2-1-1986

A study and systematic data collecting and analysis of changes in production control system

Frank Adae

A STUDY AND SYSTEMATIC DATA COLLECTING AND ANALYSIS OF CHANGES IN PRODUCTION CONTROL SYSTEM

by

Frank K. Adae

As Abstract

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Printing in the College of Graphic Arts and Photography of the Rochester Institute of Technology

February, 1986
Thesis Advisor: Prof. Walter Campbell

School of Printing
Rochester Institute of Technology
Rochester, New York

CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's Thesis of

Frank K. Adae

with a major in Printing Technology has been approved by the Thesis Committee as satisfactory for the thesis requirement for the Master of Science degree at the convocation of

_____
date

Thesis Committee:

Walter A. Campbell
Thesis Advisor

Miles Southworth
Director, School of Printing

Joseph L. Noga
Graduate Advisor

Thesis: Production System

ACKNOWLEDGEMENT

I would like to express my appreciation to the thesis committee for their assistance in the study of this project. The development of an idea generally represents the work of many persons. I owe my sincerest thanks to those persons who lent their expertise and support towards the completion of this project; those include Prof. Walter Campbell, my advisor, for his patience, help and guidance, Prof. Joseph Noga, Graduate Advisor, for his patience and several useful meetings with me, Mr. T.B. Barker of Center for Quality and Applied Statistics for his assistance with the statistical analysis, Prof. Miles Southworth for involving me in this topic area after I could not find any appropriate topic under his jurisdiction, and most of all my wife Theresa (Tess) for her tireless support throughout the frustrating period of putting this report together.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The purpose of this study is to measure the effectiveness of a change in workflow in an order entry department of a forms manufacturing plant. The difference is measured between the original and the revised workflow systems to draw conclusions on a quantitative basis.

The original workflow procedure was set up for the job ticket, composed of the paper work and the artwork, to travel together through the first six of nine operations in the order entry department. Then the artwork split from the paper work and was forwarded to the art department, where the mechanical artwork was created, while the paper work continued through operations in the order entry department.

The revised system split the artwork from the paper work and forwarded it to the art department after going through three operations, but the paper work continued through all of the order entry department operations.

The study revealed that the art department can create the mechanical artwork with adequate instructions, while the paper work of the order continued in the order entry department without disrupting the proudction control system. The revision therefore, created coordination of re-assignment of some responsibilities in order to furnish the art department with its needs.

Cutting down on the operations that the artwork had to go through in the order entry department meant that jobs were forwarded to the art department at a faster pace, and through the subsequent departments in the factory without disrupting any of the operations.

CHAPTER I

INTRODUCTION

This study was necessitated by the need to have an effective workflow system to increase productivity in the order entry department by getting the artwork (job jacket) to the art department at the earliest possible time, but within the framework of the existing production procedure briefly discussed below. Furthermore, management was embarking on a plant-wide four-week normal delivery program, allowing four days for a normal-delivery order in the order entry department and less than four days for rush jobs. This meant reduction of about one to two weeks production time of orders in the order entry department. The production time for each order in the order entry department was measured between the time that the order was received and when the artwork was forwarded to the art department.

The products involved in this study are: (1) continuous form - a pin-fed continuous form, either a single-ply or multiple-ply, and (2) Unit Set form - either a multiple-ply form or single-ply form usually padded in sets.

There were nine operations in the order entry department that each order had to go through. The paper work and the artwork - contents of the job ticket - were requried to travel through the first six of the nine operations

together as a unit, then the artwork (job jacket) was split and forwarded to the art department, while the paper work continued through the rest of the operations in the order entry department.

The operations in the order entry department are listed here in the sequence of the workflow: Receiving Clerk, Editing, Edit-in-put, Planning (revised point of departure for the artwork received directly from Editing), Material Clerk, Standard Clerk (original point of departure for the artwork), Scheduling, Schedule-in-put and Collection File. These operations are briefly explained in Chapter III.

There were two production forms included in the paper work, but for lack of a better system, these forms were designed to move the job ticket in a single-channel type of production, that is, to some degree, each subsequent operation depended on the previous operation's information provided on the form(s) to function. The production control set up made it impossible to route the job ticket any other way.

The production control procedure encompassed a computer inventory system. Two of the first six operations furnished the computer system with inventory information, namely: Receiving Clerk - part of this operation was to log the new order in the computer system and the Edit-in-put operation which up-dated the computer inventory system

by entering the information gathered as the job ticket moved through the operations. Lots of mechanical problems plagued the computer system. The malfunction averaged at least once a week and for a period of three to four hours, sometimes longer. During this time, the single-channel type of workflow was interrupted; new orders could not be entered in the computer inventory system as part of an order receiving process; and order(s) in progress could not continue with production from edit-in-put and beyond.

The revised workflow procedure got the artwork (job jacket) to the art department after three operations in the order entry department, but no change in paper work flow. This was made possible by instituting a multiple-channel workflow system allowing different routes for the artwork and the paper work.

This study will analyze these two areas: (1) The original workflow network including the two production forms and the idleness of production during the period of computer malfunction; and (2) The revised workflow network, and how it affects movement of the job ticket through the operations. Likewise, the possibility of recommendation for elimination of some position(s).

Basically, workflow network as this study entails, is the way activities and events in the incoming-processing-outgoing cycle of an operation are sequenced.

CHAPTER II

LITERATURE REVIEW

Improvement consists of altering an existing system by varying degrees. These include changes in work methods, rearrangements of facilities, flow of work, handling of materials, etc. The alteration in this study refers to flow of work of a Production Control system.[1]

Production Control may be described as a design and use of a systematic procedure to establish methods and regulate the operations of an activity.[2]

The function of production is the process by which goods or services are provided.[3] The function of control is the coordination of the production activities to produce a product or provide service on schedule.

Lead Time: Lead time can take on many meanings, it may apply to individual orders or operations. The total manufacturing time needed to perform all necessary operations in a plant starting from raw material to the finished product is the manufacturing cycle time. Each manufacturing cycle time is the sum of many individual lead times. The greatest portion of lead time usually comes from the time a job spends waiting to be processed. The process time represents a small fraction of the manufacturing cycle time for most orders. One of the major areas

in which improvement could be sought to reduce lead time is the order processing time, this is the time which elapses as soon as an order leaves the customer until it is being scheduled into production in a make-to-order plant. This lead time segment of the manufacturing cycle time is related to this study. Before an attempt is made to reduce lead time of production, a sample of actual orders completed recently must be analyzed to determine the elements of the lead time, such as setup time, run time, delays and particularly paper processing time. To accomplish this a frequency distribution chart, similar to Figure 6 can be maintained by production control department. As the orders are received and released, a tally is made of the actual lead time.

