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AN EMPIRICAL ANALYSIS OF A USAF ECONOMIC ORDER QUALITY PARAMETE--ETC(U)
SEP 78 J CARRILLO, D G PEABODY

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AN EMPIRICAL ANALYSIS OF A USAF ECONOMIC ORDER QUANTITY PARAMETER

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Donald G. Peabody, Captain, USAF

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This thesis effort looked into some of the inventory policies involved in managing United States Air Force expendable supply items. The general theory that is used is the economic order quantity (EOQ) as used by the Air Force Logistics Command which is a modification of the Wilson Lot size formula. The primary policy issue which was addressed was the holding cost factor of the EOQ formula. To predict the results of policy changes, an inventory simulation model, Inventory System Simulator, was employed. This model took data from Oklahoma City Air Logistics Center files for the period of Fiscal Year 1971—1975 and projected total costs per year of the sampled items in procurement costs, carrying costs and backorders. Output from the model is displayed in tabular and graphical form. The effort resulted in an analysis of the general trends that can be expected when holding cost policy is changed.

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AN EMPIRICAL ANALYSIS OF A USAF ECONOMIC ORDER QUANTITY PARAMETER

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

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Chapter 1

OVERVIEW

Introduction

Expendable supply items comprise 70 percent (3:23) of the Air Force Logistic Command's (AFLC) inventory and are valued at approximately $1.8 billion. Annually, an estimated 515,800 Economic Order Quantity (EOQ) items costing over $733 million are required. The size and importance of this inventory pose significant challenges to AFLC management due to its dynamic growth (10; 14). Defense expenditures have increased steadily over the past decade. More sophisticated weapon systems have caused spiraling costs in both their procurement and sustained support. A part of the burden of Air Force material management, at depot level, falls upon the Air Logistics Center (ALC) (16).

The Air Force has placed increased emphasis on the study and evaluation of management concepts and techniques used by the ALC in computing EOQ. To minimize excess inventories and stock-outs which are costly, AFLC mounted an extensive analysis to investigate the feasibility of identifying those areas of holding costs which might lend themselves to more accurate determination. The rationale for analyzing holding cost factors was "that any increased accuracy that could be obtained would be used to calculate a more accurate and, therefore, lower cost EOQ [2:45]."

Statement of the Problem

Considering the value of inventories maintained within AFLC and the ever increasing emphasis on lower spending by the military, it is essential that AFLC managers be able to examine the effects of various policy decisions prior to the implementation of those policies. This would allow managers to select the most effective policy for the given circumstances. One area in which this approach has not been used is in the selection of the holding cost factor used in calculating EOQ (16).

The EOQ calculations resulting from the holding cost policy affects not only the total inventory on hand, but also the total carrying costs incurred and, possibly most important, the back orders experienced by the users, the base supply activities. At present, no easily accessible tool is available for AFLC managers to assess the effect of a holding cost policy on these factors.[1]

---

[1]This was confirmed by a search of the literature and interviews with the AFLC Director of Material Requirements office and the Director of Management Science office. The search included the Defense Documentation Center (DDC), the Defense Logistics Studies Information Exchange (DELSIE), the Air Force Business Research Management Center (AFBRMC), the Air Force Institute of Technology (AFIT) faculty, and the AFIT Branch Air University Library including periodical literature, memorandums, and AFIT theses.

Operational Definitions

Focusing on the scope of this study, only the following definitions were considered:

1. Backorder—a demand not satisfied; a shortage (4:83).

2. Buy dollar—budgeted appropriations made available for procurement (16).

3. Carrying cost—normally considered synonymous with holding cost; however, in this study, it refers to costs resulting from policy decisions (16).

4. Demand—a valid requirement for material placed upon the supply system by an authorized customer (1:2).

5. EOQ—the quantity to order which will minimize the computed total annual costs described by the Wilson Lot-Size model (5:11).

6. Frequency of demand—number of requisitions submitted by authorized users for a National Stock Number (NSN) item over a specified period (7:VII-7).

7. Holding cost—the cost of holding an inventory. Included in these costs are insurance, taxes, breakage, pilferage, warehouse operations, opportunity and obsolescence cost (cost alternative investments) (5:111).

8. Implied shortage cost—the assumed cost of a shortage based on management decisions relative to the number of days of forecast delay in availability of material or funds available for inventory level. Cost per year per shortage (9:B-42).

9. Serviceable return—an NSN item returned to the ALC from the user which can be reissued to another authorized user (7:VII-7).

Background

AFLC provides management direction for USAF centrally managed, expendable supply items in accordance with Department of Defense Instruction (DODI) 4140.39. AFLC responsibility includes providing general policies for buying expendable items in order to "insure maximum results in terms of supply availability and economy." The EOQ equation is the tool used to accomplish this purpose (1:1). The quantity derived from the EOQ equation provides the most economical quantity to order at one time.

The ALCs of AFLC provide the direct item management of the centrally managed, expendable items (1:1-2). Information on an expendable item is fed into the computer each time a transaction involving that item occurs and, using the AFLC D062 Buy Computation Program, the status of the item inventory is determined. When stock levels of the item reach a designated minimum value, a buy quantity is calculated, using the EOQ equation, and the desired quantity is ordered.

The factors considered in the EOQ equation,

$$EOQ = \sqrt{\frac{2AC}{H}}$$

are the demand quantity over a specified period (A), the cost of ordering (C), and the holding cost factor (H). This formula, referred to as the Wilson Lot-Size formula, is the classical formula for computing order quantity (11:29-40). The basic Air Force EOQ computation is similar to the classical EOQ formula; however, derivation of the factors (A, C, and H) that make up the formula does vary (1:7). A noticeable difference exists in the calculation of the holding cost. "Industry usually computes holding costs as a percentage of on-hand inventory for each item in the inventory system [2:45]," while the Air Force computes it as a percentage of the total inventory at each ALC (16).

This study centers on the holding cost portion of the equation. The holding cost and the factors that make up holding cost are expressed as a percentage of the total cost of the items. The holding cost is a consolidation of the various costs of maintaining a stock level of items. The factors that make up the holding cost are storage costs, opportunity costs of money invested, and obsolescence costs. AFLC has established constant rates for opportunity cost and storage cost of 10 percent and 1 percent respectively (17:Encl.4:1). The third factor, obsolescence cost, is calculated separately for each ALC. This factor is determined by the formula, $OB = \frac{D}{I}$, where D is the value of items that have been disposed of during the last year by the ALC, and I is the dollar value of on-hand and on-order inventory assets for the ALC (16). The disposals represent items discarded due to technical obsolescence, excesses, deterioration, and other causes. The obsolescence factor is included in the computation of EOQ as a damper to decrease the order quantity on items that are becoming obsolescent before they can be issued for use. AFLC policy concerning disposal has been adjusted in recent years to insure items are not disposed of if they are still usable by other authorized U.S. government agencies. This has generally decreased the obsolescence factor and resulted in a change in the holding cost factor of the EOQ equation from 32 percent in 1974 (5:4) to the current low at one ALC of 16 percent (1:11-17).

In assessing the holding cost factor, one must consider many basic management principles which are relevant and impact upon the subsequent EOQ calculations. Of particular interest to this research effort is the application of Pareto's Law to the annual demand rate. Pareto's Principle of Maldistribution states:

> Very often a small number of important items dominate the results while at the other end of the line are a large number of items whose volume is so small that they have little effect on the results [9:10].

To enhance management of high value items, AFLC has categorized EOQ items based on their dollar-demand rate; that is, based on item cost times the annual demand. These value categories are assigned Supply Management Grouping Codes (SMGC), each with its own management criteria. This code "denotes the category in which an item is managed and the degree of management intensity required [1:1]." Total demands (recurring, Foreign Military Sales, and nonrecurring) not including serviceable returns are used to determine the SMGC. The projected annual demand rate is the basis for grouping all EOQ items into the four groupings below.

1. SMGC code X for projected annual demand rate of \$0.00—\$500.00.

2. SMGC code T for projected annual demand rate of \$500.01—\$5000.00.

3. SMGC code P for projected annual demand rate of \$5000.01—\$50,000.00.

4. SMGC code M for projected annual demand rate greater than \$50,000 (1:1).

These groups have been combined in other studies in an attempt to assist in the management of the EOQ items (16).

AFLC has been faced with questions regarding the validity of its procedures for calculating EOQ, including its methods of obtaining the holding cost (2:45). Studies that have been conducted have recommended changes to the current system. One of these studies was an AFIT thesis effort which addressed holding cost as a factor in the construction of an inventory model. Conclusions from this effort included the recommendation that technical obsolescence and shelf life be assessed to determine their effect on the inventory quantities (12:73).

Another study accomplished by the Air Force Academy in 1975 generally evaluated the EOQ calculations and recommended further study into the obsolescence factor. In the specific investigation of EOQ techniques to obtain price discounts, a recommendation was made to AFLC that consideration should be given to using a variable obsolescence factor instead of a constant value (2:49).

These studies have prompted AFLC managers to express concern about the ability of the present EOQ computation system to provide the most effective order quantities. This concern has manifested itself in a search for improving the EOQ formula in its entirety or by analyzing each of the individual parts (16). In further efforts to determine the effect of policy actions, AFLC contracted for the development of the Inventory System Simulator (INSSIM) model. This model employs the DO62 computation procedures, currently in use by AFLC, and actual demand history to provide a realistic simulation of AF requirements. This model was designed to allow users to adjust factors within the program and thus allow analysis of various facets of the system (7:I-1 to I-3).

This research effort was designed to provide AFLC managers with more information that can be used in establishing EOQ policy. The INSSIM model was used to predict behavior of the system and develop tools for AFLC managers to use in evaluating the effectiveness of proposed policies. The information generated by this model includes backorders and total carrying costs. With backorder information, managers would be better able to predict the backorders expected to occur once they had received the approved EOQ acquisition budget for a given year. With this knowledge, they could determine if the resulting backorder levels were within acceptable ranges or what holding costs would provide appropriate backorder ranges. The amount of backorders affects the total carrying costs and ultimately results in lower storage costs. When items are on backorder, they are not available for the user but are accumulating storage and interest expense. Upon delivery by the manufacturer, they are sent immediately to the user and little, if any, of the expected holding cost expense will be incurred. The carrying cost forecasts would provide managers insight into the total carrying costs that would result at the various backorder levels (1).

Research Objectives

The objectives of this research effort are to:

1. Determine the expected backorder levels resulting from different dollar investments at selected holding cost policies.

2. Determine the expected total carrying cost resulting from different backorder levels at selected holding cost policies.

3. Determine the effect of separating the EOQ items into value categories on the results of the above objectives.

Research Questions

The following research questions will be answered with respect to holding cost policies.

1. What changes occur in expected backorder levels as different dollar investments and holding cost policies are varied?

2. What changes occur in total carrying cost as different backorder levels and holding cost policies are varied?

3. What changes occur in expected backorder levels, buy dollars, and total carrying cost when EOQ items are separated into value categories (<$500, $500—$5000, >$5000) and the holding cost policies are varied?

Chapter 2

RESEARCH METHODOLOGY

Data and Treatment of the Data

This chapter describes the data needed, the research methodology, population, sample and how the data was treated, analyzed and evaluated.

Data

The data for this research was ratio level data taken from the history files of AFLC. It was composed of items used to support current weapon systems of the Air Force. Additional data to be used in this effort was created by the INSSIM model (16).

The population. The population to be investigated in this study consists of all EOQ items in the inventory of the Oklahoma City ALC (OC-ALC). The OC-ALC was chosen because data was available from a previous study conducted by AFLC/XRS. All EOQ items are managed using data generated by demand activity, number of items, and dollar value of items (7).

The sample. The sample taken within OC-ALC was based on HQ AFLC criteria. Items which did not meet the established criteria were eliminated. Of the 95,690 EOQ items (14) at OC-ALC valued in excess of $458 million (10), 13,867 EOQ items were used. This reduction in quantity of items was accomplished by applying the following criteria:

1. All items considered were in the inventory during the FY 71—FY 75 time period.

2. Items in the inventory assigned to an obsolete weapon system (i.e., B-58) were omitted.

3. Items with NSN changes which could not be matched with a suitable substitute were omitted.

4. Items having quarterly demands that were considered to be extreme were omitted. This included demands which were either zero or were extremely large (more than double the average of the time period considered) (16).

Due to the large amount of computer space needed to run the INSSIM model, a sampling system was used to determine sample size and content. The equation that was used to determine the sample size is (15:268):

$$N = \left(\frac{\sigma \; Z\alpha/2}{A} \right)^2$$

where: N = sample size

σ = standard deviation

Z = standard normal statistic

α = significance level = 0.05

A = precision = 0.1

The precision was selected to be within ten percent of the standard deviation. This resulted in a calculated sample size of 384, which was used as a guide in establishing the sample size for all samples that were considered.

The samples were further defined based on the dollar-demand categories that they were in. The first sample was composed of 400 items from all SMGC categories. This sample will hereafter be referred to as Category 1 items. A Statistical Package for Social Sciences (SPSS) program was used to determine the percent of the items that fell into each of three other categories. These categories varied from the SMGC categories only in that they include serviceable returns. The results reflected that 40.6 percent of the items were less than $500 (hereafter referred to as Category 2), 39.3 percent were greater than $500 but less than $5000 (hereafter referred to as Category 3), and 20.1 percent were greater than $5000 (hereafter referred to as Category 4). These percentages were then used to determine the number of items to be drawn from each category to get a proportionate sample. Another computer program was used to extract data from an AFLC history tape. This program employed a systematic sampling[2] technique to draw the appropriate number of items of each category from the tape.

---

[2]"In this approach every kth element in the population is sampled, beginning a random start with an element from 1 to k [8:153-154]."

This sample will only be considered representative of the selected inventory since the sample selection was from only that group; therefore, generalizations can be made to the portion of the OC-ALC inventory that meets the AFLC criteria. Since each ALC uses different costs for ordering in calculating its respective EOQ, the results of this effort may not be used for the ALCs other than at OC-ALC.

Specific Treatment of the Data

The data needed. The data that was required to perform the comparative analysis consists of three types of data which are used to compute holding cost, carrying cost and backorders. These three types of data are the number of demands, number of serviceable returns and the frequency of demands generated by the weapon system by NSN (16).

The source of data. The data was obtained from HQ AFLC's previously prepared computer magnetic tapes (hereafter referred to as tapes) (6).

The data collection instrument. One data collection instrument was needed to obtain the required data. It consisted of creating a new set of AFIT master tapes on the Honeywell-635 Computational Resources for Engineering And Simulation, Training, and Education (CREATE) computer system to preclude the accidental damaging of the AFLC master tapes and subsequent data loss. Creating a tape refers to a tape which is made available by CREATE and is assigned to the user as required. A simulation model, the INSSIM, written in FORTRAN language, was used to duplicate the data handling procedures of the DO62 Buy Computation Program.

Prior to running the INSSIM model, the data was processed and collated many times before it was in the proper format. A general description of the flow of the data and a flowchart (Figure 1) is provided to better understand how the data was handled during the course of this thesis effort. The flowchart reflects a very simplified version of the interaction of the many computer programs required to run the INSSIM model, which in itself includes a large number of subroutine programs.

Data from the AFIT master tape containing 13,867 items was processed through a computer program designed to prepare the data for SPSS analysis, which subsequently was stored on tape. The SPSS program then provided the percentage of items of each of the dollar value categories that existed on the master tape. These percentages were then utilized with the systematic sampling procedure in separate computer programs to extract the number of items needed from each dollar value category to correspond with the identified percentages. The required number of items were extracted in a manner consistent with the systematic sampling technique and each set of data was stored on a tape. For the

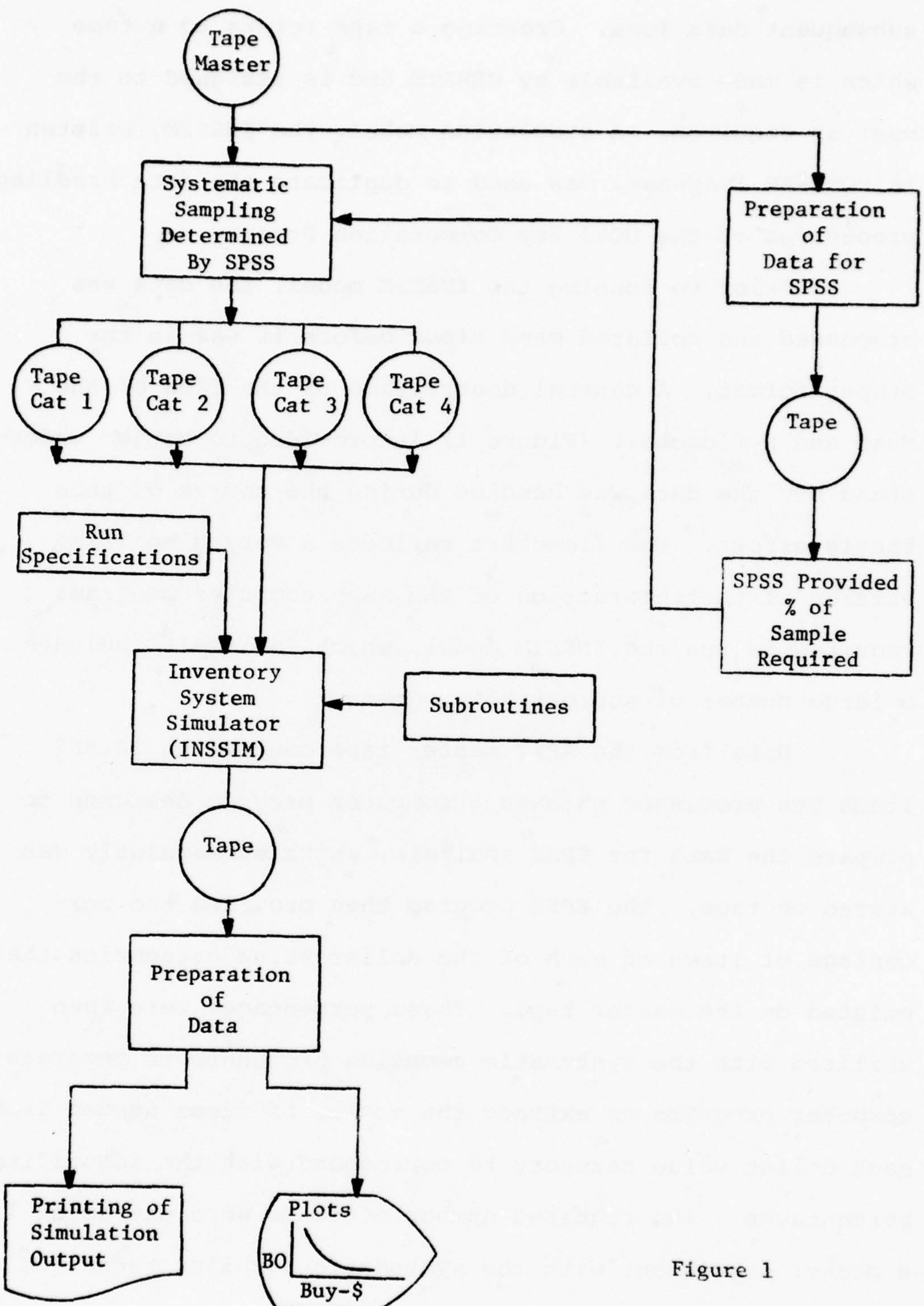

Figure 1

Data Flowchart

Category 1 data tape, the data was accumulated from the master tape by extracting from the low and proceeding to the next higher dollar value categories. Verification of the number of items contained was made by dumping each tape and executing a record count procedure. The tapes then contained the number of items necessary for Category 1, Category 2, Category 3 and Category 4.

Depending on the dollar value category chosen, tape data was then input to the INSSIM model and simulation commenced. Other internal inputs were previously made in the form of run specifications which combined with the many subroutine programs designed to produce the simulation output which was then stored on a tape. The data was then processed through a series of computer programs to permit its printing in final format and to perform the calculations necessary for plotting buy dollars and carrying costs against backorders. The combined programs are displayed in Appendix D.

Research Design

Areas to be addressed. This research was conducted to address three areas: First, the effects of changes to the holding cost factor on backorder levels at set buy-dollar levels (procurement dollars) to determine an optimal holding cost; second, the effects of changes to the holding cost factor on backorder levels and carrying cost levels to determine an optimal holding cost policy; and finally, the effects of separate value categories on the total combined dollar value of all EOQ items.

INSSIM model. The INSSIM model provides the capability for the user to change several factors in handling the inventory (7:Ch.VII). These factors can be varied by changing input cards to the program. Figure 2 shows the various factors which can be adjusted and the values that were used for most of this research effort. The management methods to be used (C5) were set to reflect the current AFLC management policies. The management parameters (C6) identify the AFLC minimum and maximum EOQ. A minimum safety level is set only to avoid negative values and, due to the method of calculating safety level as selected on C5, the maximum safety level is not used. The system parameters (C7) reflect the AFLC policies for OC-ALC effective 1 June 1978 (13). Seven of the eight shortage costs selected follow a logarithmic function. The exception was the shortage cost of 600, which was inserted within the range because it is close to the present shortage costs experienced by AFLC (16). The holding cost is the primary factor which was varied during this effort. The other factors were only varied to attempt to explain the behavior of the holding cost curves.

A major related factor which was addressed while using the INSSIM model was to determine the number of replications required to insure that steady state had been

```
(C1)  RUN-ID.    10  TITLE.  400 ITEMS ---


(C2)  OUTPUT CONTROLS...(NOTE.  1=YES)

ITWRT          IT.WRITE =  1
IOUT           SUMMARY  =  0
IGRAPH         GRAPHS   =  0
IPUNCH         PUNCH    =  1


(C3)  DEBUG FLAGS

               IDBUG =  0
               IEBUG =  0
               IFBUG =  0
               IGBUG =  0
               IHBUG =  0

ITRACE         START TRACE AT    0  FOR ITEM 1
ISTRAC         STOP TRACE AT    0


(C4)  ITEM INPUT FILES

INLU           FILE =  7
INTYPE         TYPE =  2   (1 = BCD; 2 = BINARY)
NDEM           QTRS = 24


(C5)  MANAGEMENT METHODS TO BE USED

ICDFOR         FORECAST FORMULA  =  1
ICDSIG         STD DEV  FORMULA  =  1
ICDEOQ         EOQ      FORMULA  =  2
ICDSL          SAFETY STK  CODE  =  3
ICDSLL         SAFETY LIMIT CODE =  1
ICDBG          BUDGET GUIDE CODE =  1
ICDSR          RETURNS CODE      =  1
```

Figure 2

INSSIM Run Parameters

(C6) MANAGEMENT PARAMETERS

EOQMIN	MIN EOQ(MNTHS)	6.0000
EOQMAX	MAX EOQ(MNTHS)	36.0000
SLMIN	MIN SAFETY LV(MNTHS)	0.
SLMAX	MAX SAFETY LV(MNTHS)	40.0000

(C7) SYSTEM PARAMETERS

COSHLD	HOLDING COST/$-INV		0.1600		
CSHORT	SHORTAGE COST	10.	31.6	100.	316.
		600.	1000.	3162.	10000.
COSORD(1)	SMALL ORDER COST		272.9900		
COSORD(2)	LARGE ORDER COST		556.5700		
CSTBRK	COST BREAK-POINT		19500.0000		

(C8) SIMULATION SIZE

NRUN	NUMBER OF RUNS	4
INQTR	NUMBER OF QUARTERS	12
NREPL	NO. OF REPLICATIONS	100
NITEM	NO. OF ITEMS/REPL	1
NDHIS	NO. OF HISTORY QTRS	8

Figure 2 (continued)

reached within the model. As such, the initial attempts were directed towards identification of past AFLC efforts in determining this number; however, no documented research was found to indicate that the model had been validated. Other projects were also undertaken by AFLC/XRS using the INSSIM model with 100 replications (6). This lack of availability of data concerning the number of replications can partially be attributed to the very recent acquisition of the INSSIM model by AFLC in August 1977. The effect of this nonavailability of data on model validation and its impact on the model generated data will be discussed later in Chapter 3.

Due to this lack of data, six simulation runs were made on the INSSIM model where only the number of replications was changed while holding the other variables constant. The number of replications ranged from 20 to 120 and were increased in increments of 20. In addition, two other simulation runs were made at 101 and 110 replications. All results were evaluated using a computer plotter to better portray any noticeable differences and to assess whether the selected range reflected that steady state had been reached.

Research plan. The INSSIM model was used to generate the expected data for backorder level, buy dollars and total carrying costs. The model parameters were varied by the operator to generate the needed data at various holding cost factor values. The lowest holding cost factor was set at

12 percent since, under current AFLC policy, this is the lowest possible value that it can assume (16). Present policy dictates that 10 percent be attributed to opportunity cost and 1 percent to storage cost. The holding cost factor was incremented by 2 percent per run up to a factor of 32 percent. This encompasses the range of values that are envisioned for future use or have actually occurred within the last four years (16). Increments of 4 percent were then used in the range from 32 percent to 40 percent. Based on AFLC historical data and on experimentation, the upper limit was considered appropriate.

Backorder levels were observed both as requisition-backorders and unit-backorders in weeks per year. The number of backordered requisitions is a measure used by AFLC to monitor the backorder condition. Since the number of requisitions is a factor of the number of units per requisition, a more appropriate measure of the backorder status may be the number of backordered units (16).

