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An Annual Planning Model for Food Processing: An Example of the Tomato Industry

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AN ANNUAL PLANNING MODEL FOR FOOD PROCESSING: AN EXAMPLE OF THE TOMATO INDUSTRY

Samuel H. Logan [1]

Food processors often face operations which differ from the continuous, year-around operations of most manufacturing firms. Food processing is generally highly seasonal because of the biological growth patterns of the commodities which are the major inputs in the processing function. Also, the raw product may be perishable in its fresh state, input quality may be variable, and the flow of raw product to the processing plant during the harvest season is uncertain, depending largely on the climatical whimsy of nature. Although multiple products are characteristic of many industries, food processors seldom use the planned batch-type of production found in other manufacturing industries. Batch production in manufacturing operations typically means exclusive production of one of a number of products for a time period, then a switch to the production of a different product. But, many food processing firms must be able to channel raw product into a variety of final goods being produced simultaneously on independent processing lines, a characteristic demanded by the perishability and quality variability of the raw product.

Production management literature offers a variety of planning tools dealing with inventories and procurement of inputs (for example, see Hillier and Lieberman 1980, or Dilworth 1983). However, the perishability (i.e., the nonstorable nature) of raw food products as well as the uncertainty of the available produce supply prevents the application of many of these models by food processors to their major input--raw farm products. Such models, however, can be useful in planning inventory levels for secondary, nonperishable inputs such as cans, cartons, and recipe ingredients given an expected flow of raw product to the processing plant.

The short processing season and the raw product characteristics outlined above emphasize the need for annual, aggregate planning and scheduling by the processor prior to the harvest season in order to make efficient use of plant facilities and resources. Most food processors make such plans several months in advance of the actual processing season, realizing that weather conditions will likely alter the annual plan when the processing actually begins.

This paper presents a computer model for developing such an annual, aggregate plan. Specifically, it is designed for a tomato processing firm which converts whole tomatoes into a variety of products packaged in different sizes of containers. The goal of the systems model is to find a least-cost plan of operation over the processing season, given a projected arrival pattern of raw product to the plant. For firms which may stipulate delivery dates (or planting dates) to their producers (growers), the model will also determine expected acreage and planting dates needed to provide the scheduled arrivals of tomatoes at the plant.

Tomato processing follows the operational traits outlined in general terms above. Different varieties and quality of tomatoes arrive daily during the harvest season. Quantities of arrivals of raw product are not uniform over the season, but begin slowly in early summer, reach a peak which is maintained for several weeks, then taper off in the early fall weeks. These tomatoes can be converted into various products: whole (peeled) tomatoes, sauce, paste, puree, tomato juice, and catsup. These products, in turn, can be packed in various sizes of cans and containers.

While the average interval between planting and harvesting of tomatoes generally is about 150 days, the actual length of this period depends on temperature and other climatic factors, a situation which may produce unexpected shortages and gluts of raw product within the same processing season.

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The initial planning for the upcoming processing season is done during the winter months when the year's aggregate production goal is determined and that quantity is allocated among the various final products which can be produced at the plant. These initial decisions are based on maximizing some objective function such as profits and/or on meeting prior commitments (e.g., contracts) to producers or customers. Once the quantity targets have been established, it is the task of the production manager to plan the short term (weekly) operations of the plant for the processing season.

The plant operations consist of several more or less independent stages.[2] As used in the analytical model later, these stages are defined as:

I. Receiving and general preparation. The incoming tomatoes are unloaded from trucks, washed, and routed to either whole tomato processing or processed products processing.

II. Preparation-whole tomatoes. Tomatoes allocated to whole tomato processing are washed, and checked for foreign matter and/or mold. Tomatoes not meeting these initial checks are disposed of; the other tomatoes are further sorted for color, texture, and grade. Tomatoes meeting the color, texture, grade requirements are peeled and continue to the whole tomato processing operations; the others are diverted to processed products processing.

III. Preparation-processed products. Those tomatoes initially allocated to processed products from Stage I are washed and sorted for foreign matter and/or mold, ground (chopped) and sent as hot broken tomatoes to the appropriate evaporators.

IV. Filling and processing-processed products. Material from Stage III is blended into the particular final product desired and sent to the appropriate filling and can sterilizing line where the cans are sealed.

V. Filling and processing-whole tomatoes. The raw material from Stage II is sent to a particular whole tomato canning line where the cans are filled, syrup is added, and the cans are sealed.

VI. General processing. Canned items from Stages IV and V are cooked and the seams are inspected.

VII. General service. This stage provides general, common service to the above operations and includes mechanical repair, electrical operations, personnel administration services, and quality control.

VIII. Brites stacking. The cans from the various canning lines (with the exception of those from Stage IX) are cooled, stacked on pallets, and covered for transportation to the warehouse.

IX. Cooling floor. Cans from certain whole tomato canning lines are stacked while hot and are air cooled prior to storage.

X. Pack receiving. Items from Stages VIII and IX are received and stored at the warehouse.

Most processing plants are similar in organization to the above format; however, minor differences will be found among specific plants. Furthermore, the particular aspects of the model developed in this paper are representative of actual plant operations and can easily be modified to fit particular situations in other applications.

These functions emphasize the need for harmonious combinations of the capacities and operations of the different stages to assure a smooth flow of product through the plant while avoiding idle time (excess capacities).

The major canning operations (Stages IV and V) are performed on a series of can filling lines, each of which has some limiting output capacity for a given final product. While some lines can be utilized to process more than one final product (e.g., sauce or paste), the line can process only one alternative product at a time and will generally be used for one product for an extended length of time (e.g., a week) to avoid the costs involved with a product changeover. Furthermore, each line is oriented to a fixed can size which is determined by the technical nature of the

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2. For a detailed discussion of tomato processing operations see Uyeshiro (1972).

equipment on that line. Thus, the initial management decision about the quantity of individual final products to be produced determines the priorities with which the raw product is sent to the specific processing lines. Although the raw product flow may be common to several canning lines, the lines operate with little interaction with each other because of the equipment constraints.

While the firm's initial production goals of the various final products rest on optimizing some objective function (e.g., profit maximization), once the flow of raw product begins, the production manager is generally concerned with minimizing the variable cost of producing a given weekly level of output.[3] In this context, the basic decisions each week are then at what rate per time period (hour) to produce and how many time periods (hours or shifts) per week to operate.

The rate of production refers either to the amount of final product (e.g., cases of canned tomatoes) processed per period of time or the equivalent quantity of raw material processed in the same period of time.[4] The rate of output per hour on a particular processing line generally can be varied to some degree; however, the capacity of that line eventually reaches some technically imposed limit. Furthermore, the labor required to operate the line at reduced output levels does not decrease proportionately, but often remains near the amount needed for capacity output. Thus, the lowest labor cost per unit of output for a given canning line is often achieved near (or at) the peak capacity production. Because of this factor, plants tend to operate canning lines at or near capacity and vary the plant's aggregate rate of output via duplicate or multiple lines rather than altering production on a given line.

The other decision variable in planning for a particular aggregate weekly output is the number of time periods, or number of shifts, operated. Several combinations of rate and time of production can yield a given output, but costs will vary with the different combinations (see French et al., 1956). Labor agreements generally stipulate some minimum number of hours to be worked, either daily or weekly, but the manager can schedule overtime work or add additional shifts of operation. Overtime hours significantly increase wage costs (at 1.5 times the regular pay for overtime), and additional shifts may require a premium payment (e.g., $.10 per hour extra pay) for the evening and night shifts.

Other factors, however, complicate the decisions on rate and time of production. For example, if the plant works less than three shifts per day, the processing equipment must be cleaned at the end of the final shift, boilers must be turned off between the current day's last shift and the next day's first shift, then started again. Operating three shifts per day for the entire week on fewer lines (lower rate of output) may eliminate most of these cleanup and heating costs, even though the labor costs may increase.

The rate and time dimensions of production operations have been discussed for food processors by French et al. (1956). In their theoretical model for deriving the optimal rate and time of production, the time dimension was generally viewed as linear for a given rate of production. That is, output and cost for several time periods was simply a linear multiple of a single period level, with possible adjustment for added overtime costs in some periods. This specification is appropriate for a single line operation; however, in the case of tomatoes, it is possible that not all the lines used in the first shift will be used in the second or third shifts. If a firm allocates a certain proportion of its output to whole, peeled tomatoes and the remainder to processed products, it may be able to process the former quantity in one shift per day, but need to work two or more shifts on the processed lines, depending on the design and capacities of the various canning lines. Thus, the total plant processing cost function represents many combinations of rates and times of production, and could be viewed as

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3. Only variable costs of processing are considered in this study inasmuch as the plant facility itself is fixed. Thus only variable costs are relevant to the operating decisions.

4. Given the commonality of the basic raw product, tomatoes, in this study, it is more convenient to consider rate of output in terms of raw product equivalent.

$$TC = \sum_i C_i S_i$$

where TC = total variable processing costs

C_i = variable cost per shift of operating line i

S_i = number of shifts worked by line i.

The goal of the planning process is to consider the cost trade-offs between rates of output and the time periods worked each week in such a manner as to find the lowest variable cost to process a given level of raw product.

Objective

In order to plan procurement of labor and other inputs, given the planned arrivals of raw tomatoes, management first must determine through its advanced planning function outlined above the expected rate of output and number of hours (or shifts) to be worked for each week of the processing season. This plan, in turn, is used to derive the number (and costs) of employees as well as the quantities (and costs) of other inputs required to achieve the planned production levels.

The goal of this paper, therefore, is to present a computerized annual, aggregate planning systems model which can generate for a tomato processor such a seasonal plan or schedule in terms of rates and hours of output that would minimize the cost of producing a set level of output. Given the discrete nature of expansion and contraction of output caused by the use of multiple canning lines as well as the relative constancy of labor over wide ranges of output for a given line, the model must search among the feasible alternative combinations of rates and time of output to find that combination which yields the lowest cost for processing the week's expected arrivals of raw tomatoes.[5] Furthermore, the model should calculate the expected required acreage and time of planting which will yield the expected weekly quantities of raw product.

The model presented here is based on operating specifications for an existing California tomato processing plant with a given number of processing lines and a fixed combination of possible final products. Many of the input requirements and their associated costs were provided by the processing company; however, other data were obtained from previous studies, other industry sources, and published historical data. The quantity of tomatoes to be processed over the entire season is predetermined as are the desired proportions of total output to be assigned to the various final products.

Methodology and Model

An Overview

As indicated above, the planning model is designed to produce weekly operating schedules and costs; however, these derivations are based on several prior management decisions and a set of input data. These management decisions include specification of (a) the annual quantity of tomatoes to be processed, (b) the allocation of these quantities to the various final products (i.e., whole peeled tomatoes or processed products), (c) the priority with which the various products are to be produced (this priority stipulates the order in which the various product canning lines will be utilized), (d) the beginning and ending weeks of the plant's operating season, and (e) the

5. Several methods of aggregate planning have been reported in other studies including the linear decision rule developed by Holt, et al. (1955), the search decision rule reported by Taubert (1968), and linear programming as discussed by Bowman (1956). The method employed in this paper would more nearly reflect Taubert's search decision rule process. Because the labor costs of adding a new line to the plant's operations are more or less fixed (indivisible) over a large range of output and because of the importance of labor costs of associated operations which are not related directly to any one canning line, the linear programming approach was not utilized in this study.

quantities of raw product arriving each week. This latter item (e) may be a management decision if delivery dates are specified for the plant's growers, or, as in the case of this model, the proportions of the annual quantity arriving each week can be based on past historical data.

The basic initial data include technical coefficients for (a) the efficiency level (percent of rated capacity) with which the plant operates, (b) damage allowance levels for inputs such as cans and cartons, (c) conversion of raw product into the various final products, (d) physical input requirements for labor, utilities, cans, cartons and other inputs, (e) yields of tomatoes obtained by growers, and (f) heat unit (temperature) requirements for tomato plant growth. In addition to the technical coefficients, additional data are needed relating to the costs of the inputs and historical weather (temperature) data.

The model then determines the quantities to be processed each week of the season, and sets the number of days to be worked each week. Frequently the quantities of whole tomatoes and processed products to be processed in a given week can be accommodated by any one of several combinations of canning lines being operated and numbers of shifts worked. The planning model finds each of these feasible alternative combinations and determines the labor and clean-up (evaporator clean-up and boiler start-up) costs associated with each combination. Most of the other costs (e.g., cans, cartons, etc.) remain fixed regardless of the combination selected, so only the labor and clean-up costs for each feasible alternative combination are examined; the alternative with the lowest such costs is then selected as that week's planned schedule. The costs of all other inputs are then added to determine the week's total operating costs.

In addition, given the yield data, the total acreage required to supply the plant with the week's planned deliveries is calculated. Furthermore, using historical temperature data and the concept of heat-units (degree-days) to estimate time between planting and harvest, the model will specify planting dates for different geographical regions supplying the plant.

The weekly schedule is printed out as well as a seasonal summary table of costs. The procedure just described is also shown in Figure 1.

An additional benefit (to the scheduling per se) of such a computerized method of planning is the ability to adjust the plan to different sets of assumptions related to the arrival rates of raw product, desired proportions of final product forms, or costs of the individual inputs.

Processing Plant Definition

The processing plant in this model possesses 12 independent canning lines, seven of which produce only whole tomatoes (in some form) in various sizes of cans and five of which produce processed products either as sauce and puree or as paste. Of the latter five lines, two lines can produce either sauce and puree or paste; the other three lines produce only paste.

The individual line data regarding product type, can size, and capacity in cases of final product per hour are given in Table 1 along with the conversion coefficients to change the capacity figures to pounds of raw equivalent. The rated hourly capacity of each canning line is determined by the technical (mechanical) limitations of the equipment on that line.

The lines are numbered to indicate the priority with which they are to be added to the production sequence. This priority reflects the order in which the management wishes to produce the given products. Thus, for whole tomatoes, the initial product would begin with line 1 producing 303 size cans and expand through line 7 with 2-1/2 can size.

In this model, the lines 8 and 12 will be used to produce sauce and puree until the season's goals for those products are met and then will be changed to produce paste for the remainder of the season.

In terms of raw product equivalent, the plant has a rated hourly capacity of about 47 tons of whole, peeled tomatoes, 122 tons of paste, and 42 tons of sauce and puree. If the plant produces only whole tomatoes and paste, total rated capacity is 169 tons per hour; if it processes whole tomatoes, paste, and sauce and puree, the total rated capacity is 159 tons per hour.

Figure 1

Input Basic Data

(Annual pack, proportion of weekly arrivals, proportions for various products, technical production relationships, cost relationships, temperature data, etc.)

Determine Weekly Arrivals

Allocate Weekly Arrivals to Whole
Tomatoes, Processed Products

Find Number of Working Days for the Week

Find Average Daily Output of Whole
Tomatoes and Processed Products

Find Production Combinations of Shifts and
Lines Needed to Can Week's Pack

Calculate Week's Labor Requirements, Labor Costs, and
Cleanup Costs for Each Feasible Production Combination

Select Lowest Cost Option as Week's Production Plan

Calculate Cost of Other Inputs

Calculate Number of Cases Produced on Each
Canning Line and Number of Cans Needed

Find Total Cost of Operations for Week T

Find Number of Acres Needed to Supply Week's Pack

Calculate Planting Date for Week T

Repeat for Each Week of Season

Find Total Costs of Season's Operation

Table 1. Canning Lines, Products, Can Sizes, Output Capacities, and Conversion Coefficients

Line	Product	Can Size	Capacity (Cases/hour)	Lbs. Raw Product/Case[a] Conversion Coefficient
1	Whole	303	350	28.000
2	Whole	303	450	28.000
3	Whole (stewed)	303	550	28.000
4	Whole	10	200	45.388
5	Whole	10	400	45.388
6	Whole	2-1/2	140	49.420
7	Whole	2-1/2	450	49.420
8	Sauce & Puree	10	420	113.470
	Paste	10	350	213.972
9	Paste	48/6	430	95.040
10	Paste	24/12	500	114.972
11	Paste	48/6	430	95.040
12	Sauce & Puree	2-1/2	300	123.550
	Paste	2-1/2	125	232.980

[a]Derived from Brandt _et al_., 1978, p. 114.

The rated line capacities in Table 1 are those associated with 100 percent operation; however, allowances must be made for downtime resulting from breakdowns and other stoppages. In this case, the rated capacities were multiplied in the computer model by a factor of .7 to obtain the actual line capacities, based on estimates from a tomato processing firm.

Labor Requirements and Costs [6]

The hourly labor requirements for the 10 stages of operation given earlier were obtained from industry sources. The various tasks performed by individual workers in each stage are shown in Appendix Table 1 along with the base hourly wage rates.[7] The base hourly pay applies to the first shift of the day. A $.10 per hour premium is added for the second shift, and a $.15 per hour premium is added for the third shift. Overtime pay is 1.5 times the appropriate regular hourly scale.

Much of the direct labor required in tomato processing operations is more or less constant regardless of the rate of output. For example, most of the labor needed in the receiving and general preparation operations, the general processing operations, the general service functions, the brites stacking, cooling, and finished pack receiving operations remains essentially unchanged no matter how many canning lines are being operated or what final products are being produced. Thus, the number of workers shown for each task for a particular canning line represent full capacity operation for that line. In the plant specified for this application, a total of 235 employees are required for full capacity operation (all 12 lines functioning). However, of that number 185 are required even if only the first line is canning.

