Computer Layout and Design of Grain Storage Facilities

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Computer Layout and Design of Grain Storage Facilities

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INTRODUCTION

GRAIN storage facility may represent one of the largest single investments made by a farmer. An incorrect design may prove costly because comparable systems often differ in purchase price by several thousand dollars. Another consideration is that the least cost facility relative to initial investment may have the greatest annual expense. Farmers who are about to purchase and/or construct a grain storage facility often seek economic and engineering information from neighbors, builders and equipment dealers. The information they receive is, for the most part, qualitative in nature based on the past experiences of the individuals consulted. The design engineer may be in an excellent position to give sound quantitative information. However, the large number of variables that should be considered when designing a grain facility usually makes comparison of several different systems impractical. To provide a detailed design and cost analysis for several modifications of comparative storage systems usually exceeds the time allotted by engineers or contractors for that purpose. Yet, the producer needs accurate detailed data when making a large and important investment. To meet the needs of the farmer, and to assist the contractor, equipment dealer and engineer in their planning, the computer design simulation BNDZN was developed.

PROGRAM INFORMATION

BNDZN (pronounced “Bin Design”) was developed primarily for the design of new facilities using a centralized layout. However, other bin arrangements and older facilities for which expansion is planned may also be evaluated by the program.

The program output may be divided into both design and economic information. Input and output data are arranged so that interested parties can readily examine and compare each design and economic factor related to the system. Alternate plans may be compared by making additional runs of the program. BNDZN allows the designer to concentrate on system concepts rather than mathematical computations and, in effect, convert the specifications of the engineer into a form suitable for his client with a minimum of time and expense.

To put the size and scope of the program into perspective, there are more than 200 inputs related to facility design and approximately 500 economic inputs. Each of these may be specified by the designer, using either a value he chooses or a default value established within the program. The only parameter that must be specified is the design capacity of the facility. The program output may be divided into both design and economic information. Input and output data are arranged so that interested parties can readily examine and compare each design and economic factor related to the system. Alternate plans may be compared by making additional runs of the program. BNDZN allows the designer to concentrate on system concepts rather than mathematical computations and, in effect, convert the specifications of the engineer into a form suitable for his client with a minimum of time and expense.

The program is presented as a computer listing and written in 4354 BASIC. The input data are in the form of a program deck. The output is tabulated on a form sheet. The program uses subroutines and functions as defined in Table 1. The program can be run on equipment with a disk drive and printer. The program is designed to be run on a typewriter or keyboard with no difficulties. The user is furnished a manual which includes the program listing and instructions for use. The program is furnished on a diskette and is delivered by mail.

**TABLE 1. ROUTINES USED IN BNDZN**

<table>
<thead>
<tr>
<th>Name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subroutines</strong></td>
<td></td>
</tr>
<tr>
<td>1. OURBN</td>
<td>Sizes each storage bin relative to capacity and pertinent dimensions.</td>
</tr>
<tr>
<td>2. YOURBN</td>
<td>Determines the capacity and dimensions of facilities which have</td>
</tr>
<tr>
<td></td>
<td>irregularly spaced bins of different sizes.</td>
</tr>
<tr>
<td>3. LOCATE</td>
<td>Assigns a coordinate location for each bin and determine the lengths</td>
</tr>
<tr>
<td></td>
<td>of unloading augers.</td>
</tr>
<tr>
<td>4. AERATE</td>
<td>Determines the aeration requirements for each bin.</td>
</tr>
<tr>
<td>5. LAYERD</td>
<td>Establishes the equipment requirements for layer drying.</td>
</tr>
<tr>
<td>6. BATCHD</td>
<td>Establishes the equipment requirements for batch-in-bin drying.</td>
</tr>
<tr>
<td>7. PORTD</td>
<td>Establishes the equipment requirements for portable drying.</td>
</tr>
<tr>
<td>8. WET</td>
<td>Sizes and locates the wet holding bin.</td>
</tr>
<tr>
<td>9. LAYER</td>
<td>Determines the bucket elevator discharge height for layer drying.</td>
</tr>
<tr>
<td>10. BATCH</td>
<td>Determines the bucket elevator discharge height for batch-in-bin drying.</td>
</tr>
<tr>
<td>11. PORTDR</td>
<td>Determines the bucket elevator discharge height for portable dryers.</td>
</tr>
<tr>
<td>12. BUCKET</td>
<td>Specifies the bucket elevator design requirements.</td>
</tr>
<tr>
<td>13. DOWNSP</td>
<td>Calculates the downspouting requirements.</td>
</tr>
<tr>
<td>14. PIT</td>
<td>Specifies the pit design parameters.</td>
</tr>
<tr>
<td>15. PAUGER</td>
<td>Sizes 8-in. U-trough augers.</td>
</tr>
<tr>
<td>16. UAUGER</td>
<td>Sizes 6-in. tube augers.</td>
</tr>
<tr>
<td>17. ROFFA</td>
<td>Designs overhead (roof) augers.</td>
</tr>
<tr>
<td>18. ELECMO</td>
<td>Establishes commercially available electric motors from calculated</td>
</tr>
<tr>
<td></td>
<td>power requirements.</td>
</tr>
<tr>
<td>19. ECON</td>
<td>Determines a bill of materials, estimates energy consumption,</td>
</tr>
<tr>
<td></td>
<td>establishes purchase and annual costs.</td>
</tr>
<tr>
<td>20. PSYCH (Payne et al. 1972)</td>
<td>Psychrometric chart routine used in routines involving drying</td>
</tr>
<tr>
<td></td>
<td>requirements.</td>
</tr>
<tr>
<td><strong>Functions</strong></td>
<td></td>
</tr>
<tr>
<td>1. TABEX (Llewellyn)</td>
<td>Used for linear interpolation.</td>
</tr>
<tr>
<td>2. TABEXE (Llewellyn)</td>
<td>Used for linear interpolation.</td>
</tr>
<tr>
<td>3. PS</td>
<td>Used with PSYCH.</td>
</tr>
<tr>
<td>4. HFG</td>
<td>Used with PSYCH.</td>
</tr>
</tbody>
</table>
There are 20 subroutines and 4 functions which do the design computations. Table 1 has a listing of these routines and the general purpose of each. The main body of the program reads the specifications of the designer and refers required calculations to the appropriate subroutine or function. These calculations are then returned to the main body where they are formulated into output data.