Outputs from the INSSIM model were graphed to reflect the effect of changes of holding cost on the other factors. One graph (see Figure 3) reflects expected backorder levels as a result of dollars available for purchases. In addition, empirical data is available (Appendix A) for evaluating the relationship of backorders and buy dollars in more detail and for providing a better insight to answering research question 1. This trend information provides the manager with more flexibility on how a given procurement budget can be allocated.

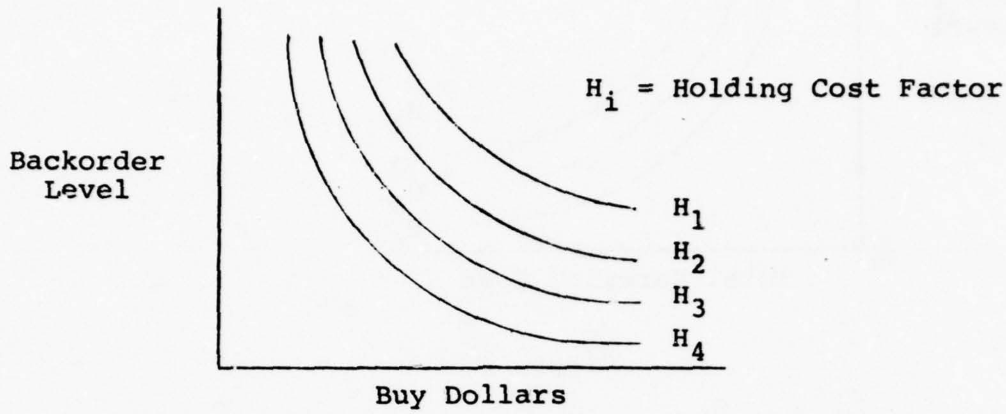

Figure 3

Buy Dollars Versus Backorder Level

Another graph (Figure 4) reflects total carrying costs as a result of given backorder levels. Empirical data is also available for evaluating the relationship of total carrying costs and backorder levels in more detail and providing a better insight to answering research question 2. However, only the trend information derived from the relationships that are observed can be utilized by the manager while he is attempting to meet his allocated target for total carrying cost.

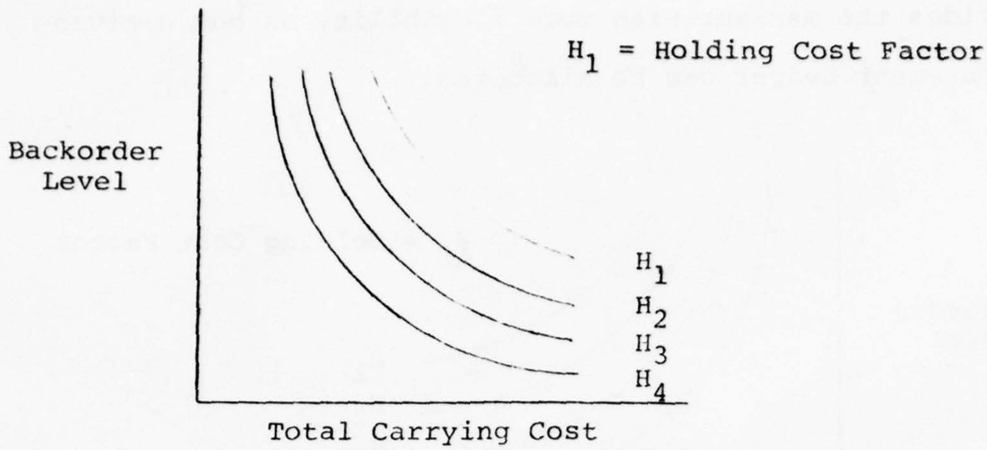

Figure 4

Total Carrying Cost Versus Backorder Level

Further insight into the relationships between these factors was obtained by also considering the three separate value categories of EOQ items in an effort to answer research question 3. Portrayal of the data in graph and empirical form is identical to the combined value categories and subject to the same type of evaluation. The value categories chosen for this portion of the study are the Category 2, Category 3, and Category 4 EOQ items as previously defined.

An additional effort was made to determine if the holding cost could be related to the implied shortage cost factor. Shortage cost information was extracted from the output of the INSSIM model and was evaluated to determine if the values at the successive holding cost factors followed a pattern when the implied shortage cost was held constant. This output was then plotted using the same variables that were used for the holding cost curves. This analysis was conducted only on Category 1 items and the implied shortage costs which were used were limited to: 100, 316, 600 and 1000. This adequately encompasses the current implied shortage cost of OC-ALC which is currently $390 (13). The analysis did include all thirteen of the holding cost factors that were addressed previously.

Assumptions and Limitations

1. It is assumed that the INSSIM model approximates the AF EOQ inventory system and that it is a reliable predictor of system characteristics and values.

2. It is assumed that AFLC managers have the authority and flexibility to adjust the holding cost factor in order to maximize management effectiveness.

3. The number of items considered in any run of the INSSIM must be limited unless more computer space is requested and approved.

Chapter 3

DATA PRESENTATION AND ANALYSIS

General Comments

The simulation outputs from the INSSIM model were extracted and placed in tabular form while the same data was plotted on graphs to provide more visible trends. The tabular data for all four separate value categories and selected graphical data are available in Appendices A, B, and C. Use of the tabular data will be required to extend the ranges on some graphs due to the narrow ranges employed. These narrow ranges were used to show maximum separation between data points. In general, all value categories exhibited an inverse relationship when buy dollars or carrying costs were plotted against requisition or unit back-orders. This relation was expected since as more buy dollars or carrying costs were involved, a lower number of requisition or unit-backorders would be required. The opposite holds true for backorders with a decrease in buy dollars or carrying cost. It must be pointed out that all the data points involved can only be generalized to the selected inventory identified in Chapter 2.

Macro Analysis

Initial review of the graphical data was conducted by separately addressing the backorders versus buy dollars, backorders versus carrying costs, and a comparison of all dollar categories while considering all of the holding cost factors identified earlier. This permitted a macro review which was followed by a micro approach later in this chapter.

Backorder versus buy dollars for category 1. The general trend in the holding cost lines can be seen in Figure 5 and from Appendix B. In comparing the curves for various holding costs, it appears that the right end of the curve reflects a relatively constant backorder level, though the dollar amount does fluctuate somewhat. The middle portion of the curve is not as predictable since, frequently, the curves cross in this area. Generally speaking, the unit-backorder level decreases for a given investment when the holding cost factor is varied from 0.12 to 0.16. From a holding cost factor of 0.18 up to 0.26, the curve increasingly shows somewhat of a step function. This step begins to disappear at a factor of 0.28 and from that point up to 0.40 the backorder level decreases for any set cost. The left end of the curve consistently reflects a sharp increase in the unit backorder level. If the curves are observed from a set backorder level, the buy dollars decrease as the

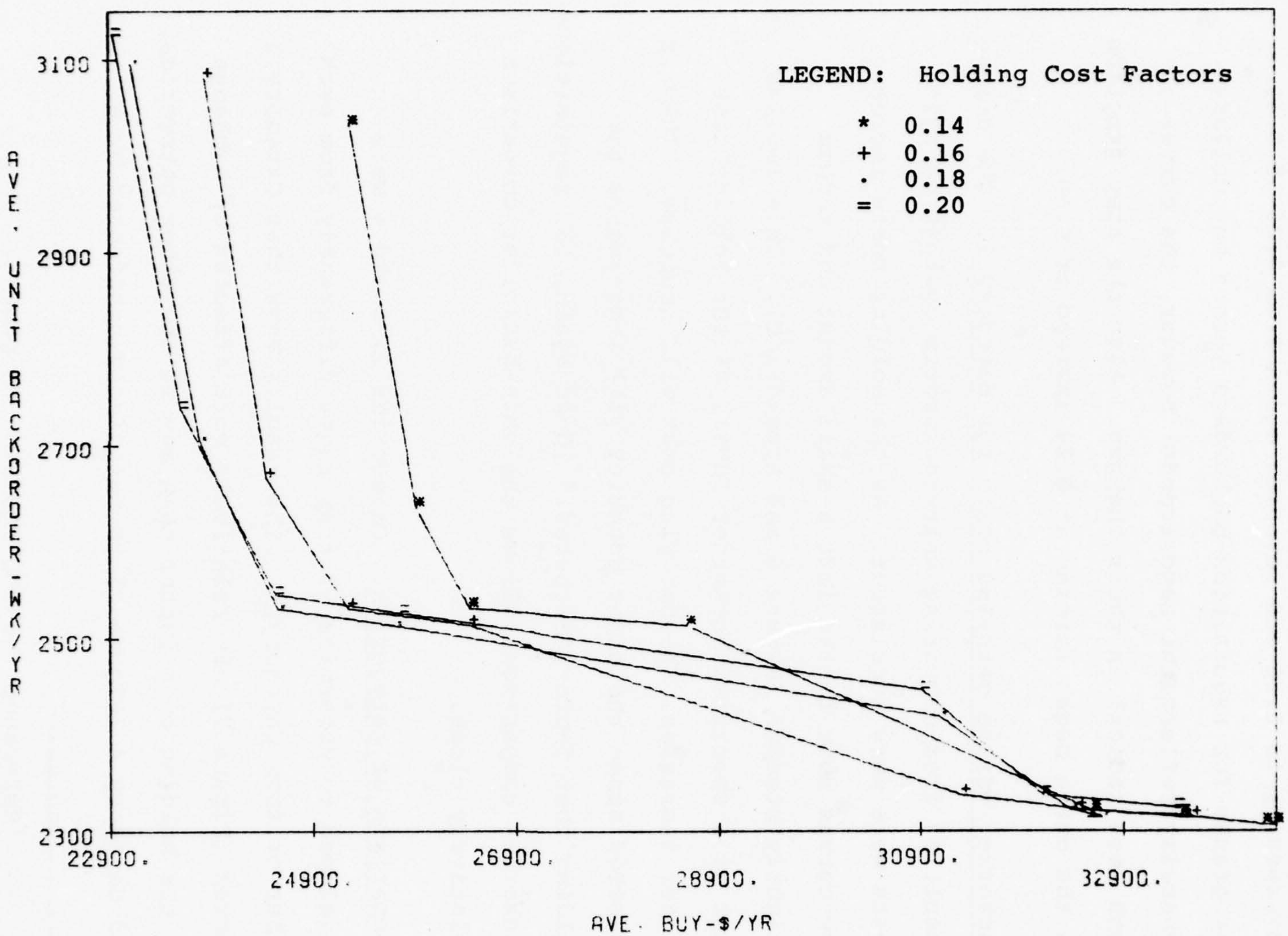

Figure 5

Category 1—Buy Dollars Versus Unit Backorders with Holding Cost of 0.14, 0.16, 0.18 and 0.20

holding cost varies from 0.12 to 0.20. This trend then reverses up to 0.26 and reverses again from 0.26 to 0.40. The graphs for requisition-backorders versus buy dollars generally reflect the same trends; however, the curves are much less radical in their changes. Also the step function on the curve began forming at 0.24 instead of 0.18.

Backorder versus carrying costs for category 1. The graphs resulting from comparing unit-backorders against carrying costs were very consistent. As the holding costs increase, the curves move to the left a small amount and become slightly steeper (Figure 6 and Appendix C). This implies that at a specified backorder level, as the holding cost factor increases, the carrying cost will decrease. This is expected since the order quantity will increase as the holding cost factor decreases.[3] Once again, the requisition-backorder comparison follows the unit-backorder comparison relatively close.

Comparison of categories. Categories 2, 3 and 4 were developed to determine if they react differently from each other or from Category 1. The results show that Category 2 curves (Figure 7) are relatively more affected by a change in the holding cost factor than any of the other categories, and Category 4 (Figure 8) is relatively unaffected by a

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[3]Reference the EOQ equation on page 4.

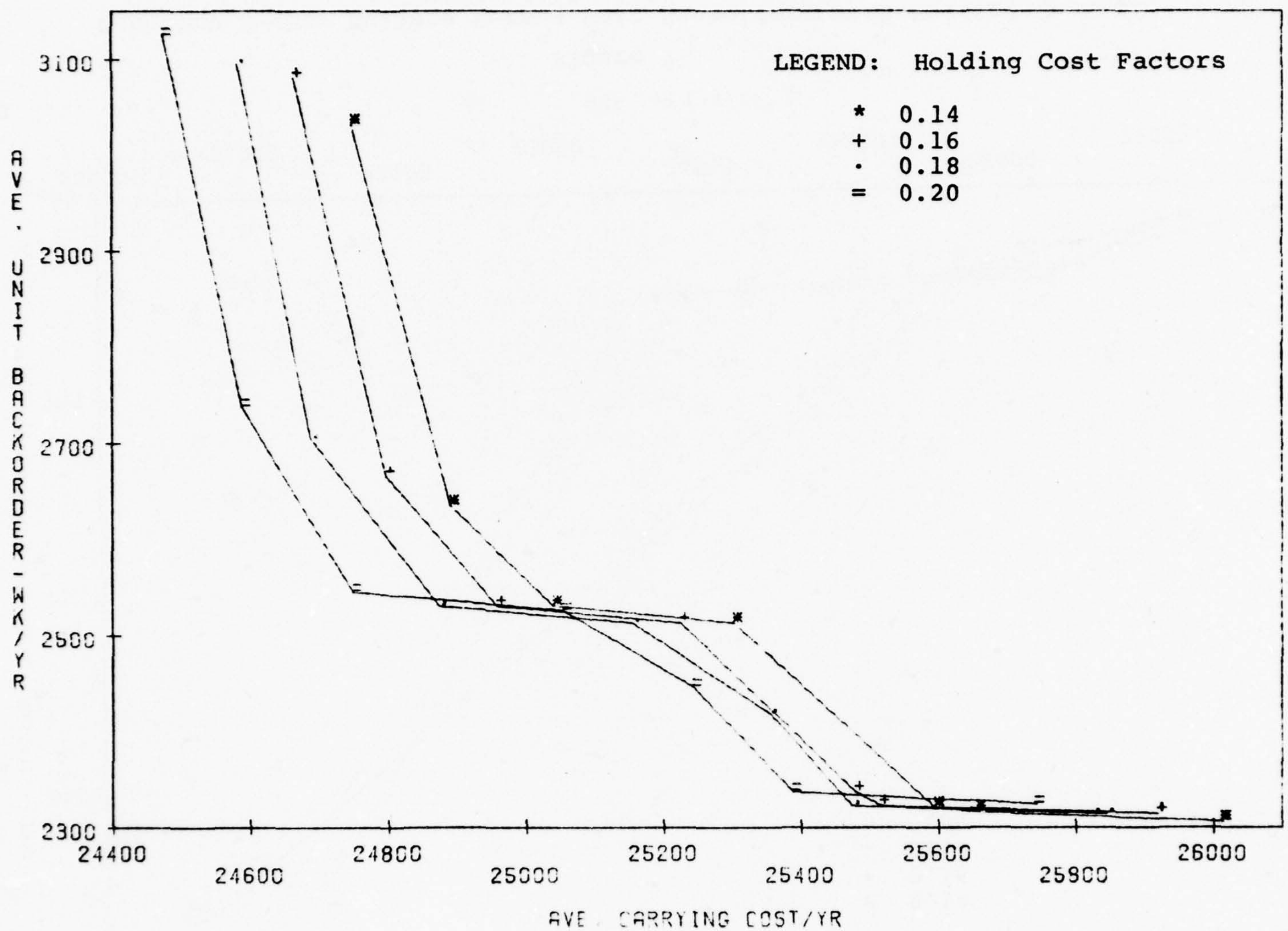


Figure 6

Category 1—Carrying Costs Versus Unit Backorders with Holding Cost of 0.14, 0.16, 0.18 and 0.20

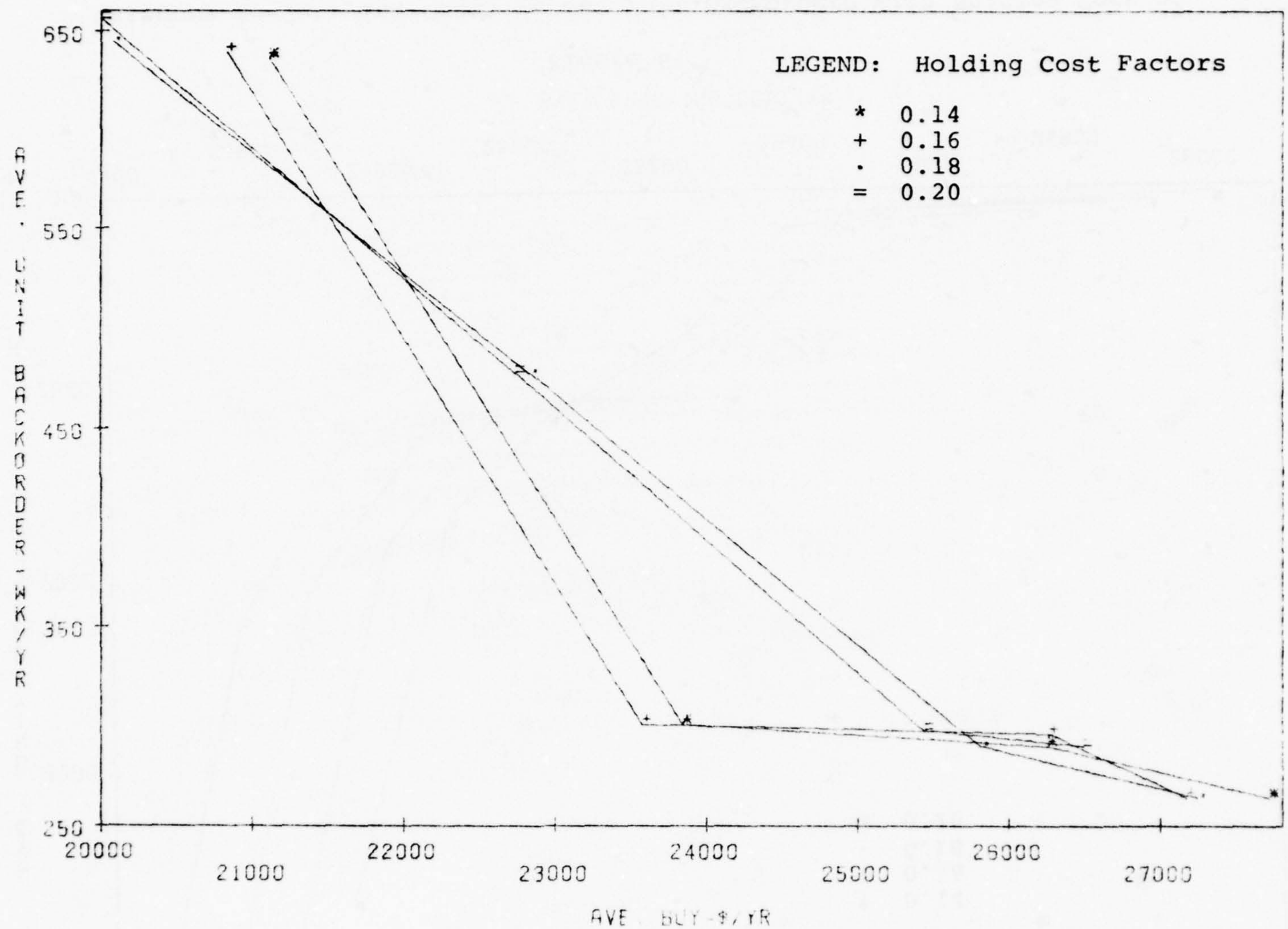


Figure 7

Category 2—Buy Dollars Versus Unit Backorders with Holding Cost of 0.14, 0.16, 0.18 and 0.20

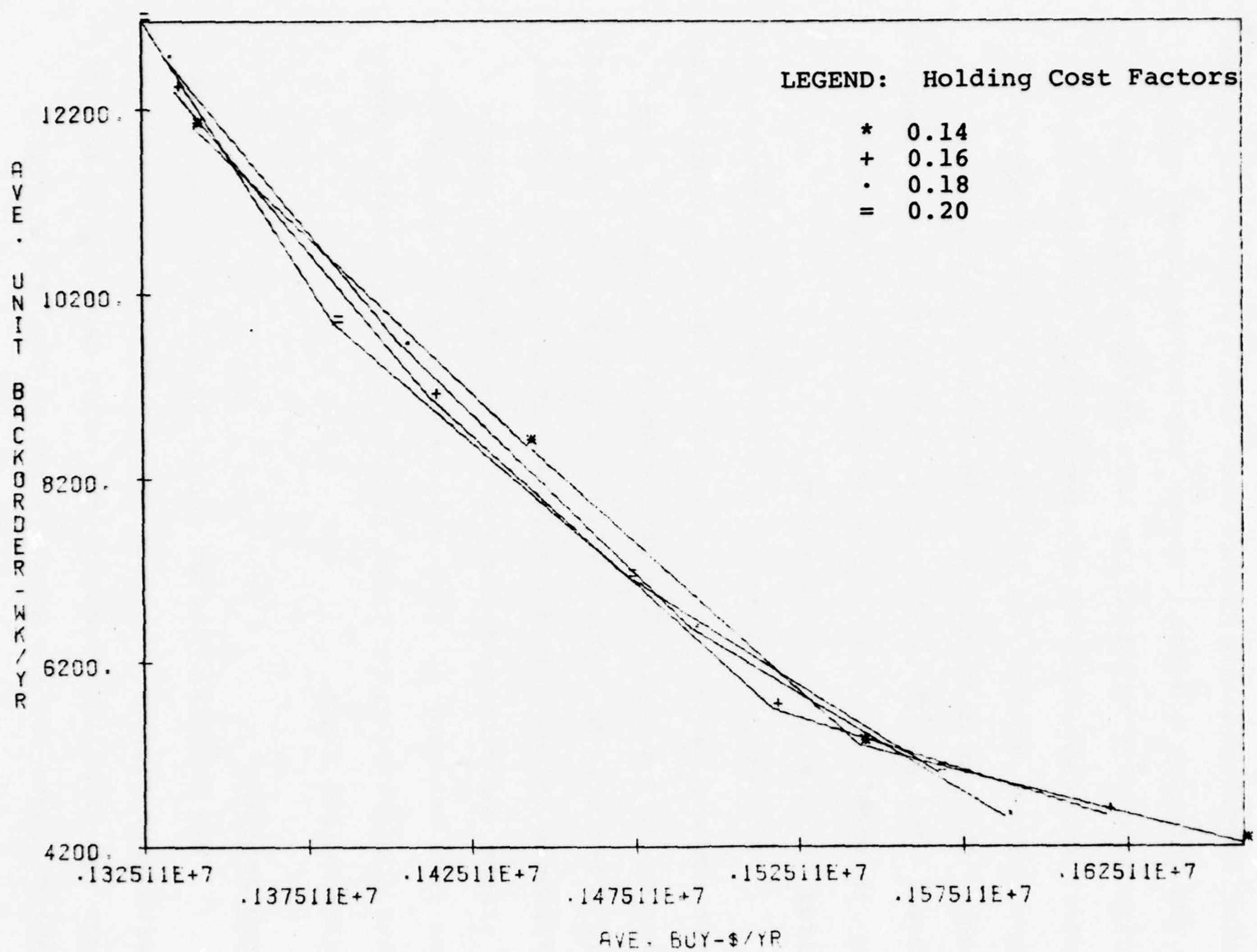


Figure 8

Category 4—Buy Dollars Versus Unit Backorders with Holding Cost of 0.14, 0.16, 0.18 and 0.20

change in the holding cost factor. This is, however, deceiving since a small change in the Category 4 curve represents a much larger absolute change than does a similar adjustment to the Category 2 curve. Though the curves in all categories generally moved to the left as the holding cost factor increased, between any two curves, portions of the curve may not move to the left and may in fact move to the right. This is most prominent in the midsection of the curves. The result is that it is difficult, if not impossible, to make a reliable statement about the behavior of the system in this area of the curve.

In comparing Category 1 to the other Categories, the first obvious difference is the lack of the step function in Category 2, 3 and 4. This deviation was present in Category 1 and will be discussed in the next section. A second difference is the relative movement of the curves. The set of graphs which is most similar to the Category 1 graphs come from Category 2. This seems to indicate that the low value items effect the total sample more than do the other, higher valued items.

Micro Analysis

The data and plotted graphs in all four value categories were further evaluated using nonstatistical analysis. Areas specifically addressed were major deviations, implied shortage costs and the steady state of the INSSIM model.

Major deviations. Based on the results available after running the INSSIM model, attempts were made to explain the major deviations from the plotted trends regardless of dollar value category. Three major deviations were observed.

1. Category 1 graphs reflected an inconsistency which will be referred to as a step function. This inconsistency (Figure 9) appeared as a hump in the curve. In attempting to determine the cause of the step function, the INSSIM model was rerun with various management parameters. Two variations resulted in changes in the curve. The results were:

a. The maximum EOQ was increased to 40. This caused a shift of the curve down and to the right; however, it had very little affect on the shape of the curve.

b. The minimum safety level was increased to four. This shifted the low shortage factor points down and to the right, generally decreasing the size of the graph. The adjustment caused a change in the shape of the step function; however, the step function was not eliminated.

c. The minimum EOQ was increased from six to eight. This change had no affect on the curve.