While order processing is a complex system beyond the scope of this study, it is important to recognize its contribution to lead time and to control it as well as factory lead times. Reducing paper work lead time can improve a company's performance as much as new processing equipment. For example, copying machines can make it possible to get a customer's order to scheduling promptly in order to start work before beginning the required formal paper work such as typing the order, edit it, etc. However, this may not be exactly applicable to some plant's production control system, depending on the product.[4]

> In most intermittent operations, analysis of the lead time will indicate that the greatest gains are to be made in reducing waiting time at individual operations.[5]

In the Flow Shop type of control system, segregation of an order is not attempted, all pertinent parts have to stay together. The flow of production is somewhat continuous and uninterrupted from one work station to another.

The epitome of the flow shop is the typical mass production plant manufacturing consumer goods, for example, an oil refinery. The facilities or machines are often special purpose, that is, they are designed for the exclusive production of one product or a limited number of products.

This control system correlates with continuous type of production, which basically requires that the machines used are located in accordance with the sequence of operations to produce the product. The distinguishing characteristics of flow or continuous production control include fixed rate of production, and the same flow path, which is similar to a single-channel workflow or fixed route.[6]

The original procedure of the order entry department workflow somewhat approached a flow shop system, because it was disigned for the job ticket to stay together as if an order cannot be segregated through the operations before scheduling.

In the Job Shop control system, the mixture of products is high and production is separated in terms of tickets representing individual jobs produced either to fill customers' orders or for inventory replenishment. It requires a high degree of control for each order progressed through the subsequents of operations in the production cycle. Each job may follow a different path through the network.

The facilities or machines are usually "general purpose" because they can be adjusted rather easily to accommodate a variety of output, for example, physical size, quantity, materials, etc.

This control system correlates with an intermittent type of production. The distinguished characteristics include assigning a job number to the order when received from the customer, the equipment or facilities are usually arranged in accordance with the type of operation that is to be performed, and not according to the sequence of operation of the product.[7]

The job shop or intermittent type of production seems to have the characteristics of the revised procedure of workflow in the order entry department because the revised procedure allows an order to be segregated to follow different paths.

Work Sampling: Work sampling is a method of taking observations of an activity to determine the amount of time being spent to perform any or all parts of the activity. This is a management tool which was first reported by a British statistician L.C. Tippett in 1935, and has since 1952 been described by C.L. Brisley as "work sampling."

Work sampling has a wide application of uses including many forms of Production Control. Perhaps the most useful purpose is in the measuring of indirect labor, which otherwise cannot be measured accurately.[8]

> Briefly, work sampling consists of taking instantaneous observations of an activity at random intervals of time, tallying the observations on an appropriate observation sheet, and calculating the per cent of the tallies under each descriptive category to the total number of observations made. The percentage approximates the percentage of the time of each part of the activity defined to the total time of all parts of the activity.[9]

Evaluation: It is important for management to measure the effectiveness of the system. The two methods of evaluation are qualitative and quantitative. Qualitative evaluation is generally a subjective opinion, whereas quantitative evaluation is based on numerical measure of the item being evaluated.[10]

FOOTNOTES FOR CHAPTER II

[1]J. William Gavett, Production and Operation Management, (New York: Harcourt Brace & World, Inc., 1968), p. 118

[2]Evans D. Scheele, William L. Westerman, Robert J. Wimmert, PRINCIPLES and DESIGN of Production Control System, (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1960), p. 1

[3]Richard J. Hopeman, Production, 3rd ed. (Columbus, Ohio: Charles E. Merill Publishing Co., 1976), p. 3

[4]G.W. Plossl, O.W. Wight, Production and Inventory Control, (Englewood Cliffs, N.J.: Princtice-Hall, Inc., 1967), pp. 303, 305

[5]Ibid, p. 304

[6]Scheele, Westerman, Wimmert, Op cit., pp. 29, 30

[7]James Harnsberger Greene, Operation Planning and Control, (Homewood, Ill: R.D. Irwin, 1967), pp. 13, 14

[8]Scheele, Westerman, Wimmert, Op. cit., p. 266

[9]Scheele, Westerman, Wimmert, Op. cit., p. 267

[10]Pradip N. Khandwalla, The Design of Organization, (New York: Harcourt Brace Javanovich, Inc., 1977), p. 505

CHAPTER III

ORIGINAL PROCEDURE

The plant employs about 150 people including 25 in the order entry department. There are five main departments which are listed here in the order of production sequence: Order Entry, Web Preparatory (Art Department, Camera & Platemaking), Press, Collator/Bindery, and Shipping. The plant runs three shifts per day for five days per week in three departments, namely: Platemaking - Web Preparatory, Press and Collator/Bindery departments. The operations are performed with the following equipment: (1) Web Preparatory - Two IBM composers for typesetting, six paste-up boards, two image assembly tables, two process cameras (vertical and horizontal), and three plate processing units (automatic platemaker, flip-top nuArc platemaker and computer programmed horizontal platemaker), (2) Press - Seven 17" Business Forms Web Presses - two used for continuous forms with interchangeable cut-off heads for different form sizes and glue applicator unit, and five used for unit set forms ranging from one to three-color, (3) Collator - Five 17" collators - One 8-station, one 4-station, one 3-station, and two 2-station, all with interchangeable

cut-off heads of these multiples: 2-5/6", 3-4/10", 4-1-4", 5-2/3", & 8-1/2", and (4) Bindery - Six bindery equipment - Three shrink wrappers and three cutters.

