컴퓨터 프로그램에 의한 飼料工場의 設計

Computer Programming of Feed Mill Layout

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摘 要

본 연구는 미국의 사료공장 중 주종을 이루고 있는 형식을 분석하여 일반적인 Model로 개발하였고 이 Model을 설계할 수 있는 Computer Program을 개발하였다. Model에 적용된 규모는 10ton/hr로부터 50ton/hr 이었고 종류는 돼지 및 닭 사료공장과 완전히 pellet화된 소 사료공장이었다.

개발된 Computer Program은 1개의 Main Program과 3개의 Subprogram으로 구성되어 있고 29개의 Input data를 사용하게 되어 있다. 이 Computer Program의 output은 다음과 같다.

1. 공장의 Dimension
2. 곡물저장 및 원료 bin의 수량 및 규모
3. 각 기계의 규모 및 성능
4. 총 작업시간 및 전기 소모량

위와같은 사료공장의 일반화 된 Model 및 이를 설계하기 위한 Computer Program은 사료 생산의 소요동력, 노동력 및 투자자본까지 추정할 수 있게 하였으며 이 분야에서 학문적으로 처음 시도하여 본 것이다.

I. Introduction

There are many different kinds, type and size of formula feed mills in the U.S.A. It is rare to find feed mills which have the same system layout (even if they produce the same type and kinds of feed) since each of the feed mills is designed and built based on a particular set of conditions.

It is a long-cherished desire in the feed industry to compare the different types, kinds or/sizes of feed mills in terms of energy consumption, labor requirements and capital requirements. There are many factors to be considered and much effort is needed in the design of a single feed mill. Thus, it is almost impossible to design a combination of all different sizes and kinds of feed mills. For the reason above, the simplest idea, but the most difficult to perform, would be to construct a general feed mill model and develop a computer program for each design.

So far, little has been studied in this area. General, but very valuable information, has been introduced through "Feed Manufacturing Technology" published by the American Feed Manufacturing Association (1976). Also with the support of AFMA, "Environmental Controls for Feed Manufacturing and Grain Handling" was published (Briggs et al., 1971). A general guide line for dust control, noise, occupation safety and other environmental factors were presented for feed mill design. Vosloh (1968, 1976) reported on the costs and capital requirements of feed mills. In his study, the model mills were constructed by surveying the data from the trade associations, equipment manufacturers and feed manufacturers.

Thus, the primary objectives of the study are:

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1) to construct general models of a feed mill; and 2) to develop a computer program of its design.

II. Model Mill

Swine and poultry feed mills and complete pelleted dairy feed mill are selectdd for the model' mill for a production range from 10 ton/hr to 50 ton/hr. In order to develop a model mill, typical feed mills are analyzed by dividing into eight subsystems: receiving system; storage system; grinding system; mixing system; pelleting system; bulk loadout and bagging system; liquids storage and handling system; and miscellaneous system such as the dust control system. The flow diagram of system of model mill is presented in Figure 1.

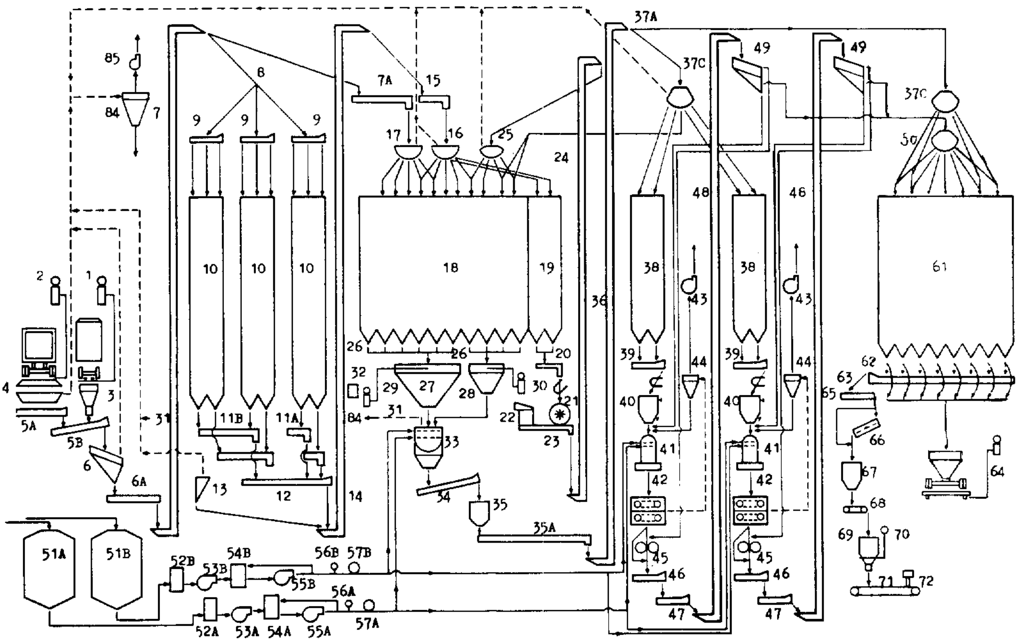


Fig. 1. Flow diagram of whole system

1. Basic Operation and Subsystems of the Model Mill

The dry ingredients are received either in bulk or in bags. The bulk ingrediants such as grain, meat, fish meal and limestone are delivered by rail or truck in hoppers. Hopper cars are discharged to the receiving hoppers. These ingredients are conveyed from the receiving hopper to the receiving scalper through drag conveyors. None economic foreign materials and tramp metals are removed during the cleaning process. After the process, the materials are conveyed and elevated through drag conveyors and bucket elevator. And then, these ingredients are sent to either working bin, via screw conveyors and turnhead distributor, or outside storage bins, via diverter valves and horizontal conveyor. Whole grain and large volume soft ingredients, such as soybean meals, are stored in outside bins adjacent to the main building. Other soft bulk ingredients stored in working bins above the mill area. Bagged ingredients are unloaded from rail or truck and loaded on pallets, moved by forklift truck, and stored in the warehouse. The receiving system plan considered in the study is shown in Figure 2.