Since the step function could not be eliminated by varying the input parameters, it appears to result from the interaction of the many variables in the model rather than by limits imposed by the operator. Also, since the step function did not occur in Category 2, 3 or 4, the

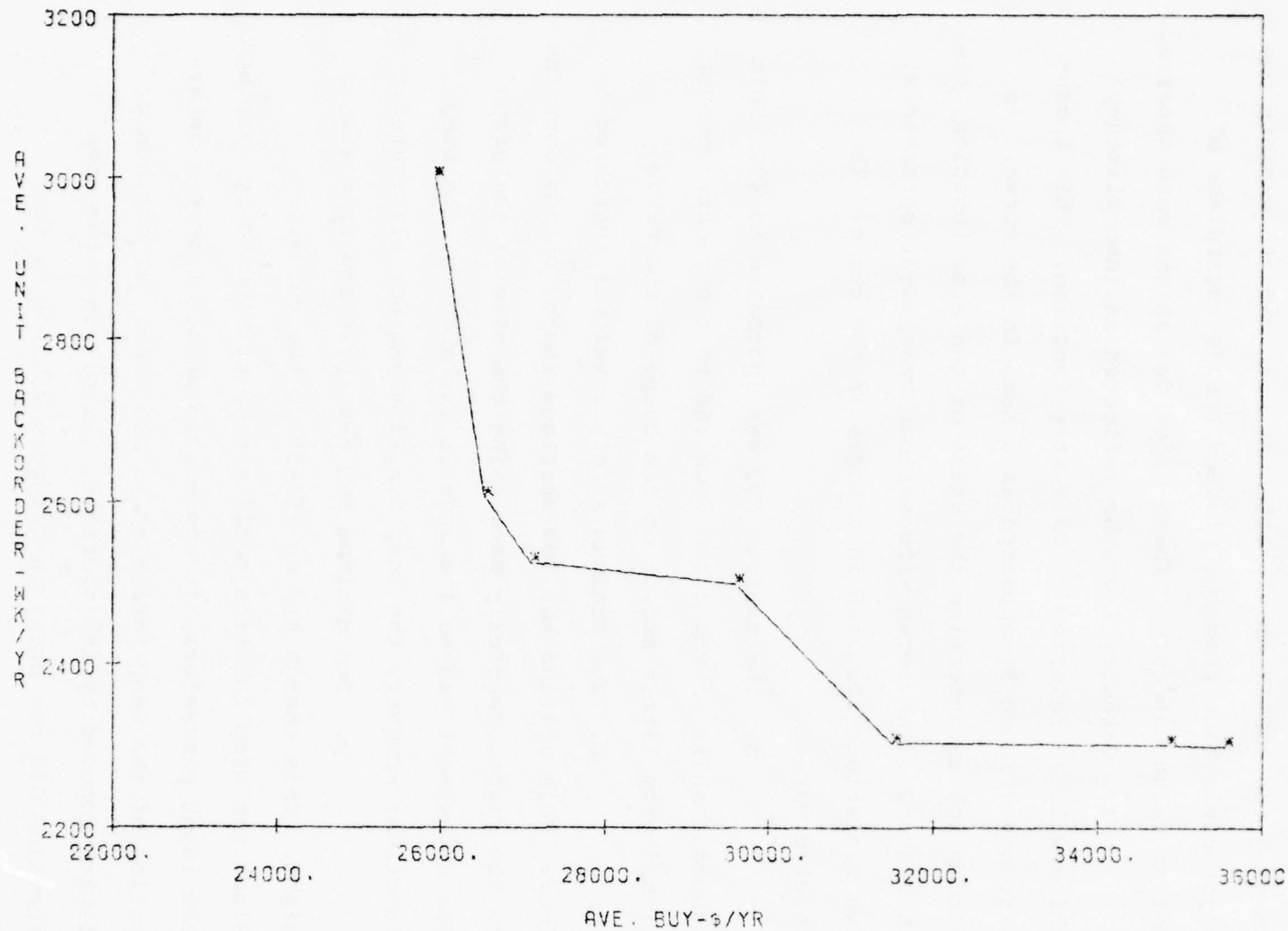


Figure 9
Deviation 1—Step Function

interaction between variables affected by the dollar demand of the items appears to cause this deviation.

2. The second deviation which occurred was a grouping of the points that were plotted at the two ends of the curves (Figure 10). This was noticeable on the graphs for all categories. In about one-half of the cases, the points were located close together and in the remainder the two end points were identical. This grouping occurred at both ends of the curves for Category 2 and Category 3. The curves for Category 1 showed grouping at the right end of the curves on all graphs, but they showed a gradual grouping at the left end of the curves as the holding cost factor was increased. The grouping occurred only at the left end of the curve for Category 4 items. The pattern of movement of the points from one curve to another indicate that the ends of the curves should be extending much farther. Changes in the management parameters of the model did not eliminate the grouping. The probable cause of this deviation is the calculations performed within the model. These same calculations may be the cause of the third deviation, the hook.

3. A third deviation found on some of the graphs is a hook at the right end of the buy dollar versus backorder curve, starting at the $3162 point (Figure 11). This occurred when the buy dollar amount actually decreased at the highest implied shortage cost instead of increasing.

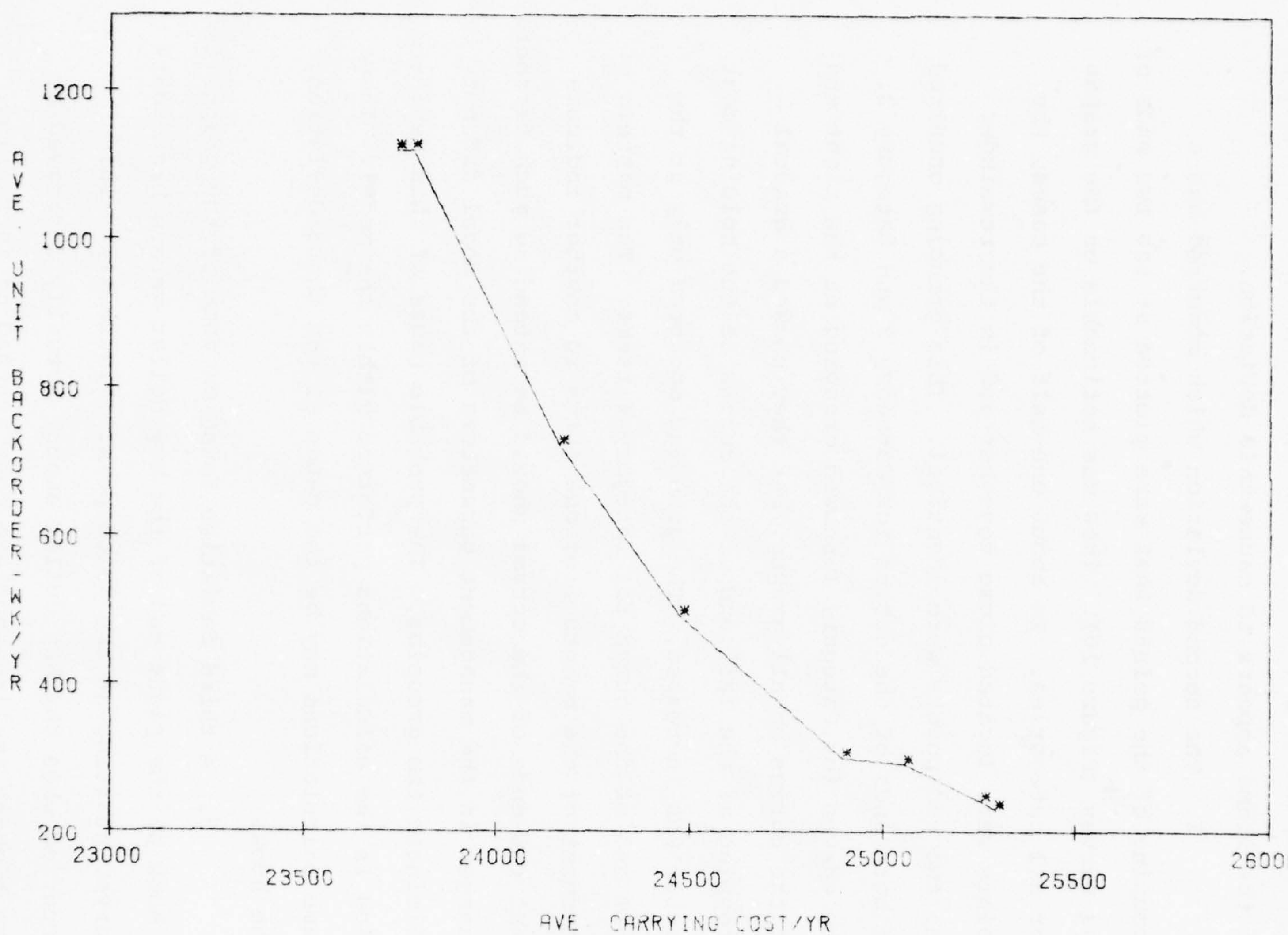


Figure 10

Deviation 2—Shortage Cost Data Points in Close Proximity

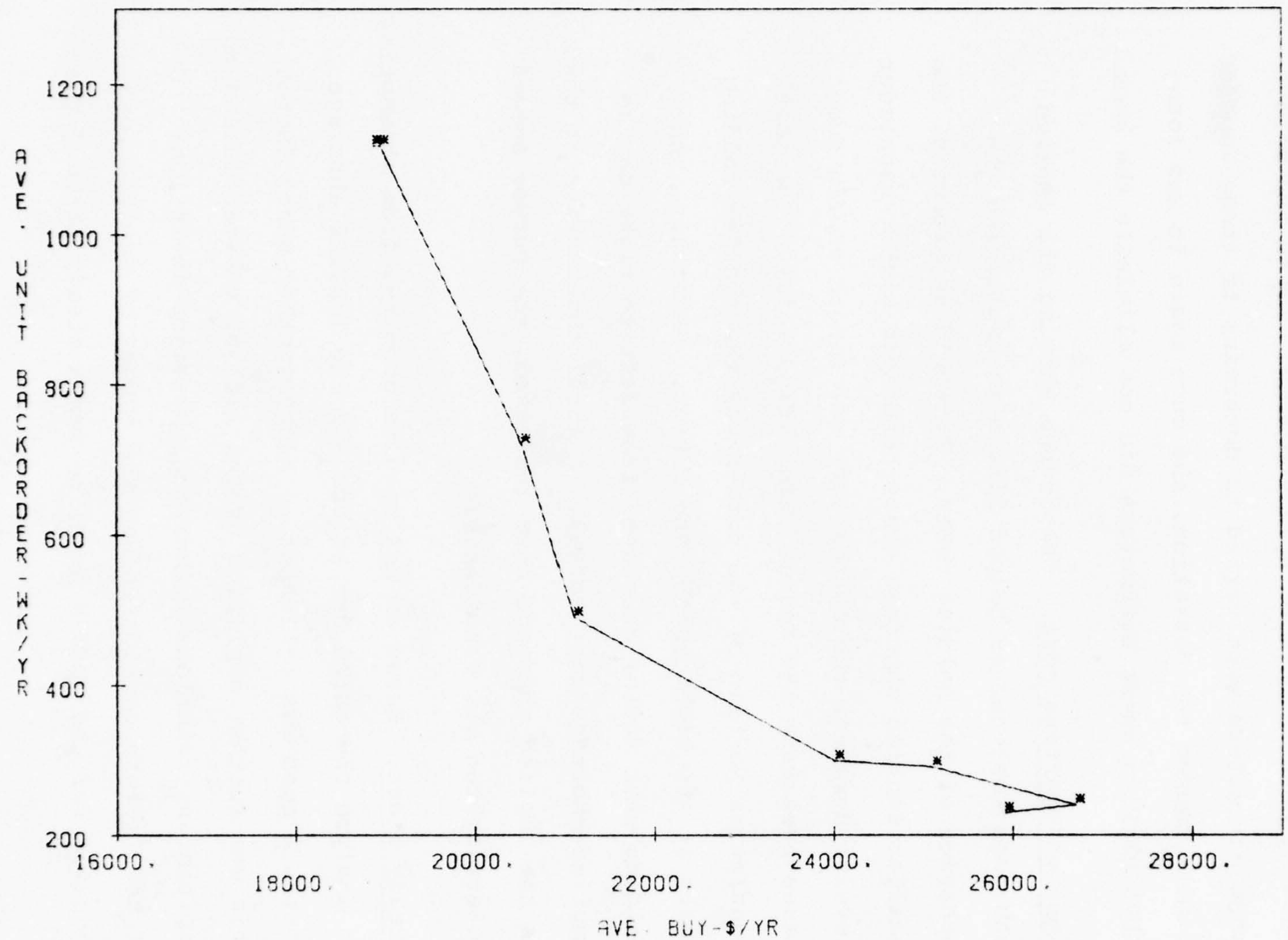


Figure 11

Deviation 3—The Hook

This phenomenon occurred in Category 2 and Category 4 at holding cost factors of 0.22 and 0.24. Again the management parameters were varied to determine if these imposed limits caused the deviation, and once again it was found that varying these parameters did not eliminate the hook.

Implied shortage cost. The graphs showing the implied shortage cost curves helped little in explaining the behavior of the holding costs. As would be expected, the smaller implied shortage costs generated higher backorder levels; however, the curves were not smooth and in some cases even made 180 degree turns (Figure 12). The most consistent portion of the curves was the smaller holding costs at the right end of the curves. Generally, the holding cost factor decreased from left to right on the implied shortage cost curves. A final observation is that as the implied shortage cost increased, the curves seemed to straighten out considerably.

Steady state. Based on the results acquired from attempting to analyze the three deviations and the implied shortage costs, a need was reflected to address other model factors. This was further amplified by the lack of substantiation to explain any relationship between the major deviations. One of the factors considered was the number of replications required for the INSSIM model to reach steady state. The

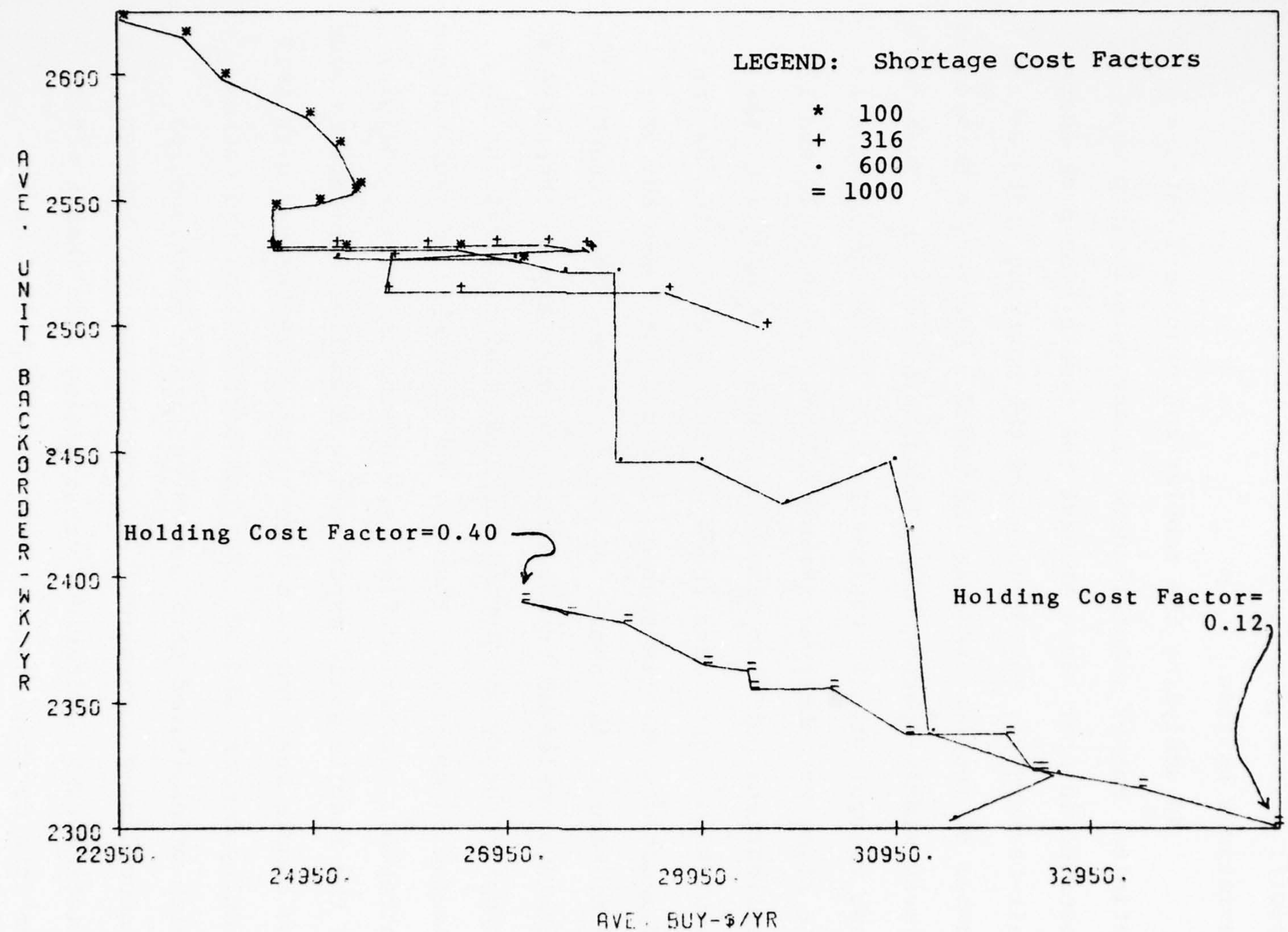


Figure 12

Implied Shortage Cost Curves

appropriate changes were made in the simulation size (C8) specifications in a further effort to explain why the major deviations existed.

In analyzing the tabular and graphical data, a definite, rather smooth, curve-linear relationship was observed in most cases amongst the requisition-backorders, unit-backorders, buy-dollars and the carrying costs as the number of replications was increased. However, a horizontal zigzag widely-spaced pattern (consisting of eight shortage cost values) with approximately a 25 degree deflection to the right was observed (Figure 13) on the 101, 110 and 120 replications per item simulation runs. In addition, the simulation output data showed an increase in value as the replications were increased; however, they were not proportionate to the number of replications. These graphical displays reflected trends that were contrary to the current accepted theory on varying the number of replications in simulation modeling. That is, as the number of replications increases, greater confidence was expected in the validity of the results while experiencing a smaller variance between the sample mean and each data value. Discussions with AFIT faculty members and AFLC/XRS/LOR personnel on the causes which precipitated this non curve-linear relationships produced many suggestions and possible causes; however, the existing time limitations constraining this thesis effort prevents further research into the identified areas.

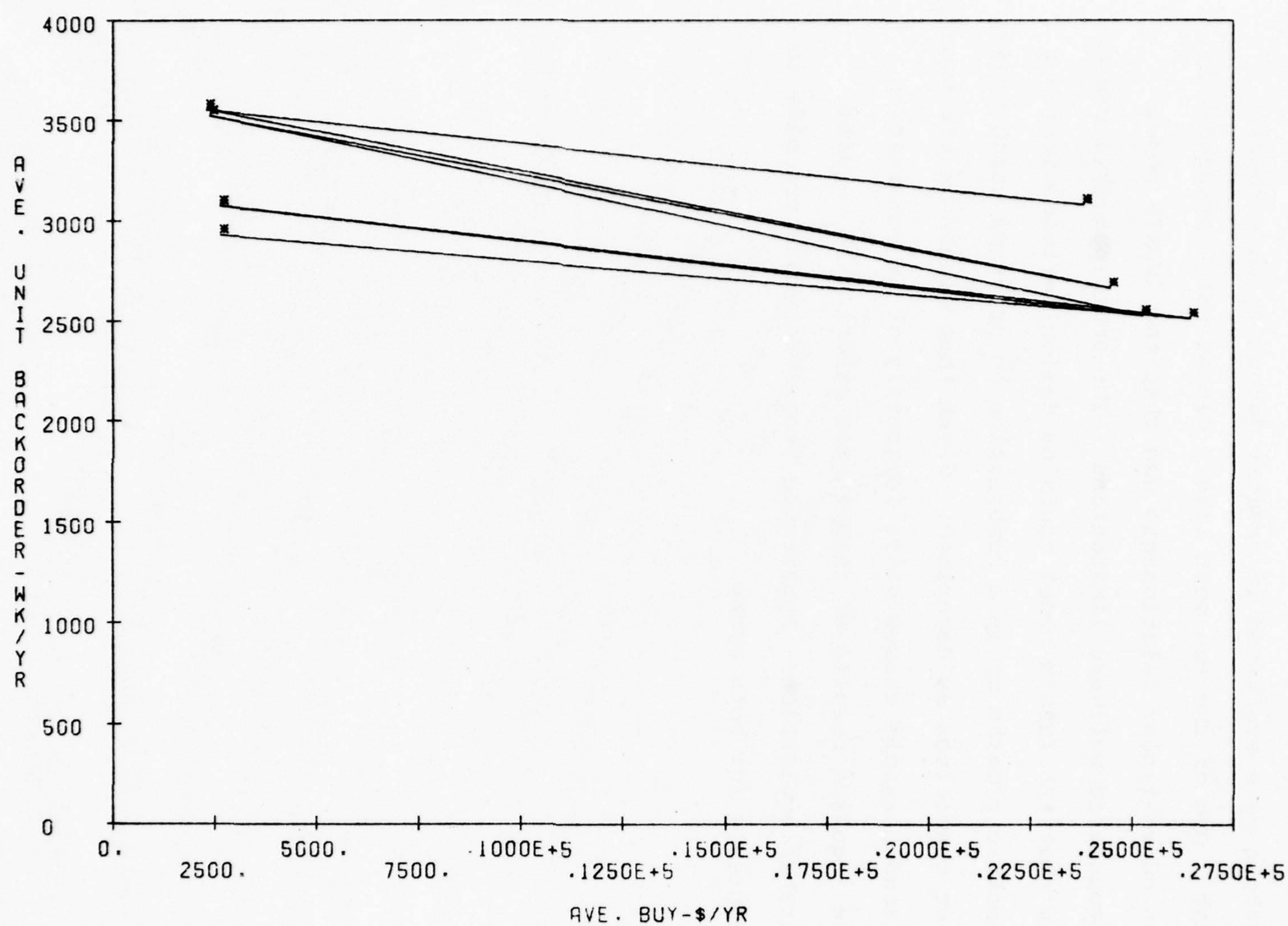


Figure 13

Simulation Run with 101 Replications

Only two of the most likely causes of the zigzag pattern were evaluated in greater detail by this thesis team. One of the two most likely causes which produced the non curve-linear relationship was that the INSSIM model encountered software limitations. The other possible cause was that the INSSIM model contains design deficiencies in a specific program or in a combination of programs which manifest themselves as described. Given that either of the two stated possible causes exist separately or in combination, the acquired results of this thesis effort will require further evaluation. Applicable recommendations are made in Chapter 4 for both areas.

Chapter 4

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Though specific values cannot be obtained from the results of this effort, some general conclusions can be drawn.

Research question 1. Graphs that show the backorder levels and buy dollars were generated to observe the behavior of these factors with respect to the holding cost curves. As the holding cost factor was increased, the general movement of the curves was to the left. This means that a manager who is restricted by a set budget for EOQ procurement would expect the backorder level to decrease if he increased the holding cost factor. This may not, however, be true for all holding cost factors. The portion of the curve which reflects values closest to the current AFLC policies is the least consistent and thus the least predictable.

Research question 2. The carrying costs resulting from maintaining an inventory is a function of the backorder level and the holding cost factor. If a manager has determined that he can expect a certain backorder level, any decrease in the holding cost factor would result in an increase in carrying cost.

Research question 3. When EOQ items were separated into groups based on their dollar-demands, a definite difference could be seen. The resulting curves were smoother than the curves generated by the combined sample in Category 1. They also differed from each other in the shape and relative spacing of the curves. The curves for the high cost items, Category 4, showed relatively uniform shape and spacing. On the other hand, the curves for the low cost items, Category 2, were less uniform and were very similar to the Category 1 curves. None of the categories consistently followed the general left to right movement of the holding cost curves as the holding cost factor decreased. In all categories, there were instances where a curve or a part of a curve moved to the right when the holding cost factor was decreased. These inconsistencies make it extremely difficult, if not impossible, to predict the effect of changing the holding cost factor.

As mentioned above, the Category 2 curves most closely duplicate the curves of Category 1. Since the Category 4 curves represent greater absolute changes in the units being measured, it was expected that they would have a greater influence on the Category 1 curves. This expectation was based on Pareto's Law; that is, a small number of items (the high dollar-demand items) dominate the results. However, in this effort, the graphs appear to indicate that the smaller dollar-demand items affect the results.

Recommendations

During this research, areas were identified which are presented for further study and consideration. In doing so, we attempt to share our findings so that others may use the conclusions presented as a starting point for other research.

1. Update the OC-ALC historical data base tape used for this thesis effort. This should increase the reliability of the INSSIM model results.

2. Validate the model with respect to the number of replications required to reach steady state. In the interest of austere funding, a nomograph for confidence intervals and computer cost estimates could be developed to reduce unnecessary computer core usage.

