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ANALYSIS OF BOTTLING AND STORAGE OPERATIONS AT BROWN FORMAN DISTILLERS CORPORATION

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Introduction: This paper describes a simulation model developed for the analysis of the bottling and storage operations and facilities of the Brown-Forman Distillers Corporation in Louisville, Kentucky. The paper evolved from a continuing study of the bottling and storage operations at the Brown Forman bottling facility, which began in the Fall of 1978.

Brown Forman is the largest Kentucky based distiller. In its bottling operation at Louisville it bottles around five hundred different product types on eleven non-identical parallel production lines. The production lines are non-identical in that each product has a preferred processor. The changeover costs of the different products are sequence dependent (the cost of changeover from one product type to the next is dependent on the size, shape, etc. of both the products). The sequence dependent changeover times for the products range from fifteen minutes to eight hours.

The production at Brown Forman at present is scheduled based on orders received. The scheduling is done by an experienced scheduler, who schedules the orders relying only upon his judgement. The advantages of this procedure are obvious; first the inventory is kept to a minimum since the production is scheduled based on actual orders. Second, the scheduler, being experienced, is able to keep track of the inventory position and determine the production requirements reasonably well. The shortcomings to this procedure are that future demands are not estimated and therefore there is a high probability of frequent line changes. These result in high set-up costs and low production efficiencies while production support activities, such as manpower scheduling and the ordering of bottles, packages, etc., are made very difficult. Moreover, the 'efficiency' of the scheduling procedure is dependent upon the presence of the experienced scheduler. Owing to the large set-up costs and production inefficiencies involved, the management at Brown Forman wished to develop a scheduling system which minimized set-up and inventory costs while also satisfying the demand requirements. Such a system was designed by Alexander [1], who utilized an algorithm developed by Driscoll [2] in the scheduling system.

The management at Brown Forman also wanted to analyze some strategic decision alternatives. These are briefly stated below.

1. Addition of a new bottling line.
2. Increasing the present warehouse capacity.

The favorable effects that could be achieved by the first alternative were; a) To increase the capacity of lines which were already running to capacity. b) To reduce inventory costs (management felt that with the addition of one more bottling line there would be sufficient capacity to meet the demand even in the peak months without utilizing any inventory stocks) and, c) To reduce set-up costs. (Set-up costs on some existing lines would be reduced since some products from these lines would be transferred to the new line).

The second alternative was considered because management felt that by increasing the amount of inventory carried, the set-up costs would be reduced and the production efficiency would be increased. Among the inputs management required for the analysis of these alternatives were,

(i) The present utilization of bottling lines
(ii) The storage space required under different scheduling strategies

A simulation model was constructed to provide these inputs to management. This paper details the construction and experimentation with this simulation model. Another input required by management was an analysis of costs. This analysis has yet to be completed.

Model Construction: The model was constructed using GPSS. The model structure is illustrated in Figures 1 & 2. The objectives of the model, as previously stated, were to provide inputs with regard to present line utilization, storage space requirements and line utilization under different scheduling policies. The scenarios constructed using the model studied behavior of the system under present conditions; simulated what would happen if forecasted demands were utilized to preschedule the lines and if demands for the peak months were met in the nearest low demand month. The outputs of the simulation scenarios included line utilizations and minimum, maximum and average stock levels from which the storage space requirements could be calculated.