Outside storage bins, inside working bins and a warehouse are provided for storage of the receiving ingredients. The outside bins are prepared for a large quantity of materials received through the bulk receiving system. Then, these ingredients are to be conveyed and elevated by the conveyor and bucket elevator, and then distributed into any selected inside working bin through a turnhead distributor for daily uses. Of these ingredients, grains are transferred into the hammermill surge bin, ground through the hammermill and stored inside bins again.

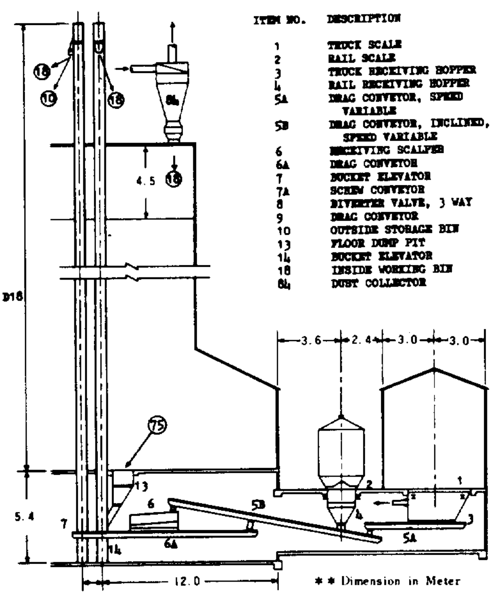


Fig. 2. Receiving system plan

An overhead bin cluster is chosen for the ingredients to provide gravity flow, where possible, into mixing and other system. Some soft ingredients received through the bulk received system are stored directly in these bins. The bagged ingredients are stored in the warehouse and then transferred to either these bins or the mixer. Also, pellet mash bins are provided (if pellets are produced) on the top of pellet mill. Premixes with their carrier are stored in the inside working bins. The storage system plan (top view) considered in the study is presented in Figure 3.

Whole grain such as corn or grain sorghum

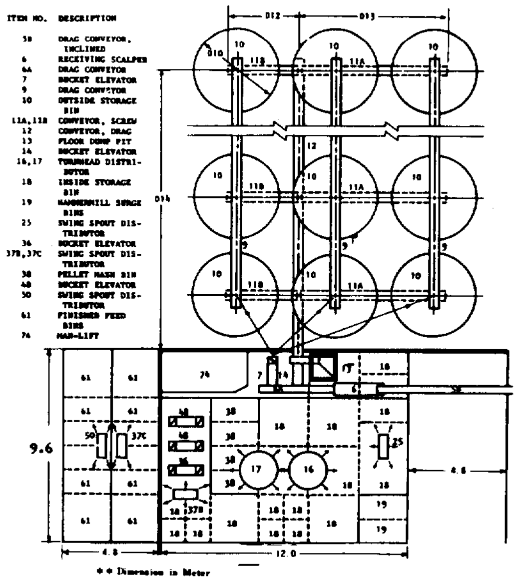


Fig. 3. Storage system plan(top view)

are ground before mixing with other ingredients. In this model, the grains to be ground are transferred from the outside bins to the hammermill surge bins located above the hammermill and then conveyed to the hammermill by screw feeder. After processing is done, the ground grains are to be elevated by a mechanical system and distributed to the working bin again. Then these ground grains will be blended with other feed ingredients in the mixing system. The grinding system plan considered in the study is presented in Figure 4.

The mash ingredients drawn from working bins are fed into a hopper scale, weighed, and discharged to the mixer by control from a central control panel. The bagged ingredients, stored at the warehouse, are brought to the mixing area, weighed, and dumped into the mixer. In a large scale mill, minor ingredients are weighed at a minor scale hopper and fed to the mixer in order to save time. Liquids such as molasses, or fat may be added through a manifold pipe in the mixer.

After the mixer, well blended feed is to be discharge into the surge hopper which is directly mounted below the mixer. Before the next batch

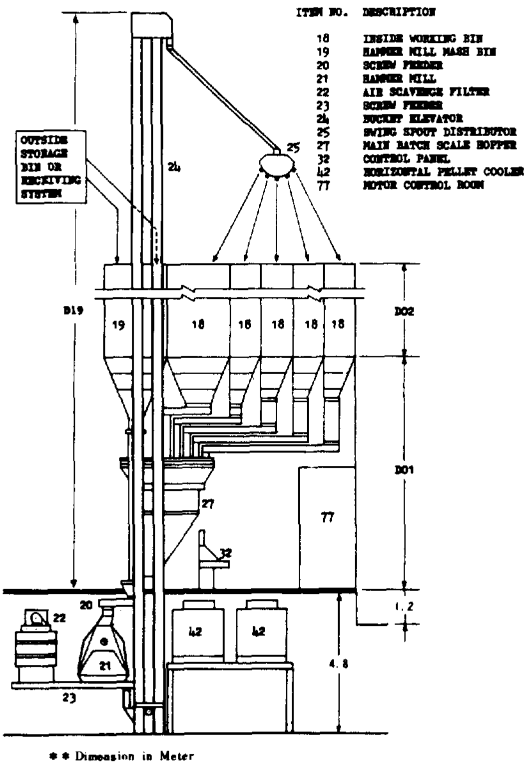


Fig. 4. Grinding system plan.