3. Compare data from this research effort with data from only one weapon system at OC-ALC. This comparison of trends would further assist in determining how well the system is being modeled.

4. Explore the model's behavior using other ALC's data. Comparison of trends observed could identify the effects of whether similar AFLC policies require different approaches.

5. Investigate why simulated output data for requisition-backorders, unit-backorders and carrying costs exhibit extremely large changes each year for three years.

Since the model averages the data every third year, data loss is experienced.

APPENDIX A

TABULAR DATA OF SIMULATION OUTPUT FOR ALL CATEGORIES

TABLE 1

CATEGORY 1 OUTPUT DATA

Holding Cost	Shortage Cost*	Requisition Backorder	Unit Backorder	Buy Dollars	Carrying Cost
0.12	10.0	363	3000	25939	24797
	31.6	326	2605	26538	24968
	100.0	325	2525	27095	25111
	316.0	311	2499	29588	25415
	600.0	283	2303	31505	25752
	1000.0	281	2301	34848	25763
	3162.0	279	2299	35541	26119
	10,000.0	279	2299	35544	26120
0.14	10.0	367	3032	25282	24748
	31.6	343	2634	25920	24890
	100.0	329	2530	26450	25040
	316.0	316	2513	28601	25302
	600.0	286	2321	32579	25595
	1000.0	288	2316	33462	25656
	3162.0	280	2307	34280	26011
	10,000.0	280	2307	34391	26013
0.16	10.0	369	3080	23844	24663
	31.6	344	2666	24457	24798
	100.0	329	2530	25265	24958
	316.0	316	2513	26449	25225
	600.0	295	2338	31291	25479
	1000.0	288	2323	32452	25515
	3162.0	280	2314	33471	25918
	10,000.0	280	2314	33584	25921
0.18	10.0	383	3094	23117	24581
	31.6	346	2704	23784	24688
	100.0	329	2530	24562	24875
	316.0	316	2513	25705	25155
	600.0	309	2419	31084	25354
	1000.0	288	2323	32373	25474
	3162.0	280	2314	32683	25826
	10,000.0	280	2314	32530	25845
0.20	10.0	397	3124	22949	24476
	31.6	360	2737	23594	24589
	100.0	343	2546	24550	24751
	316.0	329	2526	25774	25054
	600.0	319	2446	30904	25243
	1000.0	303	2337	32098	25389
	3162.0	290	2324	33455	25743
	10,000.0	290	2324	33413	25740

TABLE 1 (continued)

Holding Cost	Shortage Cost	Requisition Backorder	Unit Backorder	Buy Dollars	Carrying Cost
0.22	10.0	413	3142	23856	24407
	31.6	360	2763	24354	24450
	100.0	343	2548	24993	24672
	316.0	333	2530	27793	24916
	600.0	319	2429	29795	25234
	1000.0	303	2337	31065	25339
	3162.0	290	2324	32495	25666
	10,000.0	290	2324	32671	25664
0.24	10.0	413	3160	24278	24381
	31.6	366	2821	24752	24420
	100.0	343	2552	25373	24645
	316.0	333	2531	27747	24959
	600.0	319	2446	28911	25106
	1000.0	303	2356	30287	25171
	3162.0	290	2333	31907	25537
	10,000.0	290	2333	32085	25535
0.26	10.0	416	3164	24201	24337
	31.6	396	2855	24843	24364
	100.0	346	2555	25419	24577
	316.0	332	2529	27808	24888
	600.0	319	2446	28072	25038
	1000.0	303	2355	29463	25110
	3162.0	290	2333	31911	25470
	10,000.0	290	2333	31985	25470
0.28	10.0	420	3145	23855	24266
	31.6	369	2860	24566	24298
	100.0	346	2571	25206	24508
	316.0	333	2532	27349	24793
	600.0	327	2521	28058	24851
	1000.0	303	2363	29437	25066
	3162.0	290	2333	31388	25411
	10,000.0	290	2333	31452	25415
0.30	10.0	420	3160	23473	24222
	31.6	378	2952	24149	24259
	100.0	346	2583	24900	24463
	316.0	333	2532	26827	24752
	600.0	327	2521	27516	24802
	1000.0	303	2365	28988	24985
	3162.0	291	2333	31432	25290
	10,000.0	291	2333	31933	25312

TABLE 1 (Continued)

Holding Cost	Shortage Cost	Requisition Backorder	Unit Backorder	Buy Dollars	Carrying Cost
0.32	10.0	420	3163	23150	24153
	31.6	379	2993	23895	24188
	100.0	346	2598	24026	24383
	316.0	332	2531	26108	24666
	600.0	327	2526	26995	24729
	1000.0	303	2382	28152	24886
	3162.0	291	2342	31810	25310
	10,000.0	291	2342	32310	25331
0.36	10.0	417	3169	22685	24100
	31.6	381	3030	23054	24130
	100.0	343	2615	23626	24297
	316.0	332	2531	25183	24515
	600.0	328	2526	25730	24641
	1000.0	301	2390	27115	24792
	3162.0	293	2345	31385	25263
	10,000.0	293	2345	31905	25281
0.40	10.0	416	3164	22125	24020
	31.6	380	3038	22459	24050
	100.0	342	2622	22980	24192
	316.0	332	2531	24492	24424
	600.0	328	2527	25174	24555
	1000.0	303	2385	27577	24709
	3162.0	293	2345	31572	25164
	10,000.0	293	2345	32306	25227

TABLE 2

CATEGORY 2 OUTPUT DATA

Holding Cost	Shortage Cost	Requisition Backorder	Unit Backorder	Buy Dollars	Carrying Cost
0.12	10.0	337	1109	20900	24217
	31.6	256	746	20999	24543
	100.0	217	634	21827	24819
	316.0	127	301	23452	25151
	600.0	117	290	26198	25626
	1000.0	105	264	27959	25718
	3162.0	97	240	28508	25876
	10,000.0	93	229	28516	25868
0.14	10.0	337	1109	20069	24084
	31.6	293	944	20106	24354
	100.0	219	636	21116	24680
	316.0	127	301	23847	25183
	600.0	117	290	26252	25454
	1000.0	105	264	27714	25596
	3162.0	97	240	28928	25733
	10,000.0	93	229	28887	25732
0.16	10.0	337	1109	19796	24004
	31.6	307	986	19831	24244
	100.0	221	639	20836	24576
	316.0	127	301	23579	24875
	600.0	117	290	26263	25320
	1000.0	105	264	27169	25451
	3162.0	97	240	28928	25614
	10,000.0	93	229	29195	25611
0.18	10.0	337	1109	19097	23906
	31.6	327	1057	18959	24046
	100.0	222	644	20087	24457
	316.0	174	477	22833	24688
	600.0	117	290	25811	25199
	1000.0	105	264	27247	25367
	3162.0	97	240	28714	25534
	10,000.0	93	229	28924	25546
0.20	10.0	337	1109	19500	23826
	31.6	331	1085	19573	23872
	100.0	225	655	20006	24312
	316.0	174	477	22736	24584
	600.0	125	298	25437	25099
	1000.0	117	290	26489	25286
	3162.0	97	240	28017	25464
	10,000.0	93	229	28002	25476

TABLE 2 (continued)

Holding Cost	Shortage Cost	Requisition Backorder	Unit Backorder	Buy Dollars	Carrying Cost
0.22	10.0	345	1118	19471	23756
	31.6	340	1093	19537	23798
	100.0	247	708	20032	24206
	316.0	185	490	21632	24532
	600.0	125	298	24454	24975
	1000.0	117	290	25643	25156
	3162.0	97	240	27655	25334
	10,000.0	93	229	27277	25340
0.24	10.0	345	1118	18877	23741
	31.6	345	1118	18948	23782
	100.0	249	719	20529	24162
	316.0	185	490	21097	24479
	600.0	125	298	24011	24898
	1000.0	117	290	25108	25059
	3162.0	97	240	26704	25060
	10,000.0	93	229	25906	25295
0.26	10.0	346	1122	18491	23674
	31.6	346	1122	18583	23713
	100.0	250	724	20006	24080
	316.0	185	494	20638	24400
	600.0	127	301	24059	24781
	1000.0	117	290	24835	24956
	3162.0	97	240	26466	25148
	10,000.0	93	229	25692	25185
0.28	10.0	349	1141	18069	23633
	31.6	349	1141	18197	23683
	100.0	255	750	19550	24041
	316.0	191	513	20683	24334
	600.0	136	310	23152	24672
	1000.0	117	290	24555	24870
	3162.0	97	240	25928	25069
	10,000.0	93	229	26417	25105
0.30	10.0	363	1166	18302	23595
	31.6	363	1166	18415	23643
	100.0	263	798	19139	23988
	316.0	194	531	20235	24285
	600.0	136	312	22531	24592
	1000.0	118	291	24251	24778
	3162.0	97	240	25526	24993
	10,000.0	93	229	26214	25040

TABLE 2 (continued)

Holding Cost	Shortage Cost	Requisition Backorder	Unit Backorder	Buy Dollars	Carrying Cost
0.32	10.0	365	1203	17915	23516
	31.6	365	1203	18015	23561
	100.0	266	832	18745	23901
	316.0	194	532	19757	24192
	600.0	136	327	21836	24513
	1000.0	118	297	23646	24727
	3162.0	97	244	25071	24943
	10,000.0	93	233	25715	25003
0.36	10.0	359	1246	17681	23464
	31.6	359	1246	17761	23501
	100.0	260	825	18411	23818
	316.0	199	550	19483	24093
	600.0	135	326	22120	24426
	1000.0	125	301	23004	24599
	3162.0	97	244	24628	24814
	10,000.0	97	244	25423	24884
0.40	10.0	360	1287	16869	23397
	31.6	360	1287	16953	23432
	100.0	264	782	17523	23738
	316.0	216	616	19634	23993
	600.0	141	335	21873	24281
	1000.0	129	312	23195	24465
	3162.0	104	254	24029	24681
	10,000.0	103	250	24875	24779

TABLE 3

CATEGORY 3 OUTPUT DATA

Holding Cost	Shortage Cost	Requisition Backorder	Unit Backorder	Buy Dollars	Carrying Cost
0.12	10.0	949	7065	166516	114684
	31.6	933	6969	168182	114836
	100.0	882	6345	176893	117017
	316.0	619	4342	200077	123131
	600.0	525	3918	211089	126940
	1000.0	464	3659	214880	128374
	3162.0	457	3644	223856	130560
	10,000.0	448	3511	226085	131541
0.14	10.0	978	7523	162654	113735
	31.6	974	7459	164416	113908
	100.0	930	6853	171608	115515
	316.0	720	4904	192495	121627
	600.0	533	4057	213382	125813
	1000.0	481	3889	218878	126985
	3162.0	471	3797	220794	129222
	10,000.0	464	3688	225018	130410
0.16	10.0	964	7624	166025	113124
	31.6	959	7551	165257	113217
	100.0	913	6901	177078	114702
	316.0	736	5127	185127	120326
	600.0	554	4279	207465	124325
	1000.0	511	4056	218152	126372
	3162.0	487	3925	220621	128681
	10,000.0	480	3805	225520	129792
0.18	10.0	944	7757	160729	113016
	31.6	941	7487	160796	113097
	100.0	908	6698	165405	114439
	316.0	760	5314	181267	118986
	600.0	573	4440	202969	123169
	1000.0	533	4165	214735	125440
	3162.0	489	3976	221651	127755
	10,000.0	484	3862	224568	128942
0.20	10.0	941	7779	158787	112594
	31.6	936	7436	158674	112675
	100.0	905	6824	163717	113960
	316.0	776	5406	176765	118182
	600.0	608	4603	198059	122218
	1000.0	548	4259	209768	124401
	3162.0	505	4033	216080	127102
	10,000.0	499	3918	224185	128244

TABLE 3 (continued)

Holding Cost	Shortage Cost	Requisition Backorder	Unit Backorder	Buy Dollars	Carrying Cost
0.22	10.0	952	7716	158544	112128
	31.6	951	7706	158552	112174
	100.0	927	6986	162313	113325
	316.0	811	5755	172512	117401
	600.0	618	4805	193528	121048
	1000.0	557	4375	206007	123842
	3162.0	524	4119	213947	126714
	10,000.0	515	3997	219004	127958
0.24	10.0	967	8088	156109	111734
	31.6	957	7921	156155	111807
	100.0	930	7172	158517	112878
	316.0	833	5990	169115	116816
	600.0	671	4856	188817	120014
	1000.0	603	4588	202053	123078
	3162.0	540	4206	212875	125899
	10,000.0	529	4025	217900	127424
0.26	10.0	966	8235	155236	111644
	31.6	966	8235	155308	111668
	100.0	935	7415	157985	112693
	316.0	856	6163	168524	116522
	600.0	684	5040	183848	119299
	1000.0	597	4623	199668	122327
	3162.0	544	4299	211593	125247
	10,000.0	530	4078	217728	126901
0.28	10.0	992	8561	153928	111341
	31.6	992	8561	153964	111348
	100.0	959	7677	155871	112237
	316.0	853	6289	168681	115931
	600.0	697	5145	184404	118787
	1000.0	592	4650	197752	121684
	3162.0	539	4362	211282	124845
	10,000.0	524	4116	217023	126546
0.30	10.0	986	8837	153931	111147
	31.6	986	8837	154429	111154
	100.0	951	7936	155201	111991
	316.0	851	6323	166322	115266
	600.0	725	5336	180439	118279
	1000.0	605	4749	195214	121190
	3162.0	544	4375	211014	125322
	10,000.0	530	4158	213859	125902

TABLE 3 (continued)

Holding Cost	Shortage Cost	Requisition Backorder	Unit Backorder	Buy Dollars	Carrying Cost
0.32	10.0	984	9016	153135	110879
	31.6	984	9016	153164	110884
	100.0	964	8269	153411	111700
	316.0	857	6421	165594	114839
	600.0	741	5484	178258	117994
	1000.0	635	4768	191756	120681
	3162.0	541	4416	208696	124184
	10,000.0	530	4208	212550	125792
0.36	10.0	1008	9346	152498	110556
	31.6	1008	9346	152510	110557
	100.0	977	8689	153405	111180
	316.0	886	6646	161739	114154
	600.0	804	5735	173930	117064
	1000.0	664	4933	188642	119752
	3162.0	566	4513	208751	123544
	10,000.0	552	4273	211261	125053
0.40	10.0	1020	9027	149745	110237
	31.6	1020	9027	149747	110237
	100.0	1001	8906	151180	110715
	316.0	900	7048	161278	113559
	600.0	852	5995	171614	116236
	1000.0	708	5152	184528	118989
	3162.0	585	4598	208694	123176
	10,000.0	564	4319	213017	124992

TABLE 4

CATEGORY 4 OUTPUT DATA

Holding Cost	Shortage Cost	Requisition Backorder	Unit Backorder	Buy Dollars	Carrying Cost
0.12	10.0	1160	13482	1336164	442943
	31.6	1160	13482	1335915	442944
	100.0	1088	11497	1353263	449757
	316.0	800	8021	1453337	479875
	600.0	625	4851	1578096	507207
	1000.0	496	3922	1687031	538735
	3162.0	377	2850	1923140	607426
	10,000.0	338	2530	2057649	652770
0.14	10.0	1172	13685	1331780	442201
	31.6	1172	13685	1331780	442201
	100.0	1089	11999	1341172	446620
	316.0	877	8552	1442155	473313
	600.0	670	5298	1543471	496625
	1000.0	527	4233	1660462	527934
	3162.0	379	2929	1881955	598831
	10,000.0	325	2497	2042723	647209
0.16	10.0	1201	13916	1320919	440794
	31.6	1201	13916	1320919	440794
	100.0	1132	12389	1335412	444180
	316.0	892	9046	1413539	467851
	600.0	712	5700	1517296	491361
	1000.0	562	4551	1618325	518750
	3162.0	370	2911	1853589	591979
	10,000.0	325	2522	2032967	639430
0.18	10.0	1217	14281	1320413	440172
	31.6	1217	14281	1320413	440172
	100.0	1190	12749	1332483	442958
	316.0	950	9637	1404035	463044
	600.0	737	6564	1492249	484924
	1000.0	570	4531	1587427	510548
	3162.0	387	2976	1843273	584379
	10,000.0	325	2547	2043178	637694
0.20	10.0	1199	14387	1313954	439697
	31.6	1199	14387	1313954	439697
	100.0	1206	13168	1325111	441675
	316.0	963	9875	1383286	459111
	600.0	741	7107	1473174	481747
	1000.0	633	5004	1567102	504103
	3162.0	396	3047	1820748	578346
	10,000.0	328	2567	2019877	633620

TABLE 4 (continued)

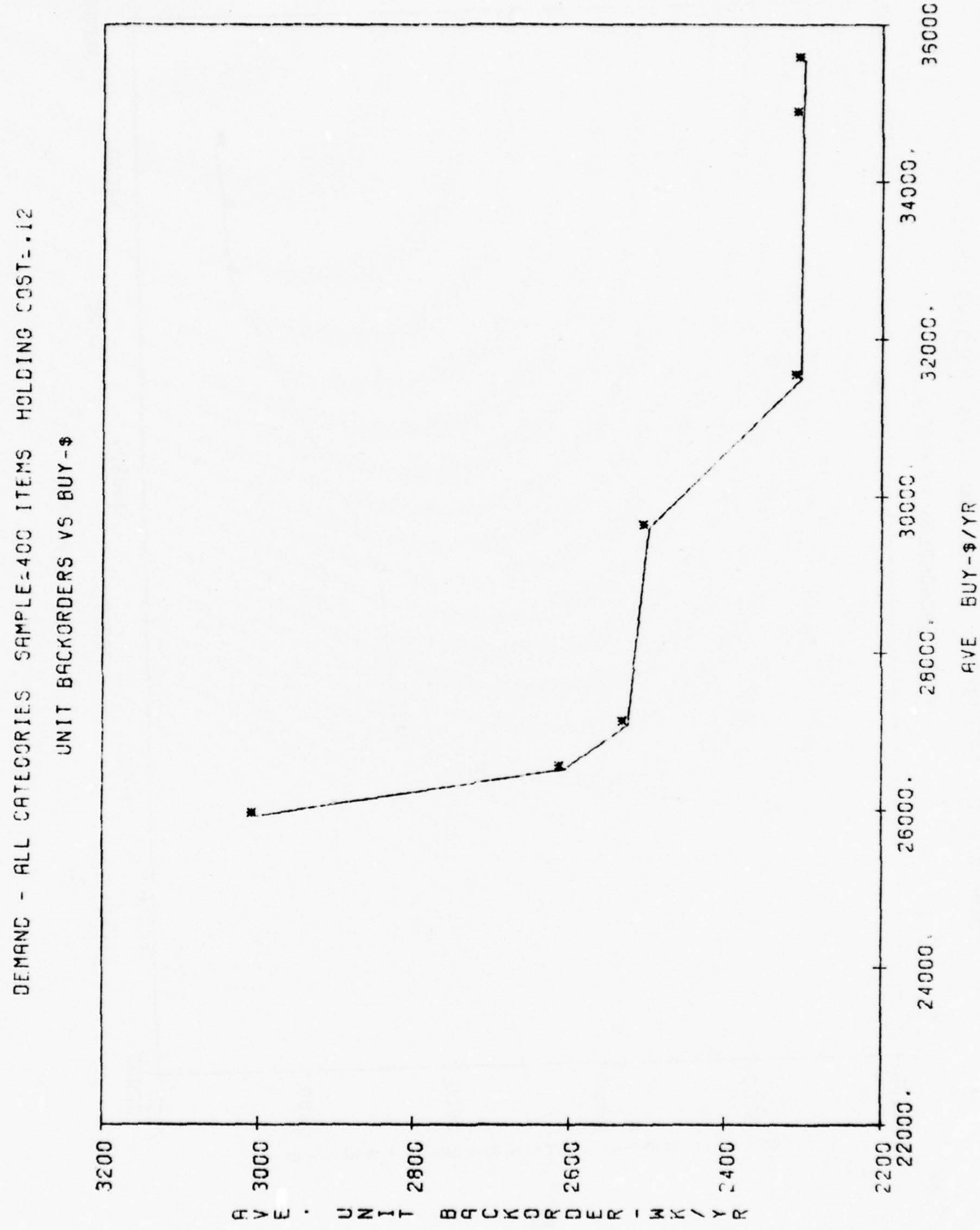
Holding Cost	Shortage Cost	Requisition Backorder	Unit Backorder	Buy Dollars	Carrying Cost
0.22	10.0	1209	14636	1309456	439394
	31.6	1209	14636	1309456	439394
	100.0	1220	13762	1319365	440900
	316.0	1015	10356	1366419	457001
	600.0	796	7611	1447682	478025
	1000.0	654	5042	1544670	498599
	3162.0	404	2981	1801879	573578
	10,000.0	340	2672	2015647	630694
0.24	10.0	1226	14879	1307680	439148
	31.6	1226	14879	1307680	439148
	100.0	1239	14200	1313124	440472
	316.0	1074	11037	1358079	454210
	600.0	838	7927	1438171	474135
	1000.0	671	5263	1520889	492639
	3162.0	409	3050	1779641	568439
	10,000.0	346	2692	1988958	626172
0.26	10.0	1222	15008	1305341	438917
	31.6	1222	15008	1305341	438917
	100.0	1201	14457	1308245	439924
	316.0	1074	11332	1348120	452041
	600.0	854	8217	1431045	471647
	1000.0	682	5487	1502187	489600
	3162.0	410	3104	1777740	564166
	10,000.0	342	2585	1976798	623072
0.28	10.0	1226	15057	1305934	438655
	31.6	1226	15057	1305934	438655
	100.0	1215	14563	1306205	439413
	316.0	1087	11487	1346937	450905
	600.0	869	8769	1414191	469388
	1000.0	704	5736	1486199	486497
	3162.0	425	3194	1755813	557564
	10,000.0	342	2602	1968224	619972
0.30	10.0	1243	15237	1308625	438819
	31.6	1243	15237	1308625	438819
	100.0	1235	14746	1309107	439405
	316.0	1113	11304	1342534	450240
	600.0	882	8934	1407985	467001
	1000.0	722	6042	1489216	483858
	3162.0	438	3273	1738701	551621
	10,000.0	342	2612	1956896	617955

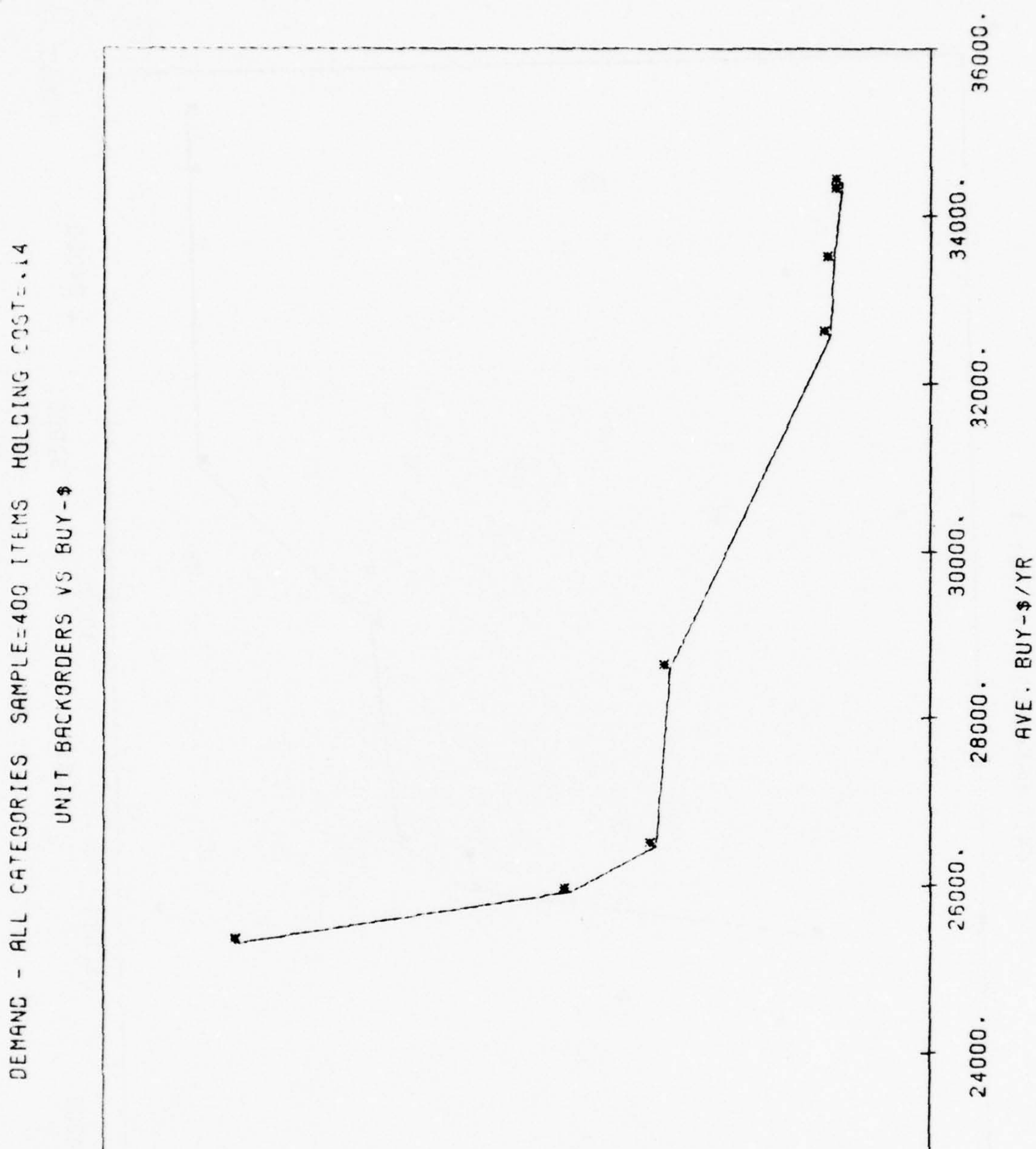
TABLE 4 (continued)