The computer model utilizes a concept of labor options in developing the appropriate labor requirements for a given output. Initially, a base labor force for operating the first line of whole tomato processing is specified as labor option A. This option shows the labor needed to initiate operations of the plant on only the one canning line, but includes the labor requirements for all of the associated operations in receiving, general processing, general service, etc. As additional whole tomato processing lines are engaged, the incremental labor requirements (different options) are added to the initial labor option. Because the processed products lines can be operated independently with any combination of whole products lines, a base labor option (Labor Option H) for the first processed product line (line 8) is established which adds the incremental labor needed to the labor determined for the whole tomato operations. The subsequent labor additions for the other processed products lines are added to that base processed products labor option. The processed products labor requirements are then added to whatever combination of whole products lines is used. Both the whole tomato canning lines and the processed products lines are added to the operations in the sequence indicated by their line number. This sequence reflects the firm's priority for producing the various final products, a priority which may be based on such factors as expected market conditions or contractual arrangements with the firm's customers. Of course, these sequences and their associated labor requirements can be changed to adapt to new market or contractual conditions.

It is possible (and even likely), however, that the processed product lines may work additional shifts without the whole products lines in operation. In this case, a separate base labor option for the first processed products line must be defined which includes those general functions that occur regardless of which canning lines are working. Labor Option M is defined as the base requirement for line 8; the other options add the incremental labor to the base requirement as other processed products lines are opened.

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6. In this planning model, only the direct (hourly) labor requirements for the processing lines are considered. For a discussion of other labor requirements see Uyeshiro (1972).

7. The wage rates were obtained for 1983 from industry sources and include an allowance of 35 percent for fringe benefits.

The requirements for the various labor options are given in Appendix Table 2.

Other Inputs

The other major inputs included in the aggregate planning model include utilities (electricity, gas, water), lye (required for whole tomato processing), cans, salt, and cartons.

Utility requirements were derived from previous work by Uyeshiro (1972), and from industry estimates. The requirements in physical units are given in Table 2.

Uyeshiro (1972, p. 123) presents total annual electrical, gas, and water costs by product type for a large tomato cannery. Each of these costs was converted to a cost per ton of raw product for each of the three basic products considered here. If the cost rate per physical unit used for a particular utility is the same for use in the various products processing, a ratio of the costs per ton provides an approximate ratio of the physical requirements for the different usages. Uyeshiro's electrical costs show equal levels of costs per ton of raw material processed for puree and paste, while the electrical cost per ton of raw material processed into whole tomatoes was 4.25 times that level. Thus, $4.25R(Xw) + R(Xp) = KWH$

where R = KWH per ton of raw material processed into processed products
Xw = tons of raw material used in whole tomatoes per time period
Xp = tons of raw material used in processed products per time period
KWH = total electrical usage per time period.

Based on an actual plant usage of 2,800,000 KWH for an annual production of 135,000 tons, R = 10.008 and 4.25R = 42.532 KWH per ton.

Similar procedures were used to estimate requirements for natural gas and water. The ratios of gas usages were whole tomatoes 1, puree 1.43, and paste 1.05. Applied to an annual usage of 2,596,150 therms, the requirements given in Table 2 are obtained.

The estimated water requirements ratios did not vary significantly by product type, so the water consumption from actual plant data of 127,748,398.8 gallons resulted in a per ton use of 946.284 gallons. This level compares quite favorably with the average of 50 gallons/per case of final product requirement estimated by Uyeshiro (1972, p. 54), (946.284 gallons per ton of raw material processed is about 52 gallons per case of final product processed, on the average).

Costs of utilities were estimated at \$.07 per KWH for electricity, \$.52 per therm for natural gas, and \$.0004 per gallon for water.

The amount of lye used for processing whole tomatoes was 2.5 gallons per ton of raw product, based on industry sources. The cost was \$1.16 per gallon.

The quantities of cans and cartons required are easily calculated from the number of cases of final product produced on each canning line. Five can sizes are used in this plant application with the following numbers of cans per case: No. 303, 24 cans per case; No. 2-1/2, 24 cans per case; No. 10, 6 cans per case; 6 ounces, 48 cans per case; 12 ounces, 24 cans per case. A .005 allowance for damaged (unusable) goods was added to the can and carton requirements.

Based on price quotations obtained from industry sources, the costs of the cans and the appropriate cartons were set at:

Can Size	Cost/Can	Cost/Carton (1983)
No. 303	\$.113	\$.178
No. 2-1/2	.167	.265
No. 10	.467	.225
6-ounce	.065	.143
12-ounce	.096	.138

Table 2. Utility Requirements for Tomato Processing[a]

Final Product	Electricity (KWH/ton raw product)	Natural Gas (therms/ton raw)	Water (gal./ton raw)
Whole Tomatoes	42.532	17.553	946.284
Sauce & Puree	10.008	25.101	946.284
Paste	10.008	18.431	946.284

[a]See text for explanation of the derivation of these figures.

The other major variable input was salt, a factor which may vary as recipes change. In this case, salt was utilized only for whole tomato products in the form of tablets per case of final output. The requirements and cost per tablet were:

Can Size	No. of Tablets	Cost/Tablet (1983)
No. 303	24	$.0030
No. 303 (stewed)	24	.0022
No. 10	12	.0099
No. 2-1/2	24	.0053

Evaporator Clean-up and Boiler Start-up Costs

For the plant in this problem, one evaporator is used for each processed product canning line. Each time one of these lines ceases production (e.g., the associated line works only one or two shifts per day), the evaporator must be cleaned and prepared for use the following day. With three shift operations, of course, this cost is avoided on a daily basis and may be incurred only once a week or even every other week, depending on the number of days worked. An estimated cost of $300 for chemical compounds per cleanup, obtained from industry sources, was used as the nonlabor cost of evaporator cleanup.

In addition to the evaporators, tomato processing requires large quantities of hot water. Two boilers were stipulated for the plant, one with a capacity of 120,000 pounds and one with 80,000 pounds capacity. Operations of less than three shifts per day generally entail shutting down the boilers and then reheating them for the next day. Boiler company personnel estimated that the cost of reheating the 120,000-pound capacity boiler at $2,000 per occurrence and the cost of reheating the 80,000-pound capacity boiler at $1,340 per occurrence. The larger boiler was assumed to handle the requirements from lines 8, 9, and 10, while the smaller boiler was assigned to the lines 11 and 12.

Thus, the combined cleanup and boiler start-up costs per occurrence for the processed products lines were estimated as follows:

Line	Boiler Start-up	Evaporator Clean-up	Total
8	$2,000	$300	$2,300
8, 9	$2,000	600	2,600
8, 9, 10	2,000	900	2,900
8, 9, 10, 11	3,340	1,200	4,540
8, 9, 10, 11, 12	3,340	1,500	4,840

Production Options

Given the production capacities in raw product equivalent (including the adjustment for down time), the model calculates the possible production options available to the production manager. These production options show the maximum amounts of raw product that can be processed per day for the various combinations (sequences) of lines being operated and shifts being worked. Three sets of calculations are needed: (1) production options for processing whole tomatoes on various lines for different number of shifts worked per day; (2) production levels for processing products over lines 8 through 12 for different numbers of shifts per day when sauce and puree are being processed on lines 8 and 12 and paste on lines 9 through 11; and (3) production levels over lines 8 through 12 when paste is also being produced on lines 8 and 12.

Given the priority sequence with which the lines are utilized, (see Table 1) the production options for whole tomatoes are derived by multiplying the hourly capacity of line 1 by 8 hours, then adding to that the hourly capacity of line 2 multiplied by 8 hours, and so on, through line 7. The process is repeated using 12 hours for 1.5 shift operations, 16 hours for 2 shifts, 20 hours for 2.5 shifts, and 24 hours for 3 shifts. This process implicitly assumes that expansion of output is accomplished by operating those lines being utilized the same number of shifts rather than using line 1 for, say, two shifts and line 2 for only one shift. Given the nature of the labor requirements for the associated operations which are independent of the lines operating, this specification is reasonable. Thus, there are 35 combinations of rates and times, or production options, for whole tomatoes. (Five shift possibilities times seven line possibilities per shift.)

This process is also used to determine two sets of production options for processed products. When producing sauce and puree on lines 8 and 12, production from line 8 becomes the initial base output to which are added sequentially the outputs from the other canning lines as they are used. The total number of production options for the five canning lines of processed products is 25. (Five shift possibilities times five line possibilities per shift).

The other set of processed products production options is calculated in the same manner as the second, only lines 8 and 12 are used to process paste.

The Initializing Management Decisions

The basic initializing decisions required to begin the seasonal operation computations include (1) the total quantity of raw product (in tons) to be processed over the season; (2) the beginning and ending dates of the processing season; (3) the proportions of total seasonal production to be allocated to whole tomatoes, sauce and puree, and paste; and (4) the proportions of total quantity processed each week of the season.

At this point the plan can be developed. The week's scheduled arrivals are first allocated to whole products and to processed products. Each allocation is then divided by the maximum, three-shift processing capacity of the plant for the appropriate product (whole or processed products) to determine the minimum number of days the plant has to operate. The larger of the two calculations becomes the number of days worked. Given the labor contracts and the flow of raw product to the plant during the week, the minimum number of days of operation is five, even if the quantity to be processed can be accommodated in less time. As the tomato harvest increases during the middle of the processing season, the flow of tomatoes to the plant during the week may force the plant to operate more than five days, even though the total quantity could be processed in only five days. (A five-day week would require storing raw product arriving on Saturday until Monday for processing, an interval which would result in spoilage of the product; hence, the use of a six-day week becomes necessary.)

If the arrival of raw product exceeds the amount that can be processed in seven days, the excess material is carried over to the following week.

Once the number of days of operation is determined, the average daily output of processed products is calculated and used to select the feasible production combinations of canning lines for each of the five shift possibilities. The feasible option from each shift alternative is defined as that production option whose quantity is closest to, but greater than, (or equal to) the average daily output requirement of processed products. Thus, a maximum of five production options--one from each of the shift possibilities--can be selected to produce the week's processed product requirement. Initially, these feasible options are selected from those combinations which include production of sauce and puree. This procedure is used until the plant has met the seasonal requirements of sauce and puree at which time the production options are selected from the third set described above which uses lines 8 and 12 to produce paste.

The same type of procedure is used to find the feasible production options for producing whole tomatoes.

Each feasible production option for producing whole tomatoes is then combined with each feasible option for producing processed products to yield all possible feasible combination of lines and shifts which can be used to accomplish the week's output. Without any constraint, there would be 25 possible combinations each week (one option for each of the five shift alternatives for both whole and processed products). However, the model is constrained to consider only alternatives in which the number of shifts worked in producing processed tomatoes is equal to or greater than the number of shifts producing whole tomatoes. This constraint results from the larger allocation of raw product to processed products and from labor contract stipulations.

Thus, the possible feasible combinations are reduced to 15 for a five-day or six-day week. These 15 combinations simply show the number of shifts to be worked by the whole tomato lines in conjunction with the processed products lines and are indicated by the X's in the following tableau:

Processed Product Lines Work:

Whole tomato lines work:	1 shift	1.5 shifts	2 shifts	2.5 shifts	3 shifts
1 shift	X	X	X	X	X
1.5 shifts		X	X	X	X
2 shifts			X	X	X
2.5 shifts				X	X
3 shifts					X

Naturally, there may not be 15 feasible production combinations if the weekly quantity to be processed exceeds the plant's capacity when it operates at one shift, for example. While the number of shifts worked might be the same for two separate weeks, the production options selected as feasible might vary because of differences in the total quantity to be processed between the two weeks.

The production options selected in these 15 combinations in turn define the labor requirements and, therefore, the labor costs. The weekly labor and cleanup costs for each feasible combination are referred to as cost alternatives in the program. The cost alternative (cost of the production option combinations) which is the lowest among the feasible alternatives is selected as that week's schedule.

Operation for seven days per week requires working three shifts per day, although less than the total the number of lines may be operated.

Given the tonnage of raw product and the ensuing allocation among the various lines (final products), the week's requirements and costs of utilities, cans, cartons, and other inputs can be computed.

Acreage and Planting Dates

Specification of the weekly flow of raw product provides the basis for estimating the acreage needed to assure that quantity. In this case an average yield of 26 tons per acre was used to estimate the needed acreage values each week.

Estimating the planting date to assure harvestable tomatoes at a given week in the processing season is more complex. This facet of the planning model applies the concept of heat-units or degree-days as related to the maturing of the tomato plant. The particular method applied in this case has been presented in detail in Logan and Boyland (1983).

The heat-unit model utilizes a sine function to approximate the behavior of temperatures during the day, based on the premise that temperature efficiently represents the relevant climatic conditions for tomatoes between time of planting and time of harvest. Heat units are simply that part of the temperatures during the day which is available for plant growth and are determined by integrating the sine function between each 24-hour period (from minimum temperature in day 1 to minimum temperature in day 2). The heat unit formulation also incorporates the nature of tomato plant growth reported in the plant science literature (for example, Went 1957, Went and Cosper 1945, and Owens and Moore 1974) by including as constraints: (1) a temperature below which plan growth stops (45° Fahrenheit); (2) a high temperature (80°) above which plant growth remains unchanged for an interval up to (3) a maximum high temperature (100°) above which plant growth is retarded.

Consider a sine function of the form in Figure 2:

Temperature $= (\gamma \sin X) + \mu$

where γ = the amplitude of the sine curve and in this case is simply

$$\frac{T-t}{2} \text{ or } T-\mu$$

$$\mu = \textit{mean of the sine curve or } \frac{T+t}{2}$$

$$X = \textit{time of day in radians } (2\pi = 1 \textit{ day}).$$

The values of γ and μ are shifters of the usual sine curve which has an amplitude of 1 and a mean of 0. At X = $\pi/2$, temperature will equal T, the day's maximum; at $-\pi/2$ and $3\pi/2$, temperature will equal t, the day's minimum level. Of course, the sine function is an imperfect approximator of the day's temperature pattern since it is symmetric whereas the temperature pattern generally is not.

Given this approximation, the heat units available each day (Y) are the area under the sine curve between the two minimum values, i.e., the integral of the above function over the interval between minima. Since time in the sine function is represented in radians (1 day = 2π radians), the result divided by 2π to obtain the equivalent value of Y for one day.

If we first stipulate a base temperature, g, below which tomatoes register little or no effective growth, we can insert that in the above function as in Figure 3. The area of available heat units now is that area under the sine curve but above the base line, g. Thus , the integral is now between points a and b with the axis shifted by μ - g. Or, the function is given by

$$Y = \frac{1}{2\pi} \int_a^b [\sin X + \alpha] dx$$

where $\alpha = \mu\text{-g}/\text{T-}\mu$. Dividing the quantity μ-g by T-μ simply converts the shifter to a relative value needed in the integration process. Alpha defines the two end points of the interval on the sine curve containing the available heat units; however, because it represents a value on the temperature axis rather than on the X or time axis, it must be converted into radians by finding its arcsine.

Thus, a $= -\arcsin \alpha$ and b $= \pi + \text{arcsine } \alpha$. When $\alpha \geqslant 1$, its arcsine is defined as $\pi/2$, resulting in integration of the sine function between its two minima. In this manner, only those temperatures which are above the base level are considered in determining the available heat units.