This study, however, is concentrated on the order entry department. The main operations, flow chart Figure 1, shows a heavy line as the route of the job ticket, comprising all of the paper work and the job jacket, down to the Standard Clerk after which a hair line and a broken line indicate job jacket and paper work routes respectively. These operations are briefly explained below in the sequence that the work flows:

Receiving Clerk (One person - Keyboarding) - Coordination of all new orders was important in order to keep accurate tract of all the jobs received. This operation therefore receives all incoming jobs (artwork with specification sheet.) The specification sheet gives sales representative's price quotation in addition to the following information needed to log the job in the computer inventory system: Customer's name and address and the address where the finished product is shipped to, sales representataive's name and home office and the type of product. The computer program utilized a random numbering system to control the orders received; the system was thought to be protective device because signed and unsigned checks were printed in the plant. After the entry is made, the computer then assigns a random job

single copy; designated orders to the appropriate equipment, specifies all direct labor and materials needed for the job, but not quantities of them. The source of information is the worksheet as completed by the editing operation.

Material Clerk (One person) - Uses the materials information on the production sheet from planning to calculate all of the materials needed for each job and writes the orders on the material coding sheet received from edit-in-put, to be sent to the stock rooms.

Standards Clerk (One person) - Prepares ratings sheet for all direct labor operations which are used to charge time spent in each operation to the job cost records. Also prepares a form to be used for scheduling the job. Splits the job ticket between paper work and the job jacket - paper work goes to scheduling and continues through the operations in the order entry department, while the job jacket goes to the art department and subsequent departments.

Scheduling (One person) - Assigns dates to the operations with the aid of daily computer print-out, received from systems department updated each morning, showing complete status of all of the jobs in the plant as of 12 midnight each day. Uses Video Display Terminal to retrieve, from the computer processing unit, a more updated information during the day for change(s) to be

made if necessary, for example, if a job needed a "move-up" date. This operation also serves as an expediter.

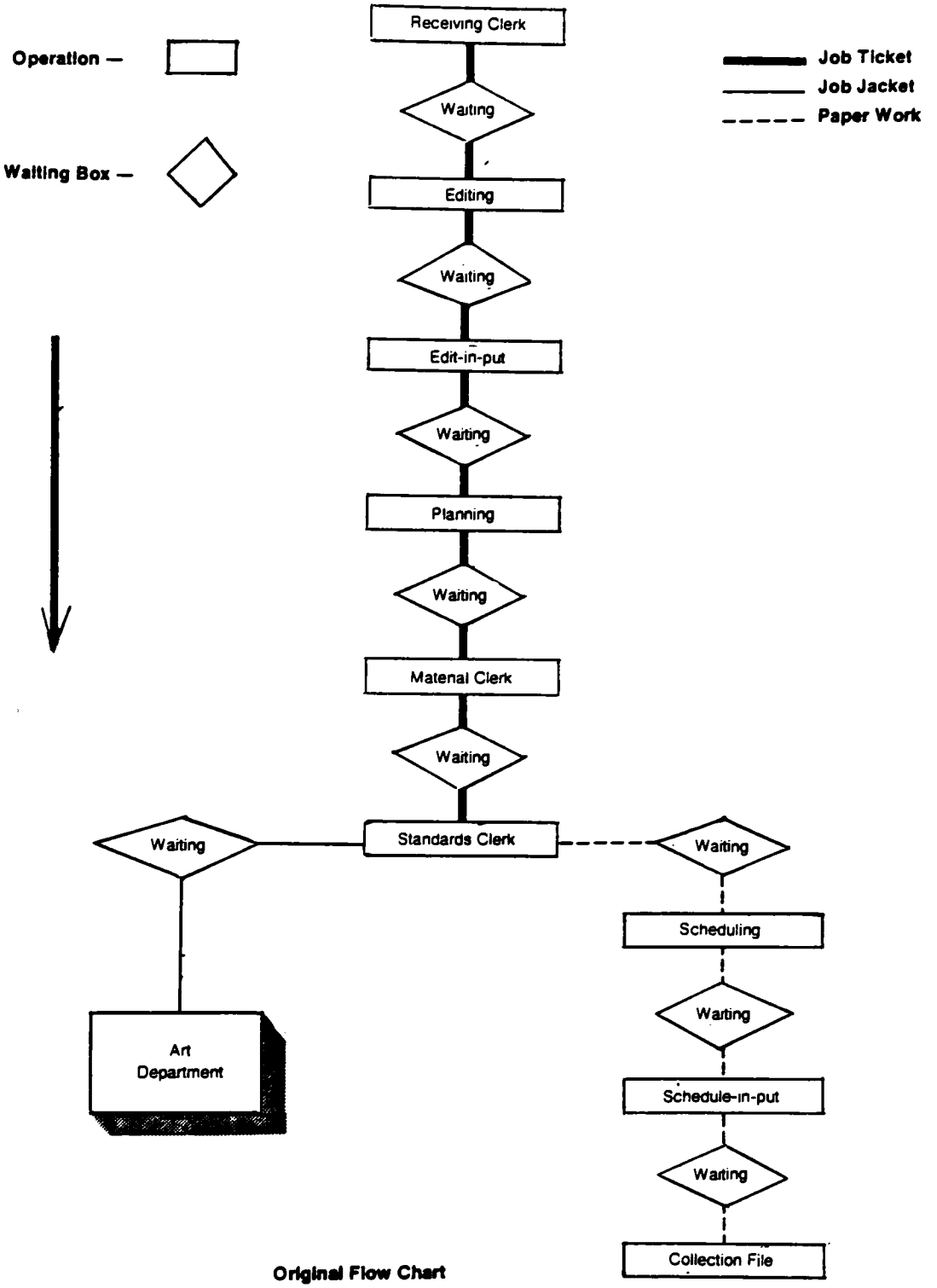
Schedule-in-put (One person - Keyboarding) - Up-dates computer inventory with the dates assigned to the order by scehduling. (There are other responsibilities for a different product which is not part of this study).

Collection File (One person - Keyboarding) - Each department notifies Collection File of completed operations of each job, for the computer file to be up-dated daily. Receives the job jacket from shipping department after shipment of the product. The job jacket is used to up-date the file with its complete information then releases the order by logging it out of the computer inventory for billing.

The rest of the employees in the order entry department do back-up for keyboarding operations, filing, buy-outs, and other miscellaneous duties.

Rush jobs traveled the same route as the normal delivery jobs, and were put in the same waiting boxes between operations at designated locations, except that they were flagged "rush." Tables 5A and 6A reflect production status for rush jobs out of the order entry department within one to four days.

Occasional spot checking of orders in the order entry department showed that many jobs had been in the department for more than one week. This information activated a study of the workflow of the Production Control system.