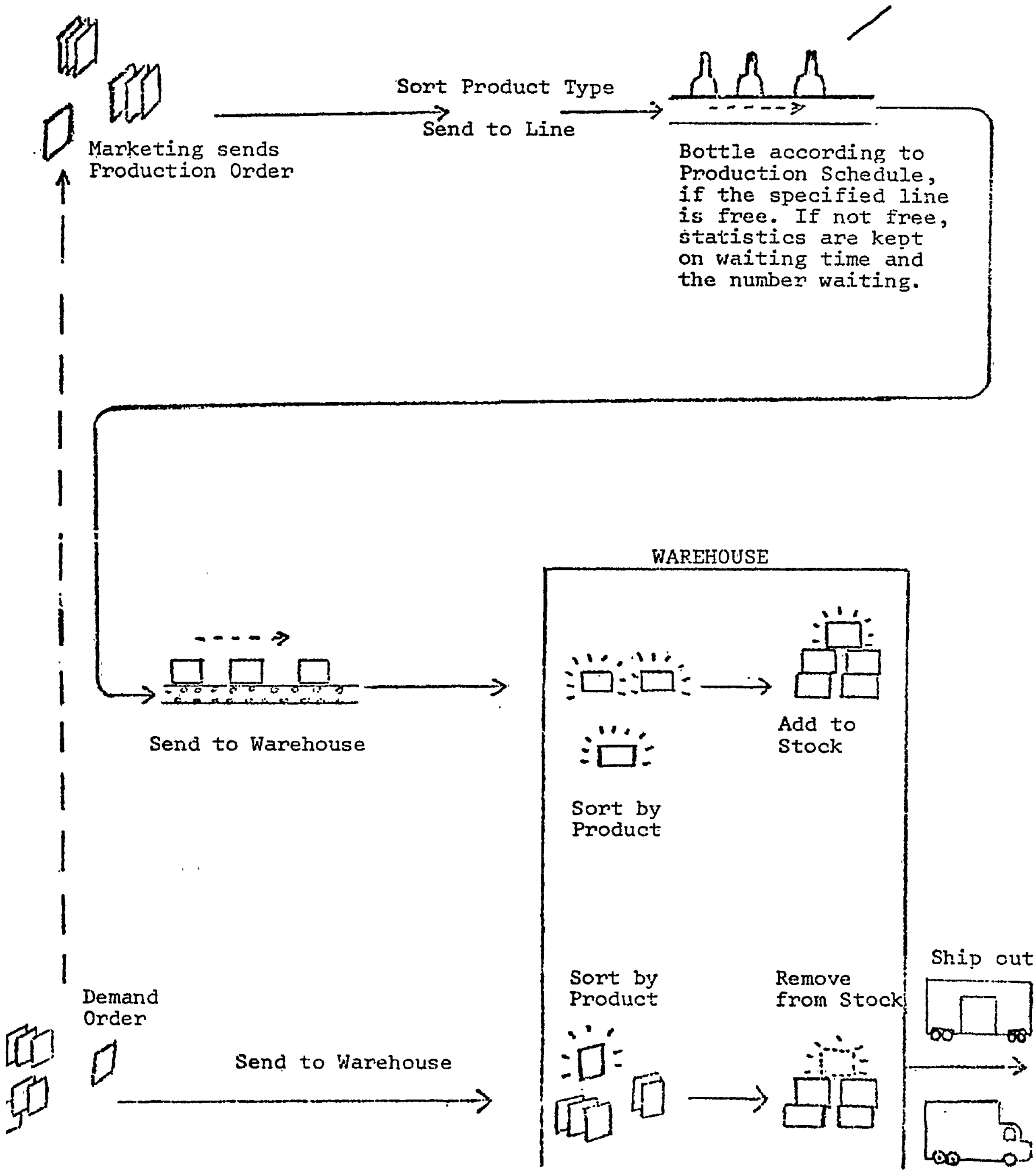


Fig. 1