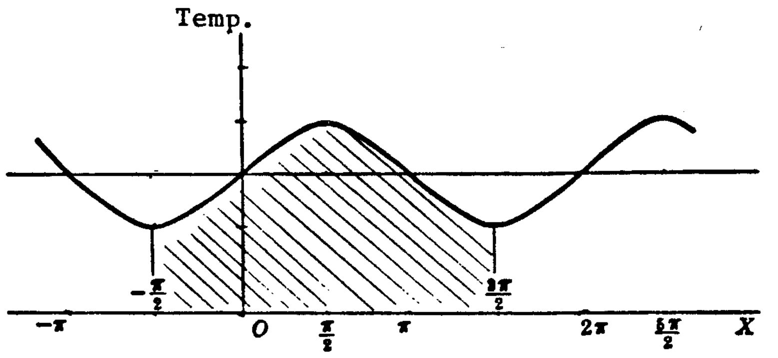

Figure 2. Daily heat units (shaded area) without temperature limits on growth

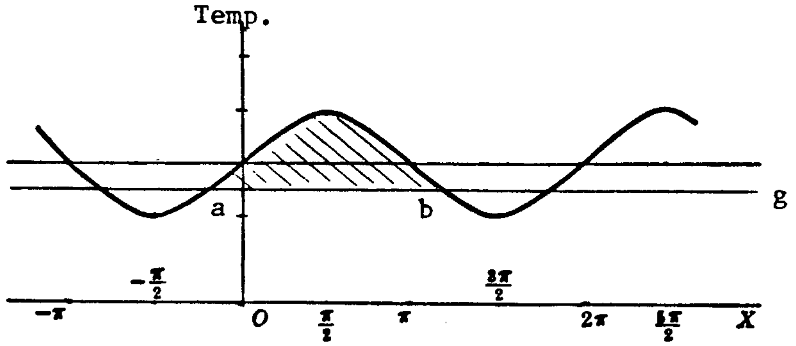

Figure 3. Daily heat units (shaded area) with lower temperature limit on growth

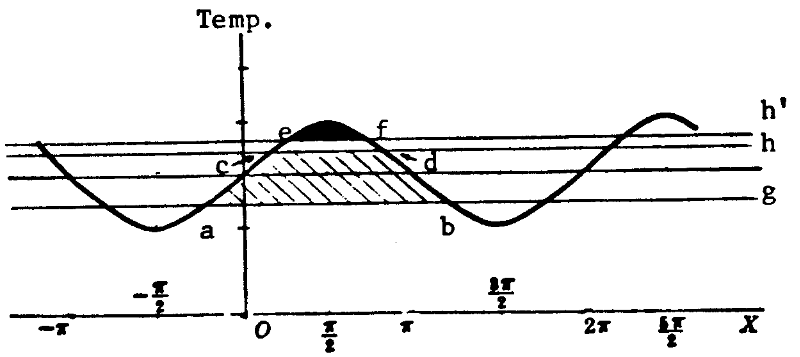

Figure 4. Daily heat units (shaded area) with both lower and higher temperature limits on growth

In addition, the growth function for tomatoes reflects a maximum level at some temperature (defined as h) and declines when temperatures exceed some extreme high (defined as h'). In this situation, we want to exclude temperatures between h and h' and include a negative effect for temperatures above h'. In other words, the area between points c and d and above line h in Figure 4 must be deleted from the previous calculations because temperatures above h do not contribute to plant growth. Furthermore, for temperatures above h' in the figure, an additional negative adjustment must be included. The alternative used here is to subtract the area above line h' from the heat-unit total after prior adjustment for g and h. In the same manner as was done previously, we define

$$\beta = \frac{h-\mu}{T-\mu}$$

and

$$\beta' = \frac{h'-\mu}{T-\mu}$$

which determine the points of intersection of the lines h and h' with the sine function. Points c, d, e, and f are found by obtaining the arcsine values of β and β'. Subtracting the integral of the sine function between points c and d and e and f, however, excludes the entire area under the curve from the sine function to the X axis, whereas we want to exclude only that portion above lines h and h'. Therefore, an adjustment is made resulting in the sine heat-unit function as [8]

$$Y = [\gamma\int_a^b [sine\ X + \alpha]dx - \gamma\int_c^d [sine\ X - \beta]dx - \gamma\int_e^f [sine\ X - \beta']dx]\frac{1}{2\pi}$$

which after integration leaves

$$Y = [\gamma[-cos\ b - (-cos\ a) + b\alpha - a\alpha] - \gamma[-cos\ d - (-cos\ c) - d\beta + c\beta]$$

$$-\gamma\,[-cos\ f - (-\cos\ e) - f\beta' + e\beta']]\,\frac{1}{2\pi}$$

Because of possible significant variation in the heat unit requirements over different geographical regions, the location of the tomatoes to be planted should be specified and the mean value of heat-units required at that location for maturity calculated (Logan and Boyland 1983). In this study the heat-unit model was applied to experimental and commercial tomato production data near Davis, California. The mean heat-unit value for 32 observations for 1965 through 1981 was 3,135 with a standard deviation of 259.

In the annual planning model, Wednesday arbitrarily was selected to represent the week during the processing season. A 10-year historical average of daily minimum and maximum temperatures was then used to determine when planting should occur to provide the necessary arrivals of harvested tomatoes during each week of processing. That is, the heat units each day are derived starting with Wednesday of week T and going backwards in time until the mean value of 3,135 heat units is reached. The day when the total equals or exceeds the 3,135 heat units defines the planting day for week T's supply.

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8. If the day's expected high temperature is less than h' or h, then that respective part of the following equation is omitted.

Frequently, tomatoes for processing originate from different geographic regions, depending on climate patterns as well as other factors. Harvesting generally begins in the southern part of the Central Valley with its warmer spring temperatures and then progresses northward furing the middle and late summer months. In scheduling potential planting dates, the model allows for different temperature data designated for particular regions and then computes the prospective planting date for each region using the heat-unit function.

To illustrate the heat-unit calculations, assume that Wednesday of the first week of processing is day 201. Based on the 10-year historical average for Davis for that day, the expected high temperature is 91.9 degrees and the expected low temperature is 54.5 degrees. Then,

$$\mu = \frac{91.9+54.5}{2} = 73.2$$

$$\gamma = \frac{91.9-54.5}{2} = 18.70$$

$$\alpha = \frac{73.2 - 45}{91.9 - 73.2} = 1.51 > 1, \textit{ so arcsin } \alpha = \pi/2$$

$$\beta = \frac{80 - 73.2}{91.9 - 73.2} = .36$$

$$\beta' = \frac{100 = 73.2}{91.9 - 73.2} = 1.43 > 1, \textit{ so restraint is not applicable}$$

$$a = -\pi/2$$

$$b = 3\pi/2$$

$$c = .37$$

$$d = 2.77$$

$$e = \textit{not applicable}$$

$$f = \textit{not applicable}$$

and

$$Y = [18.7 - \cos\ 3\pi/2 - (-\cos\ -\pi/2 + 1.51\ (3\pi/2 - -\pi/2)]$$
$$-18.7\ [-\cos\ 2.77 - (-\cos\ .37) - .36\ (2.77 + .37)]]\ 1/2\pi$$
$$= 25.28 \textit{ heat units.}$$

The same procedure would be used to calculate the available heat units for days 200, 199, etc., until the sum of the daily heat units reaches 3,135.

Summary of Model Development

Figure 1 and the following outline demonstrate how the model functions, given the above development.[9] The computer program, written in Fortran, is given in Appendix Table 4.

I. Input the following data:

A. Processing line numbers (LINE(17)), capacities in cases per hour (CAP(17)), can size (CAN(17)), and coefficients to convert a case of final product of a given can size to pounds of raw product equivalent (LAMBDA(14)).[10]

B. Number of employees in each wage class and the cost per hour for each wage class (LABOR.DAT.).

C. Labor options for a single shift giving the cumulative number of employees in each class as new processing lines are added sequentially to production (LON(17)). These options are derived from the basic number of employees for the first line (labor option A) of whole tomatoes; this number includes those general employees needed for such things as receiving and sorting. The employees needed for the remaining whole tomato lines are then added incrementally to this first option. Labor for the basic line for processed products (line 8) is labor option H. The other processed products lines' labor requirements are added incrementally to option H, which is then added to the appropriate whole tomato labor option to find the total number of employees for a given number of canning lines in operation. There are also labor options for operating the processed product lines when the whole tomato lines are inactive.

D. Daily index (1 - 365) and maximum (HITEMP) and minimum (LOTEMP) temperatures for each day.

E. Proportions of the season's raw product supply delivered each week (DISTRIB(13)).

F. Year's projected pack of raw product (X).

G. Proportions of annual raw product supply allocated to whole tomatoes (WHOLE), sauce and puree (SAUCE), and paste (PASTE).

H. Starting date for plant operations (DAYSTART).

I. Number of weeks in the processing season for the plant (IT).

J. Expected yield of raw product in tons per acre (YIELD).

K. Unit cost (price) of cans (CANCALC), cartons (CARTCALC), and raw product per ton (TONCOST, ADDTON).

L. Cleanup and shutdown cost for processed product lines (CLEAN).

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9. Definitions of the variables are given in Table 3.

10. For computational convenience, lines 8 through 12 are renumbered as lines 13 through 17 when the plant is producing paste only on processed products lines.

M. Other input requirements and their costs per unit for electricity, gas, water, lye, and salt are written directly into the program for the various final products. The weekly costs are then derived. These inputs, their requirements and unit costs, are given in Table 2.

N. Similarly, other parameters used in the calculations are written directly into the program for available productive time (.7), allowance for unusable cans and cartons (1.005), and the heat-unit constraints (g = 45, h = 80, and h' = 100).

O. The minimum days of plant operation per week are constrained to 5 for weeks 1, 2, 12, and 13 of the season and 6 for all others.

II. Calculations of costs:

A. Labor costs are calculated from the files (LABOR.DAT.) containing the cost of each labor class and the number of employees in each class on each line. The total hourly cost is determined for each labor option for each shift (including premium payment for second and third shifts) (LO(17)).

B. Find the raw product equivalent capacity of each line adjusted by expected downtime and converted to tons (Z(14)).

1. Do one set with lines 8 and 12 processing sauce and puree.
2. Do one set with all processed products lines processing paste.
3. Find hourly capacity for aggregate whole tomato product in raw product equivalent.
4. Find hourly capacity for aggregate processed products production with lines 8 and 12 producing sauce and puree.
5. Find hourly capacity for aggregate processed products production with all processed products lines producing paste.

C. Calculate production options (capacities) varying the hours (shifts) worked and the number of lines used (PO(17, 5)).

1. Define Table 1 as production options for whole tomato lines.
2. Define Table 2 as production options for processed products lines with lines 8 and 12 producing sauce and puree.
3. Define Table 3 as production options for processed products with all lines producing paste.
4. Shifts include 1, 1.5, 2, 2.5, and 3 shifts of eight hours each (SHIFTW and SHIFTP).

D. Define corresponding labor options in relation to the production options (LO(17)).

E. Define corresponding cleanup costs for production options.

F. Define lines worked for each production option.

G. Distribute the year's aggregate pack by the proportions of deliveries each week (ARRIVAL).

H. Find week's pack of whole tomatoes (XWT).

I. Find week's aggregate pack of processed products (XPT).

J. Find days to be worked in week T given allocation of arrivals of raw product (WDAYS, PDAYS).

1. Processing weeks 1, 2, 12, and 13 can have minimum of five days; all others have minimum of six days.

K. Find average daily pack of whole tomatoes in week T (XWDT).

L. Find average daily pack of processed products in week T (XPDT).

M. If days to be worked is equal to or greater than 7, go to step Q.

N. Select various production options to be evaluated for processed product lines. (Note step S for rule for use of Table 2 producing sauce and puree vs. Table 3 for producing paste only.)

1. For each shift find the production option closest (but not less than) the daily average output of processed products, thus determining the number of canning lines to be used on that shift (e.g., search Table 2 for number of lines capable of processing XPDT in one shift, the number of lines needed for 1.5 shifts, 2 shifts, etc.).

2. Find appropriate labor option and hourly cost for each of the five production options selected.

O. Select various production options to be evaluated for whole tomato production lines. For each shift find the production option closest to (but not less than) the given daily average output for whole tomatoes from Table 1, thus determining the number of lines needed to work 1 shift, 1.5 shifts, 2 shifts, 2.5 shifts, and 3 shifts.

1. Find the appropriate labor option for the five production options selected and add to the labor options found for processed products in step N. SHIFTP must be greater than or equal to SHIFTW in any combination. (Thus, there are 15 possible feasible production combinations.)

2. Find the labor cost, including overtime if required (LABOVT), of each feasible combination and add required cleanup cost to define feasible cost alternatives (COST(15)).

P. Select the lowest cost alternative from the possible 15 combinations. Some of these combinations won't be feasible, since the capacities of the smaller number of shifts may be less than the amount to be processed.

Q. Find the cost of production if the days to be worked equal 7. The plant will operate all 12 lines, 3 shifts per day.

1. Allocate any excess deliveries to the following week's arrivals.

R. Find output of each whole tomato and processed product line in raw product equivalent (XIJT(17)), and convert to cases of final product (QIJT(17)).

S. Determine if season's requirements for production of sauce and puree have been met; if so, use production option Table 3.

T. Find cost of other supplies and of raw product (GAS, ELEC, WATER, SALT, LYE, CANCOST, CARTCOST, TOMATOES).

U. Find week's total cost (TOTAL).

V. Repeat for each week of the season.

W. Find season's total costs (TOTAL).

Table 3. Definition of Variables

ACRES - acres of plantings needed to supply raw product requirements in week T.

ADDTON - premium price addition for late season tomatoes ($5 per ton for first week in October, $7.50 per ton, thereafter).

ARRIVAL - weekly arrivals of raw products (tons).

CANCALC - cost per can for various can sizes.

CANCOST - total weekly cost of cans.

CAN(17) - can size used on each line. [1]

CAP(17) - capacity of each line in cases of final product per hour.

CARTCALC - cost per carton of cartons used for various can sizes.

CARTCOST - weekly cost of cartons.

CLEAN - weekly cleanup costs (boiler start up, evaporator cleanup) associated with various production options.

COST(15) - labor and cleanup costs for each feasible combination of production options.

DAYSTART - day number for beginning of processing operations.

DISTRIB(13) - proportions of season's deliveries of raw product allocated to each week of the season.

DLABOR - daily labor cost.

ELEC - weekly cost of electricity.

GAS - weekly cost of natural gas.

HEAT - number of heat units per day.

HITEMP(305) - average maximum temperature by days where January 1 = day no. 1.

IDAY - day of week from which planting dates are calculated.

IT - week of processing season.

LABOVT - cost of overtime work in week T.

LAMBDA(14) - conversion coefficient for each processing line to change a case of final product into pounds of raw product.

LINE(17) - processing line numbers.

LON(17) - number of employees working on each line.

LOPT - labor option selected.

LOTEMPT(305) - average minimum temperature by day.

LO(17) - cost of all employees in each option working one hour.

LYE - cost of lye for processing whole tomatoes per week.

NEMPLOY(16,3) - number of employees for each cost option and shift.

PASTE - proportion of raw product to be processed as paste.

PDAYS - days required to can week's processed products.

POPT - production option selected.

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1. The numbers in parentheses used with several variables indicate the number of different values that are to be specified for that particular variable. In the case of CAN(17), for example, there are 17 can sizes to be specified; one for each canning line as defined in the program. Some can sizes may be the same for different canning lines.

Table 3 continued

PO(17, 5) - production options by line and shift.
QIJT(17) - production of final products in cases, by line in week T.
SALT - cost of salt tablets used in processing whole tomatoes in week T.
SAUCE - proportion of raw product to be processed as sauce and puree.
SHIFTP(16) - number of shifts worked by processed products lines.
SHIFTW(16) - number of shifts worked by whole tomato
TOMATOES - cost each week of raw product.
TONCOST - cost per ton of raw tomatoes.
TOTAL - total weekly cost.
WATER - weekly cost of water.
WDAYS - number of days required to can week's whole tomatoes.
WLABOR - weekly labor cost.
WHOLE - proportion of raw product to be processed as whole tomatoes.
X - year's projected pack of raw product.
XIJT - raw product equivalent processed each week by each canning line.
XPDT - average daily production of processed product in raw product equivalent in week T.
XPT - total plant production in raw product equivalent of processed products in week T.
XWDT - average daily production in raw product equivalent of whole tomatoes in week T.
XWT - total plant production in raw product equivalent of whole tomatoes in week T.
YIELD - expected yield per acre of raw product.
Z(14) - adjusted capacity in raw product equivalent of each canning line.

III. Calculate the needed acreage for each week's deliveries (ACRES).

IV. Calculate the planting dates for deliveries in week T using Wednesday (IDAY) as the representative starting point deriving expected daily heat units (HEAT) from historical data.

As an illustration of how the model operates for a given week, consider the following situation for Week 1 of a 13-week processing season (the complete season's schedule for this case is discussed in the "Results" section.)

The plant plans to process 135,000 tons of tomatoes over the season. Based on historical arrival patterns, for instance, 5.3 percent of the deliveries should arrive in Week 1, resulting in a canning level for the week of 7,155 tons (135,000 x .053). One third of the week's arrivals are allocated to whole, peeled tomatoes, or 2,361.15 tons (7,155 x .33), while the remainder, 4,793.85 tons, goes to processed products.

Operating at full capacity, the plant could process both quantities in just under three days, but given the contractual constraints, the number of days operated is set at five. This time period yields an average daily output of 472 tons of whole, peeled tomatoes, and 959 tons of processed products.

The next step is to determine the labor and cleanup costs of various alternative combinations of lines and shifts operated. Reviewing first the production options for canning the processed products, we note that the aggregate capacity of these lines is such that operating all processed products lines for either 1 or 1.5 shifts, 5 days will not permit all arrivals to be processed. Hence, the first feasible production option is to work 2 shifts and use lines 8, 9, 10, and 11 with a combined daily capacity of about 1,046 tons.[11] Working 2 shifts, 5 days for these lines results in cleanup and boiler start-up costs of $4,540 x 5 days = $22,700.

In a similar manner, we find that operating lines 8, 9, and 10 for 2.5 shifts has cleanup costs of $2,900 x 5 days = $14,500 and operating lines 8, 9, and 10 for 3 shifts has a single cleanup cost of $2,900 for the week.

The feasible production options for canning the 472 tons of whole tomatoes each day are determined by the same process using production capabilities for lines 1 through 7. Here again, the aggregate capacity for working 1 or 1.5 shifts is not sufficient to meet the week's supply. However, we can operate lines 1-7 for 2 shifts (capacity = 527 tons); lines 1-6 for 2.5 shifts (capacity 503.6 tons); or lines 1-5 for 3 shifts (capacity = 546.24 tons), 5 days.