Original Flow Chart

Figure 1

CHAPTER IV

REVISED PROCEDURE

The objective was to restructure the workflow in order to get the artwork to the art department at the earliest possible time, so that the mechanical artwork would start while the paper work continued to flow in the order entry department without disruption of the production control system. The revised procedure, flow chart Figure 2, shows a heavy line as the route for the job ticket going through two operations to editing, after which a hair line and a broken line represent flow of job jacket and paper work respectively. This workflow allowed the job jacket to be forwarded to the art department earlier than before. Furthermore, the workflow shows that a rush job was forwarded to editing directly by using separate input boxes instead of being placed in waiting boxes for normal delivery jobs.

The following is the sequence of workflow and the brief explanation which reflected the changes to the original workflow in Chapter III.:

Receiving Clerk (One person - Keyboarding) - Continues previous work putting the job ticket together for control of the orders. In addition, in case of computer breakdown

the ticket was still put together instead of waiting for the computer to be repaired. Instead of a computer assigned order number an emergency rubber stamp, shown in Figure 3 was used. The job was also flagged for easy identification, to indicate that the order was being processed without computer assigned job number. This allowed the operations in the order entry department to be performed up to and including planning. When the computer system came back on line, the order was returned to the receiving clerk from either planning or editing to be logged in the inventory control system for a number to be assigned. The order was then returned to the last operation by the receiving clerk with the "entered" box checked as required on the rubber stamp.

Editing (Four persons) - Continues previous work but when this operation is completed, the job jacket and one copy of the worksheet go to planning while the rest of the worksheet copies and salesperson's specification sheet go to edit-in-put.

Planning (Five persons) - New responsibilities were added to this operation. Planning continues to prepare the production sheet, but in duplicate instead of a single copy. Planning used to receive the job ticket including the material coding sheet from edit-in-put, for the kind

of ink and size of carton information to be provided on the material coding sheet, but planning will not receive anything from the edit-in-put. Instead the job jacket will be received from editing for the ink and carton information to be provided on a separate form and forwarded to material clerk. Planning will also forward a copy of the production sheet to material clerk from which the materials needed are calculated and ordered with the material coding sheet. Furthermore, the ratings sheet originally prepared by standards clerk will be prepared by planning. Planning then forwards the job jacket to the art department because the artwork, original production sheet and the ratings sheet provide all of the pertinent parts needed by the art department and the subsequent departments for their operations.

Edit-in-put (One person - Keyboarding) - Will receive the paper work from editing instead of the job ticket, and will continue to up-date the computer inventory, but the material coding sheet, etc. will be forwarded directly to the material clerk by-passing planning.

Material Clerk (One person) - No longer receives the job ticket. The material clerk receives the material coding sheet, etc. from the edit-in-put and a copy of production sheet with the ink and carton information on

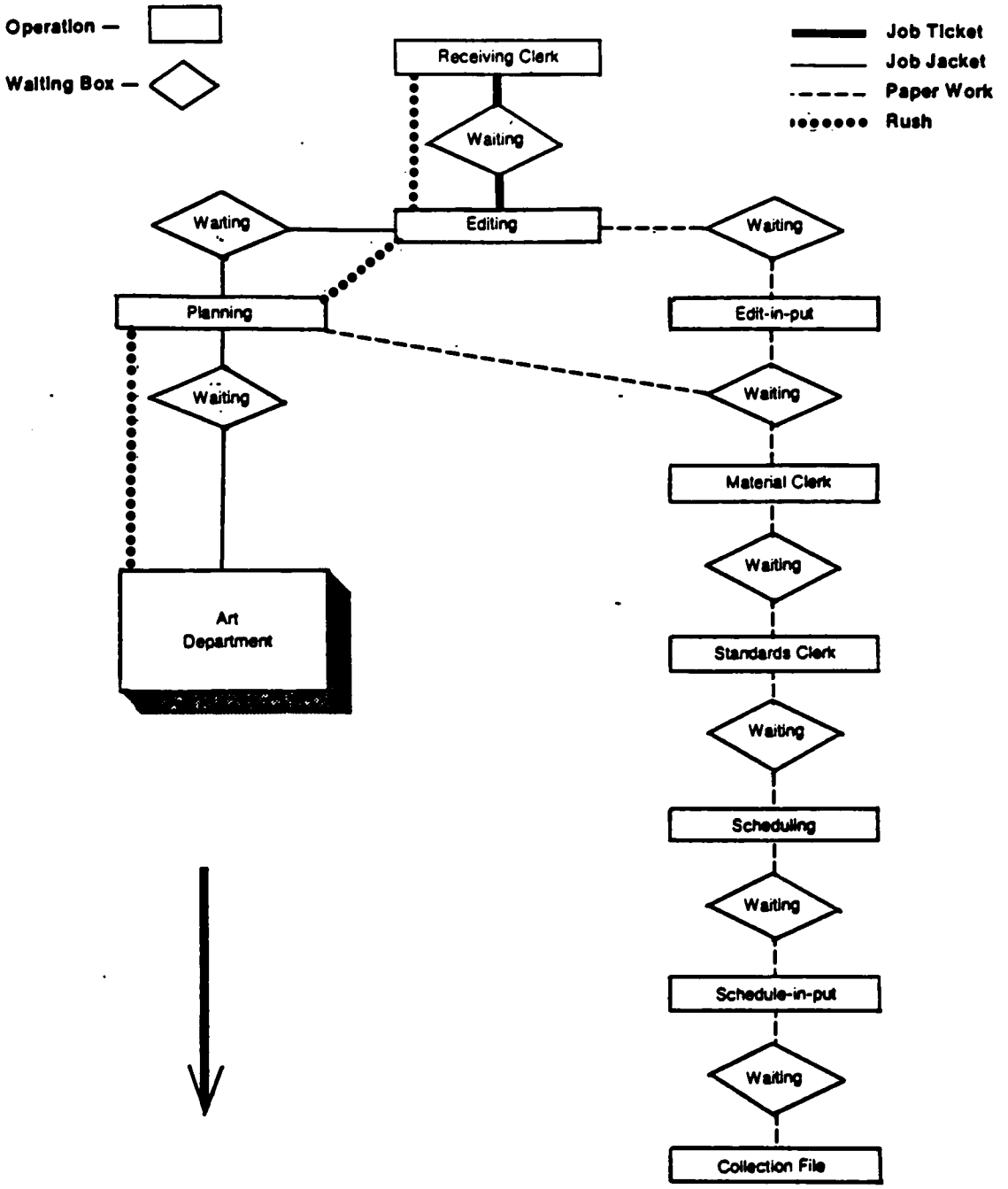
a separate form from planning. These pieces of information are merged at this point to perform the operation without changes from before.