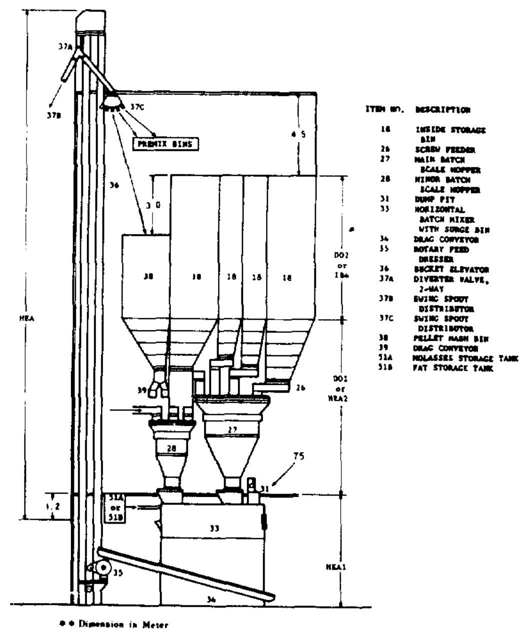


Fig. 5. Mixing system plan.

is ready to dump, the mixed feed is to be moved by a conveyor to a feed dresser to remove lumps and unwanted large size materials. The finished feed then goes to either a finished feed bin for loadout, or bagging pellet mash bins for pelleting.

Microingredients such as drugs, vitamins or minerals are weighed individually by a sensitive scale, dumped into the main mixer and mixed with ground grain (premix carrier). Then, the premix is elevated and stored in the working bins and used over a period of one or several days.

The most widely used feed mixers are vertical mixer, horizontal mixer and continuous type mixer. In this study, horizontal mixer is selected for the model Figure 5 shows the mixing system plan considered in this model mill.

The mixed feed is introduced into the pellet mill conditioner. At this point, steam and molasses, if necessary, are added to the mixed feed, which is then forced through holes in the die by a roller pressure.

The continuous flow of heated and moist pellets are fed into the cooler. After being cooled and dried, the pelleted feeds are crumbled through the crumbling mill, if necessary. These pellets or crumbles are then elevated to the top of the finished feed bin for cleaning and sizing through the scalper. Pellets and crumbles are then conveyed to the storage bin from which they are either shipped in bulk or bagged state. The pelleting system plan considered in the study is presented in Figure 6.

The finished feed, both pellets and mash, are stored in the finished feed bins until they are loaded in a bulk state on trucks or transferred to the bagging bin for packaging. In case of bulk loadout, the finished feeds are loaded on trucks beneath each bin cluster. In a bagging operation, feed is moved to the bagging bin through the conveyor. Before entering the bagging bin, pellets are screened once again in order to increase the quality of the products. Then, the finished feed flows by the

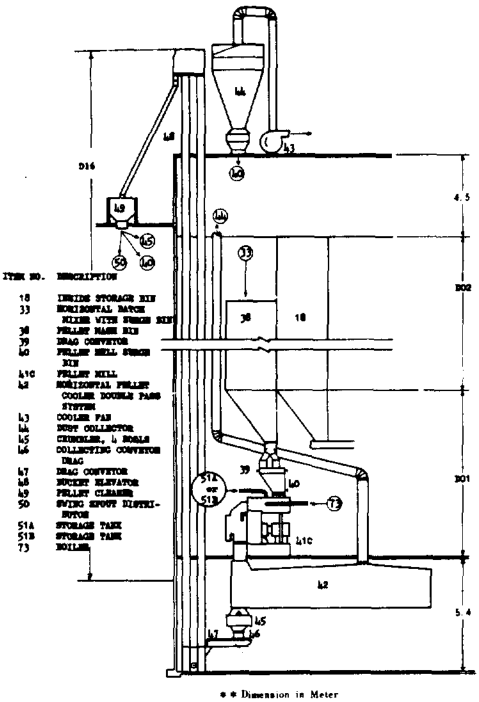


Fig. 6. Pelleting system plan.

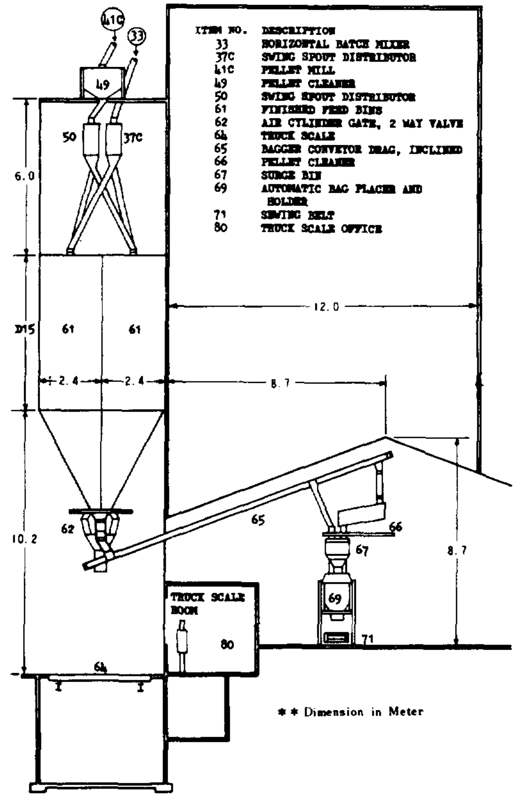


Fig. 7. Bulk loadout and bagging system plan.

feeder from the bagging through a scale set to deliver 22.5 to 45 kg, depending on the desired package. The feed is bagged, sealed and then moved to warehouse storage on pallets by a forklift truck or loaded directly onto a truck. The system plan considered in the study is presented in Figure 7.

Molasses, fat or fish soluable, are used mainly as liquid feeds in feed industry. Normally, the liquid feeds are received at the mill either by tank truck or by car quantities, although, some mills, because of limited production and storage capacity, receive drum shipments.

