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A DECISION-RULE MODEL FOR BULK TERMINAL MANAGEMENT

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This paper describes the results of a joint effort by Sunmark Industries and Management Decision Systems to address certain management needs in the operation of Sunmark's bulk terminals. Foremost among these is creating product delivery schedules for terminals serving multiple customers. Using decision rules, a model was constructed which, in addition to producing delivery schedules, could be used to simulate the operation of such terminals under various demand requirements. Management uses the model to evaluate how new customers will impact existing customer's inventory balances as well as to study the effects of changes in demand, tank size, and frequency of delivery upon the risks associated with increasing terminal utilization.

1. BACKGROUND

This paper describes some of the results of Sunmark's efforts to develop decision support systems for supply and distribution management. While these efforts have produced a number of models which are currently being used to address a variety of operating and planning questions, this paper will focus only upon the operating needs of terminals which serve multiple customers.

Most major oil companies have large distribution networks constructed over the past 50 years or more. Bulk terminals have primarily been designed to serve a company's own markets. Nevertheless, today it is common to find terminals supplying many customers as demographics and marketing efficiencies have favored particular terminal locations.

As the marketing and distribution subsidiary of Sun Company, Sunmark Industries operates over 50 bulk terminals over the eastern half of the United States. Approximately half of these currently serve independent or throughput customers which include other majors. Typically, these customers have co-mingled inventories. Any products which are co-mingled must meet minimum specifications established by the terminal operator. Products most often co-mingled today are regular gasoline, unleaded regular, and number two fuel oil.

A throughput customer is often interested in securing lighterage service to reduce trucking costs. A company with sales which are too low or too seasonal to justify the capital investment associated with maintaining or constructing a terminal also finds a throughput agreement attractive. On the other hand, it is in the interest of a terminal operator to increase utilization whenever possible.

Finally, as one would expect, there are some business risks associated with higher utilization of bulk terminal facility. Since most agreements of this type call for co-mingled product, higher utilization increases the probability that one or more customers will be in a negative book balance condition. With the cost of product approaching $50 per barrel, the terminal operator must continually be aware of exposure to negative book inventories as well as other risks as terminal volume increases.

2. PROBLEM DEFINITION

In view of the time and manpower needed to do an adequate job of scheduling deliveries for multiple customer terminals, it was obvious that a model or system was required. In this instance, a good deal was understood about the problem from the beginning. Management had certain requirements or 'rules' which were used to develop schedules. The question was, "Could these rules be used to build a model which

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would not violate any of the conditions imposed by management?"

The problem then became one of formalizing existing decision rules and enough supplemental conditions to permit the creation of a model. The following is a summary of the rules and conditions in use as the model was initially considered.

1. Total inventory levels in a tank should fall between safe, fill, and safety stock levels;

2. Tank storage permitting, a delivery should be made whenever a customer's inventory falls beneath a predetermined level;

3. Unnecessary deliveries into a terminal should be avoided;

While these guidelines are not comprehensive enough to define a model, they do provide a reasonable starting point. After some discussion, it was agreed that Rule 3 certainly needs some expansion. It may be restated as follows:

3. (Restated) Deliveries into the terminal should not unduly tie up storage capacity since the operating company's options to use any excess capacity will be reduced;

The restatement of Rule 3 is in the interest of the operating company. Flexibility is necessary to permit last minute changes in deliveries. The risk of runout is met through proper safety stock levels. The risk of an early delivery is addressed by requiring deliveries only when Rules 1 and 2 are invoked.

3. THE MODEL

A chronological presentation of additional rules adopted during the process of building the model is in order since many aspects of the problem were identified only after the commencement of model building activities. Also, this is a likely and natural development because formalization of the solution to the scheduling problem itself introduces new considerations which may not frequently be encountered in an operational mode.

This point was apparent as soon as Rules 1, 2 and 3 were applied. For example, suppose two or more customers all had inventories beneath acceptable levels. Should more than one delivery be scheduled during the same day? How should the demurrage risk be incorporated into the model? Without further elaboration, the following additional rules were established during the first few hours of building the model.

4. If several customers have book inventories beneath minimum allowable levels, the customer with the highest credit risk should be the first to bring product in;
5. If no customer is beneath minimum allowable inventory levels but the total inventory on hand is beneath safety stock levels, the customer with the lowest inventory should be the first to bring product in;
6. To reduce the risk of demurrage, only one delivery will be allowed per day.

These supplemental rules are sufficient to complete the model. Programming of the model was done in Management Decision Systems' EXPRESS--an interactive model-building language incorporating database, display, and analysis capabilities. Because the model was easy to construct in EXPRESS using the decision rules, it was up and running in its initial form in one day. A generalized flow diagram is shown in Fig. i.