Standards Clerk (One person) - No longer prepares the ratings sheet. The only responsibility left at this operation was the preparation of forms for scheduling.

Scheduling)
) No changes in either workflow
Schedule-in-put)
) or responsibilities
Collection File)

The revision in order entry department workflow necessitated some changes to be made on the production sheet. The production sheet was used by the subsequent departments--Web Preparatory, Press, Collator/Bindery. After the seven weeks testing period of the revised system, managers of the subsequent departments were asked whether they encountered any problems in performing their responsibilities as a result of the changes on the production sheet, but they all confirmed that they had no problems with the changes.

The revised procedure was approved by the plant manager and the order entry department manager based on the significant reduction of time that the orders spent in the order entry department and the favorable comments made by the other managers.



Revised Flow Chart
Figure 2

CHAPTER V

HYPOTHESIS

The following are specific theories proposed by the hypothesis:

1. Going to a multi-channel system will reduce the time spent to process an order.

2. Going to a multi-channel system would not introduce new problems that would offset the value of the time saved.

CHAPTER VI

METHODOLOGY

To properly analyze the production control system to be studied in this thesis, detailed information of the system was needed. Each operation was examined with all of the necessary materials needed to perform the operations.

In order to make an impartial comparative analysis of the original and the revised procedures, data showing overall performance was needed from each workflow network. The data was collected before and after the revision.

Sampling: In a period of seven weeks all orders received for both original and revised procedures were strictly controlled, that is, they were counted, date stamped and dated when completed. The time that each operation spent on each order was measured in day(s). For accurate collection of this data, special forms called "Production Performance Status" (PPS), Figure 4-A and Figure 4-B for original and revised systems respectively, were designed for the receiving clerk to attach to each job ticket to go through the operations, and detached at the last operation in the order entry department for the data to be recorded and evaluated. Furthermore, the

PPS questionnaire gave the breakdown of all categories of the orders.

The PPS questionnaire has multiple uses; it can serve as an evaluation tool for management since it can identify the time an order takes at each operation.

Evaluation: At the end of each day, the receiving clerk furnished the total number of orders entered into the computer system on a Daily Receipts Log, Figure 5 (the figures could be verified in the computer system if necessary). The PPS questionnaire furnished the total number of orders out of the order entry department and elapsed time. The total number of orders received and the total number of orders out of order entry department, as indicated on Daily Receipts Log and PPS questionnaire respectively, were transferred on to the Daily Work Sheet, Figure 6, at the end of each day. Information on the Daily Work Sheets were transferred on to the Weekly Work Sheet, Figure 7, at the end of each week to compute the weekly performance. These work sheets were designed with columns for all of the categories for the orders tallied. The "Day" column on the Work Sheets represented the number of day(s) the order spent in the order entry department. A check mark (√) was used to transfer the completed orders from the PPS questionnaire form on to the Daily Work Sheet.

All of the samples tallied in seven weeks, as per the weekly work sheets, were computed to determine the total output performance status, these were represented by Appendix A through I.