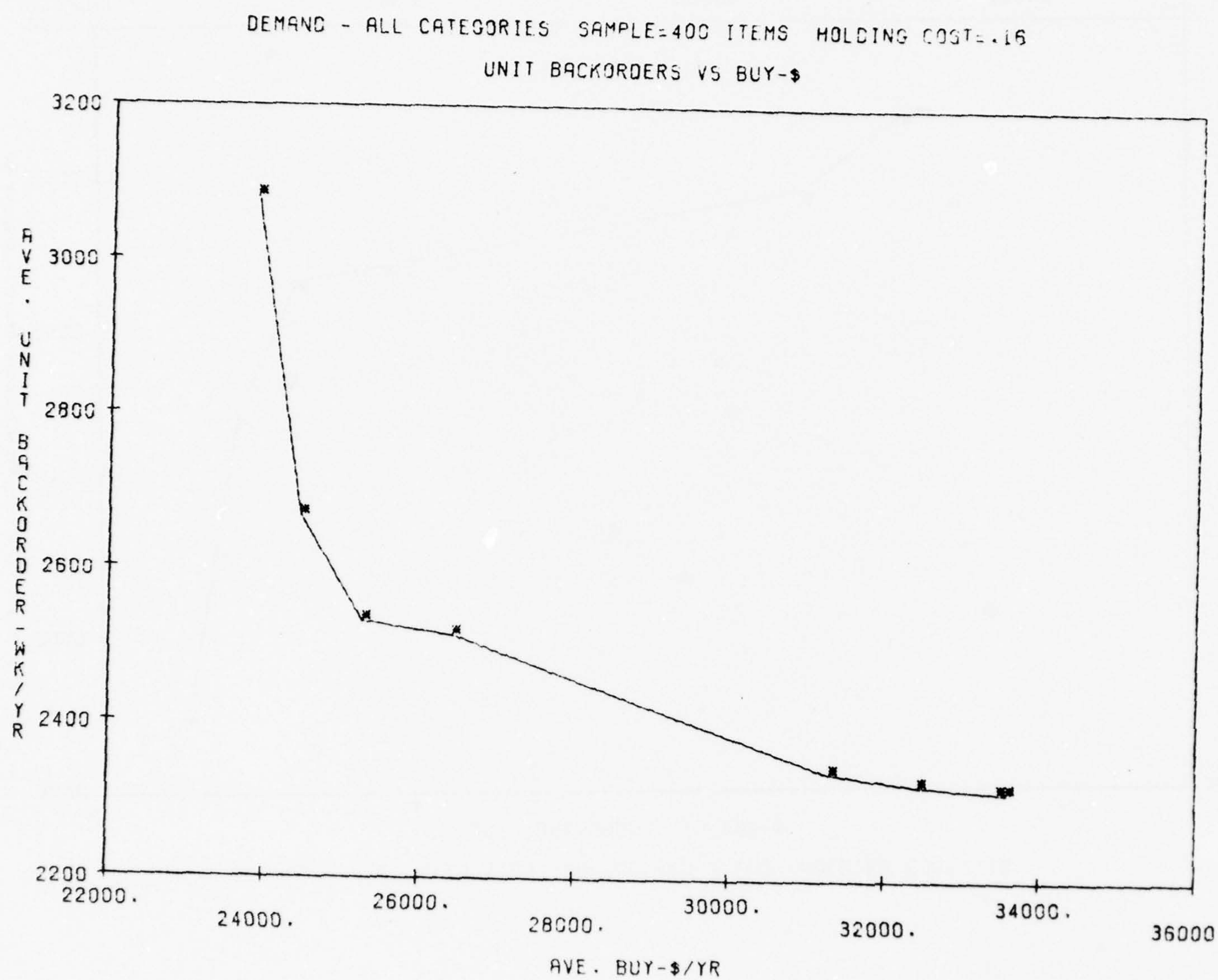
Holding Cost	Shortage Cost	Requisition Backorder	Unit Backorder	Buy Dollars	Carrying Cost
0.32	10.0	1252	15442	1310038	438728
	31.6	1252	15442	1310038	438728
	100.0	1235	14005	1310721	439134
	316.0	1092	11627	1340346	449442
	600.0	906	9179	1400931	464554
	1000.0	742	7089	1481704	482651
	3162.0	448	3339	1721218	548304
	10,000.0	348	2634	1949921	615092
0.36	10.0	1252	14559	1308669	438610
	31.6	1252	14559	1308669	438610
	100.0	1241	14013	1309205	438820
	316.0	1111	11808	1336532	447317
	600.0	956	9670	1387478	461038
	1000.0	801	7579	1444696	477756
	3162.0	469	3673	1684396	537394
	10,000.0	348	2658	1924013	605284
0.40	10.0	1256	14580	1308124	438662
	31.6	1256	14580	1308124	438662
	100.0	1249	14220	1308618	438724
	316.0	1114	11967	1331636	446024
	600.0	969	9888	1361258	457888
	1000.0	840	7977	1436723	473715
	3162.0	497	3925	1666202	530937
	10,000.0	350	2684	1900623	600188

APPENDIX B

GRAPHS OF BUY DOLLARS VERSUS UNIT BACKORDERS FOR CATEGORY 1

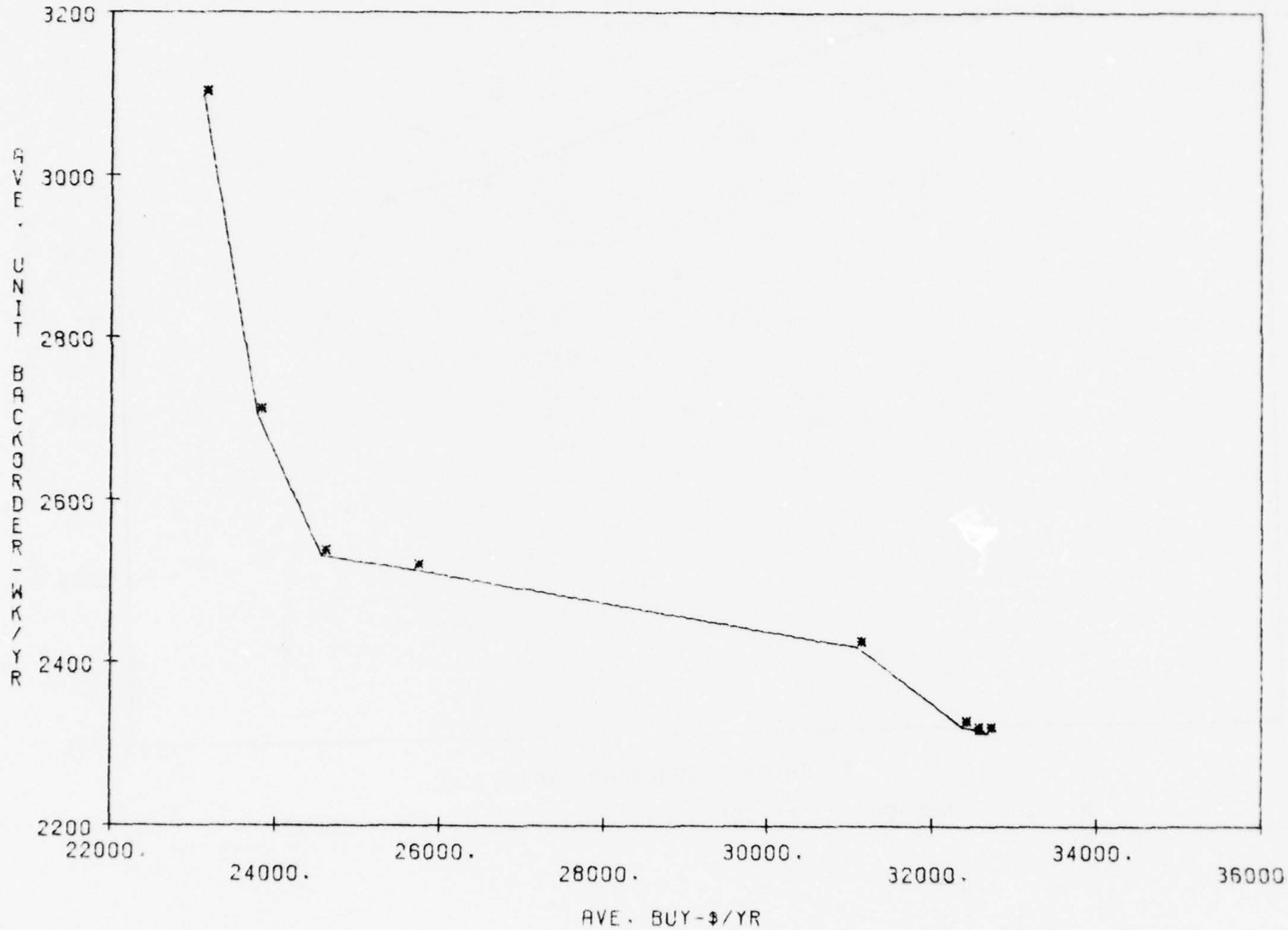

DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.12
UNIT BACKORDERS VS BUY-$
AVE. UNIT BACKORDER-WK/YR
3200
3000
2800
2600
2400
2200
22000.
24000.
26000.
28000.
30000.
32000.
34000.
36000.
AVE BUY-$/YR


DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.14
UNIT BACKORDERS VS BUY-$
AVE. UNIT BACKORDER-WK/YR
3200
3000
2800
2600
2400
2200
22000.
24000.
26000.
28000.
30000.
32000.
34000.
36000.
AVE. BUY-$/YR


DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.16
UNIT BACKORDERS VS BUY-$
AVE. UNIT BACKORDER-WK/YR
3200
3000
2800
2600
2400
2200
22000.
24000.
26000.
28000.
30000.
32000.
34000.
36000.
AVE. BUY-$/YR

DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.18

UNIT BACKORDERS VS BUY-$



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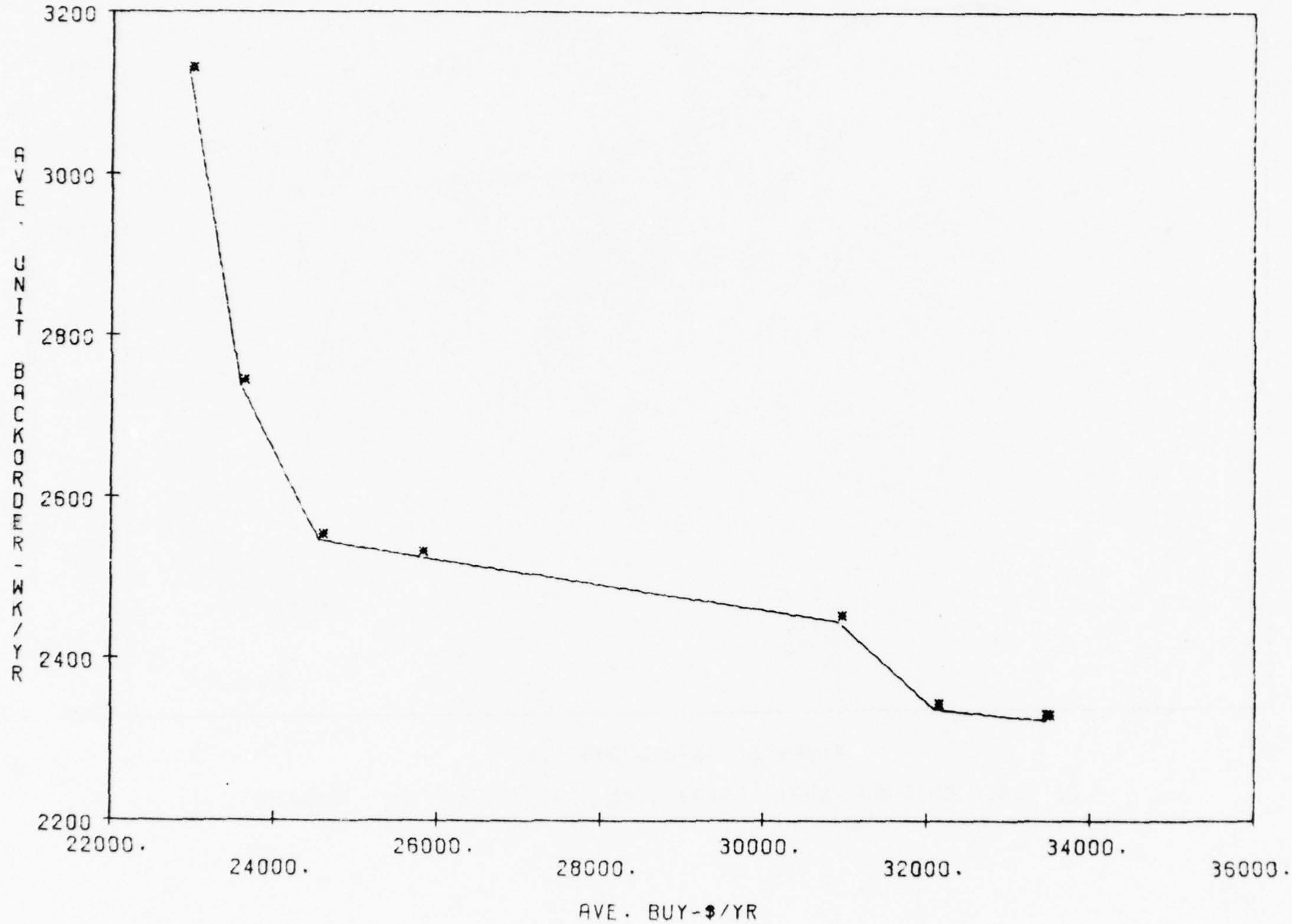
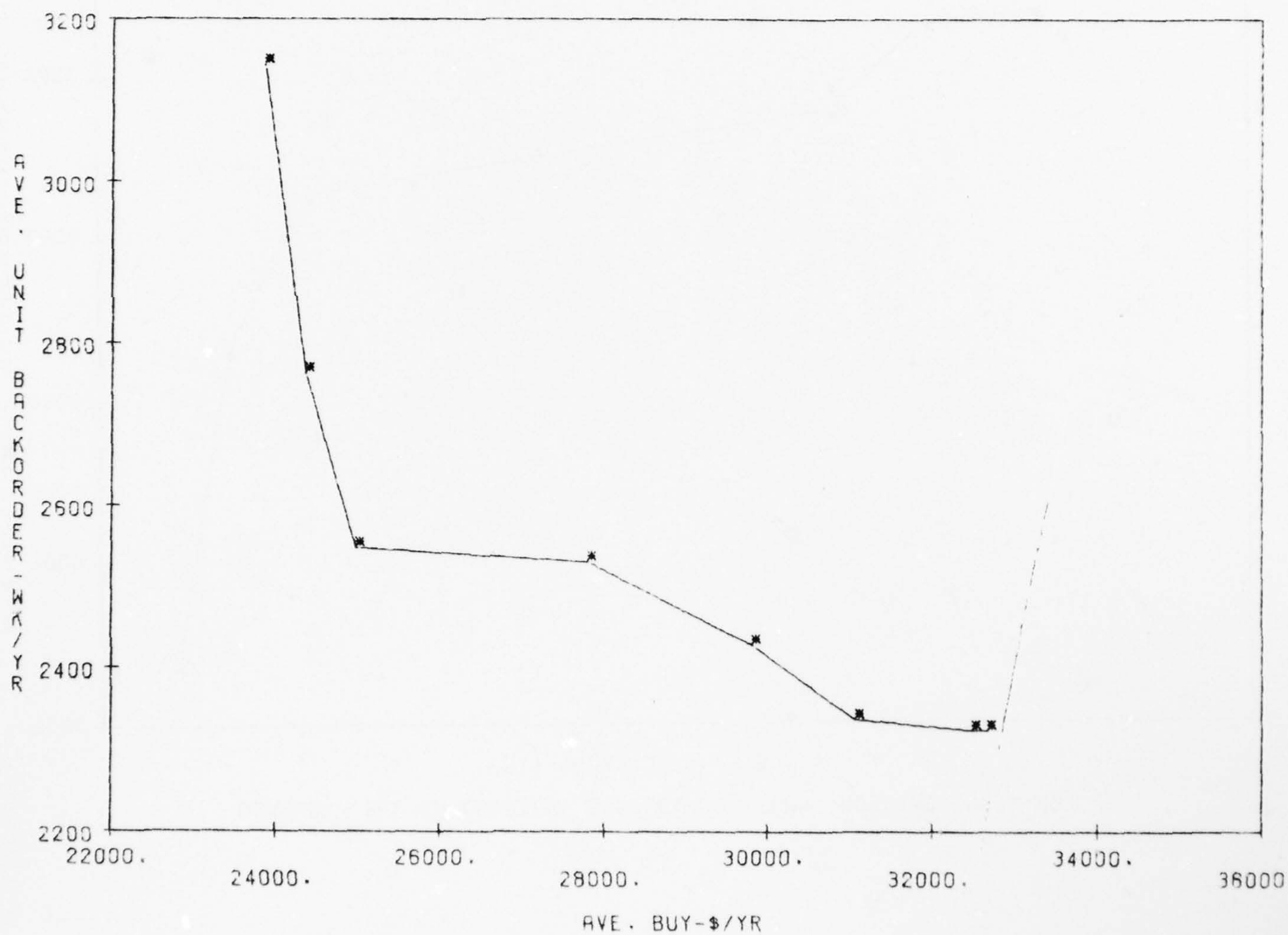
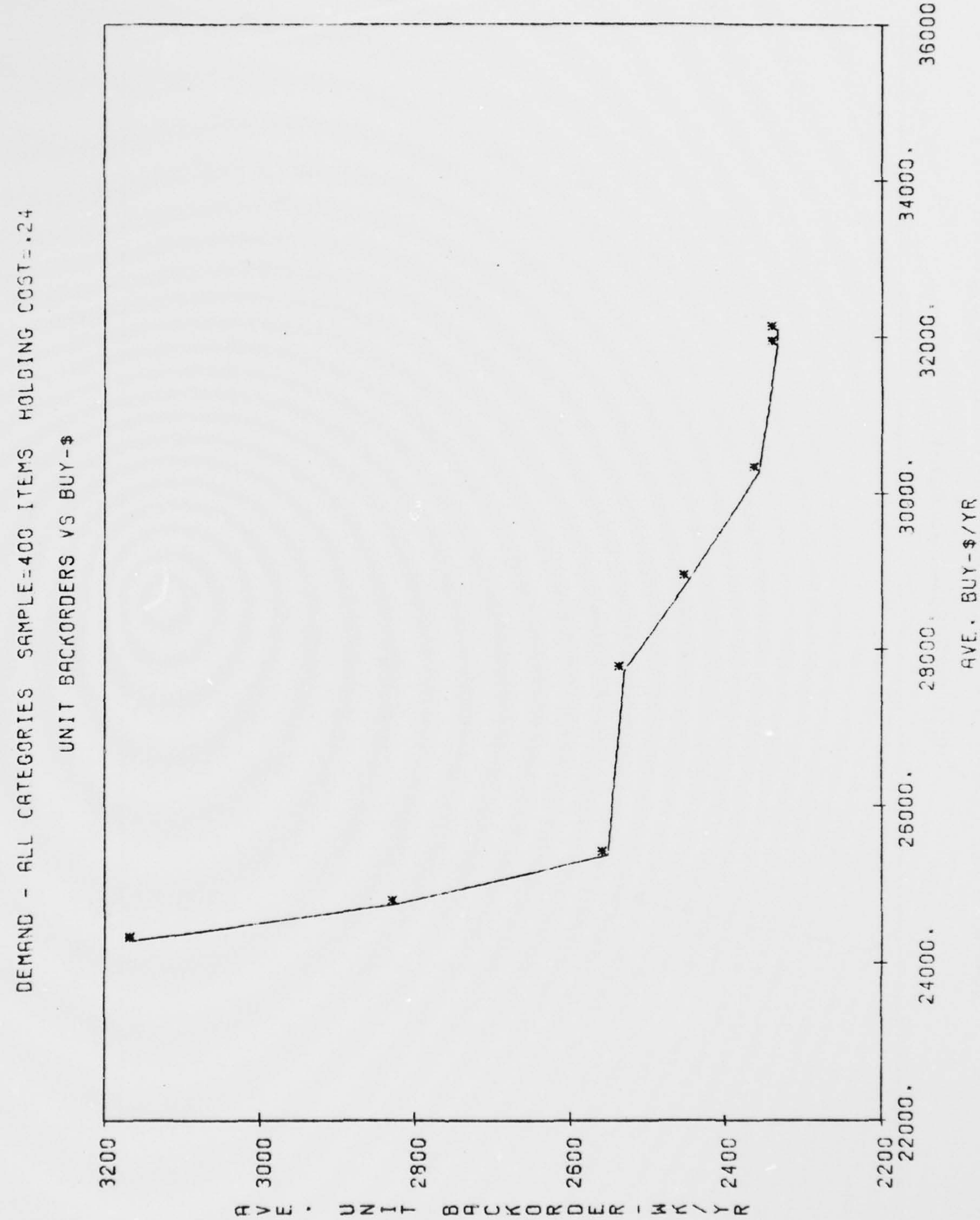
UNIT BACKORDERS VS BUY-$