The costs of these production options are found by using combined labor and cleanup costs. In this illustration, these costs are cost option 10 (2 shifts whole and 2 shifts processed), cost option 11 (2 shifts whole, 2.5 shifts processed), cost option 12 (2 shifts whole, 3 shifts processed), cost option 13 (2.5 shifts whole and 2.5 shifts processed), cost option 14 (2.5 shifts whole and 3 shifts processed), and cost option 15 (3 shifts whole and 3 shifts processed).

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11. The production options are obtained by finding the actual capacities for various sequences of canning lines when operating different numbers of shifts. For lines 8, 9, 10, and 11, operating 2 shifts, this capacity is calculated from Table 1 as follows:

([(Rated capacity/hour) x (pounds/case) x (.7)] divided by [2,000 pounds]) x 16 hours which yields the following:

Line	Actual Capacity for 2 Shifts	Cumulative Capacity
8	266.9 tons	266.9 tons
9	228.8 tons	495.7 tons
10	321.9 tons	817.6 tons
11	228.8 tons	1,046.4 tons

Cost option 10, for example, is calculated by combining the labor costs for operating lines 1 through 11 for both the first and second shifts (the sum of the 233 employees needed per shift times their respective wage rates). These labor costs equal $223,231 and, when added to the cleanup costs ($22,700) yield a cost alternative of $245,931. Applying the same procedures to the other feasible production alternatives results in cost alternatives varying from $257,422 to $327,741 (see Table 4a). Thus, the schedule selects the option (No. 10) of working 2 shifts for lines 1-11 for Week 1.

The production from each canning line is prorated on the basis of that line's proportion of the total capacity of those lines being operated which produce similar products (whole or processed). Thus, for lines 1-7 in Week 1, the total actual capacity is 32.96 tons per hour. Line 1, for instance, has a capacity of 3.43 tons per hour, equal to 10.41 percent of the total for lines 1-7. Line 1, therefore, is allocated 245.66 tons for the week (.1041 x 2,361.15 tons) of whole tomatoes.[12] This production level, in turn, equals 17,547 cases of final product (245.7 tons x 2,000 pounds divided by 28 pounds per case), or 421,138 cans (17,547 x 24 cans per case).

The related costs of the other inputs are then derived by applying the cost levels presented earlier to the production levels for this week.[13]

Results

As an initial specification, the annual pack in raw product equilavent was set at 135,000 tons; the only constraint on the length of the work week was that it be at least 5 days. Examples of the ensuing weekly schedules (as printed out by the computer) for weeks #1 and #12 are shown in Tables 4a and 4b, respectively.

The individual weekly data show the various feasible cost (production combinations) alternatives which can be used to process the week's pack and notes the lowest cost alternative selected. From that point, the number of shifts worked and the number of employees per shift are presented, and the total tonnage of raw product processed, the total output of cases of final product, and the number of cans required, are listed for each line. The week's costs for the various inputs are summarized and the required acreage and planting dates given. For computational and programming convenience, lines 8 through 12 are renumbered as lines 13 through 17 when the multiple product lines (8 and 12) are producing paste.

In the example of Week #1 in Table 4a, the only feasible cost alternatives are 10 through 15. Cost alternatives 1 through 9 are not feasible because the quantity to be processed (7,155 tons) exceeds the capacity of the plant when working less than two shifts. Cost alternative #10 utilizing 11 canning lines for two shifts has the lowest labor and clean-up costs ($245,931).

For the smaller quantity to be processed in week #12 (2,835 tons), all cost alternatives are feasible with the production option (cost alternative #1) of working 9 lines, one shift per day, five days a week, having the lowest labor and cleanup costs ($123,372).

In week #1, planting date 1 uses Davis temperatures and shows a zero value reflecting a planting date prior to February 1, a cutoff point prior to which plantings are not allowed because of higher risk of poor weather conditions. Planting date 2 is for Fresno. Thus, the model can be used to reflect the appropriate regions for raw product production for given times in the processing season.

The weekly data are summarized in an annual table as illustrated in Table 5.

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12. The totals presented are those from Table 4a. Rounding error may cause a slight difference from those total figures and the results obtained using the figures shown above in parentheses.

13. Can and carton costs are inflated by the allowance for damaged or unuseable items.

Table 4a

WEEK # 1
TABLE: 2
DAYS WORKED: 5

WEEKLY ARRIVAL: 7155. DAILY WHOLE: 472. DAILY PROCESSED: 959.

	COST	#SHIFTS WHOLE	#SHIFTS PROCESSED
10	245931	2.0	2.00
11	257422	2.0	2.50
12	267390	2.0	3.00
13	288278	2.5	2.50
14	298246	2.5	3.00
15	327741	3.0	3.00

COST ALTERNATIVE SELECTED: 10
NUMBER OF EMPLOYEES PER SHIFT: 233 233 0

LINE	CAN SIZE	CANS	XIJT	QIJT
1	1	421138	245.66	17547.45
2	1	541464	315.85	22561.01
3	1	661789	386.04	27574.56
4	3	60162	227.56	10027.12
5	3	120325	455.11	20054.23
6	2	168455	173.44	7018.98
7	2	541464	557.48	22561.01
8	3	129287	1222.52	21547.95
9	4	1058927	1048.34	22061.00
10	5	615655	1474.65	25652.32
11	4	1058927	1048.34	22061.00

LABOR	223231.23
CLEAN UP	22700.00
WATER	2708.26
GAS	71736.56
ELECTRICITY	10388.09
CARTON COSTS	41571.00
CAN COSTS	646817.63
LYE	6847.33
SALT	11679.98
TOMATOES	186030.00
TOTAL	1223709.88

ACRES: 256. PLANTING DATE1: 0 PLANTING DATE2: 34

Table 4b

WEEK # 12
TABLE: 3
DAYS WORKED: 5

WEEKLY ARRIVAL: 2835. DAILY WHOLE: 187. DAILY PROCESSED: 380.

	COST	#SHIFTS WHOLE	#SHIFTS PROCESSED
1	123372	1.0	1.00
2	142654	1.0	1.50
3	161464	1.0	2.00
4	182558	1.0	2.50
5	194453	1.0	3.00
6	171364	1.5	1.50
7	190174	1.5	2.00
8	211269	1.5	2.50
9	223164	1.5	3.00
10	218432	2.0	2.00
11	239526	2.0	2.50
12	251421	2.0	3.00
13	270595	2.5	2.50
14	282489	2.5	3.00
15	309500	3.0	3.00

COST ALTERNATIVE SELECTED: 1
NUMBER OF EMPLOYEES PER SHIFT: 228 0 0

LINE	CAN SIZE	CANS	XIJT	QIJT
1	1	218441	127.42	9101.74
2	1	280853	163.83	11702.24
3	1	343265	200.24	14302.74
4	3	31205	118.03	5201.00
5	3	62411	236.06	10401.99
6	2	87376	89.96	3640.70
13	3	55064	981.85	9177.36
14	4	541202	535.79	11275.04
15	5	314652	753.67	13110.51

LABOR	108872.81
CLEAN UP	14500.00
WATER	1073.09
GAS	26743.84
ELECTRICITY	4116.04
CARTON COSTS	16298.86
CAN COSTS	245869.61
LYE	2713.09
SALT	4569.80
TOMATOES	87885.00
TOTAL	512641.31

ACRES: 101. PLANTING DATE1: 150 PLANTING DATE2: 169

Table 5

ANNUAL AGGREGATE PRODUCTION PLAN FOR PROCESSING 135000 TONS OF TOMATOES

WEEKS	1	2	3	4	5	6	7	8	9	10	11	12	13	TOTAL
DAYS WORKED	5	10	16	22	28	34	40	46	52	57	62	67	72	72
SHIFTS(WHOLE)	2	3	3	3	3	3	3	3	3	3	2	1	1	NA
SHIFTS(PROCESS)	2	3	3	3	3	3	3	3	3	3	2	1	1	NA
EMPLOYEES/SHIFT	233	233	233	233	235	235	235	235	233	231	231	228	215	NA
RAW PRODUCT	7155	11340	12825	12825	14175	14175	14175	14175	12825	9990	7155	2835	1350	135000
PRODUCTION (CASES)														
LINE 1	17547	27811	31452	31452	34763	34763	34763	34763	31452	24500	17547	9101	8250	338172
LINE 2	22561	35757	40439	40439	44696	44696	44696	44696	40439	31500	22561	11702	10607	434792
LINE 3	27574	43703	49426	49426	54628	54628	54628	54628	49426	38500	27574	14302	12964	531413
LINE 4	10027	15892	17973	17973	19865	19865	19865	19865	17973	14000	10027	5200	0	188526
LINE 5	20054	31784	35946	35946	39730	39730	39730	39730	35946	28000	20054	10401	0	377053
LINE 6	7018	11124	12581	12581	13905	13905	13905	13905	12581	9800	7018	3640	0	131968
LINE 7	22561	35757	40439	40439	44696	44696	44696	44696	40439	31500	22561	0	0	412483
LINE 8	21547	34151	38623	38623	35623	35623	35623	35623	38623	32339	23161	9177	8454	387198
LINE 9	22060	34964	39543	39543	36471	36471	36471	36471	39543	39731	28456	11275	0	401005
LINE 10	25652	40656	45980	45980	42409	42409	42409	42409	45980	46198	33088	13110	0	466285
LINE 11	22060	34964	39543	39543	36471	36471	36471	36471	39543	0	0	0	0	321543
LINE 12	0	0	0	0	25445	25445	25445	25445	0	0	0	0	0	101782
AVG DAILY WHOLE	472	748	705	705	779	779	779	779	705	659	472	187	89	NA
AVG DAILY PROC.	958	1519	1432	1432	1582	1582	1582	1582	1432	1338	958	379	180	NA
COSTS (DOLLARS)														
LABOR	223231	335778	426976	426976	428405	428405	428405	428405	426976	332955	221354	108872	103036	4319780
CLEAN UP	22700	4540	4540	4540	4840	4840	4840	4840	4540	2900	14500	14500	11500	103620
WATER	2708	4292	4854	4854	5365	5365	5365	5365	4854	3781	2708	1073	510	51099
GAS	71736	113695	128584	128584	146181	146181	146181	146181	128584	94240	67496	26743	12735	1357126
ELECTRICITY	10388	16464	18620	18620	20580	20580	20580	20580	18620	14504	10388	4116	1960	196001
CARTONS	41571	65886	74514	74514	84276	84276	84276	84276	74514	56845	40713	16298	7606	789571
CANS	646817	1025144	1159390	1159390	1299178	1299178	1299178	1299178	1159390	864901	619456	245869	110552	12187625
LYE	6847	10852	12273	12273	13565	135>5	13565	13565	1r273	9560	6847	2713	1291	129195
SALT	11679	18511	20935	20935	23139	23139	23139	23139	20935	16307	11679	4569	2042	220157
TOMATOES	186030	294840	333450	333450	368550	368550	368550	368550	333450	259740	186030	87885	45225	3534300
TOTAL	1223709	1890005	2184138	2184138	2394082	2394082	2394082	2394082	2184138	1655735	1181173	512641	296460	22888472
ACRES NEEDED	255	405	458	458	506	506	506	506	458	356	255	101	48	4821
PLANTING DAY	1	1	1	1	1	1	1	1	1	1	1	1	1	NA

The convenience of computer simulation in testing changes in specifications, assumptions, etc., is illustrated by constraining the processing plant to work at least six-day work weeks for week 3 through 11 when the arrivals of fresh tomatoes may occur daily. Using the same 135,000-ton seasonal processing goal, the only changes are in weeks 10 and 11 which in the initial run operated only 5 days (all schedules for other weeks remain unchanged). As a result of this change, the total season's costs increase from $22,888,472 in the base model to $22,923,106 in the constrained version because of higher labor and cleanup costs.

One can also utilize this type of planning model to analyze the effects on average cost per ton of raw product processed of altering the season's pack. As an example, the season's pack was increased about 30 percent to 175,000 tons and the model was run with the work week constrained to be no less than five days (see Table 6). Using the same weekly proportions of arrivals as the base model, the plant worked 7 days for most of the season (weeks 2 through 9). The additional shifts and overtime work pushed the season's labor costs up by 34 percent to $5,798,903 from $4,319,780. Other input costs went up less proportionately; however, the cost per ton of raw product processed dropped from $169.54 at 135,000 tons per season to $168.70 for the 175,000-ton level.

In this manner the changes in costs associated with changes in output for the season can be determined by running the model with several quantity alternatives.

Other possible simulation experiments can also be made with the plant operations. Wage rates can be altered, product mixes can be varied (by altering the priority with which the canning lines operate), and, of course, the structure of the model itself can be revised (e.g., more processing facilities included).

Similarly, the plan generated by this model can be updated periodically prior to and during the processing season as additional information about such factors as weather and yields becomes available.

While the model has been developed for a particular set of plant operating conditions and technology, (i.e., input-output coefficients), the model can be made applicable to other specific plants and operations by changing its parameters directly. The model is deterministic in that the season's supply of tomatoes, the weekly arrivals, farm yields, and weather data are used at their expected value. Stochastic simulation could be developed in the context of this model to estimate the effects of the probabilistic nature of these items on the cost of production.

Table 6

ANNUAL AGGREGATE PRODUCTION PLAN FOR PROCESSING 175000 TONS OF TOMATOES

WEEKS	1	2	3	4	5	6	7	8	9	10	11	12	13	TOTAL
DAYS WORKED	5	12	19	26	33	40	47	54	61	67	72	77	82	82
SHIFTS(WHOLE)	2	3	3	3	3	3	3	3	3	3	2	1	1	NA
SHIFTS(PROCESS)	2	3	3	3	3	3	3	3	3	3	3	1	1	NA
EMPLOYEES/SHIFT	233	233	235	235	235	235	235	235	233	231	231	233	220	NA
RAW PRODUCT	9275	14700	16625	16625	18375	18375	18375	18375	16625	12950	9275	3675	1750	175000
PRODUCTION (CASES)														
LINE 1	22746	36051	40772	40772	41160	41160	41160	41160	40772	31759	22746	9012	8623	417897
LINE 2	29245	46351	52421	52421	52919	52919	52919	52919	52421	40833	29245	11587	11087	537297
LINE 3	35744	56652	64070	64070	64680	64680	64680	64680	64070	49907	35744	14163	13551	656696
LINE 4	12998	20600	23298	23298	23520	23520	23520	23520	23298	18148	12998	5150	4927	238798
LINE 5	25996	41201	46597	46597	47040	47040	47040	47040	46597	36296	25996	10300	0	467742
LINE 6	9098	14420	16308	16308	16464	16464	16464	16464	16308	12703	9098	3605	0	163709
LINE 7	29245	46351	52421	52421	52920	52920	52920	52920	52421	40833	29245	11587	0	526209
LINE 8	27932	44270	41780	41780	48149	48149	48149	48149	38529	41921	30024	8517	7890	475246
LINE 9	28597	45324	42775	42775	49295	49295	49295	49295	47336	51503	36887	10463	9694	512543
LINE 10	33253	52702	49739	49739	57320	57320	57320	57320	55042	59887	42892	12167	0	584707
LINE 11	28597	45324	42775	42775	49295	49295	49295	49295	47336	0	0	10463	0	414457
LINE 12	0	0	29843	29843	34392	34392	34392	34392	0	0	0	0	0	197257
AVG DAILY WHOLE	612	693	783	783	791	791	791	791	783	712	612	242	115	NA
AVG DAILY PROC.	1242	1406	1591	1591	1833	1833	1833	1833	1591	1446	1242	492	234	NA
COSTS (DOLLARS)														
LABOR	279505	566966	564995	564995	578134	578134	578134	578134	565809	428923	298737	111149	105283	5798903
CLEAN UP	22700	0	0	0	0	0	0	0	0	2900	2900	22700	13000	64200
WATER	3510	5564	6292	6292	6955	6955	6955	6955	6292	4901	3510	1391	662	66239
GAS	92991	147383	171447	171447	190423	190423	190423	190423	156831	122163	87495	34667	16508	1762629
ELECTRICITY	13466	21342	24137	24137	25481	25481	25481	25481	24137	18801	13466	5335	2540	249292
CARTONS	53888	85407	98843	98843	105015	105015	105015	105015	92220	73688	52776	20385	10246	1006364
CANS	838467	1328891	1523727	1523727	1627016	1627016	1627016	1627016	1435250	1121168	802998	317265	157171	15556737
LYE	8876	14067	15910	15910	16061	16061	16061	16061	15910	12393	8876	3516	1674	161381
SALT	15140	23996	27139	27139	27397	27397	27397	27397	27139	21139	15140	5999	2720	275142
TOMATOES	241150	382200	432250	432250	477750	477750	477750	477750	432250	336700	241150	113925	58625	4581500
TOTAL	1569696	2575819	2864742	2864742	3054235	3054235	3054235	3054235	2755841	2142779	1527051	636336	368433	29522388
ACRES NEEDED	331	525	593	593	656	656	656	656	593	462	331	131	62	6250
PLANTING DAY	1	1	1	1	1	1	1	1	1	1	1	1	1	NA

References

Bowman, Edward H. "Production Scheduling by the Transportation Method of Linear Programming," Operations Research, Vol. IV, No. 1, 1956.