4. USING THE MODEL

Once the model had been implemented, one additional refinement was needed before it could be used to produce delivery schedules. It is necessary to be able to pre-schedule customer's deliveries for part of the 45 to 60 day future period. This is to accomodate pipeline, barge, and tanker schedules which are often fixed several weeks in advance.

This capability was added and Sunmark began using the model to produce schedules. During the first few weeks, questions were raised which did necessitate some minor changes. However, on the whole, the model was well suited to providing useful scheduling information.

An example of a typical application of the model is shown in Figures ii through v. This example is for a 60,000 barrel (60k bbl) storage facility with initially 3 customers. The major throughput customer (Customer 1) has a schedule which is fixed over the next several weeks. The problem here is to evaluate the addition of a new customer (Customer 4).

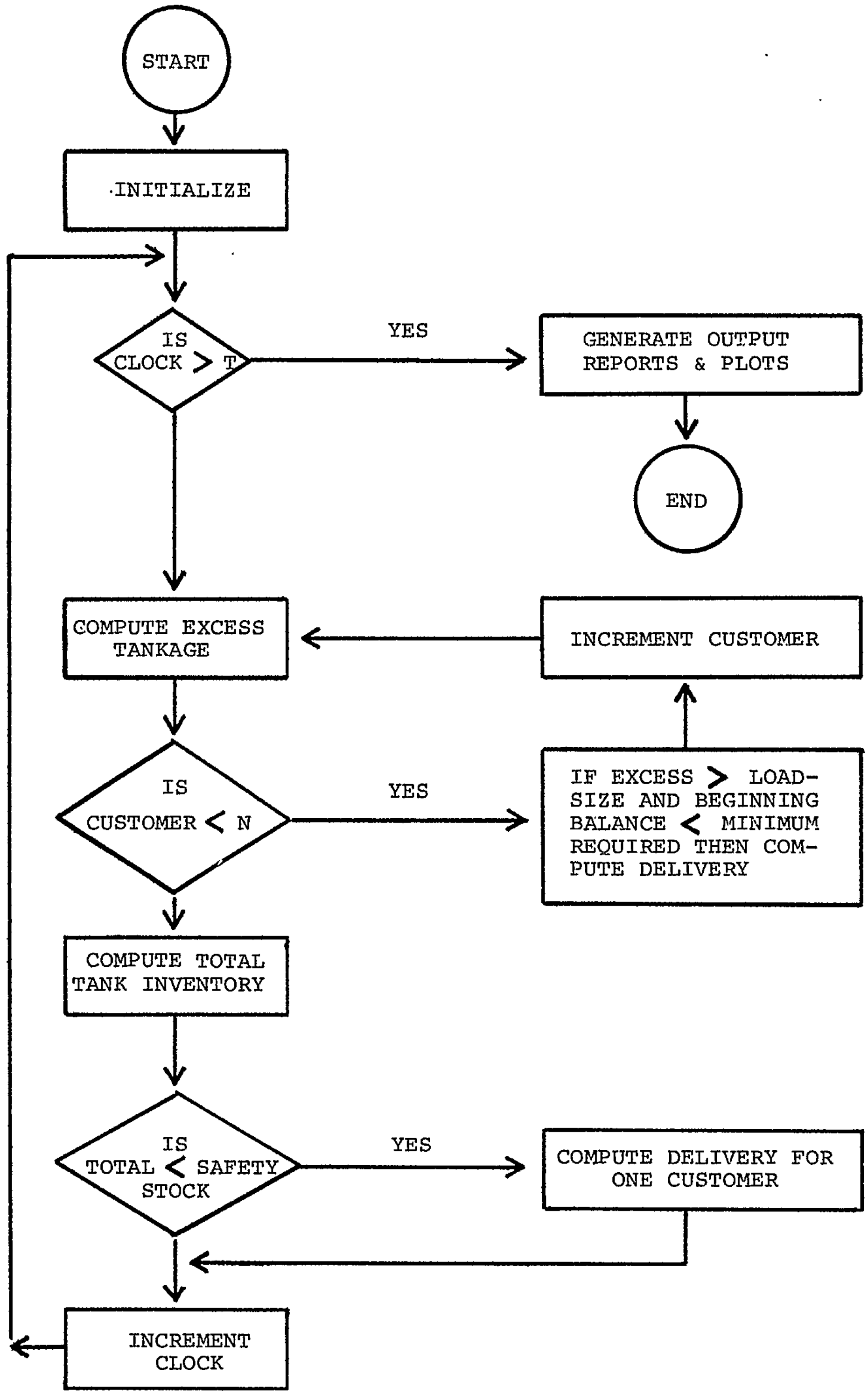

Fig. i
Generalized Flowchart

Case 1 is the initial run with conditions summarized in Fig. ii and the results shown in Fig. iii. Customer 1 has 30k bbl deliveries into the terminal beginning on Day 1 and continuing every 5 days thereafter. Customer 4 is a new customer under consideration. In Case 1, he is allowed to run a negative book balance of -10k bbl. His average daily demand is 4k bbl and he asks to receive product in 30k bbl barge shipments. He is assigned a credit ranking of 2 and an initial balance of 11.5k bbl through a spot purchase from another customer.