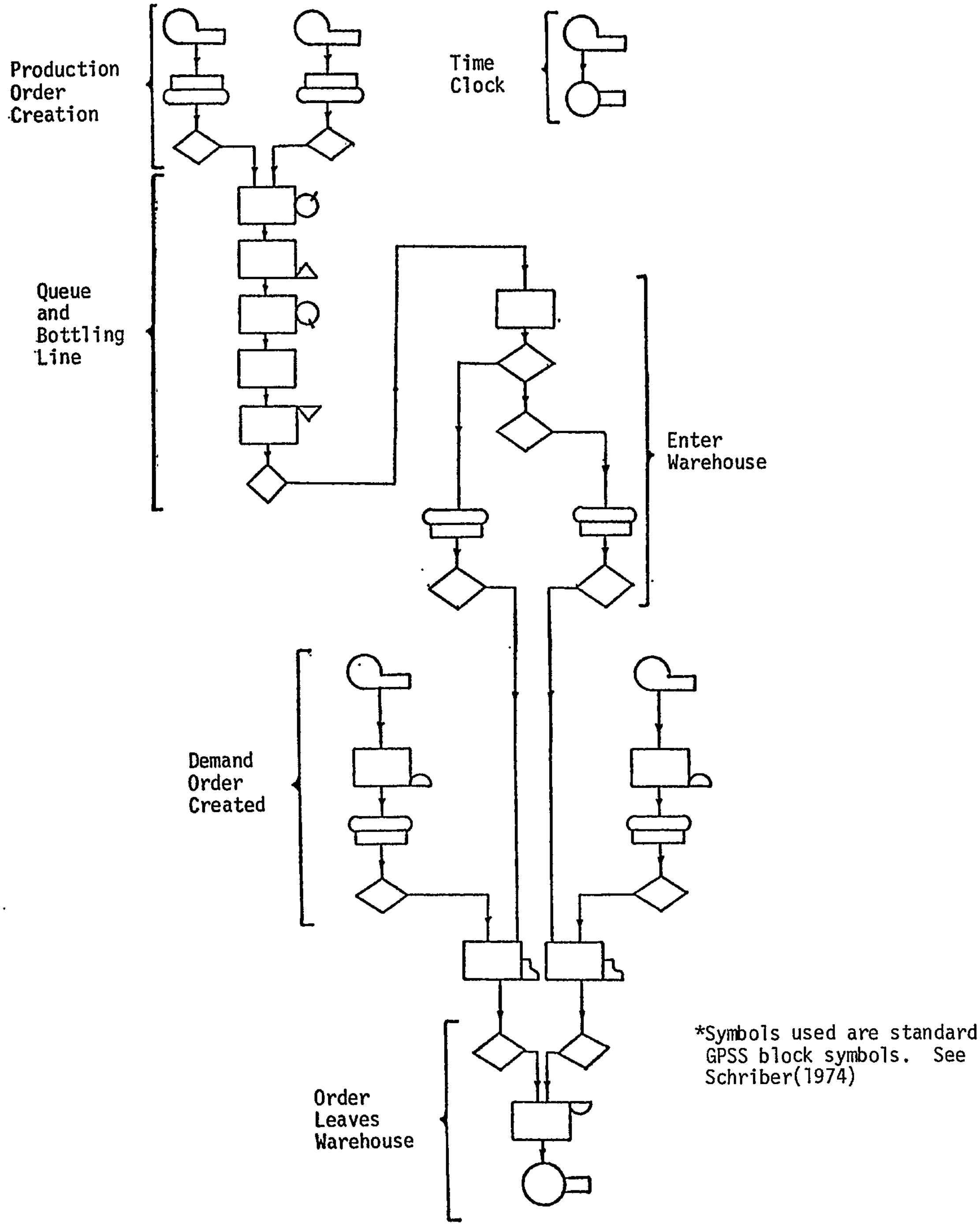
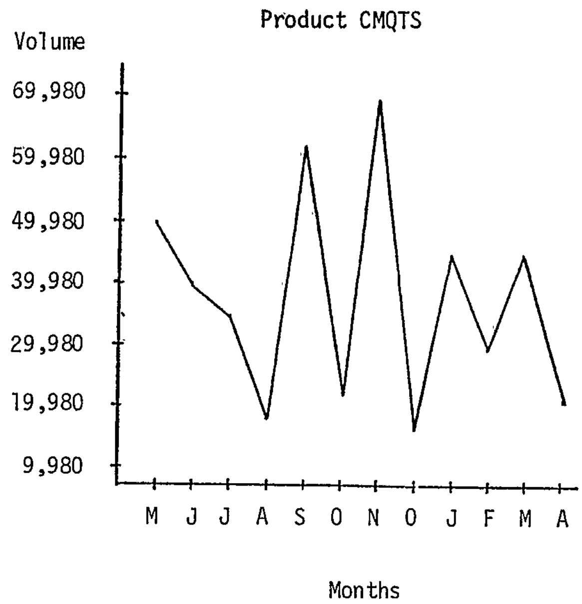