Brandt, Jon A., Ben C. French, and Edward V. Jesse. "Economic Performance of the Processing Tomato Industry," Giannini Foundation Information Series No. 78-1, Bulletin 1888, University of California, April 1978.

California League of Food Processors. California Tomato Situation Annual Summary for 1981, Sacramento, March 1982.

Dilworth, James B. Production and Operations Management, 2nd edition, (New York: Random House) 1983.

French, B. C., L. L. Sammet, and R. G. Bressler, Jr. "Economic Efficiency in Plant Operations with Special Reference to the Marketing of California Pears," Hilgardia (University of California), Vo. 24 (19), July 1956, p 543-721.

Hillier, Frederick S. and Gerald J. Lieberman. Introduction to Operations Research, 3rd edition, (San Francisco: Holden-Day, Inc.) 1980.

Holt, Charles C., Franco Modigliani, and Herbert A. Simon. "A Linear Decision Rule for Production and Employment Scheduling," Management Science Vol. 2, No. 1, October 1955, pp. 1-10.

Logan, Samuel H. and Patricia B. Boyland. "Calculating Heat Units via a Sine Function," Journal of The American Society for Horticultural Science, Vol. 108 (6), November 1983, pp. 977-980.

Owens, Thad O., Jr. and E. L. Moore. "A Comparison of Various Methods of Calculating Heat Unit Requirements of Tomato," Mississippi Agricultural and Forest Experimental Station, Technical Bulletin 70, 1974.

Taubert, William H. Jr. "A Search Decision Rule for the Aggregate Scheduling Problem," Management Science, February 1968, pp. 343-359.

Went, F. W. "The Experimental Control of Plant Growth," Chronica Botanica, Vol. 17 (Waltham, Mass.: Chronica Botanica Co.) 1957.

Went, F. W. and Lloyd Cosper. "Plant Growth Under Controlled Conditions, VI. Comparison Between Field and Air-conditioned Greenhouse Culture of Tomatoes," American Journal of Botany, 32, pp. 643-654, 1945.

Uyeshiro, Ronald Y. Interregional Analysis of Costs in Multiproduct Tomato Processing Plants, M.S. Thesis, Purdue University, January 1972.

Appendix Table 1

Labor Classifications and Associated Hourly Wage Rates for Tomato Processors, 1983[a]

	Stage and Work Classification	Pay per Hour[a]
I.	Receiving and general preparation	
1.	Supervisor	$17.62
2.	Weigh master	13.77
3.	Janitor/cleanup	11.68
4.	Crew leader	12.62
5.	Bulk dumping worker	11.68
6.	Lift driver	12.62
7.	Flume control operator	11.68
8.	Trash sorter	10.94
II.	Preparation--whole tomatoes	
9.	Supervisor	16.60
10.	Sorter	10.94
11.	Crew leader	12.62
12.	Lye peel operator	12.96
13.	Janitor/cleanup	11.68
14.	Ingredient supplier	11.68
15.	Merry-go-round	12.62
III.	Preparation--products	
16.	Supervisor	17.62
17.	Pan operator	15.26
18.	Cook's helper	12.62
19.	Hot break worker	12.62
20.	Finisher	12.62
21.	Sauce blender	10.94
22.	Janitor	10.94
23.	Sorter	10.94
IV.	Filling and processing--products	
24.	Products supervisor	15.26
25.	Depalletizer	11.68
26.	Can chaser	10.94
27.	Seamer operator	11.68
28.	Sterilizer	10.94
29.	Janitor	10.94

Appendix Table 1 (continued)

Stage and Work Classification		Pay per Hour
V.	Filling and processing--whole	
30.	Fillêr	$10.94
31.	Crew leader	12.62
32.	Seamer operator	11.68
33.	Depalletizer	11.68
34.	Can chaser	10.94
35.	Empty can lift transporter	12.62
36.	Janitor	10.94
VI.	General processing	
37.	Cook room supervisor	17.62
38.	Seamer mechanic	16.94
39.	Seam checker	11.68
40.	Janitor	10.94
41.	Die setter	11.68
42.	Greaser	12.62
43.	Lid trucker	11.68
44.	Red light hopper	12.62
45.	Empty can shrouds	10.94
46.	Cooker mechanic	16.94
47.	Switchman	10.94
48.	Empty can supplier	16.60
VII.	General service	
49.	Supervisor	17.62
50.	Supervisor (cleanup)	13.77
51.	Boiler operator	15.26
52.	Electrician	16.94
53.	Cooking tower worker	12.62
54.	Line mechanic	16.94
55.	Sanitation worker	10.94
56.	Janitor	10.94
57.	Personnel clerk	10.94
58.	Time keeper	10.94
59.	Nurse	12.62
60.	Quality control supervisor	15.26
61.	Lab workers	11.68
62.	Oiler/greaser	12.62
63.	Screening plant worker	11.68
64.	Payroll clerk	10.94

Appendix Table 1 (continued)

Stage and Work Classification		Base Pay per Hour
VIII.	New can stacking	
65.	Supervisor	$16.60
66.	Stock checker	12.62
67.	Palletizer	11.68
68.	Hand fork truck operator	11.68
69.	Lift truck operator	13.77
70.	Transport train operator	12.62
71.	Mechanic	17.62
72.	Mechanic's helper	12.62
73.	Cleanup worker	11.68
74.	Pack accounting clerk	12.62
75.	Stretch wrap worker	11.68
IX.	Cooling floor	
76.	Stock checker	12.62
77.	Lift truck operator	13.77
X.	Pack receiving	
78.	Stock checker	12.62
79.	Lift truck operator	13.77

[a]Includes allowances of 35 percent for fringe benefits.

Appendix Table 2

Labor Requirements for Sequential Use of Tomato Processing Lines

Labor Option A (Line No. 1 Only)

	Stage	Labor Class	Number of Employees
I.	Receiving and general preparation		
	Supervisor	1	1
	Weigh master	2	1
	Janitor/cleanup	3	2
	Crew leader	4	1
	Bulk dumping worker	5	2
	Lift driver	6	1
	Flume control operator	7	2
	Trash sorter	8	28
II.	Preparation--whole tomatoes		
	Supervisor	9	1
	Sorter	10	38
	Crew leader	11	1
	Lye peel operator	12	1
	Janitor/cleanup	13	2
	Ingredient supplier	14	1
	Merry-go-round	15	1
III.	Preparation--products		
	Supervisor	16	0
	Pan operator	17	0
	Cook's helper	18	0
	Hot break worker	19	0
	Finisher	20	0
	Sauce blender	21	0
	Janitor	22	0
	Sorter	23	0
IV.	Filling and processing-products		
	Products supervisor	24	0
	Depalletizer	25	0
	Can chaser	26	0
	Seamer operator	27	0
	Sterilizer	28	0
	Janitor	29	0
V.	Filling and processing--whole		
	Filler	30	15
	Crew leader	31	1
	Seamer operator	32	1
	Depalletizer	33	4
	Can chaser	34	2
	Empty can lift transporter	35	1
	Janitor	36	2
VI.	General processing		
	Cook room supervisor	37	1
	Seamer mechanic	38	1
	Seam checker	39	2
	Janitor	40	1
	Die setter	41	1
	Greaser	42	1
	Lid trucker	43	1
	Red light hopper	44	1
	Empty can shrouds	45	1
	Cooker mechanic	46	1
	Switchman	47	1
	Empty can supplier	48	1

Appendix Table 2 (Cont.)

	Labor Option A (Line No. 1 Only)		
	Stage	Labor Class	Number of Employees
VII.	General service		
	Supervisor	49	0
	Supervisor (cleanup)	50	1
	Boiler operator	51	1
	Electrician	52	1
	Cooking tower worker	53	1
	Line mechanic	54	4
	Sanitation worker	55	1
	Janitor	56	2
	Personnel clerk	57	1
	Time keeper	58	1
	Nurse	59	1
	Quality control supervisor	60	1
	Lab workers	61	8
	Oiler/greaser	62	1
	Screening plant worker	63	1
	Payroll clerk	64	1
VIII.	New can stacking		
	Supervisor	65	1
	Stock checker	66	1
	Palletizer	67	7
	Hand fork truck operator	68	10
	Lift truck operator	69	2
	Transport train operator	70	1
	Mechanic	71	2
	Mechanic's helper	72	1
	Cleanup worker	73	1
	Pack accounting clerk	74	1
	Stretch wrap worker	75	2
IX.	Cooling floor		
	Stock checker	76	1
	Lift truck operator	77	2
X.	Pack receiving		
	Stock checker	78	1
	Lift truck operator	79	4

Given LO(A), then LO(B) = LO(A) + 1 employee #8 + 1 #10 + 1 #32
Given LO(A), then LO(C) = LO(A) + 2 employee #8 + 2 #10 + 2 #32
Given LO(A), then LO(D) = LO(A) + 3 employee #8 + 4 #10 + 3 #32
Given LO(A), then LO(E) = LO(A) + 4 employee #8 + 6 #10 + 4 #32
Given LO(A), then LO(F) = LO(A) + 5 employee #8 + 7 #10 + 5 #32
Given LO(A), then LO(G) = LO(A) + 6 employee #8 + 8 #10 + 6 #32

The following processed products labor options are added to the option selected from the set LO(A) through LO(G).
LO(H) adds 3 employee #8; 2 #16; 2 #17; 1 #18; 1 #19; 1 #20; 1 #21; 1 #22; 4 #23; 1 #24; 3 #25; 1 #26; 1 #27; 1 #28; and 1 #29
Given LO(H), then LO(I) = LO(H) + 1 employee #27
Given LO(H), then LO(J) = LO(H) + 2 employee #27
Given LO(H), then LO(K) = LO(H) + 3 employee #27 + 1 #68
Given LO(H), then LO(L) = LO(H) + 4 employee #27 + 2 #68.

Appendix Table 3

Labor Requirements for Sequential Operations of Processed Products Lines Only

Labor Option M (Line No. 8 Only)

	Stage	Labor Class	Number of Employees
I.	Receiving and general preparation		
	Supervisor	1	1
	Weigh master	2	1
	Janitor/cleanup	3	2
	Crew leader	4	1
	Bulk dumping worker	5	1
	Lift driver	6	1
	Flume control operator	7	1
	Trash sorter	8	8
II.	Preparation--whole tomatoes		
	Supervisor	9	0
	Sorter	10	0
	Crew leader	11	0
	Lye peel operator	12	0
	Janitor/cleanup	13	0
	Ingredient supplier	14	0
	Merry-go-round	15	0
III.	Preparation--products		
	Supervisor	16	2
	Pan operator	17	2
	Cook's helper	18	1
	Hot break worker	19	1
	Finisher	20	1
	Sauce blender	21	1
	Janitor	22	1
	Sorter	23	4
IV.	Filling and processing-products		
	Products supervisor	24	1
	Depalletizer	25	3
	Can chaser	26	1
	Seamer operator	27	1
	Sterilizer	28	1
	Janitor	29	1
V.	Filling and processing--whole		
	Filler	30	0
	Crew leader	31	0
	Seamer operator	32	0
	Depalletizer	33	0
	Can chaser	34	0
	Empty can lift transporter	35	0
	Janitor	36	0
VI.	General processing		
	Cook room supervisor	37	1
	Seamer mechanic	38	1
	Seam checker	39	1
	Janitor	40	1
	Die setter	41	1
	Greaser	42	1
	Lid trucker	43	1
	Red light hopper	44	0
	Empty can shrouds	45	1
	Cooker mechanic	46	0
	Switchman	47	1
	Empty can supplier	48	1

Appendix Table 3 (Cont.)

	Labor Option M (Line No. 8 Only)		
	Stage	Labor Class	Number of Employees
VII.	General service		
	Supervisor	49	0
	Supervisor (cleanup)	50	1
	Boiler operator	51	1
	Electrician	52	1
	Cooking tower worker	53	1
	Line mechanic	54	1
	Sanitation worker	55	1
	Janitor	56	2
	Personnel clerk	57	1
	Time keeper	58	1
	Nurse	59	1
	Quality control supervisor	60	1
	Lab workers	61	3
	Oiler/greaser	62	1
	Screening plant worker	63	1
	Payroll clerk	64	1
VIII.	New can stacking		
	Supervisor	65	1
	Stock checker	66	1
	Palletizer	67	4
	Hand fork truck operator	68	0
	Lift truck operator	69	1
	Transport train operator	70	1
	Mechanic	71	2
	Mechanic's helper	72	0
	Cleanup worker	73	1
	Pack accounting clerk	74	0
	Stretch wrap worker	75	1
IX.	Cooling floor		
	Stock checker	76	1
	Lift truck operator	77	1
X.	Pack receiving		
	Stock checker	78	1
	Lift truck operator	79	2

Given LO(M), then LO(N) = LO(M) + 1 employee #27
Given LO(M), then LO(O) = LO(M) + 2 employee #27
Given LO(M), then LO(P) = LO(M) + 3 employee #27
Given LO(M), then LO(Q) = LO(M) + 4 employee #27.

Appendix Table 4[a]

```
                                                   2-Mar-1984 09:04:59    VAX-
                                                   1-Sep-1983 14:57:26    DRA2:

C     PROGRAM TOMATO
C     WRITTEN BY C. BENGARD, PROGRAMMER FOR DATA SERVICES
C                                            AG ECONOMICS
C                                            UNIVERSITY OF CALIFORNIA
C                                            DAVIS, CALIFORNIA 95616
      REAL T1,T2,T3,T4,T5,A,B,C,D,E,F,TDAYS,TLABOR,TTOTAL,WCLEAN(16)
      REAL DISTRIB(13),LO(17),XIJT(17),QIJT(17),CANCALC(5),CARTCALC(5)
      REAL X,WHOLE,PASTE,SAUCE,ZWHOLE,ZPASTE,ZSAUCE,LYE,TONCOST,WAGE
      REAL SHIFTW(16),SHIFTP(16),XWDT,XPDT,XWT,XPT,TXIJT(17),WLABOR(16)
      REAL CAP(17),LAMBDA(14),Z(14),PO(17,5),HITEMP1(305),LOTEMP1(305)
      REAL TQIJT(17),HITEMP2(305),LOTEMP2(305),HEAT1,HEAT2
      INTEGER YIELD,LOPT(5),POPT(5),CAN(17),LON(17),CLEAN(5),OPT1(16)
      INTEGER COST(16),LINE(17),DAYSTART,NEMPLOY(16,3),I,K,L,TABLE
      INTEGER NNEMPLOY(17),NCANS(5),CANS(17),TCANS(17),PTABLE(32,14)
      CHARACTER*15 CTABLE(32)
      LOGICAL*1 LOOP
C     CTABLE ARE HEADINGS FOR FINAL PRINT OUT
      DATA CTABLE/'DAYS WORKED    ','SHIFTS(WHOLE)  ','SHIFTS(PROCESS)',
      1          'EMPLOYEES/SHIFT','RAW PRODUCT    ',
      1          '    LINE  1    ','    LINE  2    ',
      1          '    LINE  3    ','    LINE  4    ','    LINE  5    ',
      1          '    LINE  6    ','    LINE  7    ','    LINE  8    ',
      1          '    LINE  9    ','    LINE 10    ','    LINE 11    ',
      1          '    LINE 12    ','AVG DAILY WHOLE','AVG DAILY PROC.',
      1          '   LABOR       ','   CLEAN UP    ','   WATER       ',
      1          '   GAS         ','   ELECTRICITY ','   CARTONS     ',
      1          '   CANS        ','   LYE         ','   SALT        ',
      1          '   TOMATOES    ','   TOTAL       ','ACRES NEEDED   ',
      1          'PLANTING DAY   '/
C     DISTRIB IS WEEKLY DISTRIBUTION OF TOMATOES
      DATA DISTRIB/.053,.084,.095,.095,.105,.105,.105,.105,.095,.074,
      1       .053,.021,.01/
C     CLEAN IS CLEAN COSTS 1-5
      DATA CLEAN/2300,2600,2900,4540,4840/
C     NCANS IS NUMBER OF CANS PER CASE BASED ON CAN SIZE
      DATA NCANS/24,24,6,48,24/
C     CANCALC IS COST OF EACH CAN SIZE 1-5
      DATA CANCALC/2.726,4.028,2.816,3.136,2.316/
C     CARTCALC IS COST OF EACH CARTON BY CAN SIZE 1-5
      DATA CARTCALC/.179,.266,.226,.144,.139/
C     SHIFTW IS # OF WHOLE SHIFTS FOR EACH COST ALTERNATIVE 1-16
      DATA SHIFTW/1,1,1,1,1,1.5,1.5,1.5,1.5,2,2,2,2.5,2.5,3,3/
C     SHIFTP IS # OF PROCESSED SHIFTS FOR EACH COST ALTERNATIVE 1-16
      DATA SHIFTP/1,1.5,2,2.5,3,1.5,2,2.5,3,2,2.5,3,2.5,3,3,3/
C     READ IN LINE CAPACITES
      OPEN(1,FILE='CAP.DAT',STATUS='OLD')
C
      DO 20 I=1,14
            READ(1,'(5X,I1,F4.0,F9.0)') CAN(I),CAP(I),LAMBDA(I)
            Z(I)=CAP(I)*.7*LAMBDA(I)/2000.
20    CONTINUE
C     CAN IS CAN SIZE, CAP IS CAPACITY IN CASES PER HOUR,LAMBDA IS
C       CONVERSION COEFF FOR LBS RAW PRODUCT PER CASE, Z IS RAW
C       PRODUCT CAPACITY IN TONS PER HOUR -- ALL FOR EACH LINE
      CAN(14) = 4
      CAN(15) = 5
      CAN(16) = 4
```