In Fig. iii, the inventories shown, except for a safety stock of 0, are realistic. Under these conditions, there is little problem in maintaing satisfactory inventory levels and the schedules could be used as is.

Suppose the operating company wishes to reduce the risk of exposure to negative book balances. This can be accomodated by raising the minimum allowable inventory levels as shown in Fig. iv under Case 2. In Fig. iv, it is observed that the negative book balances of Customer 2 have been largely eliminated. However, Customer 4 was unaffected. This suggests that we are up against tank size limitations. A closer look shows the beginning balance of Customer 4 on Day 5 to be -4.5, not low enough to trigger a delivery. Since Customer 1 has prescheduled deliveries on Day 6, Customer 4 cannot bring product in until Day 7.

One of the most controllable variables in bulk product distribution is load size. Suppose Customer 4 agreed to receive 20k bbl deliveries instead of 30k bbl loads as shown in Fig. ii under Case 3. Could his book balances be brought closer to zero? Fig. v shows the results. Although some negative book balances still exist, the situation has improved. A characteristic of the model is to 'correct' undesirable mixes of inventories which are often present in the initial conditions.

While reductions in a customer's load sizes could improve inventory levels, other remedies may be considered. An increase in tank storage could be evaluated, especially if this increase involves an inexpensive switching of tanks rather than construction of new capacity. Another option is to alter Customer 1's schedule by delaying all shipments one day. These kinds of questions are continually raised as this model is employed by Sunmark's personnel.

5. OTHER RESULTS

To get some idea about the behavior of the model in a variety of operating conditions, additional studies were undertaken. A series of trials were done under conditions in Fig. vi. Here it is assumed all customers have the same minimum allowable inventory and the same loadsize.

One would expect two extreme operating environments. The first is storage constrained and is characterized by all deliveries being triggered by runouts. The second is unconstrained and is characterized by all deliveries being triggered by each customer's own inventory falling beneath minimum allowable levels. Because we have limited deliveries to one delivery per day, this second condition cannot be attained here.

Fig. vii shows the average inventory level in the tank for various size tanks. This average is over all days (60 each trial) and over the entire range of customers (1 to 9). Because we have limited deliveries to one per day, larger tank storage does not allow us to substantially increase average inventory.

Fig. viii shows the improvement resulting from an increase in tank storage for various customer levels. The curves depict the average negative book inventories to the extent that they fall beneath allowable minimums. This is a basis for accessing the potential costs associated with increasing throughput volume with or without increased storage.

Finally, Fig. ix shows the result of increasing the minimum allowable balance. Here, each customer is required to keep a balance of 5k bbls. When the customers are increased from 6 to 7, storage capacity is no longer sufficient to keep all customers above minimum allowable levels. Since higher credit ranking customers are given the first opportunity to deliver product, the lower risk customers are bypassed. It is evident that desired minimum inventory levels cannot be maintained at this level of activity for all customers.

6. CONCLUDING REMARKS

The decision rule model to produce bulk terminal delivery schedules for terminals with multiple customers has proven to be effective and easy to use. Using EXPRESS programming took less than two days. The model, in addition to producing schedules, is used to simulate the operation of the terminal under a variety of demand, capacity, and credit conditions.

CUSTOMER INITIAL CONDITIONS: CASE 1

	1	2	3	4 (NEW)
STARTING INVENTORY	3.4	1.0	7.6	11.5
MINIMUM ALLOWABLE	-10.0	-5.0	0.0	10.0
AVERAGE DAILY DEMAND	6.0	2.0	1.0	4.0
DELIVERY LOAD SIZE	30.0	15.0	15.0	30.0
CREDIT RANKING	1.0	3.0	4.0	2.0

