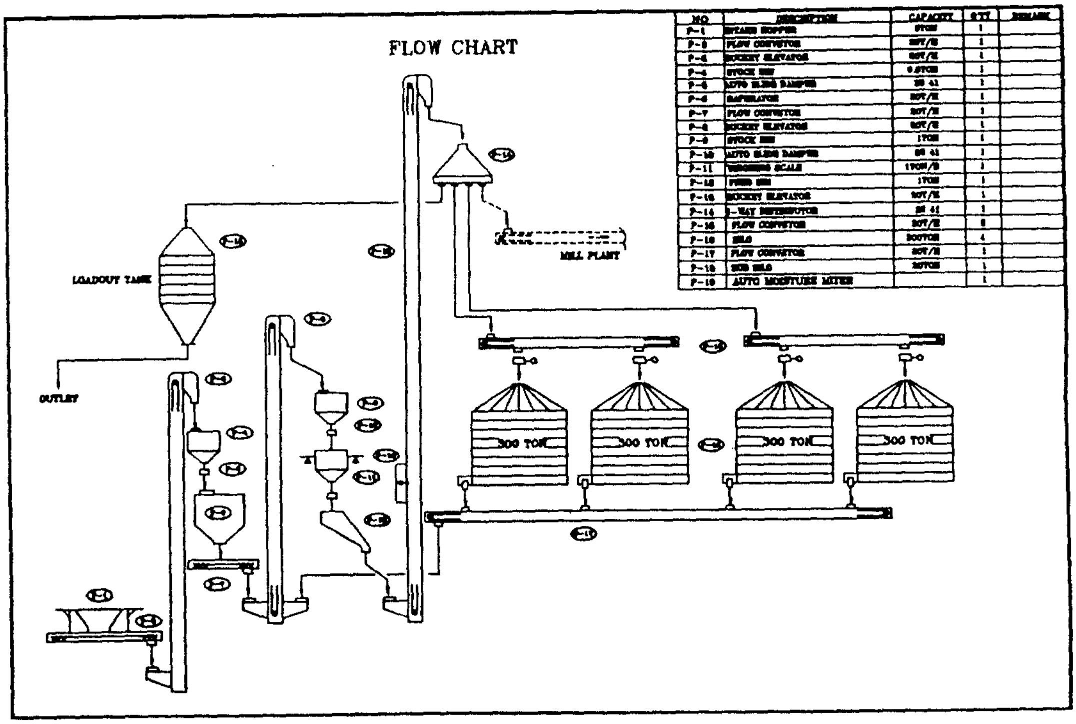


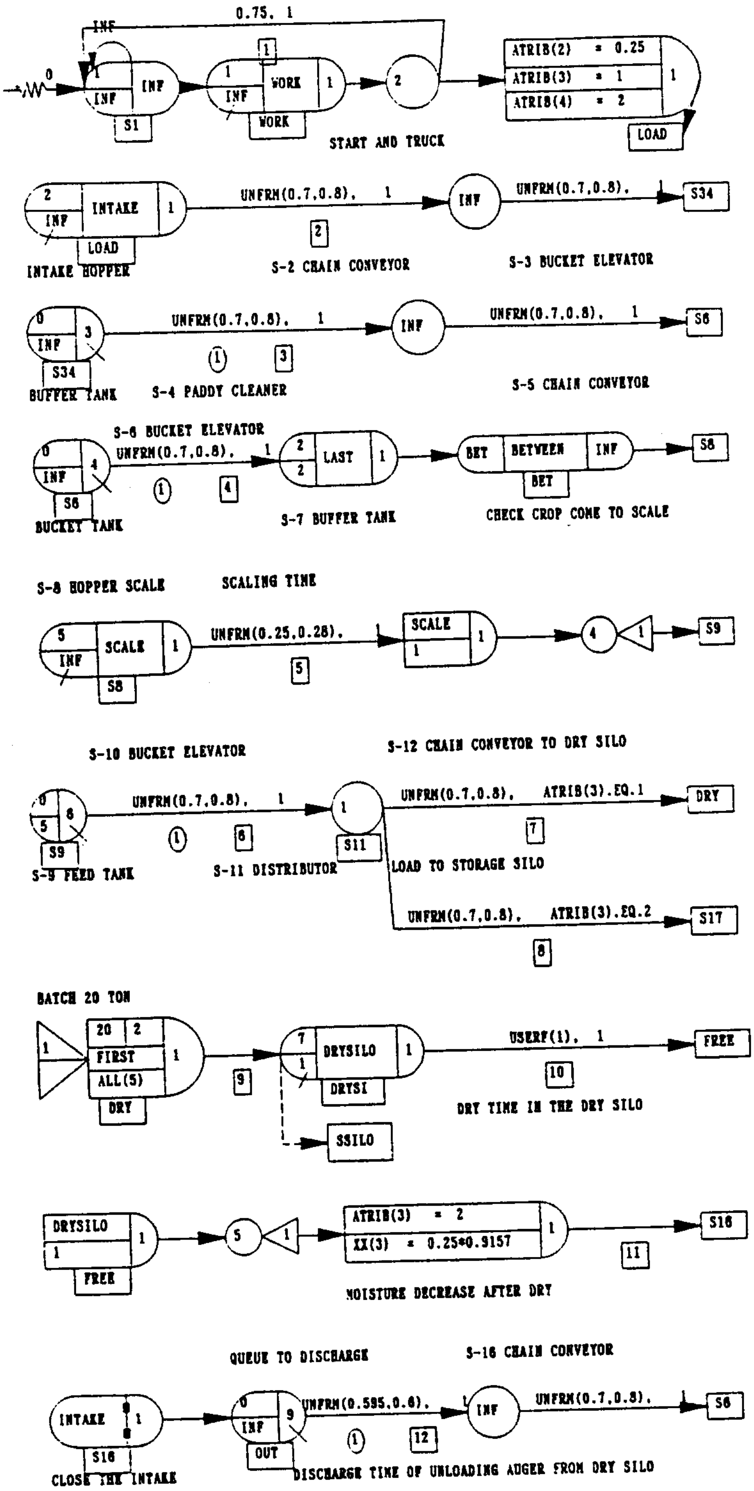
Fig 1. Layout of grain silo system

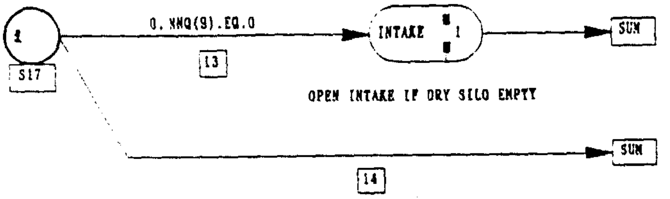


NO	DESCRIPTION	CAPACITY	Q'TY	REMARK
P-1	INTAKE HOPPER	5TON	1	
P-2	FLOW CONVEYOR	30T/H	1	
P-3	BUCKET ELEVATOR	30T/H	1	
P-4	STOCK BIN	0.5TON	1	
P-5	AUTO SLIDE DAMPER	[illegible]	1	
P-6	SEPARATOR	30T/H	1	
P-7	FLOW CONVEYOR	30T/H	1	
P-8	BUCKET ELEVATOR	30T/H	1	
P-9	STOCK BIN	1TON	1	
P-10	AUTO SLIDE DAMPER	[illegible]	1	
P-11	WEIGHING SCALE	1TON/B	1	
P-12	FEED BIN	1TON	1	
P-13	BUCKET ELEVATOR	30T/H	1	
P-14	3-WAY DISTRIBUTOR	[illegible]	1	
P-15	FLOW CONVEYOR	30T/H	2	
P-16	SILO	300TON	4	
P-17	FLOW CONVEYOR	30T/H	1	
P-18	SUB SILO	20TON	1	
P-19	AUTO MOISTURE METER		1	