[a]The notation "C" in the left margin refers to an explanatory comment on that line. These comments are not functioning components of the program.

```
                CAN(17) = 2
                CAP(14) = 430
                CAP(15) = 500
                CAP(16) = 430
                CAP(17) = 125
                CLOSE(1)
C               CALCULATE PRODUCTION OPTIONS
                DO 21 I=1,7
21              ZWHOLE=ZWHOLE+Z(I)
                DO 22 I=8,12
22              ZSAUCE=ZSAUCE+Z(I)
                ZPASTE=Z(9)+Z(10)+Z(11)+Z(13)+Z(14)
                DO 30 I=1,7
                        DO 30 K=1,5
                                IF (I.EQ.1) THEN
                                        PO(I,K)=Z(I)*(4*K+4)
                                        ELSE
                                        PO(I,K)=PO(I-1,K)+(Z(I)*(4*K+4))
                                END IF
30              CONTINUE
                DO 40 I=8,12
                        DO 40 K=1,5
                                IF (I.EQ.8) THEN
                                        PO(I,K)=Z(I)*(4*K+4)
                                        ELSE
                                        PO(I,K)=PO(I-1,K)+(Z(I)*(4*K+4))
                                END IF
40              CONTINUE
                DO 50 K=1,5
50                      PO(13,K)=Z(13)*(4*K+4)
                DO 60 K=1,5
60                      PO(14,K)=PO(13,K)+(Z(9)*(4*K+4))
                DO 70 K=1,5
70                      PO(15,K)=PO(14,K)+(Z(10)*(4*K+4))
                DO 80 K=1,5
80                      PO(16,K)=PO(15,K)+(Z(11)*(4*K+4))
                DO 90 K=1,5
90                      PO(17,K)=PO(16,K)+(Z(14)*(4*K+4))
C
C               READ IN COST OF SHIFT AND # OF EMPLOYEES
                OPEN(2,FILE='LABOR.DAT',STATUS='OLD')
C
                DO 102 I=1,79
                        READ(2,'(2X,F5.2,17I2)') WAGE,(NNEMPLOY(K),K=1,17)
                        DO 100 K=1,17
                                LON(K)=LON(K)+NNEMPLOY(K)
                                LO(K)=LO(K)+(WAGE*NNEMPLOY(K))
100                     CONTINUE
102             CONTINUE
                CLOSE(2)
C
C               READ IN HIGH AND LO TEMPERATURE AVERAGES
                OPEN(3,FILE='TEMP.DAT',STATUS='OLD')
                DO 104,I=1,305
104                     READ(3,'(3X,4F6.1)') HITEMP1(I), LOTEMP1(I),HITEMP2(I),
                1               LOTEMP2(I)
                CLOSE(3)
```

```
      C        ..................................MAIN PROGRAM.......................
               X=175000          ! SEASON'S WORTH OF TOMATOES
               WHOLE=.33         ! PROPORTION OF PACK AS WHOLE
               PASTE=.5067       ! PROPORTION OF PACK AS PASTE
               SAUCE=.1633       ! PROPORTION OF PACK AS SAUCE
               YIELD=28          ! EXPECTED YEILD PER ACRES OF TOMATOES
               DAYSTART=201      ! STARTING DAY : MID POINT OF WEEK 1
               TONCOST=26        ! COST PER TON OF TOMATOES
      C        FOR EACH WEEK DO THE FOLLOWING CALCULATIONS
               DO 10 IT=1,13
      C        INITIALIZE WEEK'S EMPLOYMENT,WHOLE OPTION # AND COST OPTIONS
               DO 140 I=1,16
               NEMPLOY(I,1)=0
               NEMPLOY(I,2)=0
               NEMPLOY(I,3)=0
               OPT1(I) = 0
      140      COST(I) = 0
               DO 105 I=1,17
               LINE(I) = 0
               XIJT(I) = 0
      105      QIJT(I) = 0
      C        CALCULATE WHETHER SAUCE(TABLE 2) OR PASTE(TABLE 3) IS PRODUCED
               IF (IT.EQ.1)THEN
                       TABLE=2          ! START WITH SAUCE
                       ELSE IF((SAUCEPRO/X).LT.SAUCE)THEN
                               TABLE=2 ! HAVEN'T MET SEASON'S SAUCE QUOTA
                               ELSE
                               TABLE=3 ! HAVE MET SEASON'S SAUCE QUOTA
                       END IF
      C        ARRIVAL IS WEEKLY DISTRIBUTION OF SEASON'S TOTAL TOMATOES
               ARRIVAL=X*DISTRIB(IT)+DIFF
               XWT=WHOLE*ARRIVAL                ! AMOUNT WEEK'S PACK AS WHOLE
               XPT=((SAUCE+PASTE)*ARRIVAL)      ! AMOUNT WEEK'S PACK AS PROCESSED
               WDAYS = XWT/(24*ZWHOLE)          ! # DAYS NEEDED TO PROCESS WHOLE
               DIFF=0
               IF (TABLE.EQ.2)THEN              ! # DAYS NEEDED FOR SAUCE OR PASTE
                       PDAYS=XPT/(24*ZSAUCE)
               ELSE
                       PDAYS=XPT/(24*ZPASTE)
               END IF
      C        SET # DAYS PER WEEK FOR PLANT TO OPERATE TO MAX OF WHOLE OR PROCESSED
               IF(PDAYS.GT.WDAYS)WDAYS=PDAYS
               IF(WDAYS.LT.5)WDAYS=5
               IF((WDAYS.GT.5).AND.(WDAYS.LE.6))WDAYS=6
               IF (WDAYS.GT.6)THEN
                       DIFF = XWT-(7*PO(7,5))
                       IF (DIFF.GT.0)THEN
                               XWT=7*PO(7,5)
                               XPT=DIFF+XPT
                               IF(TABLE.EQ.2)DIFF=XPT-(7*PO(12,5))
                               IF(TABLE.EQ.3)DIFF=XPT-(7*PO(17,5))
                               IF(DIFF.GT.0)THEN
                                       IF(TABLE.EQ.2)XPT=(7*PO(12,5))
                                       IF(TABLE.EQ.3)XPT=(7*PO(17,5))
                                       ARRIVAL=XPT+XWT
                               END IF
                       END IF
```

```
                      IF (DIFF.LT.0)DIFF=0
                      WDAYS=7
              END IF
C             CALCULATE DAILY ARRIVAL OF WHOLE, PROCESSED TOMATOES
              XWDT=XWT/WDAYS
              XPDT=XPT/WDAYS
C             CALCULATE PROCESSED PRODUCTION OPTIONS
              DO 110 I=1,5
                      LOPT(I)=0
110                   POPT(I)=0
              IF (TABLE.EQ.2)THEN
                      DO 112 I=1,5
                      DO 112 K=8,12
                              IF(POPT(I).EQ.0)THEN
                              IF (PO(K,I).GE.XPDT)POPT(I)=K
                              IF (PO(K,I).GE.XPDT)LOPT(I)=K
                              END IF
112                   CONTINUE
              END IF
              IF (TABLE.EQ.3)THEN
                      DO 120 I=1,5
                      DO 120 K=13,17
                              IF(POPT(I).EQ.0)THEN
                              IF (PO(K,I).GE.XPDT)POPT(I)=K
                              IF (PO(K,I).GE.XPDT)LOPT(I)=K-5
                              END IF
120                   CONTINUE
              END IF
              IF (TABLE.EQ.2)THEN
                      IF(POPT(5).EQ.0)POPT(I)=12
                      IF(LOPT(5).EQ.0)LOPT(I)=12
              ELSE
                      IF(POPT(5).EQ.0)POPT(I)=17
                      IF(LOPT(5).EQ.0)LOPT(I)=12
              END IF
              IF (WDAYS.EQ.7) GO TO 200 ! CALCULATE COST ALTERNATIVE 16
              LOOP = .TRUE.
C             CHECK OUT PRODUCTION OPTIONS 1-7 FOR 1 SHIFT WHOLE, 1-3 SHIFTS PROC
              DO 150 I=1,7
              IF (LOOP)THEN
                IF (PO(I,1).GE.XWDT)THEN
                      LOOP = .FALSE.
C             1 SHIFT WHOLE 1 SHIFT PROCESSED
                      IF (POPT(1).EQ.0)THEN
                        COST(1) = 0
                      ELSE
                        OPT1(1) = I
                        NEMPLOY(1,1) = LON(I)+LON(LOPT(1))
                        WLABOR(1)=(LO(I)+LO(LOPT(1)))*40
                        IF (WDAYS.EQ.6)THEN
                              LABOVT = ((XWDT+XPDT)/(PO(I,1)+PO(POPT(1),1)))*
              1                        (LO(I)+LO(LOPT(1))*12)
                              WLABOR(1)= WLABOR(1)+ LABOVT
                        END IF
                        WCLEAN(1) = CLEAN(LOPT(1)-7)*WDAYS
                        COST(1) = WLABOR(1) +WCLEAN(1)
                      END IF
```

```
C       1 SHIFT WHOLE 1.5 SHIFT PROCESSED
              IF (POPT(2).EQ.0)THEN
                COST(2) = 0
              ELSE
                OPT1(2) = I
                C=LOPT(2)+5
                NEMPLOY(2,1) = LON(I)+LON(LOPT(2))
                NEMPLOY(2,2) = LON(C)
                DLABOR = (LO(I)+LO(LOPT(2)))*8
                DLABOR = DLABOR+(LON(C)*.40)+(LO(C)*4)
                WLABOR(2) =DLABOR*5
                IF (WDAYS.EQ.6)THEN
                      LABOVT = ( (XWDT+XPDT) /(PO(I,1)+PO(POPT(2),2)))*
        1                     (1.5)*DLABOR
                      WLABOR(2) =WLABOR(2) +LABOVT
                END IF
                WCLEAN(2) = CLEAN(LOPT(2)-7)*WDAYS
                COST(2) = WLABOR(2) +WCLEAN(2)
              END IF
C       1 SHIFT WHOLE 2 SHIFTS PROCESSED
              IF (POPT(3).EQ.0)THEN
                COST(3) = 0
              ELSE
                OPT1(3) = I
                C=LOPT(3)+5
                NEMPLOY(3,1) = LON(I)+LON(LOPT(3))
                NEMPLOY(3,2) = LON(C)
                DLABOR = (LO(I)+LO(LOPT(3)))*8
                DLABOR = DLABOR+(LON(C)*.80)+(LO(C)*8)
                WLABOR(3) =DLABOR*5
                IF (WDAYS.EQ.6)THEN
                      LABOVT = ((XWDT+XPDT)/(PO(I,1)+PO(POPT(3),3)))*
        1                     (1.5)*DLABOR
                      WLABOR(3) =WLABOR(3) +LABOVT
                END IF
                WCLEAN(3) = CLEAN(LOPT(3)-7)*WDAYS
                COST(3) = WLABOR(3) +WCLEAN(3)
              END IF
C       1 SHIFT WHOLE 2.5 SHIFTS PROCESSED
              IF (POPT(4).EQ.0)THEN
                COST(4) = 0
              ELSE
                OPT1(4) = I
                C=LOPT(4)+5
                NEMPLOY(4,1) = LON(I)+LON(LOPT(4))
                NEMPLOY(4,2) = LON(C)
                NEMPLOY(4,3) = LON(C)
                DLABOR = (LO(I)+LO(LOPT(4)))*8
                DLABOR = DLABOR+(LON(C)*.60)+(LO(C)*4)
                DLABOR = DLABOR+(LON(C)*.80)+(LO(C)*8)
                WLABOR(4) =DLABOR*5
                IF (WDAYS.EQ.6)THEN
                      LABOVT = ((XWDT+XPDT)/(PO(I,1)+PO(POPT(4),4)))*
        1                     (1.5)*DLABOR
                      WLABOR(4) =WLABOR(4) +LABOVT
                END IF
                WCLEAN(4) = CLEAN(LOPT(4)-7)*WDAYS
```

```
                      COST(4) = WLABOR(4) +WCLEAN(4)
                    END IF
C        1 SHIFT WHOLE 3 SHIFTS PROCESSED
                    IF (POPT(5).EQ.0)THEN
                      COST(5) = 0
                    ELSE
                      OPT1(5) = I
                      C=LOPT(5)+5
                      NEMPLOY(5,1) = LON(I)+LON(LOPT(5))
                      NEMPLOY(5,2) = LON(C)
                      NEMPLOY(5,3) = LON(C)
                      DLABOR = (LO(I)+LO(LOPT(5)))*8
                      DLABOR = DLABOR+(LON(C)*.80)+(LO(C)*8)
                      DLABOR = DLABOR+(LON(C)*1.20)+(LO(C)*8)
                      WLABOR(5) =DLABOR*5
                      IF (WDAYS.EQ.6)THEN
                            LABOVT = ((XWDT+XPDT)/(PO(I,1)+PO(POPT(5),5)))*
         1                          (1.5)*DLABOR
                            WLABOR(5) =WLABOR(5) +LABOVT
                      END IF
                      WCLEAN(5) = CLEAN(LOPT(5)-7)
                      COST(5) = WLABOR(5) +WCLEAN(5)
                    END IF
               END IF
            END IF
150         CONTINUE
C           CHECK OUT 1.5 SHIFTS WHOLE 1.5-3 SHIFTS PROCESSED
            LOOP = .TRUE.
            DO 160 I=1,7
               IF (LOOP)THEN
                    IF(PO(I,2).GE.XWDT)THEN
                      LOOP = .FALSE.
C        1.5 SHIFTS WHOLE 1.5 SHIFTS PROCESSED
                    IF (POPT(2).EQ.0)THEN
                      COST(6) = 0
                    ELSE
                      OPT1(6) = I
                      NEMPLOY(6,1) = LON(I)+LON(LOPT(2))
                      NEMPLOY(6,2) = LON(I)+LON(LOPT(2))
                      DLABOR = (LO(I)+LO(LOPT(2)))*8
                      DLABOR = DLABOR+(LON(I)*.40)+(LO(I)*4)
                      DLABOR = DLABOR+(LON(LOPT(2))*.40)+(LO(LOPT(2))*4)
                      WLABOR(6) =DLABOR*5
                      IF (WDAYS.EQ.6)THEN
                            LABOVT = ((XWDT+XPDT)/(PO(I,2)+PO(POPT(2),2)))*
         1                          (1.5)*DLABOR
                            WLABOR(6) =WLABOR(6) +LABOVT
                      END IF
                      WCLEAN(6) = CLEAN(LOPT(2)-7)*WDAYS
                      COST(6) = WLABOR(6) +WCLEAN(6)
                    END IF
C        1.5 SHIFTS WHOLE 2 SHIFTS PROCESSED
                    IF (POPT(3).EQ.0)THEN
                      COST(7) = 0
                    ELSE
                      OPT1(7) = I
                      C=LOPT(3)+5
```

```
                  NEMPLOY(7,1) = LON(I)+LON(LOPT(3))
                  NEMPLOY(7,2) = LON(I)+LON(LOPT(3))
                  DLABOR = (LO(I)+LO(LOPT(3)))*8
                  DLABOR = DLABOR+(LON(I)*.40)+(LO(I)*4)
                  DLABOR = DLABOR+(LON(LOPT(3))*.40)+(LO(LOPT(3))*4)
                  DLABOR = DLABOR+(LON(C)*.40)+(LO(C)*4)
                  WLABOR(7) =DLABOR*5
                  IF (WDAYS.EQ.6)THEN
                        LABOVT = ((XWDT+XPDT)/(PO(I,2)+PO(POPT(3),2)))*
     1                          (1.5)*DLABOR
                        WLABOR(7) =WLABOR(7) +LABOVT
                  END IF
                  WCLEAN(7) = CLEAN(LOPT(3)-7)*WDAYS
                  COST(7) = WLABOR(7) +WCLEAN(7)
                END IF
C       1.5 SHIFTS WHOLE 2.5 SHIFTS PROCESSED
                IF (POPT(4).EQ.0)THEN
                  COST(8) = 0
                ELSE
                  OPT1(8) = I
                  C=LOPT(4)+5
                  NEMPLOY(8,1) = LON(I)+LON(LOPT(4))
                  NEMPLOY(8,2) = LON(I)+LON(LOPT(4))
                  NEMPLOY(8,3) = LON(C)
                  DLABOR = (LO(I)+LO(LOPT(4)))*8
                  DLABOR = DLABOR+(LON(I)*.40)+(LO(I)*4)
                  DLABOR = DLABOR+(LON(LOPT(4))*.40)+(LO(LOPT(4))*4)
                  DLABOR = DLABOR+(LON(C)*1.00)+(LO(C)*8)
                  WLABOR(8) =DLABOR*5
                  IF (WDAYS.EQ.6)THEN
                        LABOVT = ((XWDT+XPDT)/(PO(I,2)+PO(POPT(4),4)))*
     1                          (1.5)*DLABOR
                        WLABOR(8) =WLABOR(8) +LABOVT
                  END IF
                  WCLEAN(8) = CLEAN(LOPT(4)-7)*WDAYS
                  COST(8) = WLABOR(8) +WCLEAN(8)
                END IF
C       1.5 SHIFTS WHOLE 3 SHIFTS PROCESSED
                IF (POPT(5).EQ.0)THEN
                  COST(9) = 0
                ELSE
                  OPT1(9) = I
                  C=LOPT(5)+5
                  NEMPLOY(9,1) = LON(I)+LON(LOPT(5))
                  NEMPLOY(9,2) = LON(I)+LON(LOPT(5))
                  NEMPLOY(9,3) = LON(C)
                  DLABOR = (LO(I)+LO(LOPT(5)))*8
                  DLABOR = DLABOR+(LON(I)*.40)+(LO(I)*4)
                  DLABOR = DLABOR+(LON(LOPT(5))*.40)+(LO(LOPT(5))*4)
                  DLABOR = DLABOR+(LON(C)*1.60)+(LO(C)*12)
                  WLABOR(9) =DLABOR*5
                  IF (WDAYS.EQ.6)THEN
                        LABOVT = ((XWDT+XPDT)/(PO(I,2)+PO(POPT(5),5)))*
     1                          (1.5)*DLABOR
                        WLABOR(9) =WLABOR(9) +LABOVT
                  END IF
                  WCLEAN(9) = CLEAN(LOPT(5)-7)
```

```
                    COST(9) = WLABOR(9) +WCLEAN(9)
                  END IF
              END IF
          END IF
  160     CONTINUE
  C       CHECK OUT 2 SHIFTS WHOLE 2-3 SHIFTS OF PROCESSED
          LOOP = .TRUE.
          DO 170 I=1,7
          IF (LOOP)THEN
          IF (PO(I,3).GE.XWDT)THEN
            LOOP = .FALSE.
  C       2 SHIFTS WHOLE 2 SHIFTS PROCESSED
                  IF (POPT(3).EQ.0)THEN
                    COST(10) = 0
                  ELSE
                    OPT1(10) = I
                    NEMPLOY(10,1) = LON(I)+LON(LOPT(3))
                    NEMPLOY(10,2) = LON(I)+LON(LOPT(3))
                    DLABOR = (LO(I)+LO(LOPT(3)))*16
                    DLABOR = DLABOR+(LON(I)*.80)+(LON(LOPT(3))*.80)
                    WLABOR(10) =DLABOR*5
                    IF (WDAYS.EQ.6)THEN
                          LABOVT = ((XWDT+XPDT)/(PO(I,3)+PO(POPT(3),3)))*
          1                       (1.5)*DLABOR
                          WLABOR(10) =WLABOR(10) +LABOVT
                    END IF
                    WCLEAN(10) = CLEAN(LOPT(3)-7)*WDAYS
                    COST(10) = WLABOR(10) +WCLEAN(10)
                  END IF
  C       2 SHIFTS WHOLE 2.5 SHIFTS PROCESSED
                  IF (POPT(4).EQ.0)THEN
                    COST(11) = 0
                  ELSE
                    OPT1(11) = I
                    C=LOPT(4)+5
                    NEMPLOY(11,1) = LON(I)+LON(LOPT(4))
                    NEMPLOY(11,2) = LON(I)+LON(LOPT(4))
                    NEMPLOY(11,3) = LON(C)
                    DLABOR = (LO(I)+LO(LOPT(4)))*16
                    DLABOR = DLABOR+(LON(I)*.80)+(LON(LOPT(4))*.80)
                    DLABOR = DLABOR+(LON(C)*.60)+(LO(C)*4)
                    WLABOR(11) =DLABOR*5
                    IF (WDAYS.EQ.6)THEN
                          LABOVT = ((XWDT+XPDT)/(PO(I,3)+PO(POPT(4),4)))*
          1                       (1.5)*DLABOR
                          WLABOR(11) =WLABOR(11) +LABOVT
                    END IF
                    WCLEAN(11) = CLEAN(LOPT(4)-7)*WDAYS
                    COST(11) = WLABOR(11) +WCLEAN(11)
                  END IF
  C       2 SHIFTS WHOLE 3 SHIFTS PROCESSED
                  IF (POPT(5).EQ.0)THEN
                    COST(12) = 0
                  ELSE
                    OPT1(12) = I
                    C=LOPT(5)+5
                    NEMPLOY(12,1) = LON(I)+LON(LOPT(5))
```

```
                    NEMPLOY(12,2) = LON(I)+LON(LOPT(5))
                    NEMPLOY(12,3) = LON(C)
                    DLABOR = (LO(I)+LO(LOPT(5)))*16
                    DLABOR = DLABOR+(LON(I)*.80)+(LON(LOPT(4))*.80)
                    DLABOR = DLABOR+(LON(C)*1.20)+(LO(C)*8)
                    WLABOR(12) =DLABOR*5
                    IF (WDAYS.EQ.6)THEN
                         LABOVT = ((XWDT+XPDT)/(PO(I,3)+PO(POPT(5),5)))*
     1                            (1.5)*DLABOR
                         WLABOR(12) =WLABOR(12) +LABOVT
                    END IF
                    WCLEAN(12) = CLEAN(LOPT(5)-7)
                    COST(12) = WLABOR(12) +WCLEAN(12)
                  END IF
             END IF
        END IF
 170    CONTINUE
C       CHECK OUT 2.5 SHIFTS OF WHOLE, 2.5-3 SHIFTS OF PROCESSED
        LOOP = .TRUE.
        DO 180 I=1,7
        IF (LOOP)THEN
        IF (PO(I,4).GE.XWDT)THEN
          LOOP = .FALSE.
C       2.5 SHIFTS WHOLE 2.5 SHIFTS PROCESSED
                  IF (POPT(4).EQ.0)THEN
                    COST(13) = 0
                  ELSE
                    OPT1(13) = I
                    NEMPLOY(13,1) = LON(I)+LON(LOPT(4))
                    NEMPLOY(13,2) = LON(I)+LON(LOPT(4))
                    NEMPLOY(13,3) = LON(I)+LON(LOPT(4))
                    DLABOR = (LO(I)+LO(LOPT(4)))*20
                    DLABOR = DLABOR+(LON(I)*1.40)+(LON(LOPT(4))*1.40)
                    WLABOR(13) =DLABOR*5
                    IF (WDAYS.EQ.6)THEN
                         LABOVT = ((XWDT+XPDT)/(PO(I,4)+PO(POPT(4),4)))*
     1                            (1.5)*DLABOR
                         WLABOR(13) =WLABOR(13) +LABOVT
                    END IF
                    WCLEAN(13) = CLEAN(LOPT(4)-7)*WDAYS
                    COST(13) = WLABOR(13) +WCLEAN(13)
                  END IF
C       2.5 SHIFTS WHOLE 3 SHIFTS PROCESSED
                  IF (POPT(5).EQ.0)THEN
                    COST(14) = 0
                  ELSE
                    OPT1(14) = I
                    C=LOPT(5)+5
                    NEMPLOY(14,1) = LON(I)+LON(LOPT(5))
                    NEMPLOY(14,2) = LON(I)+LON(LOPT(5))
                    NEMPLOY(14,3) = LON(I)+LON(LOPT(5))
                    DLABOR = (LO(I)+LO(LOPT(5)))*20
                    DLABOR = DLABOR+(LON(I)*1.40)+(LON(LOPT(4))*1.40)
                    DLABOR = DLABOR+(LON(C)*.60)+(LO(C)*4)
                    WLABOR(14) =DLABOR*5
                    IF (WDAYS.EQ.6)THEN
                         LABOVT = ((XWDT+XPDT)/(PO(I,4)+PO(POPT(5),5)))*
```

```
        1                        (1.5)*DLABOR
                         WLABOR(14) =WLABOR(14) +LABOVT
                    END IF
                    WCLEAN(14) = CLEAN(LOPT(5)-7)
                    COST(14) = WLABOR(14) +WCLEAN(14)
                  END IF
             END IF
          END IF
  180     CONTINUE
  C       CHECK OUT 3 SHIFTS WHOLE, 3 SHIFTS PROCESSED
          LOOP = .TRUE.
          DO 190 I=1,7
          IF (LOOP)THEN
          IF (PO(I,5).GE.XWDT)THEN
            LOOP = .FALSE.
                  IF (POPT(5).EQ.0)THEN
                    COST(15) = 0
                  ELSE
                    OPT1(15) = I
                    NEMPLOY(15,1) = LON(I)+LON(LOPT(5))
                    NEMPLOY(15,2) = LON(I)+LON(LOPT(5))
                    NEMPLOY(15,3) = LON(I)+LON(LOPT(5))
                    DLABOR = (LO(I)+LO(LOPT(5)))*24
                    DLABOR = DLABOR+(LON(I)*2.00)+(LON(LOPT(5))*2.00)
                    WLABOR(15) =DLABOR*5
                    IF (WDAYS.EQ.6)THEN
                          LABOVT = ((XWDT+XPDT)/(PO(I,5)+PO(POPT(5),5)))*
        1                        (1.5)*DLABOR
                          WLABOR(15) =WLABOR(15) +LABOVT
                    END IF
                    WCLEAN(15) = CLEAN(LOPT(5)-7)
                    COST(15) = WLABOR(15) +WCLEAN(15)
                  END IF
             END IF
          END IF
  190     CONTINUE
          GO TO 300
  200     CONTINUE
  C       CALCULATE WORKING 7 DAYS 3 SHIFTS WHOLE, 3 SHIFTS PROCESSED
          OPT1(16) = 7
            NEMPLOY(16,1) = LON(7)+LON(LOPT(5))
            NEMPLOY(16,2) = LON(7)+LON(LOPT(5))
            NEMPLOY(16,3) = LON(7)+LON(LOPT(5))
          DLABOR=(LO(7)+LO(LOPT(5)))*24
          DLABOR=((LON(7)+LON(LOPT(5)))*2)+DLABOR
          WLABOR(16) =DLABOR*5+(DLABOR*1.5)
          WLABOR(16) =WLABOR(16)+(((XWDT+XPDT)/
          1        ( PO(5,7)+PO(POPT(5),5) ))*DLABOR*1.5)
          COST(16)=WLABOR(16)
          WCLEAN(16)=0
  300     CONTINUE
  C       CALCULATE SMALLEST COST ALTERNATIVE
          K=1
          DO 301 I=1,16
  301     IF(COST(I).GT.COST(K))K=I
          DO 310 I=1,16
  310     IF ((COST(I).LT.COST(K)).AND.(COST(I).GT.0))K=I
```

```
C       CALCULATE WHICH WHOLE TOMATO LINES ARE OPERATING
        DO 320 I=1,7
320             IF(I.LE.OPT1(K))LINE(I)=1
302     CONTINUE
        SLINE=0
        DO 322 I=1,7
322     IF(LINE(I).GT.0)SLINE=SLINE+Z(I)
        DO 324 I=1,7
        IF(LINE(I).GT.0)XIJT(I)=XWT*Z(I)/SLINE
324     IF(LINE(I).GT.0)QIJT(I)=2000*XIJT(I)/LAMBDA(I)
        L=5
        IF((K.EQ.4).OR.(K.EQ.8).OR.(K.EQ.11).OR.(K.EQ.13))L=4
        IF((K.EQ.3).OR.(K.EQ.7).OR.(K.EQ.10))L=3
        IF((K.EQ.2).OR.(K.EQ.6))L=2
        IF(K.EQ.1)L=1
C       CALCULATE WHICH TABLE 2 LINES ARE OPERATING
        IF(TABLE.EQ.2)THEN
                DO 330 I=8,12
330                     IF(I.LE.POPT(L))LINE(I)=1
                SLINE=0
                DO 332 I=8,12
332                     IF(LINE(I).GT.0)SLINE=SLINE+Z(I)
                DO 334 I=8,12
                        IF(LINE(I).GT.0)XIJT(I)=XPT*Z(I)/SLINE
                        IF(LINE(I).GT.0)QIJT(I)=2000*XIJT(I)/LAMBDA(I)
334             CONTINUE
C       CALCULATE WHICH TABLE 3 LINES ARE OPERATING
        ELSE
                SLINE=0
                DO 340 I=13,17
340                     IF(I.LE.POPT(L))LINE(I)=1
                IF(LINE(13).GT.0)SLINE=SLINE+Z(13)
                IF(LINE(14).GT.0)SLINE=SLINE+Z(14)
                IF(LINE(15).GT.0)SLINE=SLINE+Z(9)
                IF(LINE(16).GT.0)SLINE=SLINE+Z(10)
                IF(LINE(17).GT.0)SLINE=SLINE+Z(11)
                IF(LINE(13).GT.0)XIJT(13)=XPT*Z(13)/SLINE
                IF(LINE(13).GT.0)QIJT(13)=2000*XIJT(13)/LAMBDA(13)
                IF(LINE(14).GT.0)XIJT(14)=XPT*Z(9)/SLINE
                IF(LINE(14).GT.0)QIJT(14)=2000*XIJT(14)/LAMBDA(9)
                IF(LINE(15).GT.0)XIJT(15)=XPT*Z(10)/SLINE
                IF(LINE(15).GT.0)QIJT(15)=2000*XIJT(15)/LAMBDA(10)
                IF(LINE(16).GT.0)XIJT(16)=XPT*Z(11)/SLINE
                IF(LINE(16).GT.0)QIJT(16)=2000*XIJT(16)/LAMBDA(11)
                IF(LINE(17).GT.0)XIJT(17)=XPT*Z(14)/SLINE
                IF(LINE(17).GT.0)QIJT(17)=2000*XIJT(17)/LAMBDA(14)
        END IF
C       ACCUMULATE SEASON'S SAUCE PRODUCTION
        DO 345 I=1,17
345             IF((I.EQ.8).OR.(I.EQ.12))SAUCEPRO=SAUCEPRO+XIJT(I)
        ELEC=(42.532*XWT*.07)+(10.008*XPT*.07)  ! COST OF ELECTRICITY
        IF(TABLE.EQ.2)THEN
C       COST OF GAS FOR SAUCE
        GAS=(17.553*XWT*.52)+(25.101*XIJT(8)*.52)+(25.101*XIJT(12)*.52)+
        1       (18.431*XIJT(9)*.52)+(18.431*XIJT(10)*.52)+
        1       (18.431*XIJT(11)*.52)
        ELSE
```