**BASIC LAYOUT CONCEPT**

The basic concept used by BNDZN in the location of storage and handling equipment involves the utilization of an X-Y-Z coordinate system (Fig. 1). The center of this coordinate system serves as the reference point for locating bin centers and the charge and discharge points for grain handling equipment. This reference point may be located anywhere on the grid system, but the most convenient location is usually in the middle of the center building. By knowing the X-Y-Z coordinate for all charge and discharge points, one can determine the lengths of augers and downspouting in addition to the discharge height of the bucket elevator. The coordinates also allow easy location of bins and handling equipment when drawing sketches and plans for construction.

The space reserved for the location of the grain facility is divided into six areas plus the section for the center building (Fig. 2). Although there are no fixed dimensions for the areas, their relative locations remain constant. For example, the size and type of facility will regulate the space requirements of Area 1, but BNDZN assumes that Area 1 will always be located in the first quadrant of the coordinate system. The designer specifies the number of bins to be constructed and the area locations for each. Only one storage bin may be assigned to an area, thereby limiting the total number of bins in a single design to six (Fig. 3).

**OUTPUT**

To illustrate the types of information given by BNDZN, the following discussion will review each of the major output sections to include a brief critique of major input and output design parameters.

**Clientele and Designer (Fig. 4)**

Preliminary information consists of identifying the individual for whom the facility is designed and the design engineer. This allows quick identification of a program and insures the client that he is getting personalized attention.

**Bin Description (Fig. 5)**

The initial design information presented by BNDZN states the capacity of the facility based on the parameters specified by the designer. Should the facility have insufficient capacity, owing to other design constraints, a message to that effect will be printed. The stated capacity is based on filling to the bin eave height with no allowance made for compaction.

The “BIN AREA LOCATION” refers to the six areas in which bins may be constructed. The “LOCATION INDEX” specifies in which of the six areas a bin will actually be placed. The “X” and “Y” locations of the bin centers are in reference to the center of the X-Y-Z coordinate system.

The “PERFORATED FLOOR HEIGHT” and the “FOUNDATION RING HEIGHT” are specified by the designer. A height of zero in the data column indicates that the bin will not have that item.

The “BIN DIAMETER,” “BIN EAVE HEIGHT,” “BIN OVERALL HEIGHT,” “BIN CAPACITY,” “ELEVATION OF BIN FOUNDATION,” and “BIN ROOF HEIGHT,” are determined by BNDZN using given data inputs. The “RESERVED LOCATION” refers to an area designated as being reserved for purposes other than the location of a grain bin. An example would be a building located in Areas 1 and 4 such that construction would be restricted to the remaining four areas. The designer has the option of specifying a sweep auger for a bin, from which a “SWEEP AUGER HORSEPOWER” will be determined, and he may also choose to install a grain spreader.

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**FIG. 1** Coordinate system used in BNDZN.

**FIG. 2** Area locations used in BNDZN.

**FIG. 3** Schematic view of BNDZN.

**FIG. 4**
THE TOTAL CAPACITY FOR THIS FACILITY IS 43,876 BUSHELS.

THE SLOPE OF THE BIN ROOF WAS 30.0 DEGREES.