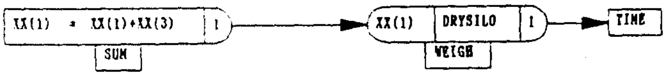
Fig 2. Flowchart of grain silo system

Fig 3 SLAM NETWORK MODEL

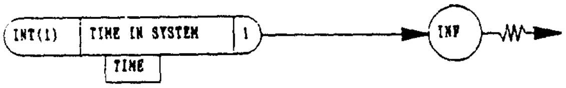




OPEN INTAKE IF DRY SILO EMPTY

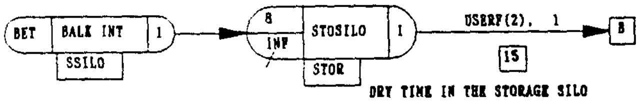


COLLECT TOTAL WEIGHT(XX(1)) COLLECTED IN THE DRY SILO

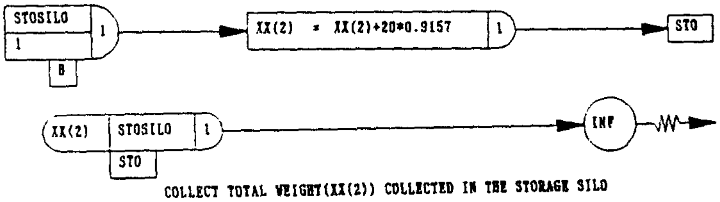


COLLECT INTERVAL TIME TO STORAGE IN THE STORAGE SILO

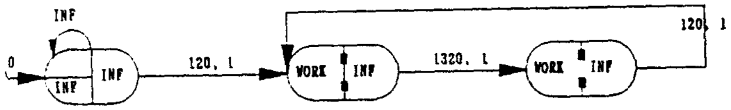
THE TIME BETWEEN ARRIVALS BALKED IN THE STORAGE SILO



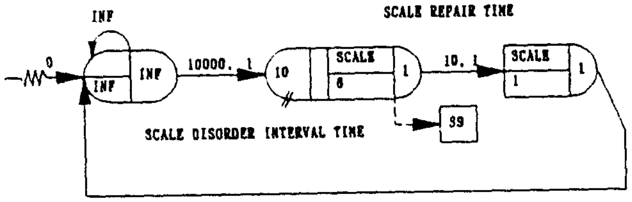
DRY TIME IN THE STORAGE SILO



COLLECT TOTAL WEIGHT(XX(2)) COLLECTED IN THE STORAGE SILO



WORKING TIME



RESOURCES BLOCK

1	SCALE	1	5
2	DRYSILO	2	7
3	STOSILO	2	8

GATE BLOCK

1	WORK	OPEN	1
2	INTAKE	OPEN	2

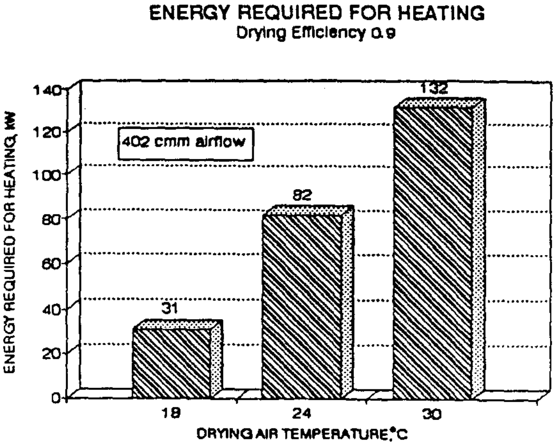


Fig 4. Energy required for heating ambient air temperature of 13.8 ℃ to 18 ℃, 24 ℃, and 30 ℃ drying air.

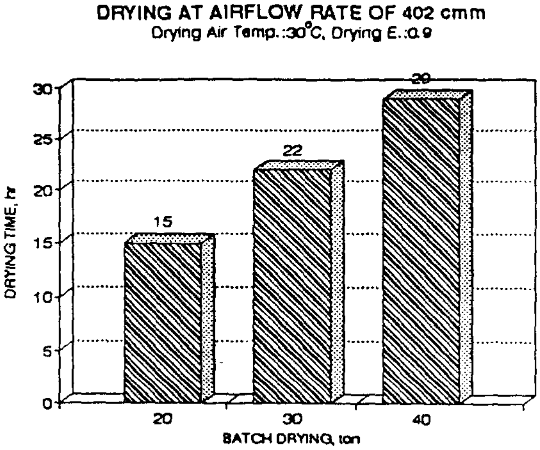


Fig 5. Drying time with different amount of batch drying.

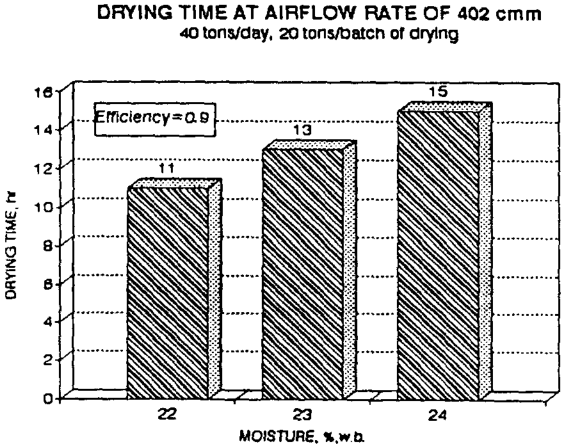


Fig 6. Drying time with different initial moisture content.