CUSTOMER INITIAL CONDITIONS: CASE 2

	1	2	3	4 (NEW)
MINIMUM ALLOWABLE	-10.0	0.0	0.0	-5.0

CUSTOMER INITIAL CONDITIONS: CASE 3

	1	2	3	4 (NEW)
MINIMUM ALLOWABLE	-10.0	0.0	0.0	0.0
DELIVERY LOAD SIZE	30.0	15.0	15.0	20.0

Fig. ii

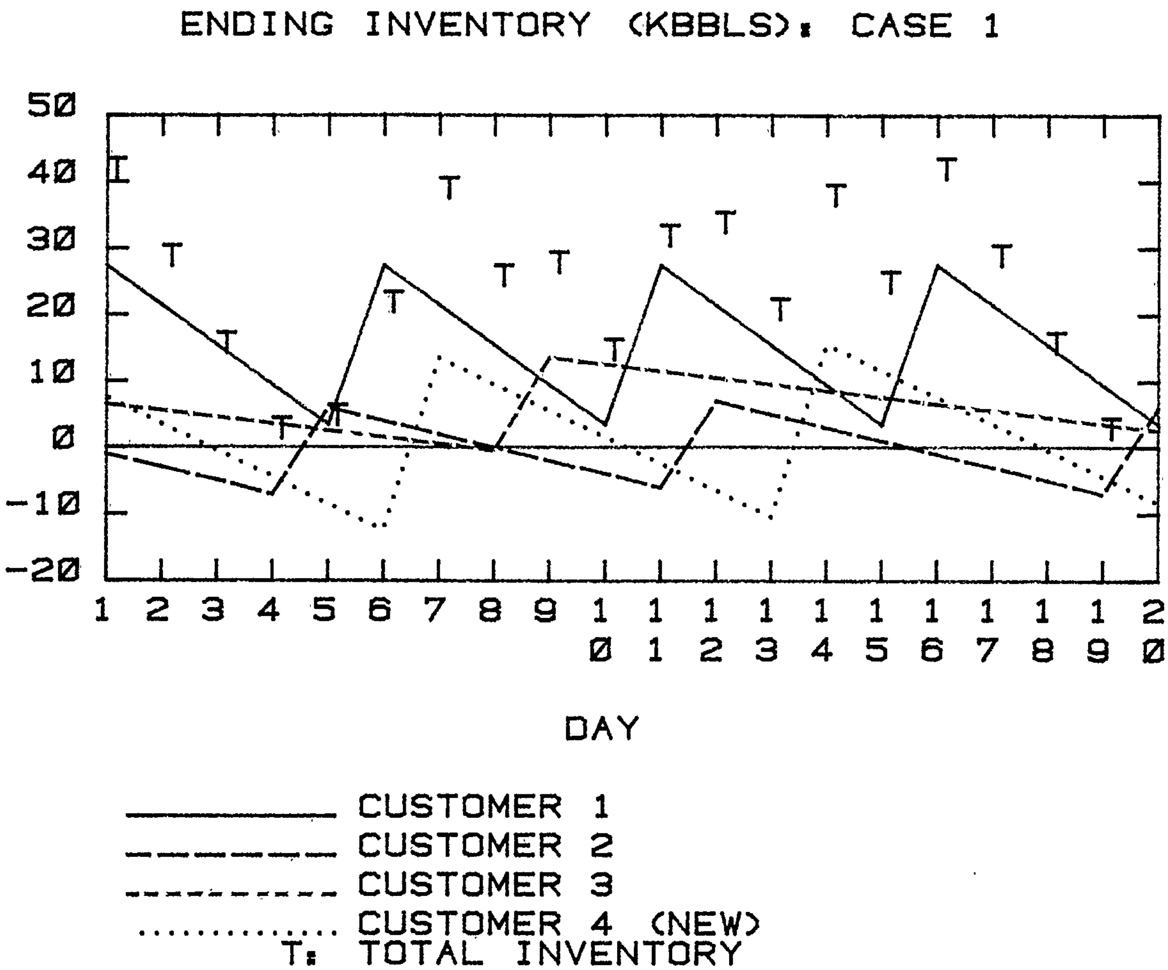
ENDING INVENTORY (KBBLS): CASE 1
50
40
30
20
10
Ø
-10
-20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
DAY
CUSTOMER 1
CUSTOMER 2
CUSTOMER 3
CUSTOMER 4 (NEW)
T: TOTAL INVENTORY