Fig. 2 - GPSS Flow Chart of Line 11*

Data Collection, Analysis, Assumptions: Detailed data on daily demand was available for only one month for products on one production line, although monthly demand data was available for all major product families. The distribution of daily demand for two product families, one of which had detailed data available, while the other did not was assumed to be the same if their monthly demand distributions were similar. The demand distributions of two products having similar monthly demand distributions are illustrated in Figure 3. The demand distributions for most of the products were found to fit the Poisson Distribution by the Kolmgrov-Smirnov test. An example of the test application is illustrated in Tables I & II.



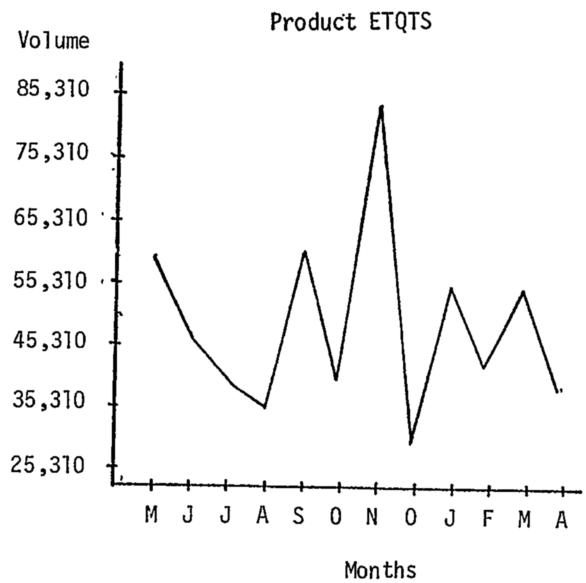


Fig. 3 - Comparison of CMQTS and ETQTS Monthly Demand Distributions

Results From Scenarios: The scenarios listing for all the product lines is too voluminous to include in this paper. The scenario outputs are illustrated by the outputs on Line 11.

The scenarios constructed are described below:
A) Scenario I dealt with the simulation of the production lines under the present philosophy of producing to order. This scenario provides a means of validating the model and also provides insight into the problems related to this operation. In Scenario I the lines were simulated during their low, medium and high volume months. The factor that was looked for in this simulation was the utilization of the lines. Table III illustrates the simulation output for line 11. These results agree with present conditions. Notice that in the high volume month, the line gets overloaded. The present scheduler stocks up for this month so that this does not occur. However, if this did occur, management would schedule overtime production.

B) Scenario II analyses the utilization of a forecasting model for scheduling production. This would greatly enhance the manpower scheduling and supplies ordering function. The forecasting model is

TABLE I

PRODUCT CMQTS DISTRIBUTION FUNCTION

Range j	Demand Order Value - X_i	i	$\overline{X}_j$	Frequency $f(\overline{X}_j)$
1	0,0,690,737	4	356.8	4/20
2	1559	1	1559.0	1/20
3	1870,2020	2	1945.0	2/20
4	2216,2375	2	2295.5	2/20
5	2695,2839	2	2767.0	2/20
6	2947,3319	2	3133.0	2/20
7	4252,4261,4556	3	4356.3	3/20
8	5798,6693	2	6235.5	2/20
9	11040,11110	2	11070.0	2/20