Liquids are pumped from the storage tank through the strainer to a heating tank by the positive displacement pump of a screw or gear type. Because of the high viscosity, the liquids are heated by using coils or jackets with hot water or low pressure steam in the heating tank up to 38°C to 93°C in the case for molasses. For fat, 60°C to 93°C and for fish soluable, 60°C is used. Then, by the force of another pump, the liquids are supplied to either the pellet mill or the mixer. Figure 8 shows the schematic view of the liquids storage and handling system considered in the study.

Also, dust collecting systems, boiler, air compresser, considered for the study. Figure 9 shows the flow diagram of the dust collecting system. Overall plans of first floor, basement, roof, and section view A-A (refer to Figure 10) are presented in Figure 10, 11, 12 and 13, respectively.

2. Equipment

The location of individual equipment is presented in each subsystem plan (Figures 2, 3, 4, 5, 6, 7, and 8) and overall plant plan (Figures 10, 11, and and 12).

The equipment is located so as not to interrupt the other unit system, even when the size

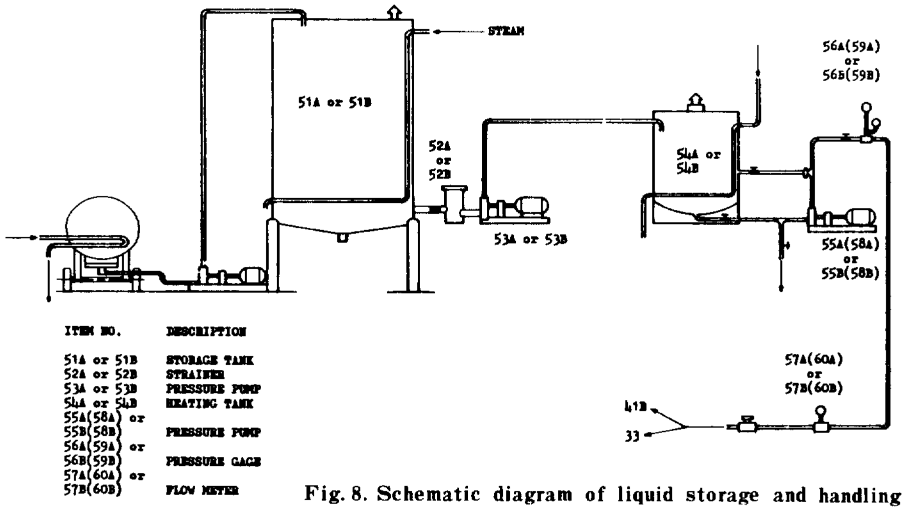


Fig. 8. Schematic diagram of liquid storage and handling system.

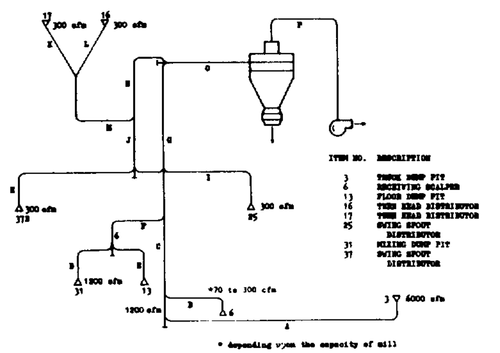


Fig. 9. Flow diagram of dust collecting system.

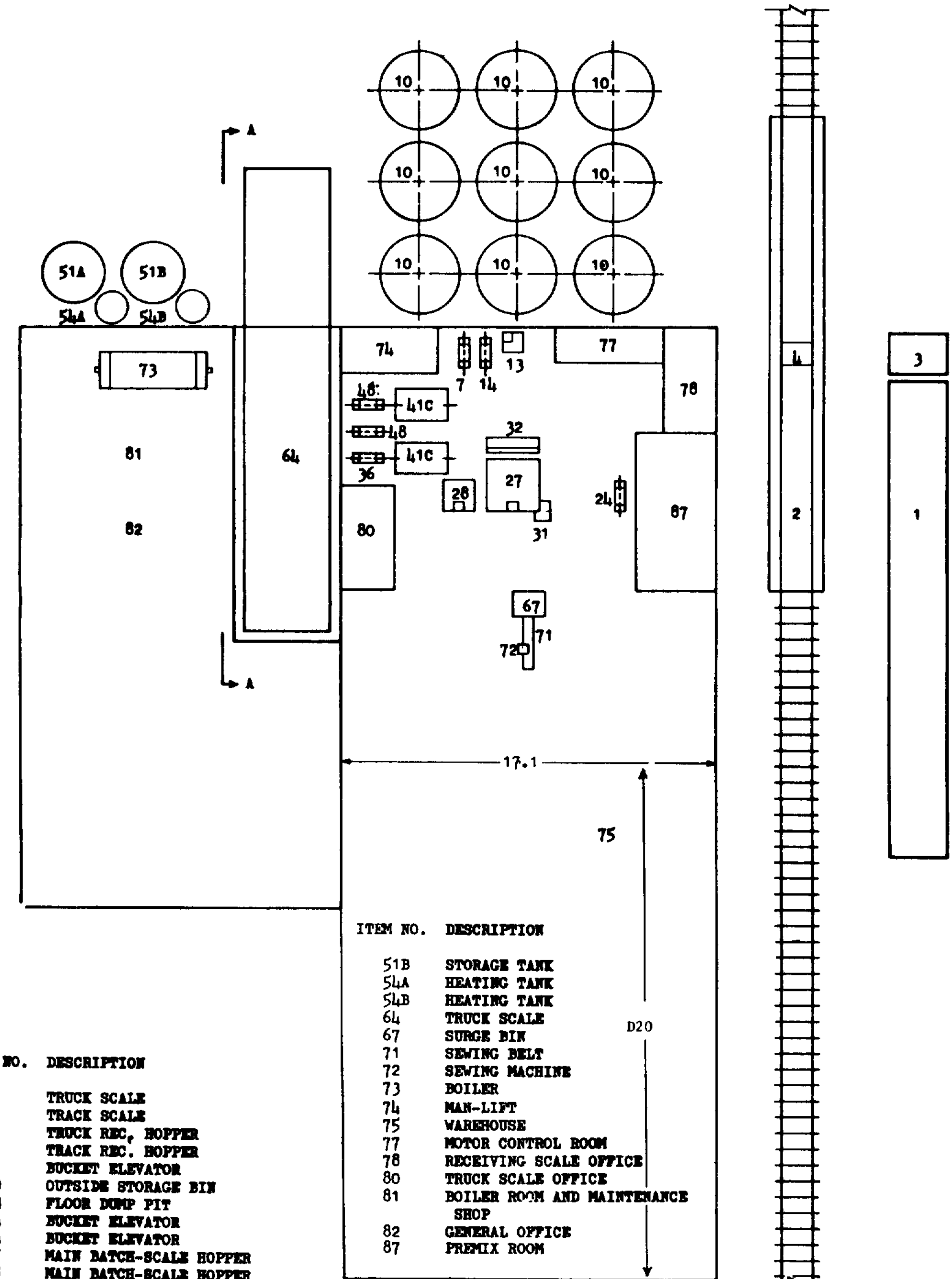
of each piece of equipment varies from small to large. Dust tight and semi-automatic types of equipment are selected for the model mill (Park, 1982). Table 1 shows the type of major equipment used in the model mill.