Fig. iii

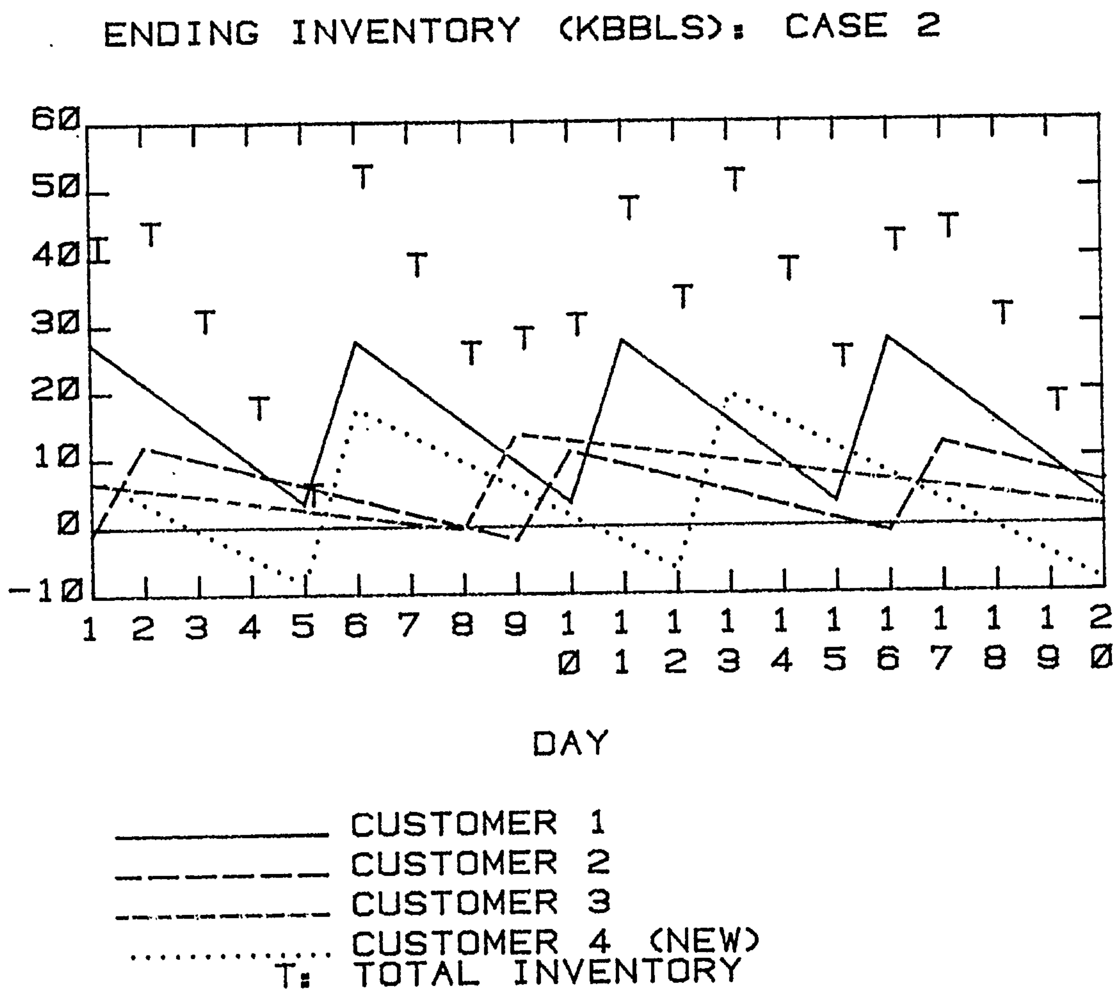
ENDING INVENTORY (KBBLS): CASE 2
60
50
40
30
20
10
0
-10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
DAY
CUSTOMER 1
CUSTOMER 2
CUSTOMER 3
CUSTOMER 4 (NEW)
T: TOTAL INVENTORY