$$E(X) = \sum_{j=1}^{9} \overline{X}_j * f(\overline{X}_j) = 3547.5$$

TABLE II

KOLGOMOROV-SMIRNOV GOODNESS OF FIT TEST

Product: CMQTS

j	$\overline{X}_j$ [1]	$F(\overline{X}_j)$ [2]	F(X) [3]	D [4]
1	.357	.2	.135	.065
2	1.559	.25	.320	.070
3	1.945	.35	.320	.030
4	2.296	.45	.536	.086*
5	2.767	.55	.536	.014
6	3.133	.65	.725	.075
7	4.356	.80	.857	.057
8	6.236	.90	.973	.073
9	11.070	1.0	1.0	0.0

[1] $\overline{X}_j$ is reduced by a factor of 1000

[2] $F(\overline{X}_j)$ is the calculated cumlative probability of $\overline{X}_j$

[3] F(X) is the Poisson cumlative probability of having X or less, where lambda = 3.5

[4] The absolute value of the difference of the cumlative probabilities

* The maximum difference, D, of the cumlative probabilities

TABLE III

SCENARIO I RESULTS OF LINE 11

Bottling Line

Monthly Volume	Number of Entries	Utilization of Line	Average Time/Case to be bottled (.01 min)
Low	38,394	.338	15.89
Medium	69,207	.560	14.59
High *	15,227	.990	15.02

Queue Before Bottling Line

Monthly Volume	Number of Entries	Maximum Contents	% of Zero Value Entries	Average T/C Waiting in Queue(.01 min)
Low	38,394	3	74.7	10.55
Medium	69,207	6	45.8	11.91
High*	15,512	235	0.8	881.72

*Line overloaded in less than three days.

simulated by introducing a production order distribution which is identical to the demand distribution. Forecasting errors would cause overstock and understock with this method of scheduling. The amount of understock would serve as an indicator of the safety stock that would have to be carried for the different products, if this method of scheduling were used. Scenario II results for line 11 are indicated in Tables IV.

TABLE IV

SCENARIO II RESULTS OF LINE 11

Stock Level

Monthly Volume	CMQTS		OFQTS		USQTS		USMLS		PEPQT	
	Final	Entries	Final	Entries	Final	Entries	Final	Entries	Final	Entries
Low	25	16,923	38	5,855	-23	8,008	5	1,845	241	5,621
Medium	-213	45,866	131	7,737	22	11,061	56	4,090	9	452
High	-320	-	81	-	-14	-	19	-	15	-

*Line overloaded in less than three days.

Stock Statistics

Table IV Cont.

Monthly Volume	CMQTS			OFQTS			USQTS			USMLS			PEPQT		
	$\bar{X}$	S	MIN	$\bar{X}$	S	MIN	$\bar{X}$	S	MIN	$\bar{X}$	S	MIN	$\bar{X}$	S	MIN
Low	-145	-17	-400	24	27	-50	-41	33	-110	6	18	-30	96	89	-50
Medium	12	138	-230	102	47	-20	-42	43	-130	20	20	-20	17	13	0
High	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

$\bar{X}$ - Mean S - Standard Deviation Min - Minimum

C) Scenario III considers different strategies for producing demand requirements, for the lines overloaded during the high demand months, in the nearest preceding low volume month. Figure 4 shows the monthly volume for line 11. It can be observed that the month preceding the peak month has a low volume, which would free production capacity to meet some of the peak month demand. The scheduling strategies analyzed were; (i) To increase production requirements in the month preceding the peak month for all products (ii) To completely eliminate selected products from production in the peak month, moving the production of these products to the preceding low month. The argument in favor of this was that it would not only make meeting the demand requirements feasible in the peak month, but would also reduce the total set-up cost in the peak month. Scenario III results for strategy (i) are shown in Tables V and VI and strategy (ii) are shown in Tables VII & VIII. This scenario indicates that moving production from peak month to low months affects the lines positively in terms of utilization. The stock levels however would have to be compared with the available storage space.