FOR THE DESIGN OF THE LAYER DRYING SYSTEM SHOWN BELOW, IT WAS ASSUMED THAT THE MOISTURE CONTENT OF THE INCORPORATING GRAIN WAS 28.0 PERCENT AND THAT THIS GRAIN WOULD BE DRIED TO 13.0 BEFORE ANY ADDITIONAL GRAIN WOULD BE ADDED TO THE BIN. THE AVERAGE OUTSIDE TEMPERATURE AND RELATIVE HUMIDITY WOULD BE 60.0 DEGREES AND 65.0 PERCENT RESPECTIVELY WITH THE TEMPERATURE OF THE DRYING AIR BEING 80.0 DEGREES. THE EFFICIENCY OF THE LAYER DRYING METHOD IS ASSUMED TO BE 75.0 PERCENT.

The “TOTAL CFM,” “DEPTH OF GRAIN,” “STATIC PRESSURE,” and “APPROXIMATE HORSEPOWER” are determined. All fan horsepowers calculated in BNDZN are based on the relationship:

Fan Horsepower =

\[ \text{cfm} \times \text{static pressure in inches of water} \]

6356 x fan efficiency

**Fig. 6 Aeration requirements.**

Following the tabular data for bin descriptions are the assumptions for layout of the facility as given by the designer. This includes data relative to bin sizing, and the location of each bin relative to the reference point of the coordinate system. In addition, the relative location of the center building is stated.

**Aeration Requirements (Fig. 6)**

The design information required for each bin includes the “CFM PER BUSHEL” and “SHEDD’S DATA MULTIPLIER” (used to determine static pressure). From this data and design values calculated previously,

**Fig. 7 Drying technique.**
HOUR, AND THAT 2200.0 BUSHELS OF GRAIN ARE TO BE REMOVED REQUIRE AN UNLOADING AUGER.

4.0 WILL BE USED TO STORE EXCESS WET GRAIN. THE NUMBER OF A COOLING EFFICIENCY OF 90.0 PERCENT WAS ASSUMED. FROM THE BIN, THE UNLOADING TIME WILL BE 2.2 HOURS. ASSUMING THAT 1000.0 BUSHELS CAN BE UNLOADED PER

SPECIFICATIONS OF 2.9 HP AND 267. RPM BASED ON A PIT AUGER LENGTH OF

458.0, 916.1, 1374.1, AND 1832.2 RESPECTIVELY.

14.0 FEET AND AN UNLOADING RATE OF 2500. BU/HR.

THE BINARY REQUIREMENTS ARE AS FOLLOWS:

THE AMOUNT OF BUSHELS WILL BE 2200. BUSHELS MAY BE DRIED IN APPROXIMATELY 16.0 HOURS WITH A COOLING TIME OF 2.1 HOURS. A FAN HORSEPOWER OF 34.52 AND AIR OUTPUT(CFM) OF 23898. AND A HEATER BTU/HOUR RATING OF 2103028.

THE CAPACITY OF THE PORTABLE DRYER WILL BE 200. BUSHELS PER HOUR OR 2400. BUSHELS PER DAY BASED ON AN AVERAGE WORKING DAY OF 12.0 HOURS. THIS UNIT WILL REQUIRE 4500431. BTU PER HOUR OF OPERATION.

A WET HOLDING BIN WITH A CAPACITY OF 412. BUSHELS AND AN OVERALL HEIGHT OF 42.7 FEET WILL BE USED IN CONJUNCTION WITH THE PORTABLE DRYER. A CLEARANCE OF 17.0 FEET WILL BE ALLOWED BETWEEN THE GROUND AND THE DISCHARGE SPOUT OF THE WET HOLDING BIN. THE BIN DIAMETER WILL BE 9.0 FEET AND THE HEIGHT WILL CONTAIN 5.0 TIERs, EACH BEING 2.67 FEET HIGH. FOR OTHER DESIGN DATA, SEE TABLE BELOW.

FIG. 10 Pit requirements.

A CONTINUOUS DRYER WILL BE USED WITH A SURGE BIN THAT CONTAINS 100.0 BU.

FIG. 11 Types of pits designed by BNDZN.

FIG. 9 Drying technique.

FIG. 8 Drying technique.

WHERE CFM = TOTAL FAN OUTPUT IN CUBIC FEET PER MINUTE (LOEWER ET AL. 1973).

DRIETING TECHNIQUE (FIGS. 7, 8, AND 9)


PIT REQUIREMENTS (FIG. 10)

THE DESIGNER SPECIFIES THE LENGTH, WIDTH, AND CAPACITY OF THE PIT AND WHETHER HE WISHES TO USE AUGER OR GRAVITY FLOW UNLOADING. THE STRUCTURES OF BOTH TYPES OF PITS MAY BE DIVIDED INTO RECTANGULAR AND TRIANGULAR SECTIONS.