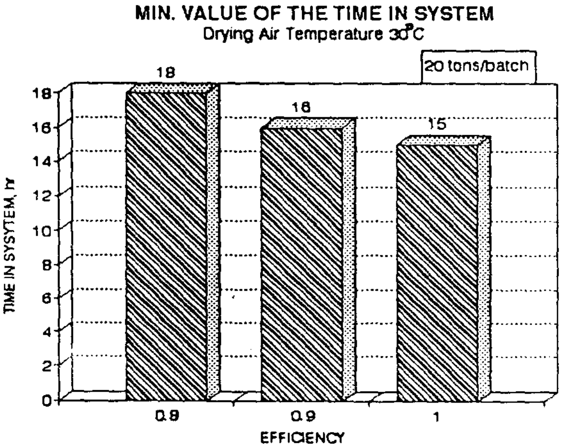


Fig 7. Minimum value of the time in system with different drying efficiency

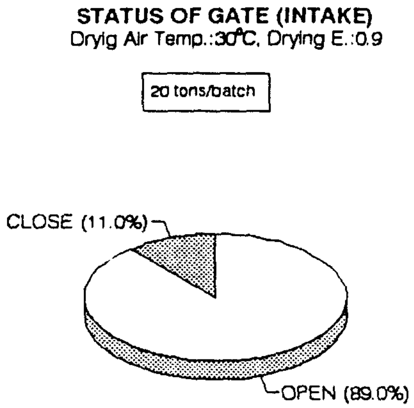


Fig 8. Status of INTAKE gate.

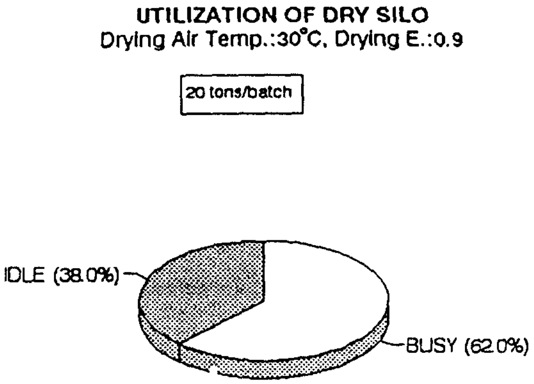


Fig 9. Utilization of drying silos.

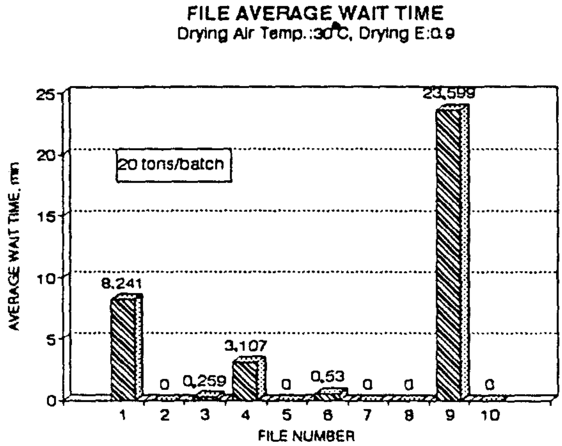


Fig 10. Average waiting time at each file(process).

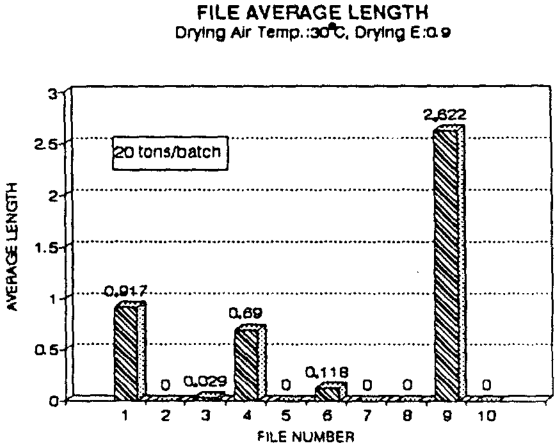


Fig 11. Average waiting entities (length) at each file(process).