3. Building Dimension

Dimensions of plants do not vary proportionately as the capacity or production rate of each types of finished feed changes. Some of the dimensions are constant within the production range and

Table 1. Type of Major Equipment Used in the Model.

Equipments	Type
Receiving and shipping scale	Electrical system
Coveyor	Mechanical Conveyor (Drag, Screw)
Bucket elevator	Low speed standard size
Receiving Scalper	Oscillating Screen
Distributor and Diverter Valve	Electric System with positive remote control
Hammer mill	Dual speed, (max. capacity 300 Hp.)
Pellet mill	Dual speed, (max. capacity 300 Hp.)
Pellet cooler	Double pass horizontal cooler
Pellet screener	Oscillating Screen
Feed finisher	Rotary feed dressor
Bagging system	Automatic bagging system
Dust collector	High performance cyclone collector
Dust collector fan	Radial wheel type fan
Outside bin	Steel bin



ITEM NO.	DESCRIPTION
1	TRUCK SCALE
2	TRACK SCALE
3	TRUCK REC. HOPPER
4	TRACK REC. HOPPER
7	BUCKET ELEVATOR
10	OUTSIDE STORAGE BIN
13	FLOOR DUMP PIT
14	BUCKET ELEVATOR
24	BUCKET ELEVATOR
27	MAIN BATCH-SCALE HOPPER
28	MAIN BATCH-SCALE HOPPER
31	DUMP SYSTEM WITH SUCTION TYPE DUST COLLECTOR
32	CONTROL PANEL
36	BUCKET ELEVATOR
41C	PELLET MILL
48	BUCKET ELEVATOR
51A	STORAGE TANK

ITEM NO.	DESCRIPTION
51B	STORAGE TANK
54A	HEATING TANK
54B	HEATING TANK
64	TRUCK SCALE
67	SURGE BIN
71	SEWING BELT
72	SEWING MACHINE
73	BOILER
74	MAN-LIFT
75	WAREHOUSE
77	MOTOR CONTROL ROOM
78	RECEIVING SCALE OFFICE
80	TRUCK SCALE OFFICE
81	BOILER ROOM AND MAINTENANCE SHOP
82	GENERAL OFFICE
87	PREMIX ROOM

**Dimension in Meters.

Fig. 10. First floor plan.

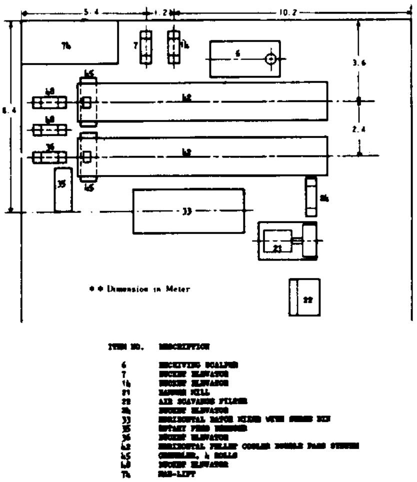


Fig. 11. Basement plan.

some are variable of plant capacity, storage capacity, or production rate of each type of finished feeds. Diameter of outside ingredient storage bins varies from 2.7 m to 5.4 m and maximum height of outside bin wall is limited as 16.5 m (Park, 1982). Also, the number of bins varies as the storage capacity changes.

Height of the inside working bin wall varies from 10.5 m to 16.5 m as the function of plant capacity, kinds of ingredients or required storage capacity. However, working bin area is fixed as 9.6 m x 12.0 m regardless of the conditions. Warehouse area is a function of amount of bagged inbound ingredient, outbound bagged feed, and their storage capacity (Park, 1982). In this model, width of the warehouse is considered as a fixed dimension and the length of that is a variable dimension (Figure 10).

Receiving area is considered as fixed dimension. Since the size of the receiving truck or rail car is assumed the same regardless of capacity of the plant.