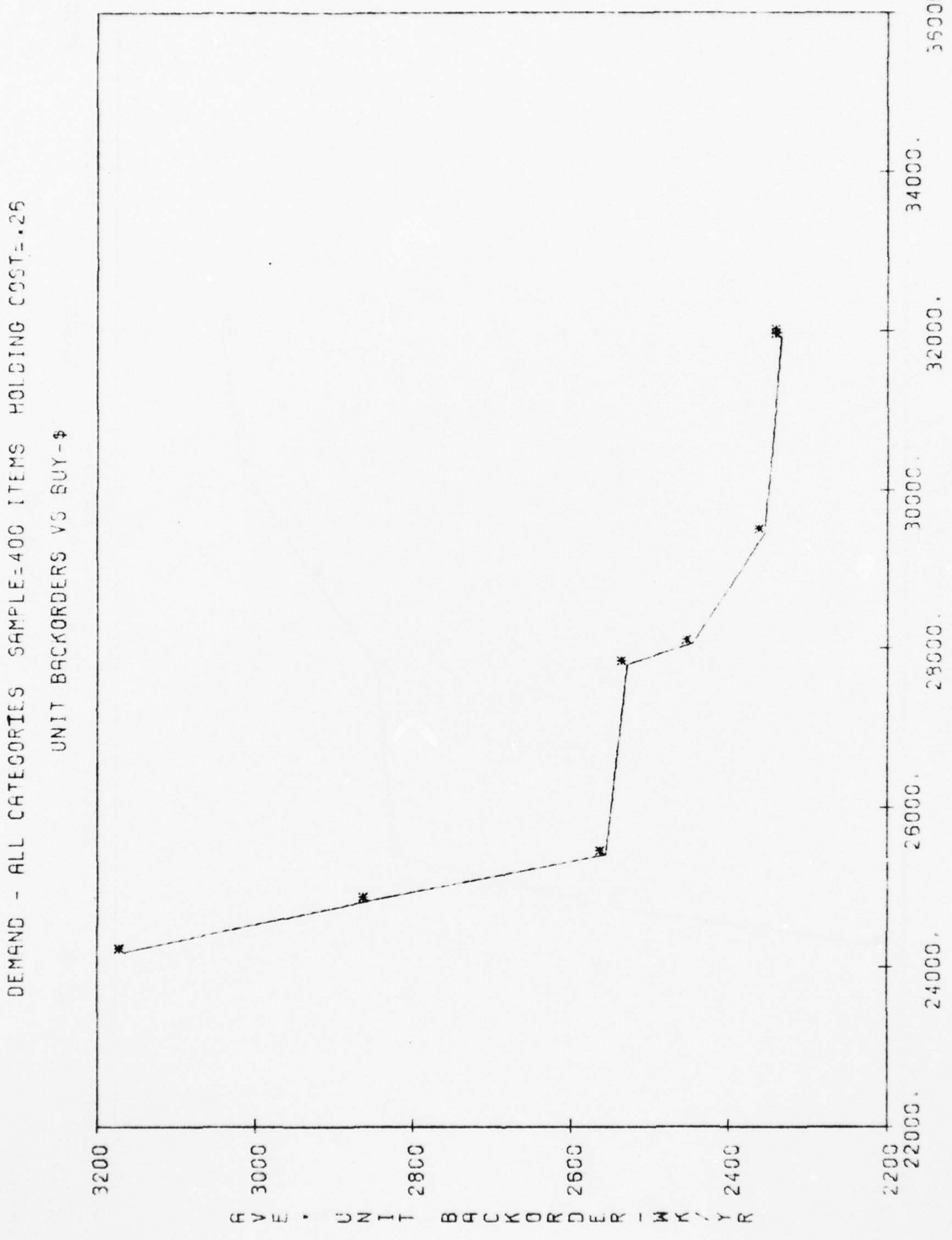


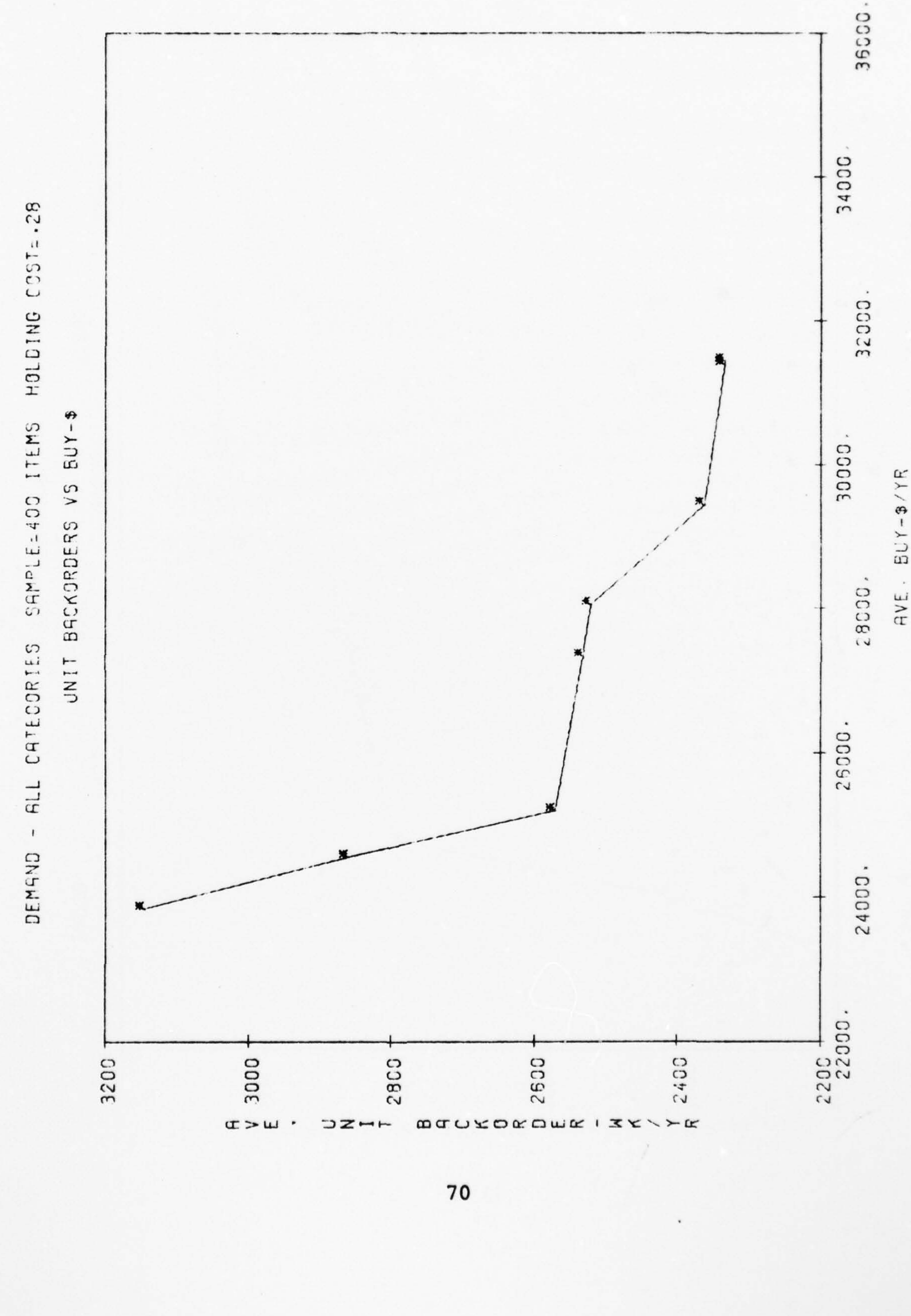
DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.22

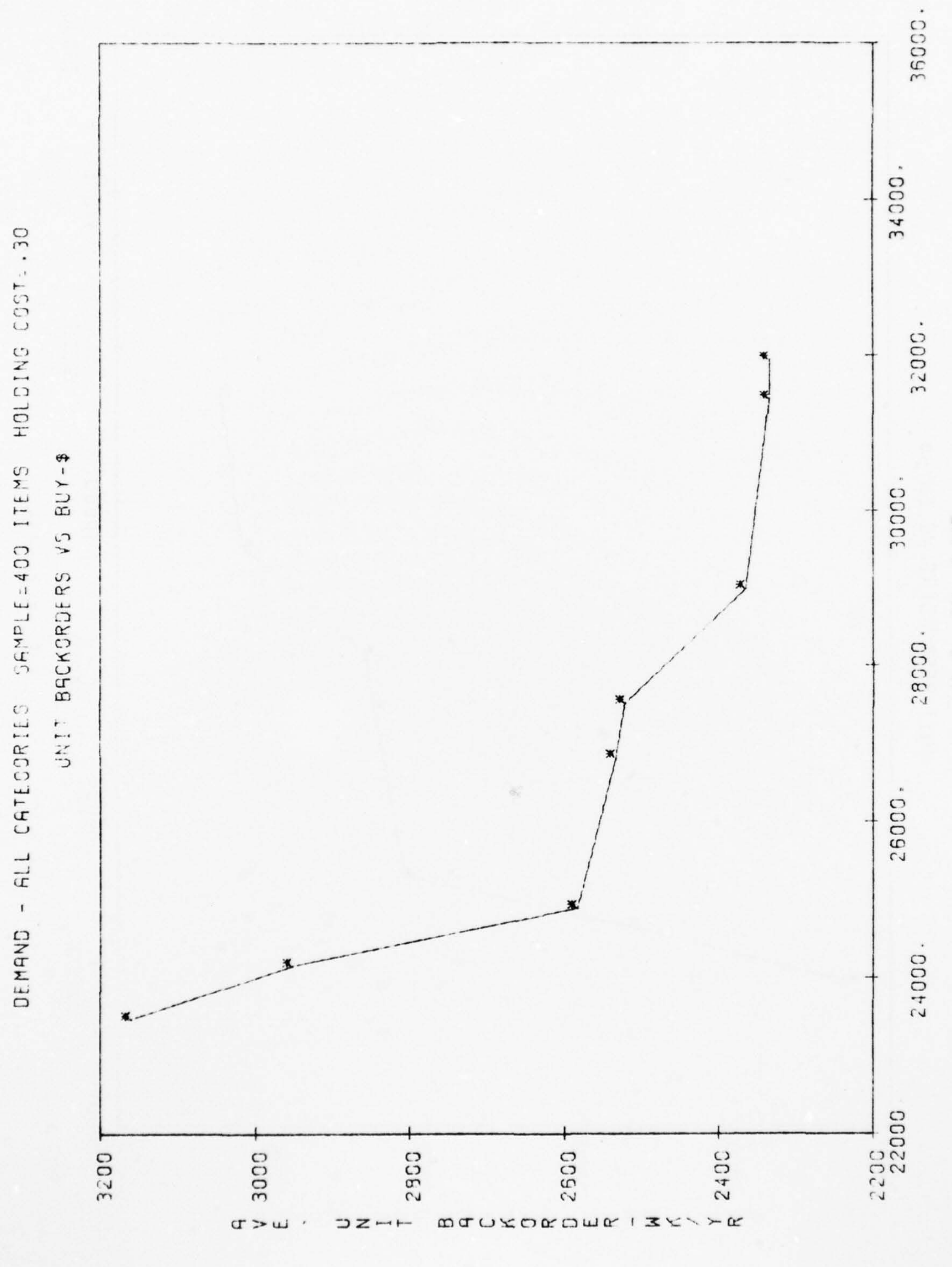
UNIT BACKORDERS VS BUY-$

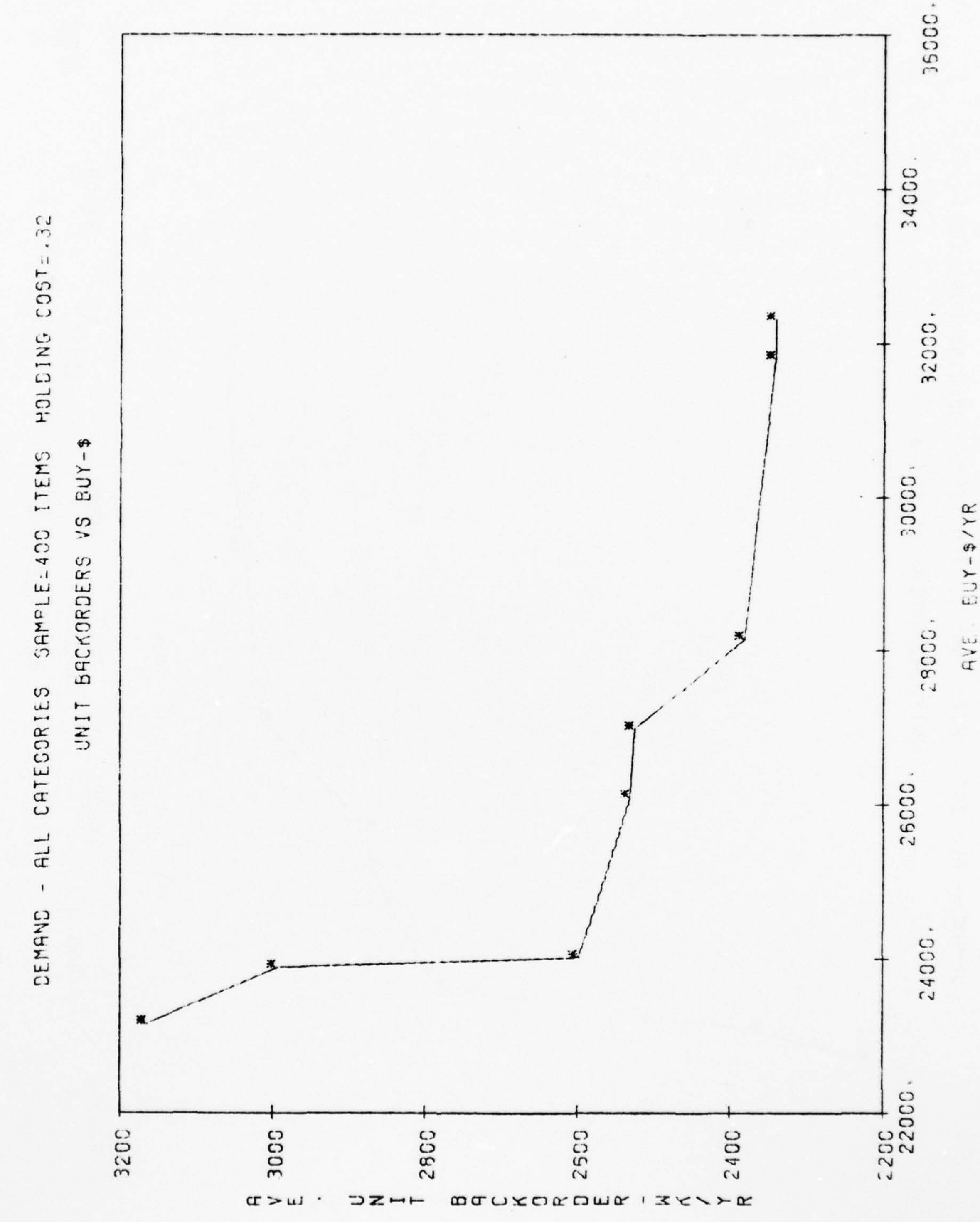


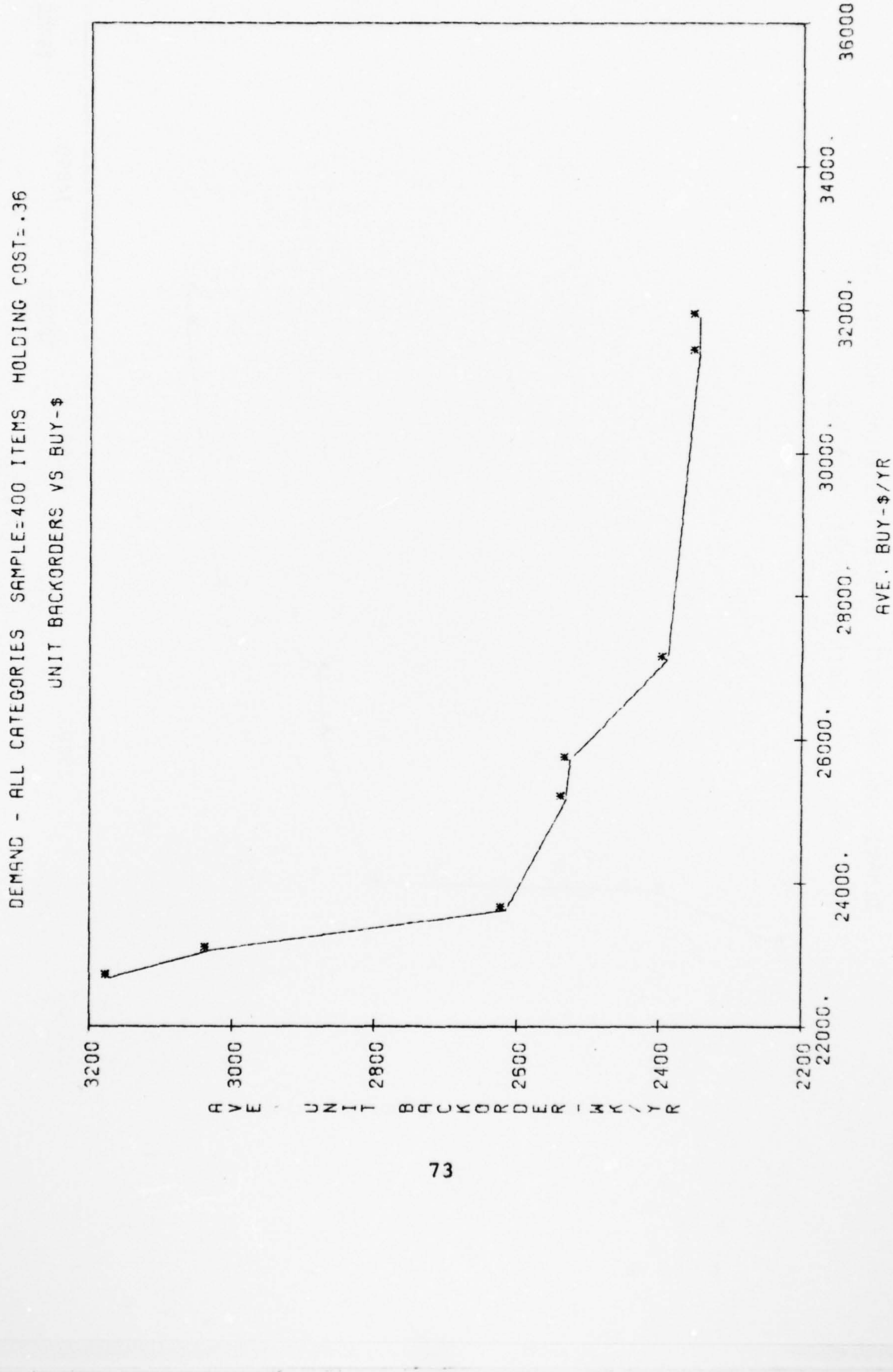

DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.24
UNIT BACKORDERS VS BUY-$
AVE. UNIT BACKORDER-WK/YR
3200
3000
2800
2600
2400
2200
22000.
24000.
26000.
28000.
30000.
32000.
34000.
36000.
AVE. BUY-$/YR

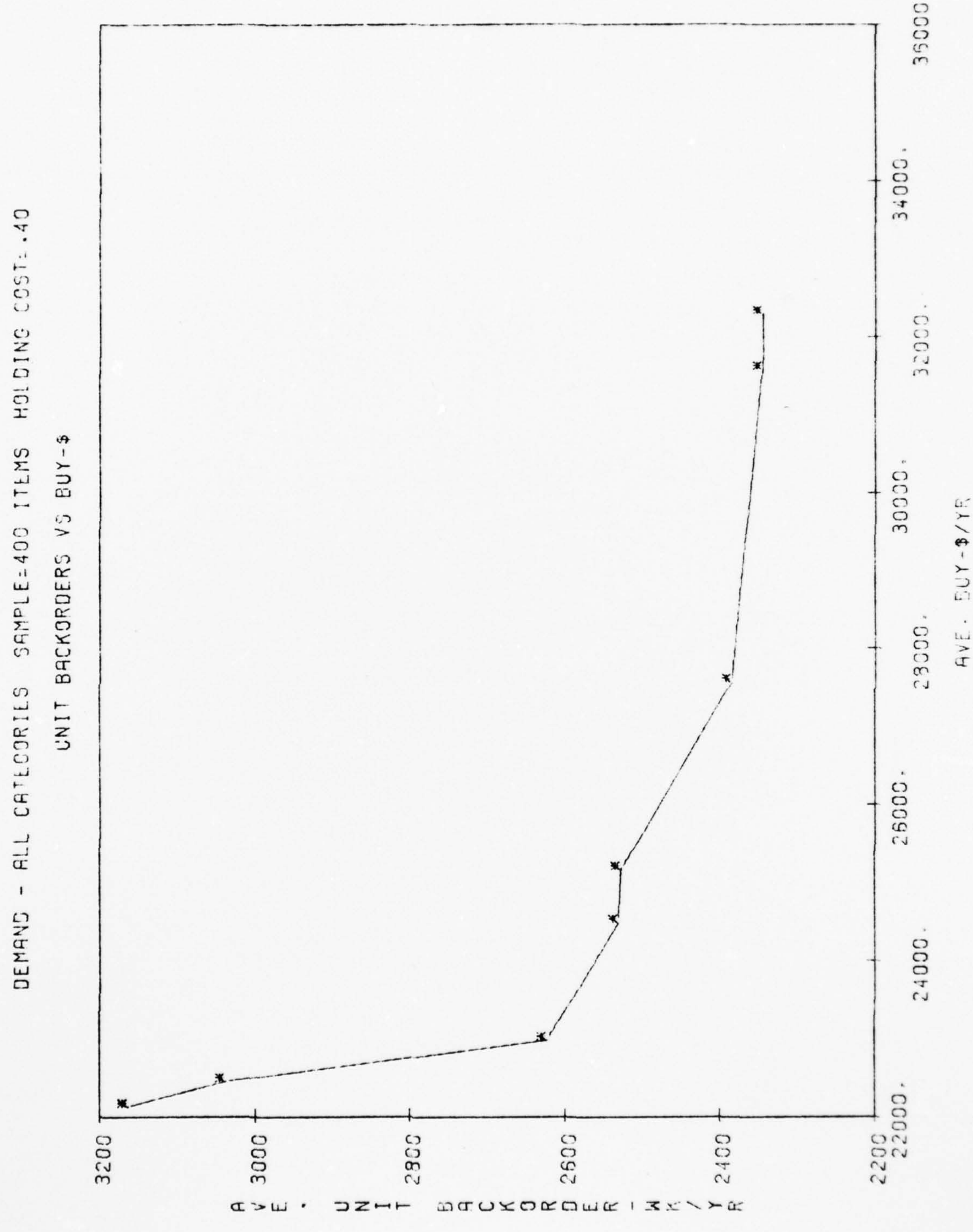

DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.25
UNIT BACKORDERS VS BUY-$
AVE BUY-$/YR
22000.
24000.
26000.
28000.
30000.
32000.
34000.
36000.
3200
3000
2800
2600
2400
2200
AVE. UNIT BACKORDER


DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.28
UNIT BACKORDERS VS BUY-$
AVE. BUY-$/YR
22000.
24000.
26000.
28000.
30000.
32000.
34000.
36000.
AVE. UNIT BACKORDER-WK/YR
2200
2400
2600
2800
3000
3200


DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.30
UNIT BACKORDERS VS BUY-$
AVE. BUY-$/YR
AVE. UNIT BACKORDER-WK/YR
22000
24000.
26000.
28000.
30000.
32000.
34000.
36000.
2200
2400
2600
2800
3000
3200


DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.32
UNIT BACKORDERS VS BUY-$
AVE. UNIT BACKORDER-WK/YR
AVE. BUY-$/YR
3200
3000
2800
2600
2400
2200
22000.
24000.
26000.
28000.
30000.
32000.
34000.
35000.


DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.36
UNIT BACKORDERS VS BUY-$
AVE. BUY-$/YR
AVE. UNIT BACKORDER-WK/YR
3200
3000
2800
2600
2400
2200
22000.
24000.
26000.
28000.
30000.
32000.
34000.
36000.

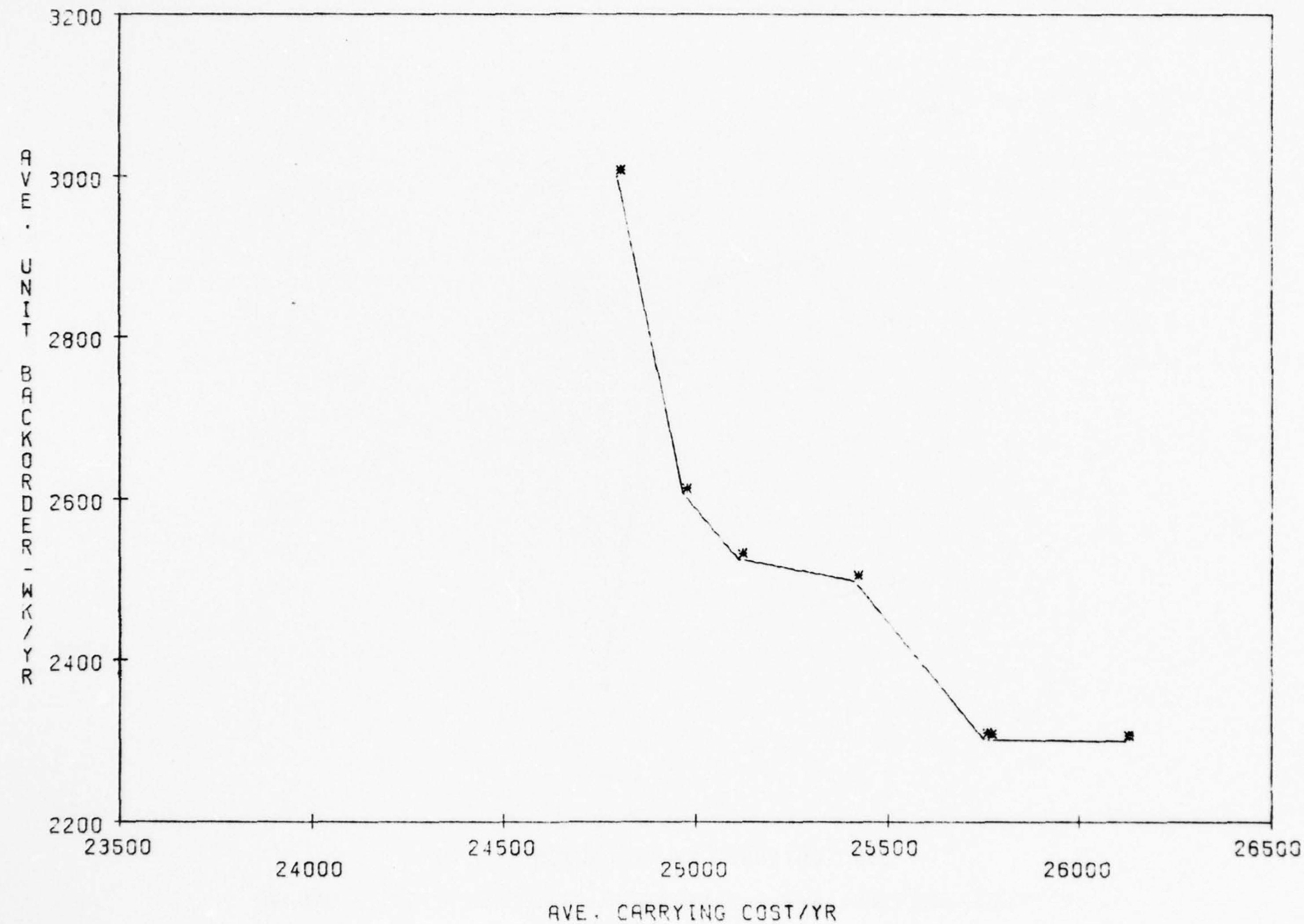

DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.40
UNIT BACKORDERS VS BUY-$
AVE. UNIT BACKORDER-WK/YR
3200
3000
2800
2600
2400
2200
22000.
24000.
26000.
28000.
30000.
32000.
34000.
36000.
AVE. BUY-$/YR