The simulation model indicates the effects of various strategies. The outputs of this simulation analysis would have to be included with the economic analyses for management to rationally make its strategic decisions.

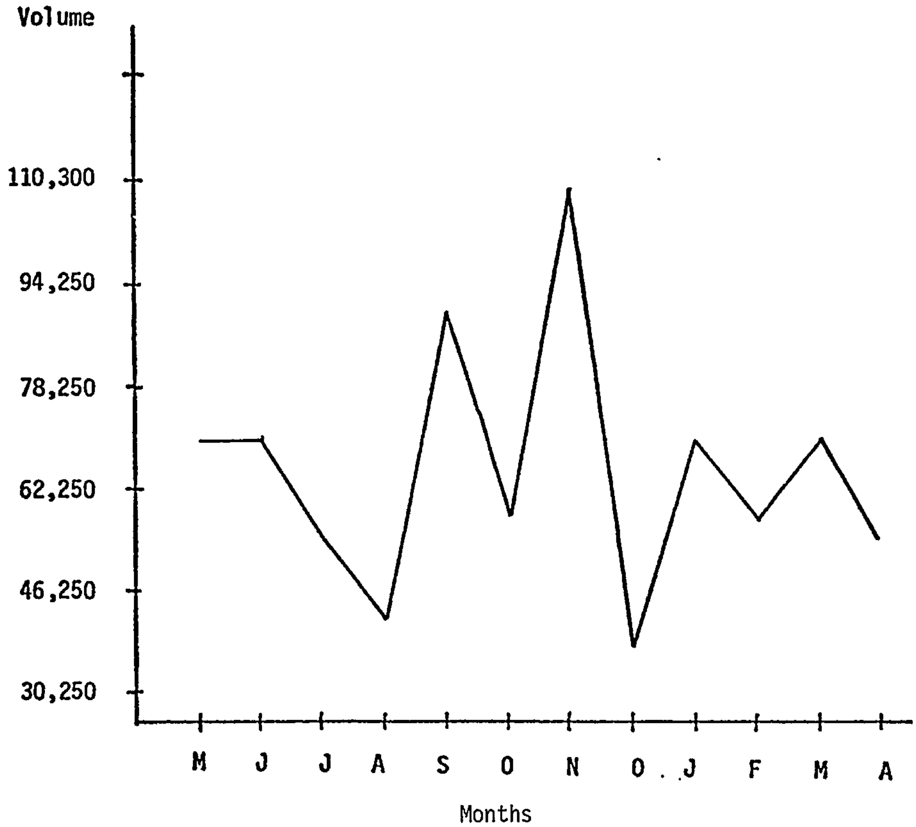


Fig. 4 - Line 11 Total Demand Volumes

TABLE V

SCENARIO III RESULTS OF LINE 11

Bottling Line

A November - orders adjusted, demand normal

B October - orders normal, demand normal

C October - orders adjusted, demand normal

Monthly Volume	Number of Entries	Utilization of Line	Average Time/Case to be bottled (.01 min)
A	88,426	.729	14.85
B	57,101	.506	15.97
C	88,461	.776	15.81

Queue Before Bottling Line

Monthly Volume	Number of Entries	Maximum Contents	% of Zero Value Entries	Average T/C Waiting in Queue(.01 min)
A	88,426	14	28.3	23.58
B	57,101	5	57.9	13.04
C	88,461	15	26.3	30.36

TABLE VI

SCENARIO III RESULTS OF LINE 11

Stock Level

Monthly Volume	CMQTS		OFQTS		USQTS		OSMLS		PEPQT*	
	Final	Entries	Final	Entries	Final	Entries	Final	Entries	Final	Entries
B	-36	23,574	-30	9,594	90	8,992	-45	8,913	-26	6,101
C	14,076	30,695	5928	12,573	5,797	11,811	5,459	11,665	-116	6,146