Fig. iv

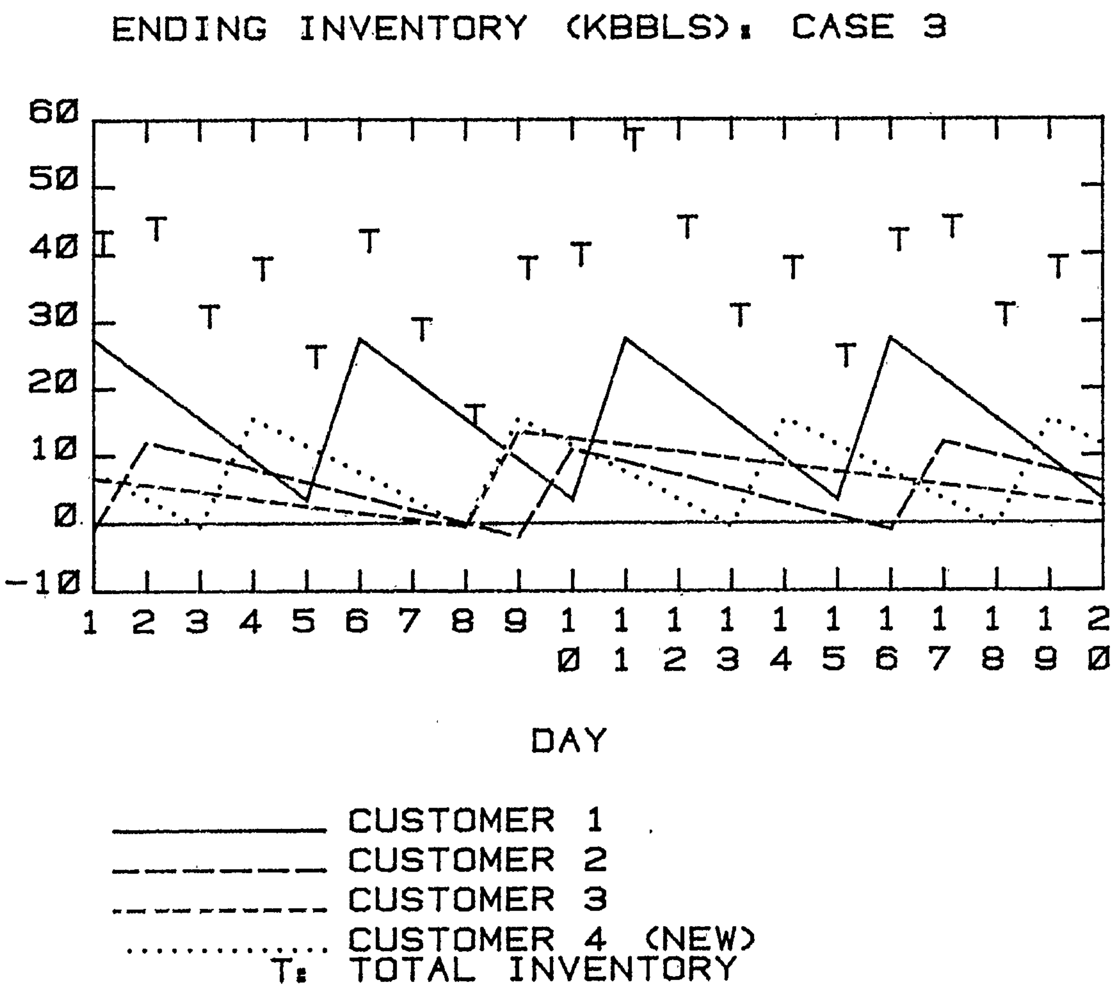
ENDING INVENTORY (KBBLS): CASE 3
60
50
40
30
20
10
0
-10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
DAY
CUSTOMER 1
CUSTOMER 2
CUSTOMER 3
CUSTOMER 4 (NEW)
T: TOTAL INVENTORY

Fig. v

CUSTOMERS	1 through 9
LOADSIZE	50k bbl
DEMAND	5k bbl/day
TANK SIZE	60,80,100,120,160,200k bbl
MINIMUM ALLOWABLE INVENTORY	-10k bbl