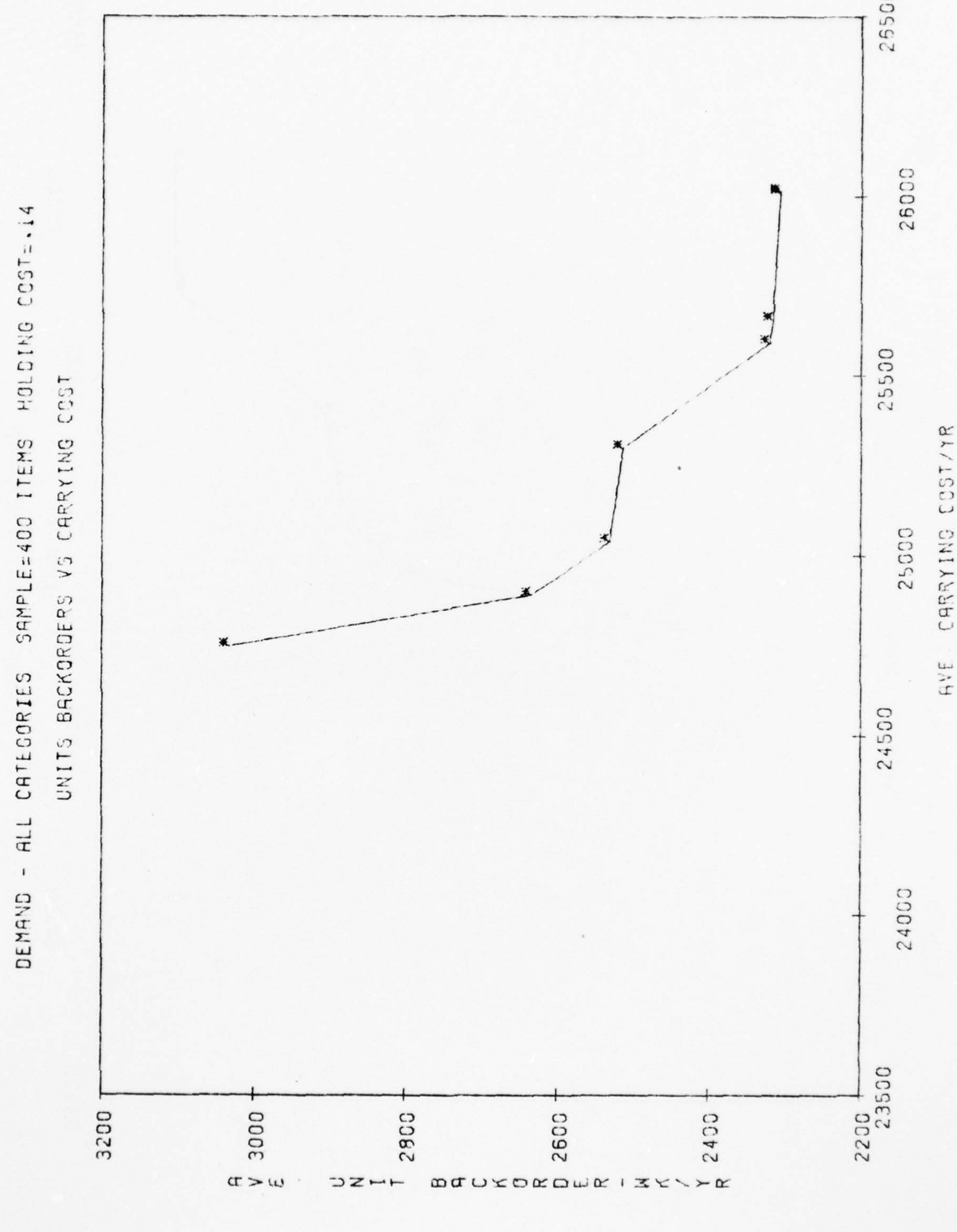
APPENDIX C

GRAPHS OF CARRYING COSTS VERSUS UNIT BACKORDERS FOR CATEGORY 1

DEMA D - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.12

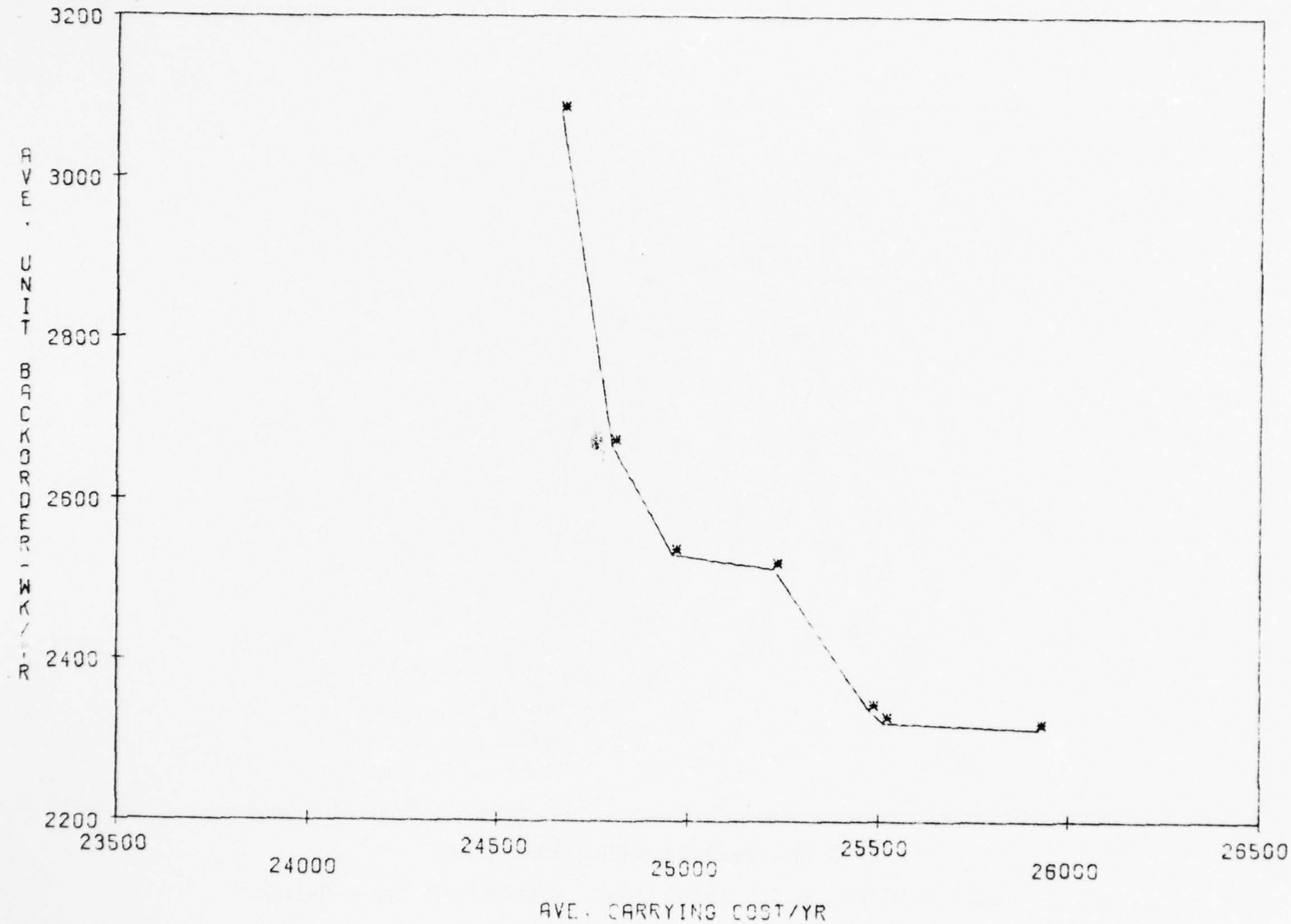
UNITS BACKORDERS VS CARRYING COST

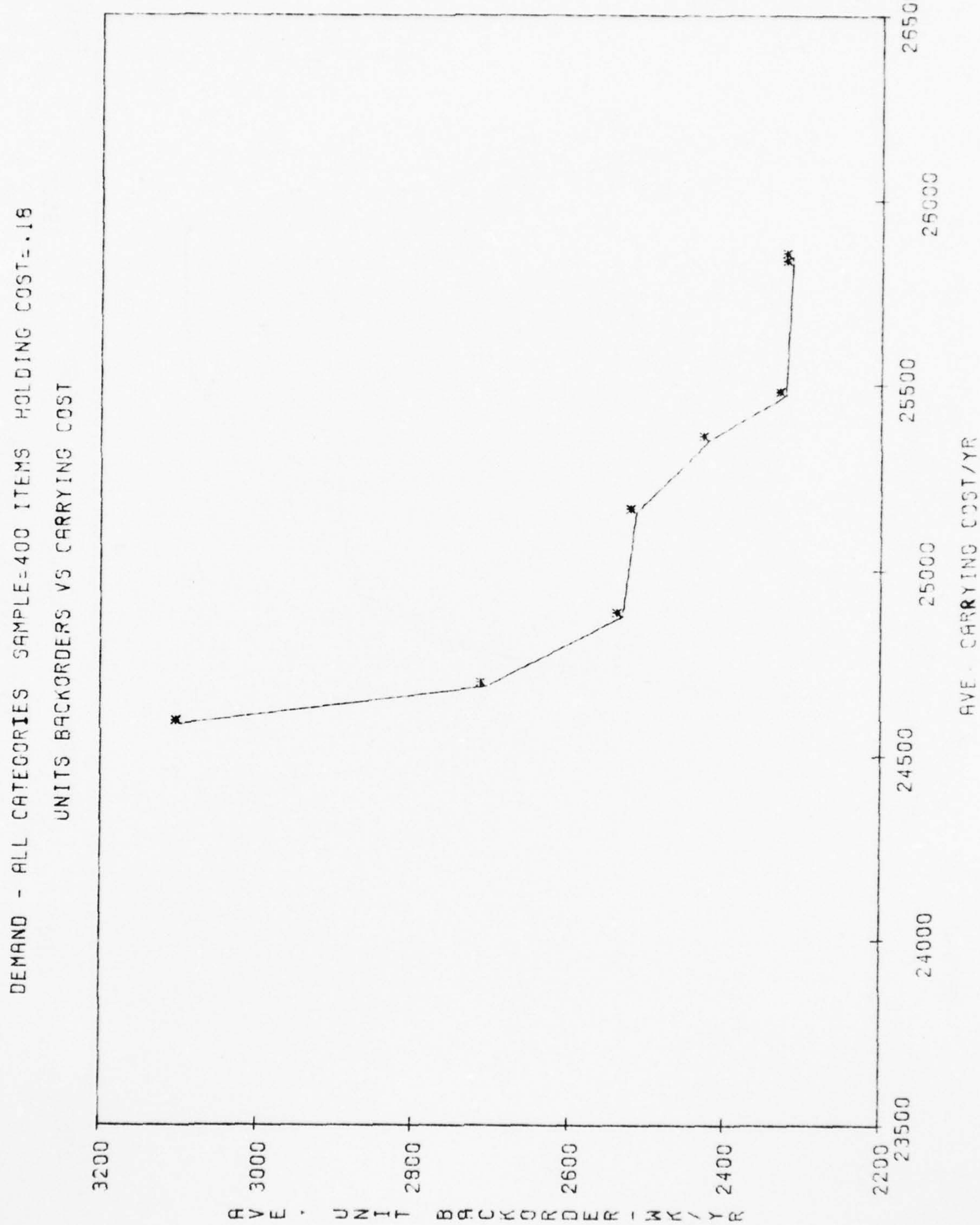



DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.14
UNITS BACKORDERS VS CARRYING COST
3200
3000
2800
2600
2400
2200
23500
24000
24500
25000
25500
26000
26500
AVE CARRYING COST/YR
AVE UNIT BACKORDER-WK/YR

DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.16

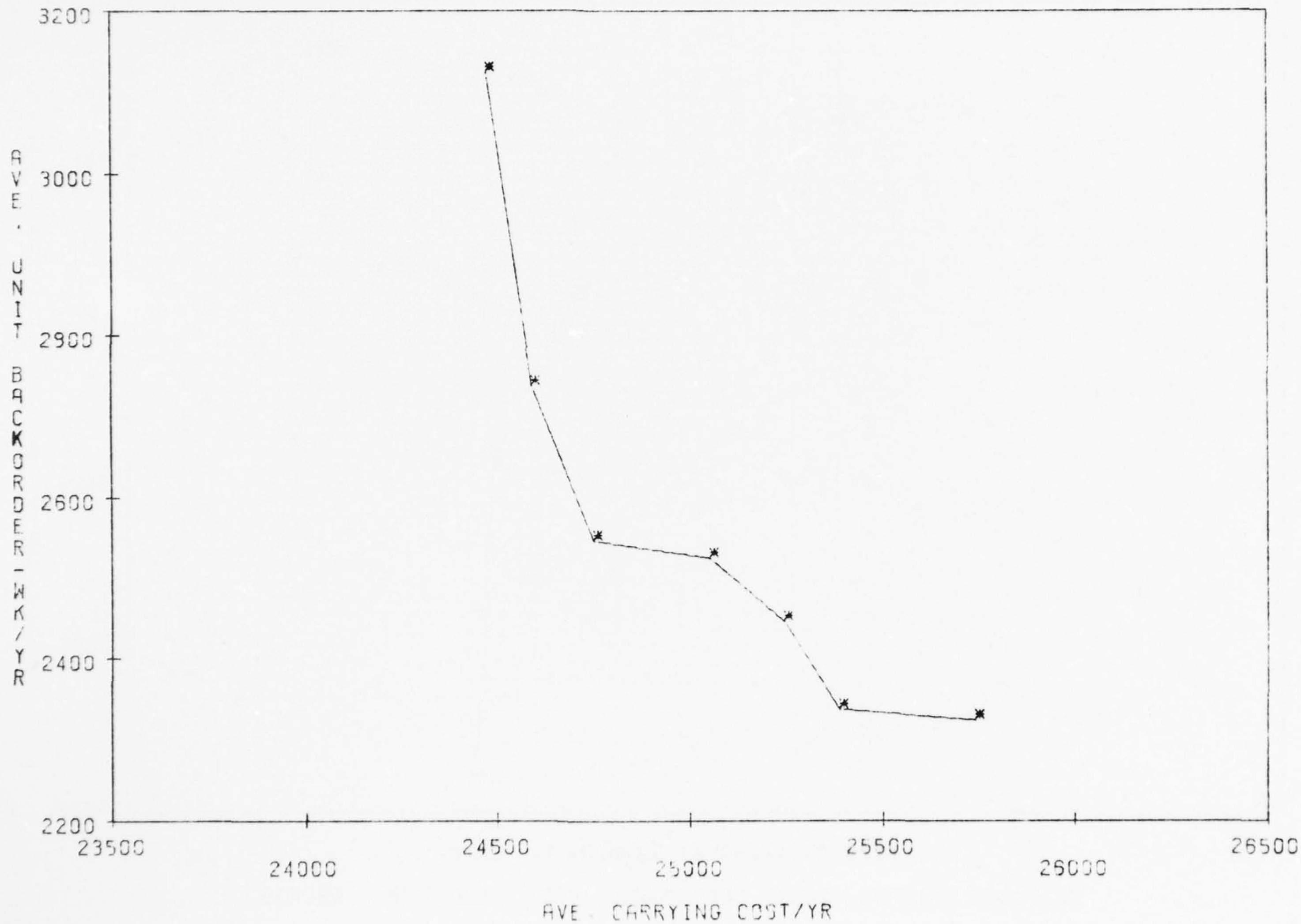
UNITS BACKORDERS VS CARRYING COST

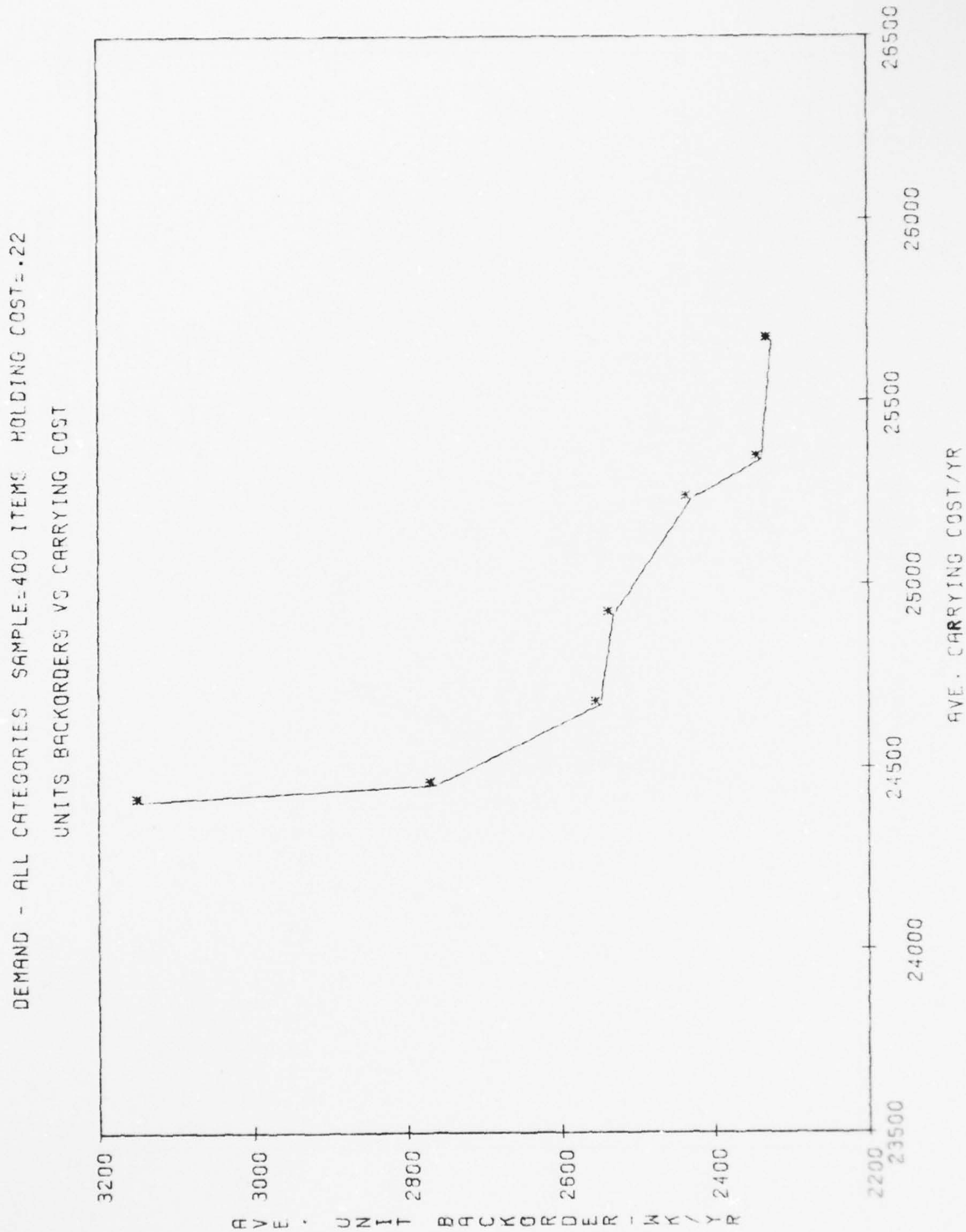



DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.18
UNITS BACKORDERS VS CARRYING COST
3200
3000
2800
2600
2400
2200
AVE. UNIT BACKORDER-WK/YR
23500
24000
24500
25000
25500
26000
26500
AVE. CARRYING COST/YR

DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.20

UNITS BACKORDERS VS CARRYING COST




DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.22
UNITS BACKORDERS VS CARRYING COST
AVE. UNIT BACKORDER-WK/YR
3200
3000
2800
2600
2400
2200
AVE. CARRYING COST/YR
23500
24000
24500
25000
25500
26000
26500

AD-A061 299 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCHO--ETC F/G 15/5
AN EMPIRICAL ANALYSIS OF A USAF ECONOMIC ORDER QUALITY PARAMETE--ETC(U)
SEP 78 J CARRILLO, D G PEABODY
UNCLASSIFIED AFIT-LSSR-36-78B NL

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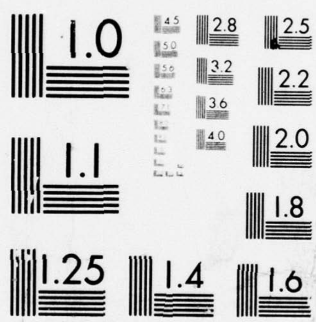


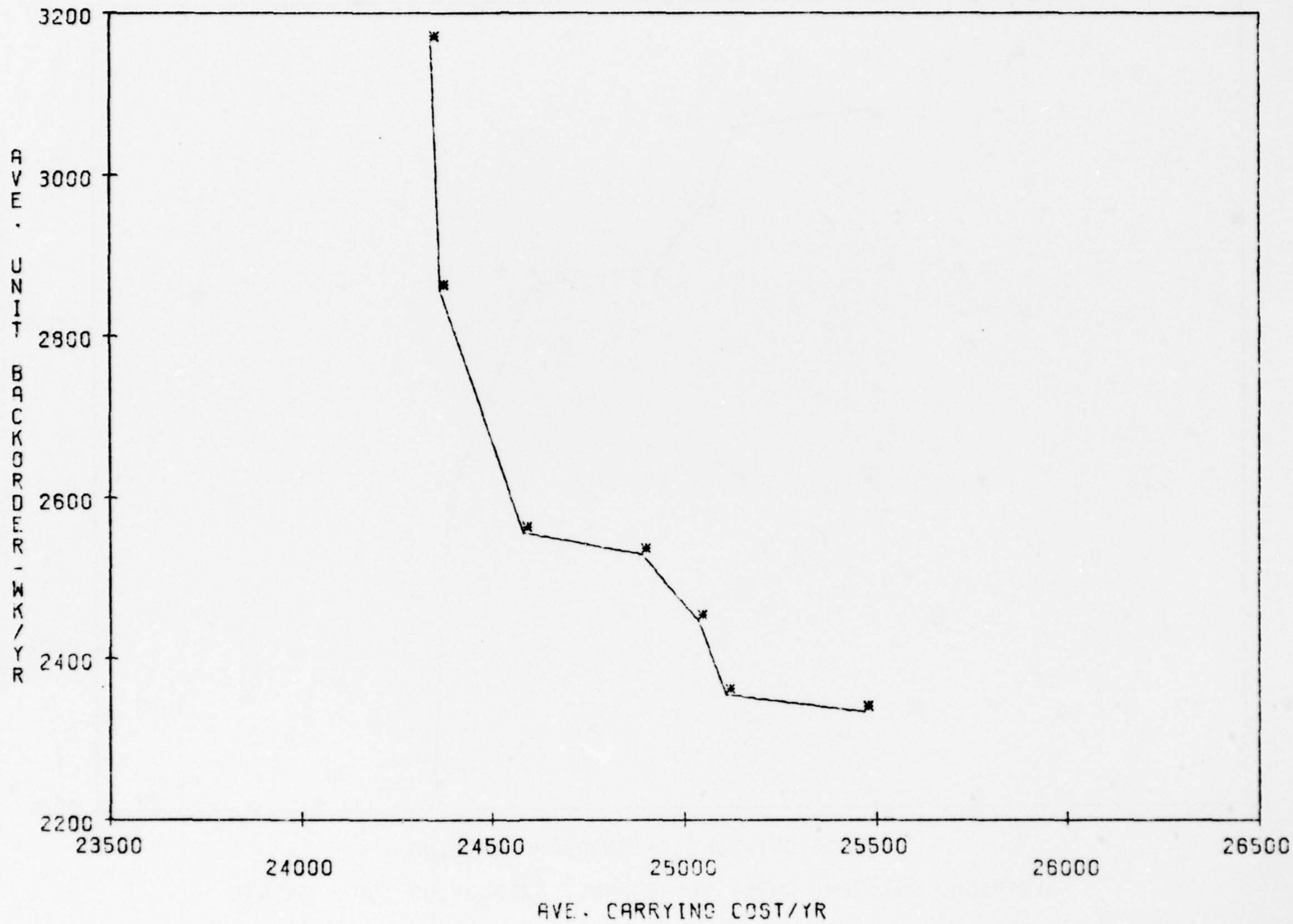
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.24