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C       COST OF GAS FOR PASTE
        GAS=(17.553*XWT*.52)+(18.431*XPT*.52)
        END IF
        WATER=946.284*.0004*ARRIVAL              ! COST OF WATER
        LYE=1.16*2.5*XWT                         ! COST OF LYE, THEN SALT
        SALT=(QIJT(1)*24.*.003)+(QIJT(2)*24.*.003)+(QIJT(3)*24.*.0022)+
        1       (QIJT(4)*12.*.0099)+(QIJT(5)*12.*.0099)+
        1       (QIJT(6)*24.*.0053)+(QIJT(7)*24.*.0053)
C       CALCULATE CAN COSTS
        CANCOST=0
        DO 350 I=1,17
        CANS(I)=QIJT(I)*NCANS(CAN(I))
350     CANCOST=CANCOST+QIJT(I)*CANCALC(CAN(I))
C       CALCULATE CARTON COSTS
        CARTCOST=0
        DO 360 I=1,17
360     CARTCOST=CARTCOST+QIJT(I)*CARTCALC(CAN(I))
C       ADDTIONAL COST PER TON FOR END OF SEASON RISK FACTOR
        ADDTON=0
        IF(IT.EQ.12)ADDTON=5
        IF(IT.EQ.13)ADDTON=7.50
C       COST OF TOMATOES
        TOMATOES=ARRIVAL*(TONCOST+ADDTON)
C       TOTAL COST
        TOTAL=ELEC+GAS+WATER+LYE+SALT+CANCOST+CARTCOST+TOMATOES+
        1       COST(K)
C       ACRES NEEDED FOR THIS WEEK
        ACRES=ARRIVAL/YIELD
C       DAY OF WEEK TO START CALCULATING PLANTING DATE AREA 1
        IDAY1=DAYSTART
        HEAT1=0
12      T1=(HITEMP1(IDAY1)+LOTEMP1(IDAY1))/2
        T5=HITEMP1(IDAY1)-T1
        T2=(T1-45)/T5
        T3=(80-T1)/T5
        T4=(100-T1)/T5
        IF (T2.GE.1)THEN
                A=-3.1416/2
        ELSE
                A=-ASIN(T2)
        END IF
        B=3.1416 - A
        IF(T3.GE.1)THEN
                EX1 = 0
        ELSE
                C=ASIN(T3)
                D=3.1416 - C
                EX1= COS(D)-COS(C)+(D*T3)-(C*T3)
        END IF
        IF(T4.GE.1) THEN
                EX2 = 0
        ELSE
                E=ASIN(T4)
                F=3.1416 - E
                EX2 = COS(F)-COS(E)+(F*T4)-(E*T4)
        END IF
        HEAT1=HEAT1+((T5/(2*3.1416))*(-COS(B)+COS(A)+(B*T2)-(A*T2)+EX1+
```