Fig. vi
ASSUMPTIONS FOR SERIES OF TRIALS SHOWN IN FIGURES vii-ix

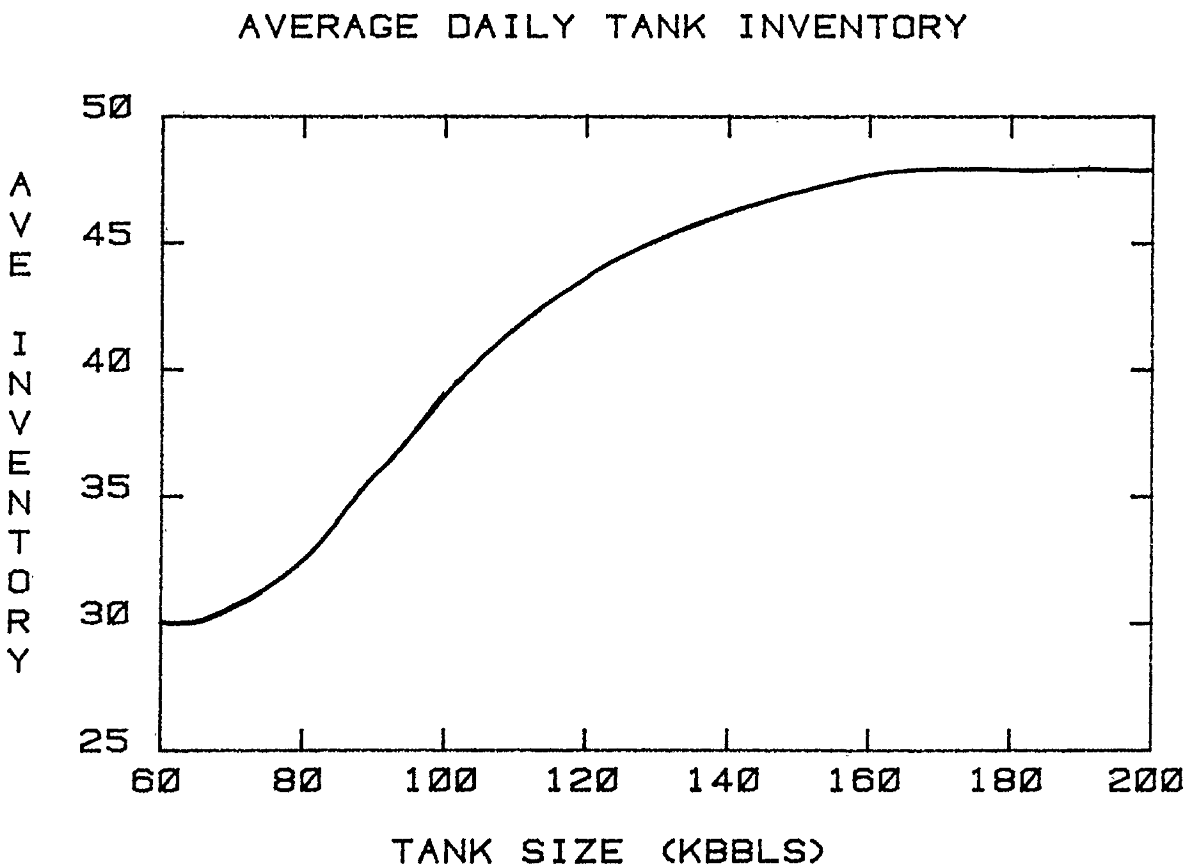
AVERAGE DAILY TANK INVENTORY
AVE INVENTORY
50
45
40
35
30
25
60
80
100
120
140
160
180
200
TANK SIZE (KBBLS)

Fig. vii

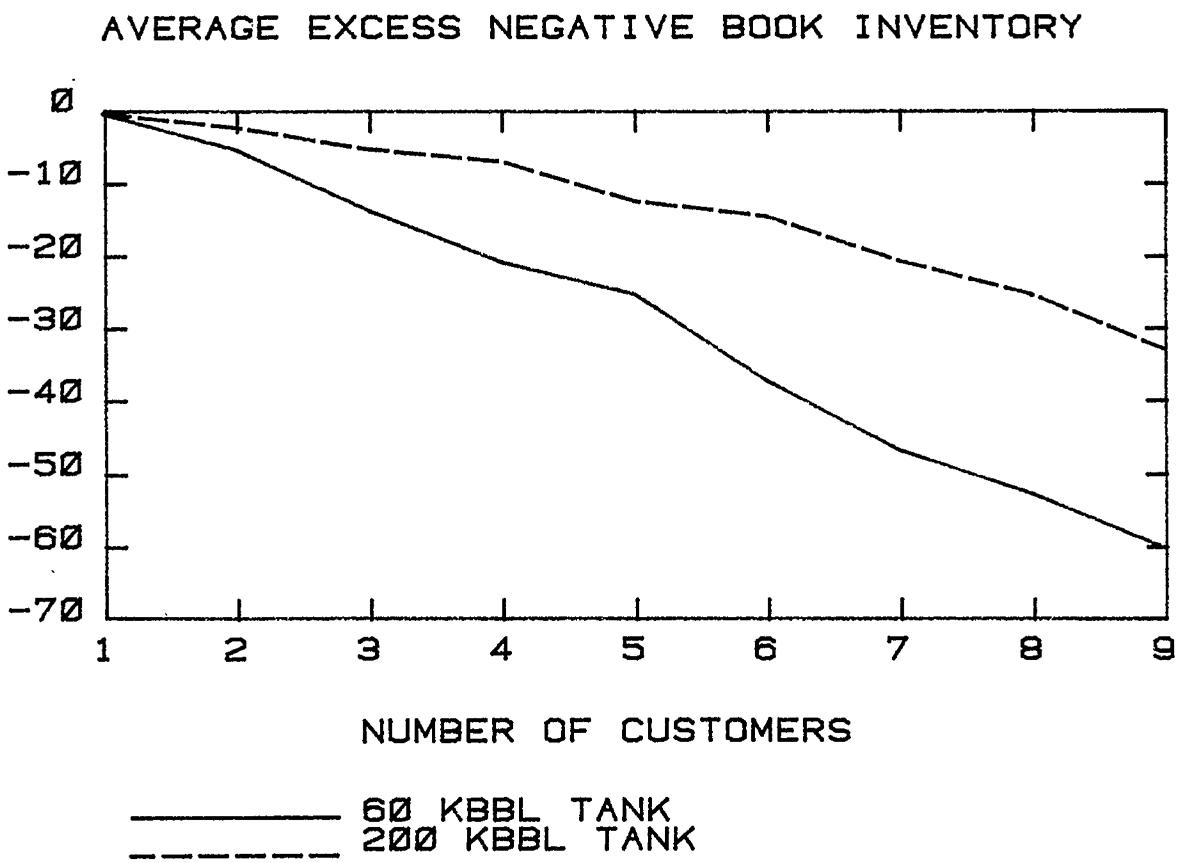
AVERAGE EXCESS NEGATIVE BOOK INVENTORY
0
-10
-20
-30
-40
-50
-60
-70
1
2
3
4
5
6
7
8
9
NUMBER OF CUSTOMERS
60 KBBL TANK
200 KBBL TANK