UNITS BACKORDERS VS CARRYING COST

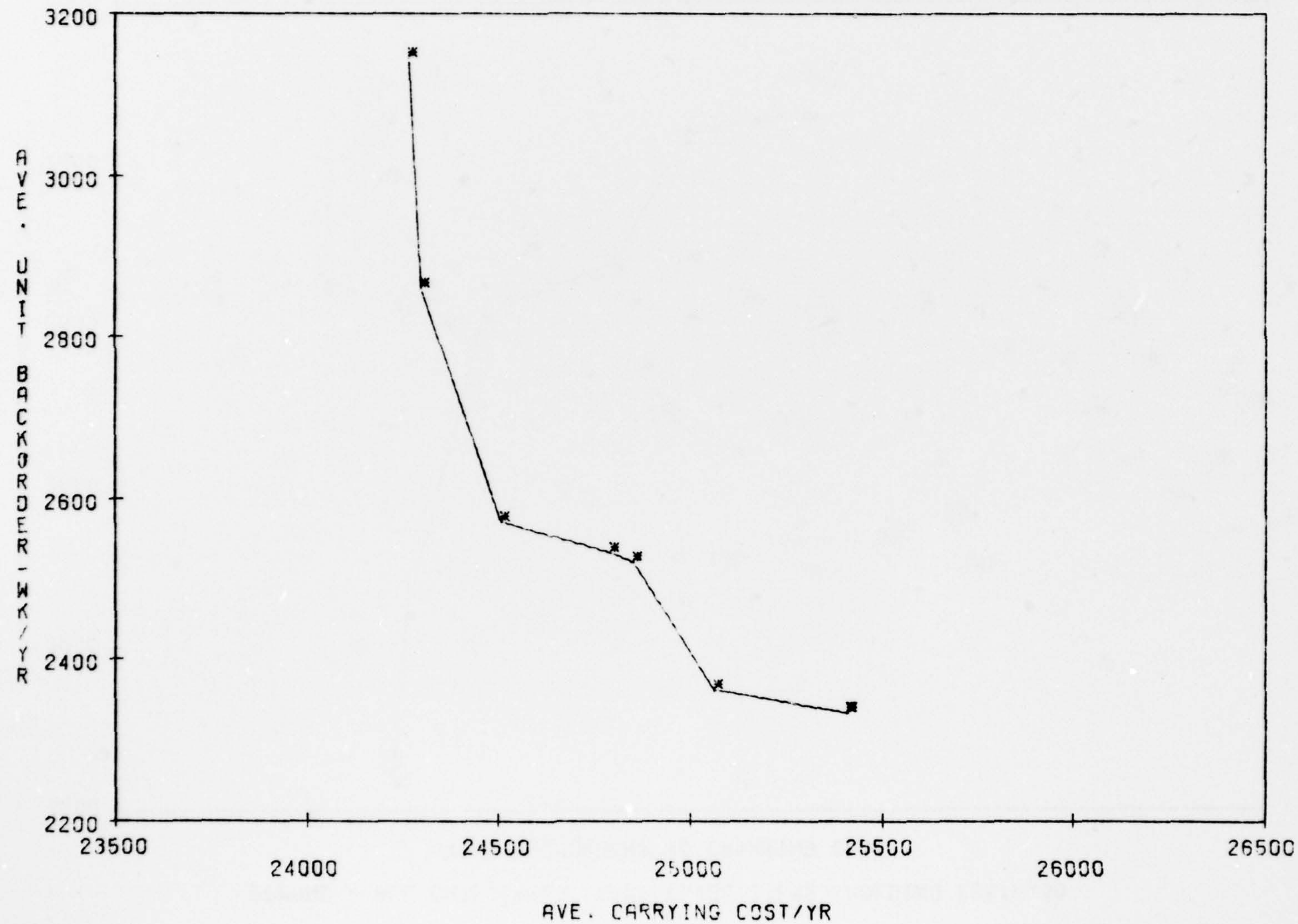
DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.26

UNITS BACKORDERS VS CARRYING COST



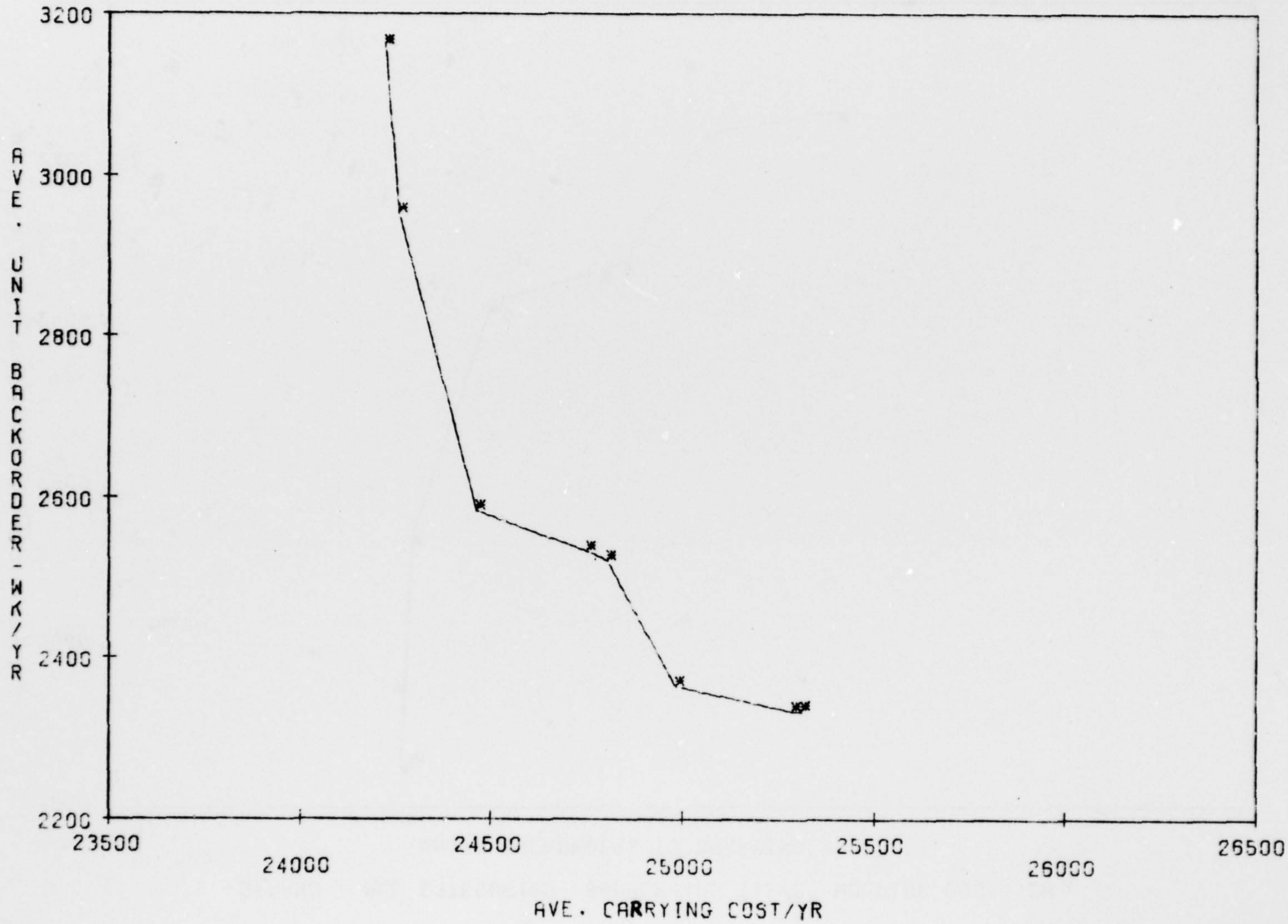
DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.28

UNITS BACKORDERS VS CARRYING COST



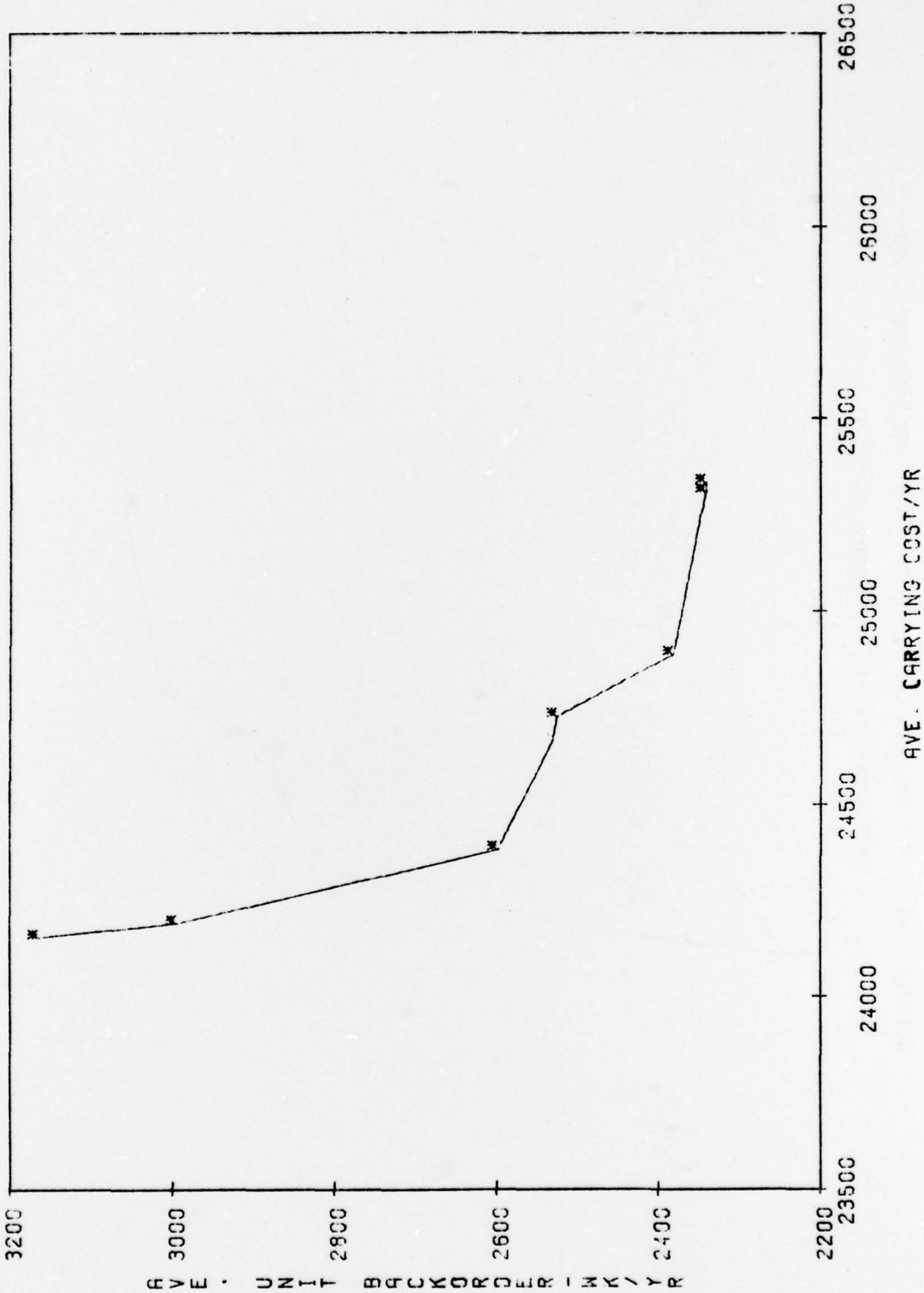
DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.30

UNITS BACKORDERS VS CARRYING COST



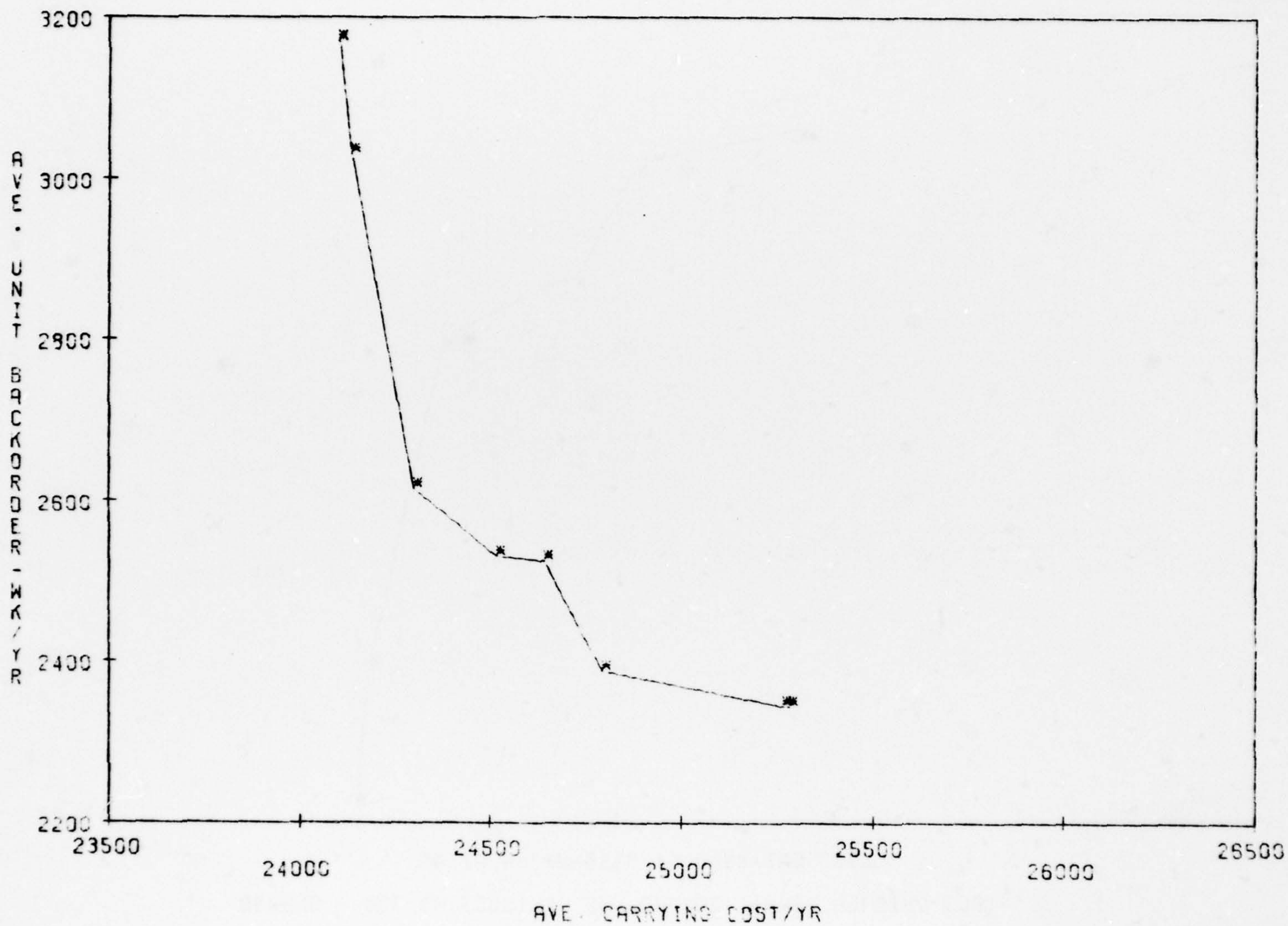
DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.32

UNITS BACKORDERS VS CARRYING COST



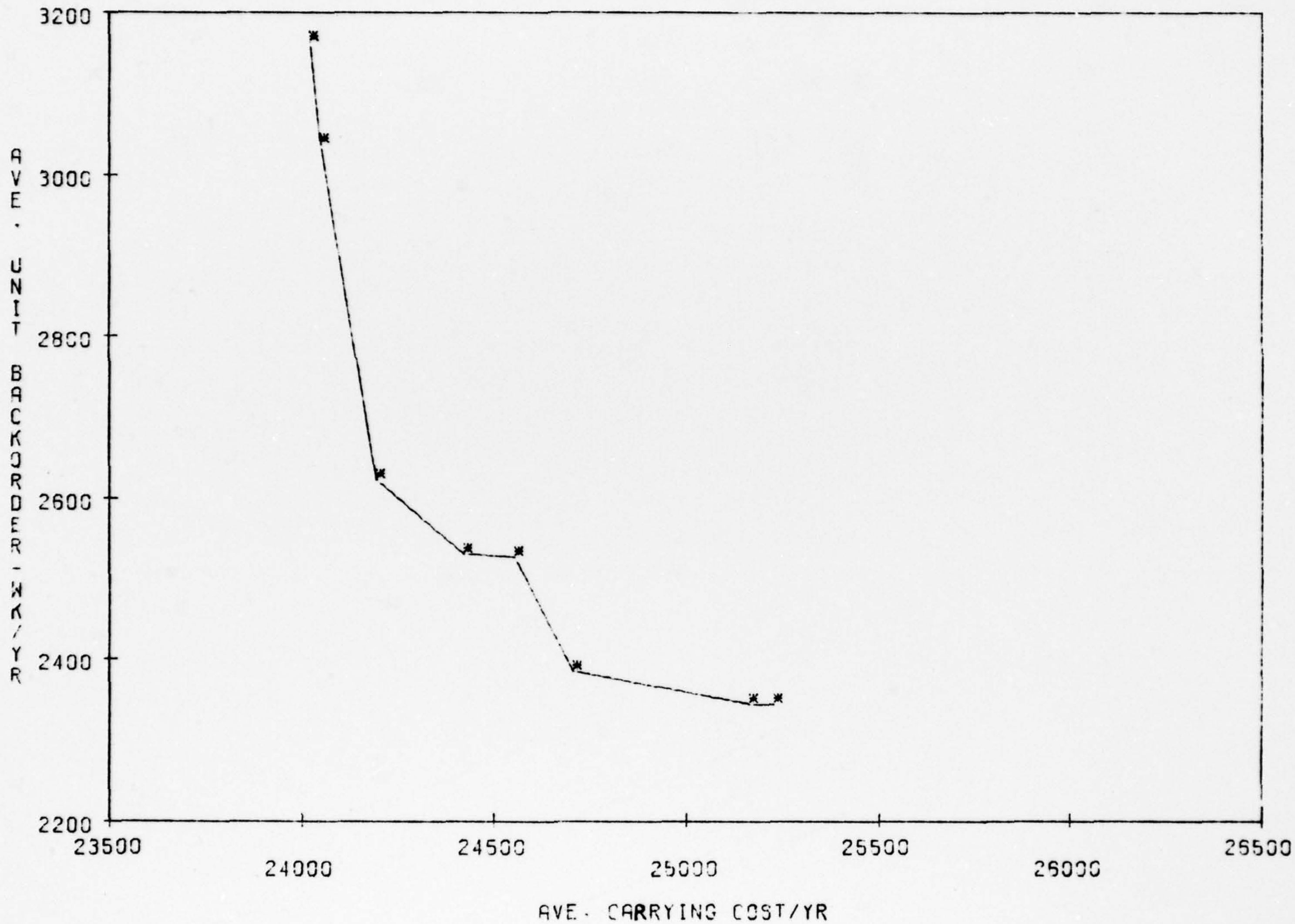
DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.36

UNITS BACKORDERS VS CARRYING COST



DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS HOLDING COST=.40

UNITS BACKORDERS VS CARRYING COST



APPENDIX D

INSSIM MODEL AND OUTPUT PROGRAMS

```
10##S,R(SL) :,8,16;;,16
20$:IDENT:WP1149,AFIT/LSG CARRILLO AND PEABODY 78B JCPSIMA
30$:USERID:REQS$IZE
40$:LIMITS:50,,,10K
50$:OPTION:FORTRAN,NOMAP
60$:SELECT:REQS/DATAB2.O
70$:SELECT:REQS/DEMPAR.O
80$:SELECT:REQS/RANDU.O
90$:EXECUTE
100$:TAPE:07,X5D,,74454,,EXTRA
110$:FILE:09,X1S
120$:OPTION:FORTRAN,NOMAP
130$:SELECT:REQS/MAIN.O
140$:SELECT:REQS/STATUS.O
150$:SELECT:REQS/DEMPAR.O
160$:SELECT:REQS/ENTERB.O
170$:SELECT:REQS/FILLBO.O
180$:SELECT:REQS/FOR576.O
190$:SELECT:REQS/FORUPD.O
200$:SELECT:REQS/INITAL.O
210$:SELECT:REQS/INITEM.O
220$:SELECT:REQS/LEVEL.O
230$:SELECT:REQS/LEVELN.O
240$:SELECT:REQS/ORDER.O
250$:SELECT:REQS/OUTCST.O
260$:SELECT:REQS/RECEIV.O
270$:SELECT:REQS/RET.O
280$:SELECT:REQS/ZERO.O
290$:SELECT:REQS/ENTER.O
300$:SELECT:REQS/SSTAT.O
310$:SELECT:REQS/OUT.O
320$:SELECT:REQS/REQ.O
330$:SELECT:REQS/REMOVE.O
340$:SELECT:REQS/WRIFEL.O
350$:SELECT:REQS/STATN.O
360$:SELECT:REQS/CUM.O
370$:SELECT:REQS/CUMB.O
380$:SELECT:REQS/INFEL.O
390$:SELECT:REQS/ITRSLT.O
400$:SELECT:REQS/RANDU.O
410$:SELECT:REQS/PLOTR.O
420$:SELECT:REQS/GP.O
430$:EXECUTE
440$:LIMITS:50,30K,,10K
450$:REMOTE:P*,SL
460$:REMOTE:$$,SL
```

```
470$:DATA:05
480  10  '400 ITEMS  ---'
490 1 0 0 1
500 0 0 0 0 0   0 0
510 7 2 24
520 1 1 2 3 1 1 1
530 6.  36.  0.  40.
540  .16  10. 31.6 100. 316. 272.99 556.57 19500
550 4 12 100 1 8
560  11  '400 ITEMS  ---'
570 1 0 0 1
580 0 0 0 0 0   0 0
590 7 2 24
600 1 1 2 3 1 1 1
610 6.  36.  0.  40.
620  .16 600. 1000. 3162. 10000. 272.99 556.57 19500
630 4 12 100 1 8
640$:FILE:07,X1R
650$:TAPE:08,X2D,,73079,,SOUTPUT/RING
660$:OPTION:FORTRAN,NOMAP
670$:SELECT:REQS/RSL1.0
680$:EXECUTE
690$:TAPE:07,X1D,,73079,,SOUTPUT
700$:FILE:09,X5S
710$:DATA:05
720 12 100 1 0 0 1 3
730$:MSG2:1,PLOT-TAPE (G012B,WP1149) CARRILLO PEABODY 78B
740$:OPTION:FORTRAN,NOMAP
750$:SELECT:EHMSE/PLOTBIN
760$:LIBRARY:A1,A2,A3
770$:EXECUTE
780$:LIMITS:08,40K
790$:PRMFL:A1,R,R,GRAPHICS.LIB/GCS/GCS3.0
800$:PRMFL:A2,R,R,GRAPHICS.LIB/GCS/CALC3.0
810$:PRMFL:A3,R,R,AF.LIB/CALLIB
820$:FFILE:27,FIXLNG/80,BUFSIZ/81
830$:TAPE:27,X1D,,,,PLOT-TAPE/WR
840$:FILE:11,X5R
850FILE 11,5,8
```

```
860NUMB 1
870TLAB DEMAND - ALL CATEGORIES SAMPLE=400 ITEMS  HC=0.16
880BLAB UNITS BACKORDERS VS CARRYING COST
890XLAB AVE. CARRYING COST/YR
900YLAB AVE. UNIT BACKORDER-WK/YR
910LSYM 1
920YCOL 2,1,8
930XCOL 4,1,8
940PLOT
950BLAB REQ. BACKORDERS VS CARRYING COST
960YLAB AVE. REQUISITION BACKORDER-WK/YR
970YCOL 1,1,8
980PLOT
990BLAB UNIT BACKORDERS VS BUY-$
1000YLAB AVE. UNIT BACKORDER-WK/YR
1010XLAB AVE. BUY-$/YR
1020YCOL 2,1,8
1030XCOL 3,1,8
1040PLOT
1050BLAB REQUISITION BACKORDERS VS BUY-$
1060YLAB AVE. REQUISITION BACKORDER-WK/YR
1070YCOL 1,1,8
1080PLOT
1090NUMB 1
1100BLAB UNITS BACKORDERS VS CARRYING COST
1110XLAB AVE. CARRYING COST/YR
1120YLAB AVE. UNIT BACKORDER-WK/YR
1130LSYM 1
1140YCOL 2,1,8
1150XCOL 4,1,8
1160PREC 6
1170SCAL 23500. 26500.  2200.  3200.
1180PLOT
1190BLAB REQ. BACKORDERS VS CARRYING COST
1200YLAB AVE. REQUISITION BACKORDER-WK/YR
1210YCOL 1,1,8
1220SCAL 23500.  26500.  250.  450.
1230PLOT
1240BLAB UNIT BACKORDERS VS BUY-$
1250YLAB AVE. UNIT BACKORDER-WK/YR
1260XLAB AVE. BUY-$/YR
1270YCOL 2,1,8
1280XCOL 3,1,8
1290SCAL 22000.  36000.  2200.  3200.
1300PLOT
1310BLAB REQUISITION BACKORDERS VS BUY-$
1320YLAB AVE. REQUISITION BACKORDER-WK/YR
1330YCOL 1,1,8
1340SCAL 22000.  36000. 250.  450.
1350PLOT
1360STOP
1370$:ENDJOB
```

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Major John Carrillo, USAF, was born and raised in San Marcos, Texas, and graduated in 1966 from Southwest Texas State College with a Bachelor of Science in Chemistry. He was commissioned through the Reserve Officers Training Corp and his assignments have included a tour in Thailand and the Caribbean. He entered AFIT, School of Systems and Logistics, in September, 1977, and will be assigned as Division Chief, Energy Management, at ADCOM, Colorado Springs, Colorado. He is married and has one son.

Captain Donald G. Peabody, USAF, was born in Galesburg, Illinois, and was raised in rural areas in central Illinois. He completed secondary education in Toulon, Illinois, and then continued his education at Western Illinois University where he received a Bachelor of Science degree in Agricultural Engineering. Captain Peabody received his commission through Officer Training School in 1971. Since that time, he has been assigned to organizations in Italy, Florida and Canada. He entered AFIT, School of Systems and Logistics, and received a Master of Science degree in Logistics Management in September, 1978. He is married and has a son and a daughter.