General office and maintenance area is considered as the function of the plant capacity (Park, 1982). In the case where a certain type of feed would not be produced, the space for its produc-

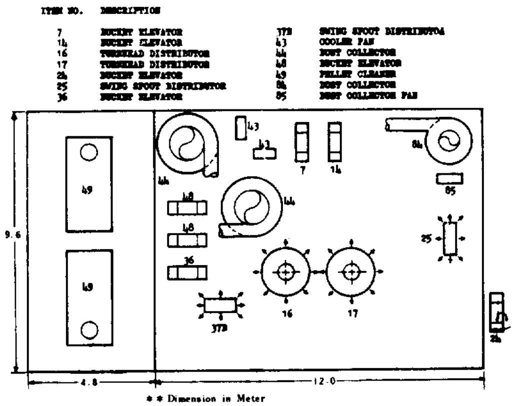


Fig. 12. Roof plan.

tion system is provided for future needs. The mill basement elevation is assumed to be 5.4 m regardless of the size of the mill.

III. Computer Program for Feed Mill Design

Based on a general model mill, a computer program is developed to determine the number, size, capacity, required horsepower, working hours and energy consumption of each individual piece of equipment, the storage bin and working bin allocation plan, and the dimension of plant building for a swine and poultry feed mill and complete pelleted dairy feed mill. For the program, 3 subprograms, 29 input data and 55 specifications for equipment data are used. The computer program for the feed mill design is summarized in Table 2.

Table 2. Program Summary Sheet

Title	Computer Program for Feed Mill Design
Author	Kyung-kyu Park Do Sup Chung Robert McEllhiney
Program language	Fortran IV
Computer system	IBM 370
Program size	Object code = 71000 Bytes Array area = 14200 Bytes No. of cards = 2300
Estimate run time	25.74 seconds to compile 0.87 seconds to execute

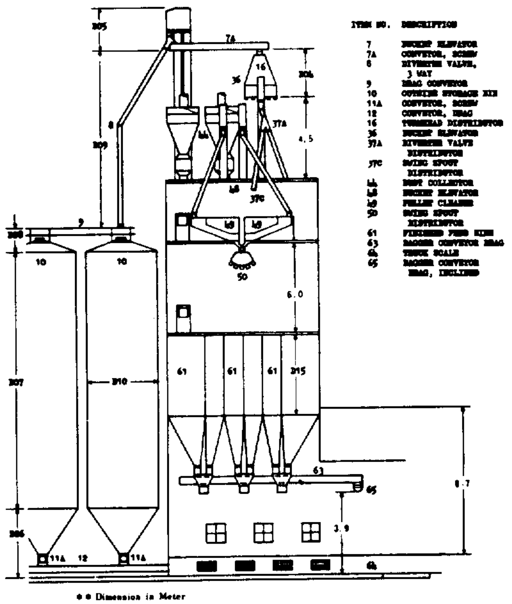


Fig. 13. Side view(section A-A).

Since this program is too big to explain in this limited paper, only computer flow chart of the pelleting system design is presented in Figure 14. Note that one who needs specific information on this program, "User's guide of computer program for feed mill design (Park, 1982)" should be referred.

1. Input Data

a. Definition of Input Data

XT = capacity of plant (8 hours operation a day), ton/day.

R(1) = production ratio of mash bulk feed to total feed production by weight, decimal.

R(2) = production ratio of mash bagged feed to total feed production by weight, decimal.

R(3) = production ratio of pellet bulk feed to total feed production by weight, decimal.

R(4) = production ratio of pellet bagged feed to total feed production by weight, decimal.

M1 = no. of ingredients received by mash bulk state, integer.

M2 = M1 + no. of ingredients received by grain bulk state, integer.

M3 = M2 + no. of ingredients received by bagged state being stored in inside bin, integer.

M4 = M3 + no. of ingredients received by bagged being stored in warehouse, integer.

DS = no. of storage days for ingredients supply.

NP = no. of premix bin based on 1.2 x 1.2 m^2 bin.

NBM = no. of minor ingredients bin based on 1.2 x 1.2 m^2.

XMD(I) = mash density of individual individual ingredients I, lbs/ft^3.

XD(I) = grain bulk density of individual ingrediants I, lbs/ft^3.

X(I) = daily usage of ingredient: I. ton/day.

MINSH = no. of minor ingredients scale hopper, equal to 1 if minor scale is used, otherwise equal to zero.

RLFM = production ratio of liquids containing feed to total feed produced at batch mixer, decimal.