THE "X" AND "Y" COORDINATE CHARGE POINTS FROM BINS 2, 3, 5, OR 6 ARE 10.0 AND 0.0.

FIG. 10 Pit requirements.

FIG. 11 Types of pits designed by BNDZN.
Bucket Elevator Requirements (Fig. 12)

Input data consists of capacity and many physical parameters of the bucket elevator. Output data specifies the discharge height of the elevator leg above the ground and data relative to horsepower, bucket spacing, belt speed, capacity, and overall height.

Downspouting Requirements (Fig. 13)

From the X-Y-Z coordinates of the top of the bin and the discharge point of the bucket elevator, the required downspouting length to each bin is determined. The designer has the option of downspouting directly to bins located in Areas 5 and 6, or to augers across from bins or supporting structures in Areas 2 or 3. If he decides on the latter, he must select between a 6 in. tube and 8 in. U-trough for the diameter of the first stage auger to allow simultaneous unloading of these bins. From information previously calculated, each unloading auger length, horsepower, and RPM is determined.

Economic Considerations (Figs. 16-21)

Each item required for the functioning of the grain facility is placed in one of several categories: BIN, PIT, BUCKET ELEVATOR, DRYING TECHNIQUE, MISCELLANEOUS

**Fig. 12** Bucket elevator requirements.

**Fig. 13** Downspouting requirements.

**Fig. 14** Unloading auger requirements.

**Fig. 15** Roof [overhead] augers.
or CONSTRUCTION. The designer assigns each item in each category an expected life to be used in calculating straight line depreciation with no salvage value. In addition, annual cost coefficients for repair, interest, taxes, and insurance are required. The estimated price for purchasing each item in each category is determined from cost arrays or equations. Each item's cost was derived from the list price of representative manufacturers with several different manufacturers being used in the overall design. The designer may choose to utilize price multipliers in altering costs. This allows him flexibility in pricing comparable equipment from different manufacturers.

From within the program, the number of base units are determined. For BNDZN, a base unit is defined as a unit for which prices may be estimated or compared. By dividing

1976—TRANSACTIONS OF THE ASAE

1135
FIG. 19 Drying technique economic information.

the expected purchase price by the number of base units, a per unit cost comparison is obtained. To illustrate this concept, BNDZN may determine

FIG. 20 Miscellaneous economic information.

that the price of a particular bin structure is $3000 with the number of base units for this particular item being 10,000 bu. The price per unit base is then 30¢/bu, a typical approach used in comparing bin structures. Similarly, the base units commonly used in comparing augers and motors are linear feet and horsepower, respectively.

FIG. 21 Construction economic information.

FIG. 22 Electricity.
After the estimated purchase price for each item in each category is determined, the total purchase price for the category is calculated. This figure allows comparison of categories as well as that of individual items.

From input data and the estimated purchase price, values for depreciation, interest, repair, taxes, and insurance are summed for each item and then for the entire category, thus giving the total annual cost for individual items and groups of items.

**Energy Requirements (Figs. 22-23)**

By storing data concerning horsepower requirements and by estimating the hours of use, the electrical expense is determined for each of the categories mentioned previously. The cost of electricity is an input, thereby allowing modification of the program to local conditions.

The amount of fuel is estimated by heater capacities, hours of operation, and dryer efficiencies. The designer specifies the cost per unit of fuel. Output includes the quantity and cost of fuel for both LP Gas and Natural Gas systems.

**Totals for Economic Considerations (Fig. 24)**

This section of BNDZN summarizes the economic information collected by the program. The purchase price for the entire facility is given. In addition, the yearly fixed and operating cost for both LP Gas and Natural Gas systems are specified. This section of BNDZN provides a quick source of information for the comparison of various storage and drying facilities.

**Verification**

BNDZN is constantly being updated with regard to cost and design information. The model has been verified to the extent that it calculates distances and volumes correctly, and that it reflects the list prices as placed into the program. Actual grain facilities and those generated by BNDZN have been compared favorably with regard to cost and design. However, because BNDZN is a design simulation, it can only reflect the design strategy and cost information given to it, and can make no judgement as to the desirability of a particular design.

**SUMMARY**

BNDZN provides a detailed engineering and economic analysis of an individualized grain facility design. Price inputs and the choice of values for design parameters may be entered to reflect a particular manufacturer or engineer, thus allowing the designer, be he layman or professional, to concentrate on the facility specifications rather than numerical computations. Various layouts and drying techniques may be readily compared with multiple runs of the program. In conclusion, BNDZN represents the application of the "systems approach" to facility design in that the total spectrum of engineering and economic analysis is considered.

For additional information concerning the availability of the program, contact the authors.

**References**