```
     1       EX2))
      IDAY1 = IDAY1-1
      IF(HEAT1.LT.3135.AND.IDAY1.GT.0)GO TO 12
C     DAY OF WEEK TO START CALCULATING PLANTING DATE AREA 2
      IDAY2=DAYSTART
      HEAT2=0
13    T1=(HITEMP2(IDAY2)+LOTEMP2(IDAY2))/2
      T5=HITEMP2(IDAY2)-T1
      T2=(T1-45)/T5
      T3=(80-T1)/T5
      T4=(100-T1)/T5
      IF (T2.GE.1)THEN
              A=-3.1416/2
      ELSE
              A=-ASIN(T2)
      END IF
      B=3.1416 - A
      IF(T3.GE.1)THEN
              EX1 = 0
      ELSE
              C=ASIN(T3)
              D=3.1416 - C
              EX1= COS(D)-COS(C)+(D*T3)-(C*T3)
      END IF
      IF(T4.GE.1) THEN
              EX2 = 0
      ELSE
              E=ASIN(T4)
              F=3.1416 - E
              EX2 = COS(F)-COS(E)+(F*T4)-(E*T4)
      END IF
      HEAT2=HEAT2+((T5/(2*3.1416))*(-COS(B)+COS(A)+(B*T2)-(A*T2)+EX1+
     1       EX2))
      IDAY2 = IDAY2-1
      IF(HEAT2.LT.3135.AND.IDAY2.GT.0)GO TO 13
C     END OF CALCULATING PLANTING DATE LOOP
      DAYSTART=DAYSTART+7
C     :::::::::::::::::::::::::::::::::::::::::::::::OUTPUT;;;;;;;;;;
      WRITE(6,'(A,A,I4)') '1','WEEK #', IT
      WRITE(6,'(1X,A,I2)') 'TABLE:',TABLE
      WRITE(6,'(1X,A,I2//)') 'DAYS WORKED:',INT(WDAYS)
      WRITE(6,'(1X,A,F8.0,A,F7.0,A,F7.0//)') 'WEEKLY ARRIVAL:',
     1       ARRIVAL,'  DAILY WHOLE:', XWDT, '   DAILY PROCESSED:',
     1       XPDT
      WRITE(6,'(1X,A)') '     COST    #SHIFTS WHOLE  #SHIFTS PROCESSED'
      DO 400 I=1,16
400   IF(COST(I).GT.0)WRITE(6,'(1X,I2,I9,F9.1,F16.2)') I,COST(I),
     1       SHIFTW(I),SHIFTP(I)
      WRITE(6,'(1X,///,1X,A,I3)') 'COST ALTERNATIVE SELECTED:',K
      WRITE(6,'(1X,A,3I6)') 'NUMBER OF EMPLOYEES PER SHIFT:',NEMPLOY(K,1),
     1       NEMPLOY(K,2),NEMPLOY(K,3)
      WRITE(6,'(//,1X,A)')'LINE  CAN SIZE    CANS        XIJT       QIJT'
      DO 410 I=1,17
410   IF(LINE(I).EQ.1)WRITE(6,'(1X,I2,I9,I12,2F12.2)')I,CAN(I),
     1       INT(CANS(I)),XIJT(I),QIJT(I)
      WRITE(6,'(1X,//,1X,A,F16.2)') 'LABOR', WLABOR(K)
      WRITE(6,'(1X,A,F13.2)') 'CLEAN UP', WCLEAN(K)
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        WRITE(6,'(1X,A,F16.2)') 'WATER', WATER
        WRITE(6,'(1X,A,F18.2)') 'GAS', GAS
        WRITE(6,'(1X,A,F10.2)') 'ELECTRICITY', ELEC
        WRITE(6,'(1X,A,F9.2)') 'CARTON COSTS', CARTCOST
        WRITE(6,'(1X,A,F12.2)') 'CAN COSTS' ,CANCOST
        WRITE(6,'(1X,A,F18.2)') 'LYE', LYE
        WRITE(6,'(1X,A,F17.2)') 'SALT' ,SALT
        WRITE(6,'(1X,A,F13.2)') 'TOMATOES', TOMATOES
        WRITE(6,'(1X,A,F16.2)') 'TOTAL', TOTAL
        WRITE(6,'(///1X,A,F7.0,A,I4,A,I4)')'ACRES:',ACRES,
        1       '  PLANTING DATE1:',IDAY1,'  PLANTING DATE2:' ,
        2       IDAY2
C       END OF WEEK'S WORK OF CALCULATIONS............................
C       NOW TIME FOR TOTALING
        TDAYS=TDAYS+WDAYS
        TXWT=XWT+TXWT
        TXPT=TXPT+XPT
        TLABOR=TLABOR+COST(K)
        TWLABOR=TWLABOR+WLABOR(K)
        TWCLEAN=TWCLEAN+WCLEAN(K)
        DO 420 I=1,17
        IF(LINE(I).GT.0)THEN
                TCANS(I)=TCANS(I)+CANS(I)
                TQIJT(I)=TQIJT(I)+QIJT(I)
                TXIJT(I)=TXIJT(I)+XIJT(I)
        END IF
420     CONTINUE
        TWATER=TWATER+WATER
        TGAS=TGAS+GAS
        TELEC=TELEC+ELEC
        TCARTCOST=CARTCOST+TCARTCOST
        TCANCOST=TCANCOST+CANCOST
        TLYE=TLYE+LYE
        TSALT=TSALT+SALT
        TTOMATOES=TTOMATOES+TOMATOES
        TTOTAL=TTOTAL+TOTAL
        TACRES=TACRES+ACRES
        PTABLE(1,IT)=TDAYS
        PTABLE(2,IT)=SHIFTW(K)
        PTABLE(3,IT)=SHIFTP(K)
        PTABLE(4,IT)=NEMPLOY(K,1)
        PTABLE(5,IT)=ARRIVAL
        DO 430 I=1,7
430     PTABLE((I+5),IT)=QIJT(I)
        DO 440 I=8,12
        IF(TABLE.EQ.2)PTABLE((I+5),IT)=QIJT(I)
440     IF(TABLE.EQ.3)PTABLE((I+5),IT)=QIJT(I+5)
        PTABLE(18,IT)=XWDT
        PTABLE(19,IT)=XPDT
        PTABLE(20,IT)=WLABOR(K)
        PTABLE(21,IT)=WCLEAN(K)
        PTABLE(22,IT)=WATER
        PTABLE(23,IT)=GAS
        PTABLE(24,IT)=ELEC
        PTABLE(25,IT)=CARTCOST
        PTABLE(26,IT)=CANCOST
        PTABLE(27,IT)=LYE
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      PTABLE(28,IT)=SALT
      PTABLE(29,IT)=TOMATOES
      PTABLE(30,IT)=TOTAL
      PTABLE(31,IT)=ACRES
      PTABLE(32,IT)=IDAY+1
10    CONTINUE
C     NOW PRINT OUT SEASON'S TOTAL
      WRITE(6,'(A,A,/)') '1','SEASONS TOTALS'
      WRITE(6,'(1X,A,I2//)') 'DAYS WORKED:',INT(TDAYS)
      WRITE(6,'(1X,A,F12.2)') 'TOTAL COST OF LABOR:', TLABOR
      WRITE(6,'(//,1X,A)') 'LINE  CAN SIZE    CANS         QIJT          XIJT'
      DO 450 I=1,17
450   WRITE(6,'(1X,I2,I8,I13,2F13.2)')I,CAN(I),INT(TCANS(I)),TQIJT(I),
      1       TXIJT(I)
      WRITE(6,'(1X,//,1X,A,F19.2)') 'LABOR', TWLABOR
      WRITE(6,'(1X,A,F16.2)') 'CLEAN UP', TWCLEAN
      WRITE(6,'(1X,A,F19.2)') 'WATER', TWATER
      WRITE(6,'(1X,A,F21.2)') 'GAS', TGAS
      WRITE(6,'(1X,A,F13.2)') 'ELECTRICITY', TELEC
      WRITE(6,'(1X,A,F12.2)') 'CARTON COSTS', TCARTCOST
      WRITE(6,'(1X,A,F15.2)') 'CAN COSTS' , TCANCOST
      WRITE(6,'(1X,A,F21.2)') 'LYE', TLYE
      WRITE(6,'(1X,A,F20.2)') 'SALT' , TSALT
      WRITE(6,'(1X,A,F16.2)') 'TOMATOES', TTOMATOES
      WRITE(6,'(1X,A,F19.2)') 'TOTAL', TTOTAL
      WRITE(6,'(/1X,A,F7.0)')'ACRES:',TACRES
C     PRINT OUT FINAL TABLE
      PTABLE(1,14)=TDAYS
      PTABLE(5,14)=X
      DO 431 I=1,7
431   PTABLE((I+5),14)=TQIJT(I)
      DO 441 I=8,12
441   PTABLE((I+5),14)=TQIJT(I)+TQIJT(I+5)
      PTABLE(18,14)=TXWDT
      PTABLE(19,14)=TXPDT
      PTABLE(20,14)=TWLABOR
      PTABLE(21,14)=TWCLEAN
      PTABLE(22,14)=TWATER
      PTABLE(23,14)=TGAS
      PTABLE(24,14)=TELEC
      PTABLE(25,14)=TCARTCOST
      PTABLE(26,14)=TCANCOST
      PTABLE(27,14)=TLYE
      PTABLE(28,14)=TSALT
      PTABLE(29,14)=TTOMATOES
      PTABLE(30,14)=TTOTAL
      PTABLE(31,14)=TACRES
      WRITE(6,'(A,40X,A,A,I8,A//)')'1','ANNUAL AGGREGATE PRODUCTION PLAN'
      1       ,' FOR PROCESSING',INT(X),' TONS OF TOMATOES'
      WRITE(6,'(A,9X,13I8,A)') ' WEEKS',(I,I=1,13), '     TOTAL'
      WRITE(6,'(1X,A15,13I8,I10)') CTABLE(1),(PTABLE(1,K),K=1,14)
      DO 460 I=2,4
460   WRITE(6,'(1X,A15,13I8,A)') CTABLE(I),(PTABLE(I,K),K=1,13),
      1       '         NA'
      WRITE(6,'(1X,A15,13I8,I10)') CTABLE(I),(PTABLE(I,K),K=1,14)
      WRITE(6,'(1X,A)') 'PRODUCTION (CASES) '
      DO 470 I=6,17
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470   WRITE(6,'(1X,A15,13I8,I10)') CTABLE(I),(PTABLE(I,K),K=1,14)
      WRITE(6,'(1X,/)')
      DO 480 I=18,19
480   WRITE(6,'(1X,A15,13I8,A)') CTABLE(I),(PTABLE(I,K),K=1,13)
      1        ,'         NA'
      WRITE(6,'(1X,/)')
      WRITE(6,'(1X,A)') 'COSTS (DOLLARS)'
      DO 490 I=20,30
490   WRITE(6,'(1X,A15,13I8,I10)') CTABLE(I),(PTABLE(I,K),K=1,14)
      WRITE(6,'(1X,/)')
      WRITE(6,'(1X,A15,13I8,I10/)') CTABLE(31),(PTABLE(31,K),K=1,14)
      WRITE(6,'(1X,A15,13I8,A/)') CTABLE(32),(PTABLE(32,K),K=1,13),
      1        '         NA'
      STOP
      END
```

PROGRAM SECTIONS

	Name	Bytes	Attributes
0	$CODE	10561	PIC CON REL LCL SHR EXE RD NOWRT LONG
1	$PDATA	895	PIC CON REL LCL SHR NOEXE RD NOWRT LONG
2	$LOCAL	9984	PIC CON REL LCL NOSHR NOEXE RD WRT LONG
	Total Space Allocated	21440	

ENTRY POINTS

Address	Type	Name
0-00000000		TOMATO

VARIABLES

Address	Type	Name	Address	Type	Name	Address	Type	Name
2-000023E8	R*4	A	2-000024AC	R*4	ACRES	2-000024A0	R*4	ADDTON
2-000023EC	R*4	B	2-000023F0	R*4	C	2-00002498	R*4	CANCOST
2-000023F4	R*4	D	2-00002450	I*4	DAYSTART	2-00002470	R*4	DIFF
2-000023F8	R*4	E	2-00002488	R*4	ELEC	2-000024B4	R*4	EX1
2-000023FC	R*4	F	2-0000248C	R*4	GAS	2-00002444	R*4	HEAT1
2-00002454	I*4	I	2-000024F4	I*4	IDAY	2-000024B0	I*4	IDAY1
2-00002464	I*4	IT	2-00002458	I*4	K	2-0000245C	I*4	L
2-000023D0	L*1	LOOP	2-00002428	R*4	LYE	2-00002414	R*4	PASTE
2-00002494	R*4	SALT	2-00002418	R*4	SAUCE	2-00002468	R*4	SAUCEPR
2-000023D4	R*4	T1	2-000023D8	R*4	T2	2-000023DC	R*4	T3
2-000023E4	R*4	T5	2-00002460	I*4	TABLE	2-000024F0	R*4	TACRES
2-000024DC	R*4	TCARTCOST	2-00002400	R*4	TDAYS	2-000024D8	R*4	TELEC
2-00002404	R*4	TLABOR	2-000024E4	R*4	TLYE	2-000024A4	R*4	TOMATOE
2-000024A8	R*4	TOTAL	2-000024E8	R*4	TSALT	2-000024EC	R*4	TTOMATO
2-000024D0	R*4	TWATER	2-000024CC	R*4	TWCLEAN	2-000024C8	R*4	TWLABOR
2-000024C4	R*4	TXPT	2-000024F8	R*4	TXWDT	2-000024C0	R*4	TXWT

2-00002490	R*4	WATER	2-00002474	R*4	WDAYS	2-00002410	R*4	WHOLE
2-00002438	R*4	XPDT	2-00002440	R*4	XPT	2-00002434	R*4	XWDT
2-0000244C	I*4	YIELD	2-00002420	R*4	ZPASTE	2-00002424	R*4	ZSAUCE

ARRAYS

Address	Type	Name	Bytes	Dimensions
2-000017F0	I*4	CAN	68	(17)
2-00000140	R*4	CANCALC	20	(5)
2-00001A68	I*4	CANS	68	(17)
2-0000026C	R*4	CAP	68	(17)
2-00000154	R*4	CARTCALC	20	(5)
2-00001878	I*4	CLEAN	20	(5)
2-000018CC	I*4	COST	64	(16)
2-000021F0	CHAR	CTABLE	480	(32)
2-00000040	R*4	DISTRIB	52	(13)
2-00000474	R*4	HITEMP1	1220	(305)
2-00000E40	R*4	HITEMP2	1220	(305)
2-000002B0	R*4	LAMBDA	56	(14)
2-0000190C	I*4	LINE	68	(17)
2-00000074	R*4	LO	68	(17)
2-00001834	I*4	LON	68	(17)
2-000017C8	I*4	LOPT	20	(5)
2-00000938	R*4	LOTEMP1	1220	(305)
2-00001304	R*4	LOTEMP2	1220	(305)
2-00001A54	I*4	NCANS	20	(5)
2-00001950	I*4	NEMPLOY	192	(16, 3)
2-00001A10	I*4	NNEMPLOY	68	(17)
2-0000188C	I*4	OPT1	64	(16)
2-00000320	R*4	PO	340	(17, 5)
2-000017DC	I*4	POPT	20	(5)
2-00001AF0	I*4	PTABLE	1792	(32, 14)
2-000000FC	R*4	QIJT	68	(17)
2-000001A8	R*4	SHIFTP	64	(16)
2-00000168	R*4	SHIFTW	64	(16)
2-00001AAC	I*4	TCANS	68	(17)
2-00000DFC	R*4	TQIJT	68	(17)
2-000001E8	R*4	TXIJT	68	(17)
2-00000000	R*4	WCLEAN	64	(16)
2-0000022C	R*4	WLABOR	64	(16)
2-000000B8	R*4	XIJT	68	(17)
2-000002E8	R*4	Z	56	(14)

LABELS

Address	Label	Address	Label	Address	Label	Address	Label
**	10	0-00001859	12	0-000019DD	13	**	20
**	30	**	40	**	50	**	60
**	90	**	100	**	102	**	104
**	112	**	120	**	140	**	150
**	180	**	190	0-00001320	200	0-0000139D	300
**	310	**	320	**	322	**	324
**	334	**	340	**	345	**	350

```
    **      410        **      420        **      430        **      431
    **      450        **      460        **      470        **      480
```

FUNCTIONS AND SUBROUTINES REFERENCED

Type	Name	Type	Name	Type	Name	Type	Name
	FOR$CLOSE		FOR$OPEN	R*4	MTH$ASIN	R*4	MTH$COS

COMMAND QUALIFIERS

```
  FORTRAN /LIST TOMATO

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(NOSYMBOLS,TRACEBACK)
  /STANDARD=(NOSYNTAX,NOSOURCE_FORM)
  /SHOW=(NOPREPROCESSOR,NOINCLUDE,MAP)
  /F77  /NOG_FLOATING  /I4  /OPTIMIZE  /WARNINGS  /NOD_LINES  /NOCROSS_REFERENCE  /NOMACHINE_
```

COMPILATION STATISTICS

```
  Run Time:          50.16 seconds
  Elapsed Time:      104.25 seconds
  Page Faults:       1008
  Dynamic Memory:    501 pages
```