Stock Statistics

Monthly Volume	CMQTS			OFQTS			USQTS			USMLS			PEPQT*		
	$\overline{X}$	S	MIN	$\overline{X}$	S	MIN	$\overline{X}$	S	MIN	$\overline{X}$	S	MIN	$\overline{X}$	S	MIN
B	-14	138	-320	57	45	-50	-10	30	-80	-10	35	-90	23	43	-90
C	7,174	4094	0	3036	1729	0	2934	1710	0	2802	1576	0	-52	57	-160

*Product PEPQT volume was not adjusted.

$\overline{X}$ - Mean S - Standard Deviation Min - Minimum

TABLE VII

SCENARIO III RESULTS OF LINE 11

Bottling Line

Monthly Volume	Number of Entries	Utilization of Line	Average Time/Case to be bottled (.01 min)
B	88,769	.67	13.59
C	88,215	.835	17.08

Queue Before Bottling Line

Monthly Volume	Number of Entries	Maximum Contents	% of Zero Value Entries	Average T/C Waiting in Queue(.01 min)
B	88,770	10	35.5	16.79
C	88,217	26	19.2	45.20

TABLE VIII

SCENARIO III RESULTS OF LINE 11

Stock Level

Monthly Volume	CMQTS		OFQTS		USQTS		USMLS		PEPQT	
	Final	Entries	Final	Entries	Final	Entries	Final	Entries	Final	Entries
B	-182	20,795	-126	14,812	-144	3,387	0	0	0	0
C	-345	23,679	-120	5,549	8	6,132	17,875	17,916	13,343	15,607

Stock Statistics

Monthly Volume	CMQTS			OFQTS			PEPQT			USQTS			USMLS		
	$\overline{X}$	S	MIN	$\overline{X}$	S	MIN	$\overline{X}$	S	MIN	$\overline{X}$	S	MIN	$\overline{X}$	S	MIN
B	-36	141	-360	-9	70	-150	-50	46	-160	0	0	0	0	0	0
C	-93	95	-345	-8	37	-120	-12	33	-100	8980	5184	0	6729	3858	0

$\overline{X}$ - Mean S - Standard Deviation Min - Minimum

APPENDIX

PRODUCT NAMES, ABBREVIATIONS AND PREFERRED PROCESSORS

Line	Items	Abbreviations
11	Canadian Mist Quarts	CMQTS
	Old Forester Quarts	OFQTS
	Ushers Green Stripe Quarts	USQTS
	Ushers Green Stripe 750 ML	USMLS
	Pepe Lopez Quarts	PEPQT
12	Old Forester Pints	OFPTS
	Ushers 4/5 Pints	UHFPT
	Old Forester 1/2 Pints	OFHPT
	Old Forester 200 ML	OOFML
	Ushers 200 ML	UHMLS
13	Early Times 1.75 L	ETL17
	Canadian Mist 1.75 L	CML17
21	Early Times Quarts	ETQTS
22	Canadian Mist 750 ML	CMMLS
23	Canadian Mist Pints	CMPTS
	Early Times Pints	ETPTS
	Canadian Mist 4/5 Pints	CMFPT
	Early Times 4/5 Pints	ETFPT
24	Early Times 750 ML	ETMLS
	Early Times 700 ML	ETOML
	Old Forester 750 ML	OFMLS
25	Early Times 200 ML	ETTML
	Canadian Mist 200 ML	CMTML

APPENDIX CONT.

PRODUCT NAMES, ABBREVIATIONS AND PREFERRED PROCESSORS

Line	Items	Abbreviations
26	Old Forester Mini	OFMNS
	Canadian Mist Mini	CMMNS
	Early Times Mini	ETMNS
	Pepe Lopez Mini	PEMNS
29	Ushers 1.75 L	USL17
	Old Forester 1.75 L	OFL17
31	Pepe Lopez 750 ML	PPQTS

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