Fig. viii

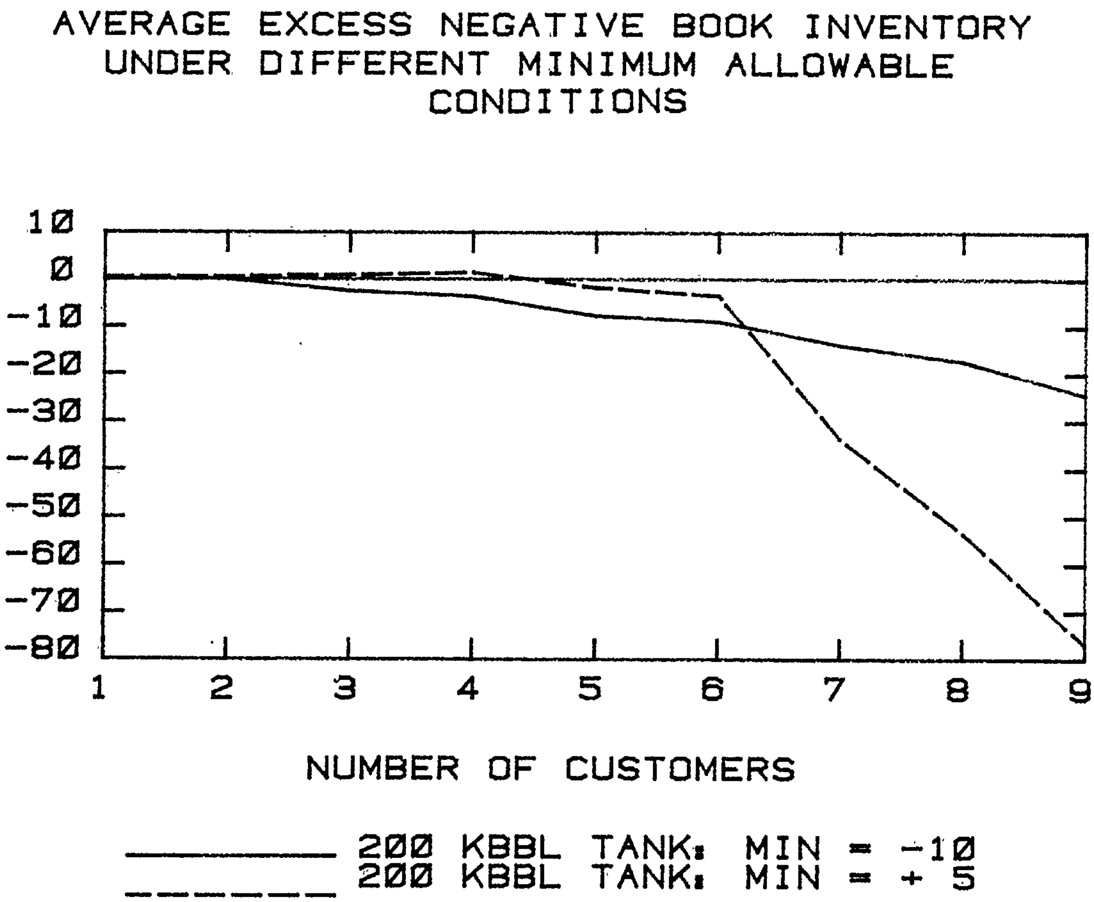
AVERAGE EXCESS NEGATIVE BOOK INVENTORY
UNDER DIFFERENT MINIMUM ALLOWABLE
CONDITIONS
10
0
-10
-20
-30
-40
-50
-60
-70
-80
1
2
3
4
5
6
7
8
9
NUMBER OF CUSTOMERS
200 KBBL TANK: MIN = -10
200 KBBL TANK: MIN = + 5

Fig. ix