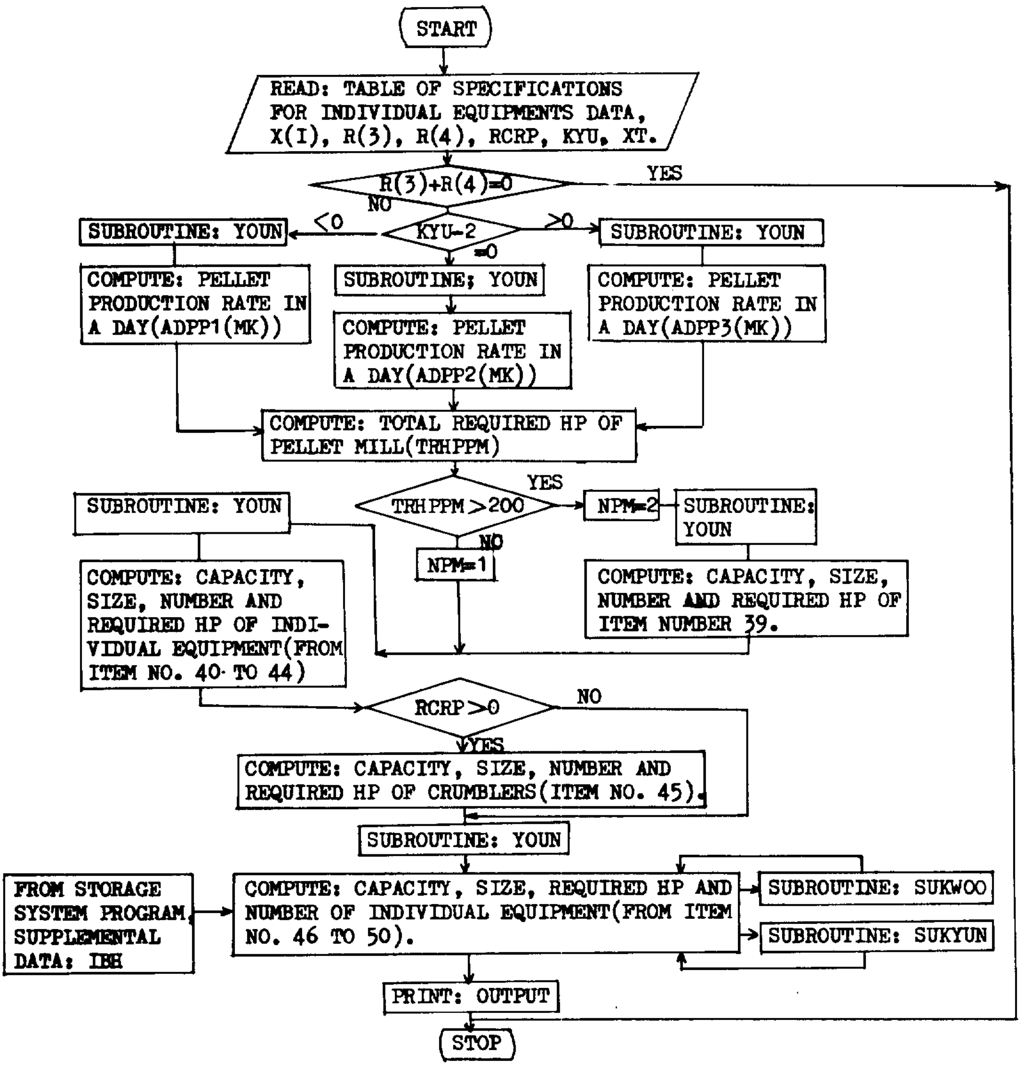
RLFP = production ratio of liquids containing feed to total pelleted feed produced at pellet mill, decimal.

RMCBM = production ratio of molasses containing feed to total feed produced at batch mixer, decimal.

RMCPM = production ratio of molasses containing feed to total feed produced at pellet mill, decimal.

RFCBM = production ratio of fat containing feed to total feed produced at batch mixer, decimal.

RFCPM = production ratio of fat containing feed to total feed produced at pellet mill, decimal.



IBH : Inside bin height.
NPM : Number of pellet mill.
KYU, R(3), R(4), X(I), RCRP and XT: Refer to input data.

SUBROUTINE YOUN, SUBROUTINE SUKWOO and SUBROUTINE SUKYUN: Refer to Subprogram.
TABLE OF SPECIFICATIONS FOR INDIVIDUAL EQUIPMENT DATA: Refer to Subprogram.

Fig. 14. Computer flow chart of pelleting system design.

FMAPM = fraction of molasses to be added at pellet mill, decimal.

FMABM = fraction of molasses to be added at batch mixer, decimal.

FFABM = fraction of fat to be added at batch mixer, decimal.

FFAPM = fraction of fat to be added at pellet mill, decimal.

RIRT = ratio of truck delivered bulk ingredients to total ingredients, decimal.

RCRP = production ratio of crumble to

total pellet produced, decimal.

NDSBII = no. of storage days for inbound bagged ingredients supply, days.

NDSOBF = no. of storage days for outbound bagged feed supply, days.

NDOBF = no. of different types of outbound bagged feed.

KYU = equal to 1 if poultry or dairy feed mill is to be programmed, equal to 3 if complete pelleted dairy feed mill is to be programmed or equal to 2 if mixed feed mill (both swine and poultry feed mill and complete pelleted dairy feed mill) is to be programmed.

2. Subprograms

Three subprograms are developed for supporting the main program. These are: SUBROUTINE, "YOUN", "SUKWOO", and "SUKYUN". Subprogram "YOUN" is used to sort the equipment specification for selecting the proper size of equipment by indicating the number in the specification for the equipment which contains the capacity, dimensions and required horsepower of equipment. Subprogram "SUKWOO" is used to determine the bucket elevator size selection. Subprogram "SUKYUN" is used for adjusting the required HP of a drag conveyor. Also, in order to reduce the size of the computer program, 55 specifications for equipment data which represent the size, capacity and required HP of individual pieces of equipment are memorized in the main program by a tabulated form to select the proper size of equipment for feed mill design.

3. Output of the Program

a. Bin layout plan such as bin size, bin number and bin allocation for each individual ingredients.

b. Number, capacity, size, length, required power, operating hours and energy consumption

Table 3. Computer output of the bin layout plan.

	INGREDIENT	DENSITY LB/CU FT	USAGE TON/DAY	NUMBER OF BIN	STORAGE CAPACITY CU FT	TONS	DAYS
INSIDE BINS	X(1)1/	40.5	25.0	1.00	2880.0	52.5	2.1
	X(2)	20.0	10.4	1.00	2880.0	25.9	2.5
	X(3)	35.0	14.5	1.00	2880.0	45.4	3.1
	X(4)	40.0	8.4	1.00	2880.0	51.8	6.2
	X(5)	37.0	4.1	0.50	1440.0	24.0	5.8
	X(6)	33.0	52.0	2.00	5760.0	85.5	1.6
	X(7)	34.0	31.0	1.00	2880.0	44.1	1.4
	X(8)	30.0	31.0	1.00	2880.0	38.9	1.3
	X(9)	35.0	4.1	0.25	720.0	11.3	2.8