EMERGENCY STAMP

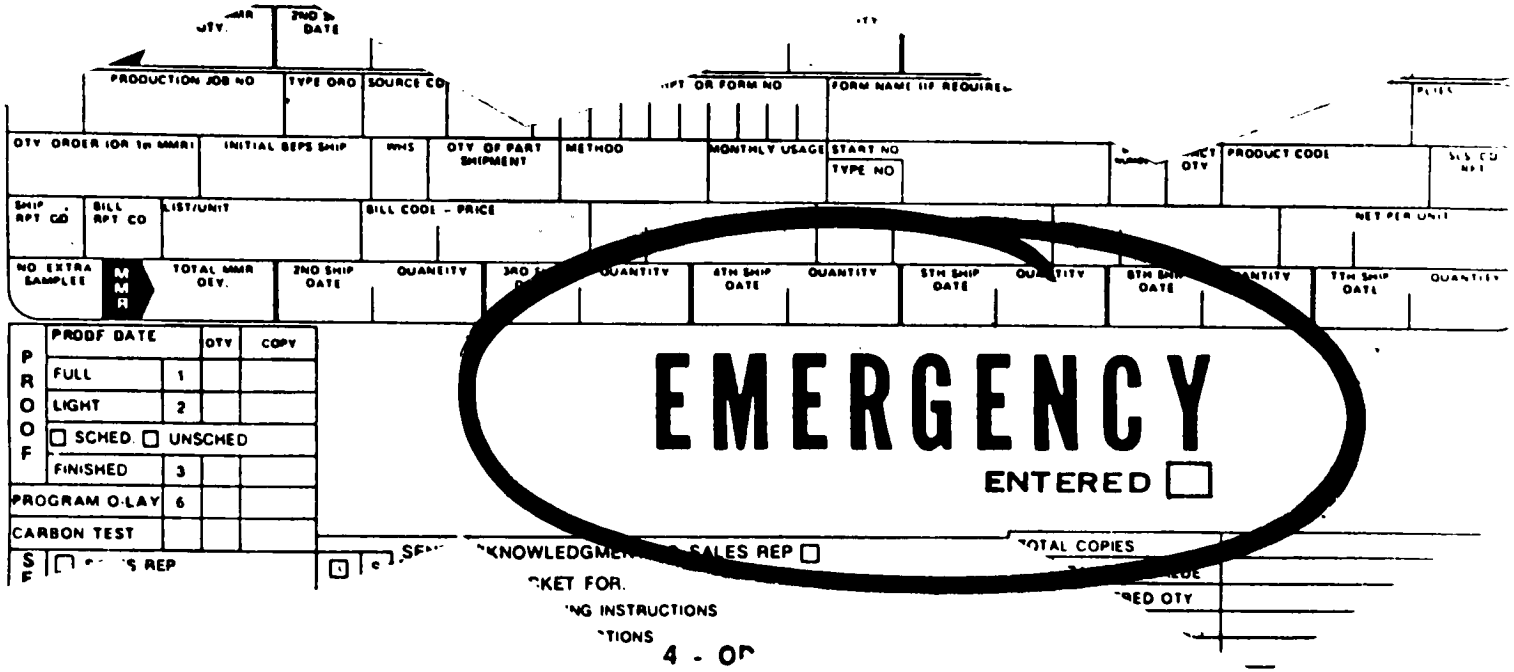


Figure 3

PRODUCTION PERFORMANCE STATUS

1 6 8 9

Job No. _____

	INITIALS	DATE	TIME RECEIVED/COMPLETED
Receiving Clerk	_____	_____	_____ _____
Editing	_____	_____	_____ _____
Edit-in-put	_____	_____	_____ _____
Planning	_____	_____	_____ _____
Material Clerk	_____	_____	_____ _____
Standard Clerk (job jacket to Art Dept.)	_____	_____	_____ _____
Scheduling	_____	_____	_____ _____
Schedule-in-put	_____	_____	_____ _____

1 = Others
6 = Regular Rush
8 = MG Rush
9 = In-House Rush

Figure 4-A
(Original Procedure)

PRODUCTION PERFORMANCE STATUS

1 6 8 9

Job No. _____

	INITIAL	DATE	TIME RECEIVED/COMPLETED
Receiving Clerk	_____	_____	_____ _____
Editing	_____	_____	_____ _____
Planning (job jacket to Art Dept.)	_____	_____	_____ _____
Material Clerk	_____	_____	_____ _____
Standard Clerk	_____	_____	_____ _____
Scheduling	_____	_____	_____ _____
Scheduling-in-put	_____	_____	_____ _____

1 = Others
6 = Regular Rush
8 = MG Rush
9 = In-House Rush

Figure 4-B
(Revised Procedure)

DAILY RECEIPTS LOG

Date _____

NEW JOB NUMBERS	
UNIT SET FORMS	CONTINUOUS FORMS
TOTAL	TOTAL

Figure 5

DAILY WORK SHEET

DAY'S TOTAL _____ DATE _____

OUT OF ORDER ENTRY DEPT. _____

DAY	OTHER	RUSH			PERCENTAGE	
		REGULAR	MG	IN-HOUSE	OTHER	RUSH

Figure 6

WEEKLY WORK SHEET

WEEK TOTAL _____ WEEKENDING _____

OUT OF ORDER ENTRY DEPT. _____

DAY	OTHER	RUSH			PERCENTAGE	
		REGULAR	MG	IN-HOUSE	OTHER	RUSH

Figure 7

CHAPTER VII

TEST RESULTS

The comparison of the original and the revised procedures were made for both products of unit set forms and continuous forms. Quantitative sampling approach was taken, that is, every order received was counted, as per Daily Receipts Log, for a period of seven weeks. During this period a total of 1114 orders for unit set forms and 848 orders for continuous forms were recorded for the original procedure. For another seven weeks, a total of 1110 orders for unit set forms and 885 orders for continuous forms were recorded for the revised procedure.

The following analysis of the test results were based on the data listed in Appendix A (Figure 9 and Figure 10). The results of the performances were measured on orders completed within one to ten days, and over ten days combined as shown in Appendix B, C, E, F, and one to four days in Appendix D.

These results had favorable review by the department managers and supervisors, with particular reference to the fact that the revision did not create any problems with their respective operations.

Analysis of the Tables

Appendix B - Combination of all categories in each procedure. Table 1-A and Table 1-B - Unit Set Forms. The original system, Table 1-A, indicated that 46% of the orders were completed within the first five days and 92% completed within ten days leaving 8% over ten days, while revised system, Table 1-B, indicated that 94% of the orders were completed within the first five days and 98% completed within ten days leaving 2% over ten days.

Table 2-A and Table 2-B - Continuous Forms. The original system, Table 2-A, indicated that 58% of the orders were completed within the first five days and 96% completed within ten days leaving 4% over ten days, while revised system, Table 2-B, indicated that all of the orders were completed within the first five days.

Appendix C - Breakdown of all categories in each product. Table 3-A and Table 3-B - Unit Set Forms. The original system, Table 3-A, indicated the following completion of orders for the first five days: Other - 36%, Rush - 58%, Management Group Rush - 33%, and In-House Rush - 90%; and within ten days the following orders were completed: Other - 90% leaving 10% over ten days, Rush - 94% leaving 6% over ten days, Management Group Rush - 100% and In-House Rush 100%. The revised system, Table 3-B, indicated the following completion of orders for the first

five days: Other - 93%, Rush - 95%, Management Group Rush - 100%, In-House Rush - 90%, and within ten days the following orders were completed: Other - 98% leaving 2% over ten days, Rush - 98& leaving 2% over ten days, In-House Rush - 98% leaving 2% over ten days.

Table 4-A and Table 4-B - Continuous Forms. The original system, Table 4-A, indicated the following completion of orders for the first five days: Other - 51%, Rush - 70.5%, Management Group Rush - 84.5%, In-House Rush - 72%, and within ten days the following orders were completed: Other - 94% leaving 6% over ten days, Rush - 99.5% leaving .5% over ten days, Management Group Rush - 100%, In-House Rush - 96% leaving 4% over ten days. The revised system, Table 4-B, all of the categories were completed within the first five days. Furthermore Tables 1-A through Table 4-B indicated the total amounts of orders for each category completed each day and the corresponding percentages.

Appendix D - Four-Day Production for each Product broken-down into Other and Combined Rush. - Table 5-A and Table 5-B - Unit Set Forms. The original system, Table 5-A, indicated that 18% of the orders were completed for Other and 46% of the orders completed for combined rush; while revised system, Table 5-B, 87% of the orders were completed for Other and 89% of the orders completed for combined rush.

Table 6-A and Table 6-B - Continuous Forms. The original system, Table 6-A, indicated that 30% of the orders were completed for Other and 65% completed for combined rush; while revised system, Table 6-B, indicated that 99% of the orders were completed for Other and 99% completed for combined rush.

Appendix E - Unit Set Forms and Continuous Forms Systems combined, brokendown into Other and combined rush. Table 7-A and Table 7-B. The original system, Table 7-A, indicated that for the first five days 42% of the orders were completed for Other, 69% completed for combined rush and 92% completed within ten days for Other leaving 8% over ten days and 97% completed for combined rush leaving 3% over ten days; while revised system, Table 7-B, indicated that 96% of the orders were completed within the first five days for Other, 97% completed for combined rush and 99% of the orders completed within ten days (nine days to be exact) for both Other and combined rush, leaving one percent each over nine days.