NO. OF HAMMER MILL SURGE BIN……; 2 (4×8 SQ ET)
NO. OF PREMIX BIN……; 4 (4×4 SQ FT)
NO. OF MINOR INGREDIENTS BIN……; 6 (4×4 SQ FT)
NO. OF EXTRA BIN……; 3 (4×4 SQ FT)
HEIGHT OF BIN (FORM TOP OF HOPPER TO BIN DECK); 45 FT
* * SIZE OF BIN IS BASED ON 8×8 SQ FT BIN * *

	INGREDIENT	DENSITY LB/CU FT	USAGE TON/DAY	NUMBER OF BIN	STORAGE CAPACITY CU FT	TONG	DAYS
	X(1)	40.5	25.0	1.00	10597.5	193.1	7.7
	X(2)	20.0	10.4	1.00	10597.5	95.4	9.2

	X(3)	35.0	14.5	1.00	10597.5	166.9	11.5
	X(4)	40.0	8.4	0.00	0.0	0.0	0.0
OUTSIDE	X(5)	37.0	4.1	0.00	0.0	0.0	0.0
BIN	X(6)	45.0 2/	52.0	2.00	21195.0	429.2	8.3
	X(7)	35.0 2/	31.0	1.00	10597.5	166.9	5.4
	X(8)	30.0 2/	31.0	1.00	10597.5	143.1	4.6
	NO. OF OUTSIDE BIN……; 9						
	NO. OF EXTRA BIN……; 2						
	DIAMETER OF OUTSIDE BIN……; 15 FT						
	HEIGHT OF BIN(FROM TOP OF HOPPER TO BIN DECK) ……; 60 FT						

1/ X(1): 49% soybean meal
X(2): Alfalfa meal
X(3): Poultry byproduct meal
X(4): 60% corn gluten meal
X(5): Meat scraps
X(6): Corn
X(7): Milo
X(8): Corn screenings
X(9): Fish meal

2/ Density of grain bulk.*

Table 4. Computer output of the pelleting system equipment.

SYSTEM	ITEM NUMBER	NUMBER	EQUIPMENT	CAPACITY	SIZE	LENGTH	REQUIRED HP	WORKING HOURS	REQUIRED ENERGY
PELLE-	38	2	PELLET MASH BIN						
TING	39	**NOT	NECESSARY**						
	40	1	PELLET MILL SURGE BIN						
	41A	1	SCREW FEEDER						
			(SPEED VARIABLE)	20 TON/HR			1.5 HP	5.75 HRS	8.62 HPH
	41B	1	FEED CONDITIONER	20 TON/HR			15.0 HP	5.75 HRS	86.25 HPH
	41C	1	PELLET MILL	20 TON/HR			200.0 HP	5.75 HRS	1150.00 HPH
	42	1	HORIZONTAL PELLET COOLER						
			DOUBLE PASS SYSTEM	24 TON/HR		25 FT	1.0 HP	5.75 HRS	5.75 HPH
	43	1	COOLER FAN	24000 CFM			50.0 HP	5.75 HRS	287.50 HPH
	44	1	DUST COLLECTOR	19240 CFM	HEIGHT	273 IN			
					DIA.	94 IN			
	45	1	CRUMBLER, 4 ROLLS	24 TON/HR			30.0 HP	2.87 HRS	86.25 HPH
	46	1	COLLECTING CONVEYOR						
			(DRAG)	1630 CU FT/HR	6 IN	7 FT	0.75 HP	5.75 HRS	4.31 HPH
	47	1	DRAG CONVEYOR	1630 CU FT/HR	6 IN	6 FT	0.75 HP	5.75 HRS	4.31 HPH
	48	1	BUCKET ELEVATOR	1755 CU FT/HR	HEIGHT	124 FT			
					BUCKET SIZE	8x5 IN			
					BELT SPEED	325 FPM			
					BUCKET SPACE	7 IN	10.0 HP	5.75 HRS	57.5 HPH
	49	1	PELLET CREANER	20 TON/HR			5.0 HP	5.75 HRS	28.75 HPH
	50	1	SWING SPOUTDISTRIBUTOR		8 WAY,	45 DEG.	0.25HP	5.75 HRS	1.44 HPH

of 95 individual pieces of equipment.

c. Dimension of feed plant such as warehouse size, building height, and elevator height etc.

Table 3 and 4 show the output of the bin layout plan and pelleting system which are parts of whole output of the program when plant capacity is 200 ton/day and production ratio of mash bulk, mash bagged, pellet bulk and pellet bagged to total feed production is 25% each, respectively.

IV. Summary and Conclusions

A typical swine and poultry feed mill and complete pelleted dairy feed mill are analyzed and divided into subsystems in order to formulate a general model mill and computer program for its design. In formulating a general model mill and computer program for its designs, the following subsystems are investigated: (1) receiving system; (2) storage system; (3) grinding system; (4) mixing system; (5) pelleting system; (6) bulk loadout and bagging system; (7) liquid storage and handling system; and (8) miscellaneous. For the study, much data and information are collected from more than 40 commercial feed mill equipment manufacturers and feed mills. The following conclusions are drawn from this study:

1. The general model mill and the computer program for feed mill design developed can be used for designing either specific poultry and swine feed mill or complete pelleted dairy feed mill for a production range from 10 ton/hr to 40 ton/hr.
2. Major output of this computer programs for designing a feed mill will result in the following outputs:
   a. The dimension of the plant.
   b. The storage and working bin number and their size.
   c. The dimension of individual equipment and its required horsepower.
   d. The operation hours and the electrical energy consumption of the individual equipment of the model mill.
3. The general model and computer program for the feed mill design developed give the bases for developing the mathmatical models of energy consumption, labor requirement and capital requirement.

V. References

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