Appendix F - Unit Set Forms and Continuous Forms systems combined without categories breakdown. Table 8-A and Table 8-B. The original system, Table 8-A, indicated that for the first five days 51% of the orders were completed and 94% completed within ten days leaving 6% over ten days.

The revised system, Table 8-B, indicated that for the first five days 96% of the orders were completed and 99% completed within ten days (nine days to be exact) leaving one percent over nine days.

CHAPTER VIII

Summary

The following is a list of reductions in time for order entry processing for jobs of various categories. This relates to jobs completed within one to four days during the seven weeks test periods for the original and revised systems. This four-day jobs processed status was needed by management:

Category	Product	Order Entry Time
Other	Unit Set Forms	69% reduction
Rush	" " "	54% "
Management Group Rush	" " "	67% "
In-House Rush	" " "	8% "
Combined Rush	" " "	43% "
All Categories Combined	" " "	61% "
Other	Continuous Forms	69% "
Rush	" "	49% "
Management Group Rush	" "	26% "
In-House Rush	" "	39% "
Combined Rush	" "	34% "
All Cagetories	" "	61% "

Category	Product	Order Entry Time
Other	Both Unit Set/Cont.	69% reduction
Rush	" " "	44% "
All Categories	" " "	60% "

CHAPTER IX

CONCLUSION AND RECOMMENDATION

The observation of the original procedure revealed that the collection of information for the computer inventory as part of the flow of the job ticket, and also the job ticket going through the first six of the nine operations in the order entry department contributed to the extended lead time of the orders. For example, a malfunction of the computer caused production to halt for as long as the computer remained not functionable which sometimes were several hours. When this interruption occurred, it started from the receiving clerk, that is, the first operation because of the random job numbers generated by the computer. Likewise, planning operation did not function because edit-in-put which is a computer operation, could not release the job ticket that planning needed to function. Furthermore, the sixth operation, standards clerk, provided information needed by the subsequent departments and therefore the job ticket had to go through that operation before the job jacket could be released to the web preparatory for the mechanical artwork to be created by the art department. However, under the original procedure the job ticket had to flow through the six operations to avoid production disruption.

The redesigned workflow in the order entry department isolated the computer inventory information from the main process of the orders, and shortened the travel of the job jacket, by reduced standards clerk's responsibilities by reassigning some of them to the planning operation. The edit-in-put received only copies of the transactions and the receiving clerk used a "by pass" stamp on the orders in case of a computer malfunction in order to continue with production. These changes created a multi-channel workflow system. New forms had to be created to coordinate these changes.

Results of comparison between the original and the revised system proved that the revised system decreased production time significantly in all categories. To arrive at this conclusion, series of tests had to be made to make sure that nothing was overlooked; including interviews with the subsequent departments' managers who confirmed that they had no problems with the revised system.

The computer generated random job numbers must be eleminated and replaced by consecutive job numbering sytem to enable the receiving clerk to assign the job numbers to the orders and then enter the numbers into the computer inventory. However, the author is of the opinion that when the random numbering system is eliminated, production with the revised procedure would not necessarily improve significantly. Nevertheless it would add to the smoothiness of the workflow.

Standards Clerk's operation may also be eliminated and the scheduling forms responsibility be added on to the scheduling operation, however, if this is not favorable then new clerical responsibilities must be assigned to this operation.

The statistics indicated that the revised system was faster than the original system. That is, the average times a order spent in order entry department for unit set form and continuous form were cut by half and more than half respectively, these statistics are detailed later in this thesis. Further, no supervisors reported any new problems caused by the revised system that cast doubts on its acceptability.

CHAPTER X

STATISTICAL ANALYSIS

H_o = The new system is not better (Null hypothesis)

H_1 = The new system is faster--number of days to complete an order is less (Alternate hypothesis)

Brief explanation of symbols used:

- $\bar{x}$ - Mean (time--measured in days)
- s - Standard Deviation (measurement of variance)
- n - Sample Size (number or orders)
- F - Ratio of Variance (determines risk level--significance)
- t - "t" Test (measurement of mean difference)

Unit Set Forms:

Original System: - $\bar{x}$ = 6.2

s = 2.6

n = 1114

Revised System: - $\bar{x}$ = 3.4

s = 1.8

n = 1110

"F" = 2.09

"t" = 29.9

Continuous Forms:

Original System: - $\bar{x}$ = 5.58

s = 2.30

n = 848

Revised System: - $\bar{x}$ = 1.92

s = .85

n = 855

"F" = 7.32

"t" = 43.49

The above figures conclude that the difference between the original system and the revised system is significant at .01 risk level, therefore the Null hypothesis was rejected.

The average time that unit set form order spent in order entry department dropped from 6.2 to 3.4 and the variance improved from 2.6 to 1.8. The average time that continuous form order spent in order entry department dropped from 5.58 to 1.92 and the variance improved from 2.30 to .85.

Computation and graphic illustrations are in Appendix G through I.

FORMULAS:

$$\text{Mean} = \frac{\Sigma XF}{\Sigma F}$$

$$\text{STD. DEV.} = \sqrt{\frac{n\Sigma fx^2 - (\Sigma fx)^2}{n(n-1)}}$$

$$\text{"F"} = \frac{S_o^2}{S_n^2}$$

$$\text{Fisher Behrens "t"} = \frac{\bar{x}_o - \bar{x}_n}{\sqrt{\frac{S_o^2}{n_o} + \frac{S_n^2}{n_n}}}$$

Figure 8

APPENDIX A

Preliminary Data

Total Unit Set Forms

Samples Collected and the Breakdown

ORIGINAL SYSTEM:

Other (Regular orders)	-	732
Rush (Regular)	-	294
Management Group Rush	-	3
In-House Rush	-	85
TOTAL ORDERS		1114

REVISED SYSTEM:

Other (Regular orders)	-	763
Rush (Regular rush)	-	284
Management Group Rush	-	11
In-House Rush	-	52
TOTAL ORDERS		1110

Figure 9

Total Continuous Forms

Samples Collected and the Breakdown

ORIGINAL SYSTEM:

Other (Regular orders)	-	571
Rush (Regular)	-	191
Management Group Rush	-	19
In-House Rush	-	67
TOTAL ORDERS		848

REVISED SYSTEM:

Other (Regular orders)	-	563
Rush (Regular rush)	-	188
Management Group Rush	-	24
In-House Rush	-	80
TOTAL ORDERS		855

Figure 10

APPENDIX B

Cumulative Production

Without Classification Breakdown

Original System vs. Revised System

TOTAL ORDERS: 1114

ORIGINAL UNIT SET FORMS SYSTEM

DAYS IN ORDER ENTRY	ORDERS	%	CUMULATIVE	
			DAY	%
1	-	-	0 - 1	-
2	17	1	1 - 2	1
3	97	9	1 - 3	10
4	194	17	1 - 4	27
5	208	19	1 - 5	46
6	198	18	1 - 6	64
7	129	11	1 - 7	75
8	98	9	1 - 8	84
9	52	5	1 - 9	89
10	35	3	1 - 10	92
Over	86	8	Over	100

Table 1-A

TOTAL ORDERS: 1110

REVISED UNIT SET FORMS SYSTEM

DAYS IN ORDER ENTRY	ORDERS	%	CUMULATIVE	
			DAY	%
1	42	4	0 - 1	4
2	313	28	1 - 2	32
3	376	34	1 - 3	66
4	242	22	1 - 4	88
5	62	6	1 - 5	94
6	11	1	1 - 6	95
7	19	2	1 - 7	97
8	7	-	1 - 8	97
9	10	1	1 - 9	98
10	4	-	1 - 10	98
Over	24	2	Over	100

Table 1-B

Original System vs. Revised System

TOTAL ORDERS: 848

ORIGINAL CONTINUOUS FORMS SYSTEM

DAYS IN ORDER ENTRY	ORDERS	%	CUMULATIVE	
			DAY	%
1	-	-	0 - 1	-
2	36	4	1 - 2	4
3	82	10	1 - 3	14
4	205	24	1 - 4	38
5	167	20	1 - 5	58
6	130	15	1 6	73
7	76	9	1 - 7	82
8	56	7	1 - 8	89
9	41	5	1 - 9	94
10	17	2	1 - 10	96
Over	38	4	Over	100

Tabel 2-A

TOTAL ORDERS: 855

REVISED CONTINUOUS FORMS SYSTEM

DAYS IN ORDER ENTRY	ORDERS	%	CUMULATIVE	
			DAY	%
1	299	35	0 - 1	35
2	368	43	1 - 2	78
3	157	18	1 - 3	96
4	22	3	1 - 4	99
5	9	1	1 - 5	100
6			1 - 6	
7	-	-	1 - 7	
8		-	1 8	
9	-	-	1 - 9	
10		-	1 10	
Over			Over	

Table 2-A

APPENDIX C

Comprehensive Classification Breakdown

ORIGINAL UNIT SET FORMS SYSTEM

Cummulative Breakdown
(Other, Rush, MG Rush & In-House Rush)

TOTAL ORDERS: 1114

DAYS IN ORDER ENTRY	OTHERS				RUSH				MANAGEMENT GROUP RUSH				IN-HOUSE RUSH			
	ORDERS	%	CUMULATIVE DAY	CUMULATIVE %	ORDERS	%	CUMULATIVE DAY	CUMULATIVE %	ORDERS	%	CUMULATIVE DAY	CUMULATIVE %	ORDERS	%	CUMULATIVE DAY	CUMULATIVE %
1	-	-	0 - 1	-	-	-	0 - 1	-	-	-	0 - 1	-	-	-	0 - 1	-
2	4	-	1 - 2	-	3	1	1 - 2	1	-	-	1 - 2	-	10	12	1 - 2	12
3	37	6	1 - 3	6	24	8	1 - 3	9	1	33	1 - 3	33	35	41	1 - 3	53
4	91	12	1 - 4	18	78	26	1 - 4	35	-	-	1 - 4	-	25	29	1 - 4	82
5	134	18	1 - 5	36	67	23	1 - 5	58	-	-	1 - 5	-	7	8	1 - 5	90
6	143	20	1 - 6	56	53	18	1 - 6	76	1	33	1 - 6	66	1	1	1 - 6	91
7	99	13	1 - 7	69	26	9	1 - 7	85	1	33	1 - 7	100	3	4	1 - 7	95
8	80	11	1 - 8	80	15	5	1 - 8	90	-	-	1 - 8	-	3	4	1 - 8	99
9	43	6	1 - 9	86	8	3	1 - 9	93					1	1	1 - 9	100
10	32	4	1 - 10	90	3	1	1 - 10	94								
Over	69	10	Over	100	17	6	Over	100								
SUB TOTAL:	732				294				3				85			

Table 3-A

REVISED UNIT SET FORMS SYSTEM

Cummulative Breakdown
(Other, Rush, MG Rush & In-House Rush)

TOTAL ORDERS: 1110

DAYS IN ORDER ENTRY	OTHERS				RUSH				MANAGEMENT GROUP RUSH				IN-HOUSE RUSH			
	ORDERS	%	CUMULATIVE DAY	CUMULATIVE %	ORDERS	%	CUMULATIVE DAY	CUMULATIVE %	ORDERS	%	CUMULATIVE DAY	CUMULATIVE %	ORDERS	%	CUMULATIVE DAY	CUMULATIVE %
1	24	3	0 - 1	3	13	4	0 - 1	4	-	-	0 - 1	-	5	9	0 - 1	9
2	188	25	1 - 2	28	93	33	1 - 2	37	7	64	1 - 2	64	25	48	1 - 2	57
3	257	34	1 - 3	62	102	36	1 - 3	73	3	27	1 - 3	91	14	27	1 - 3	84
4	193	25	1 - 4	87	45	16	1 - 4	89	1	9	1 - 4	100	3	6	1 - 4	90
5	45	6	1 - 5	93	17	6	1 - 5	95	-	-			-	-	1 - 5	
6	8	1	1 - 6	94	2	1	1 - 6	96					1	2	1 - 6	92
7	15	2	1 - 7	96	2	1	1 - 7	97					2	4	1 - 7	96
8	7	1	1 - 8	97	-	-	1 - 8						-	-	1 - 8	
9	7	1	1 - 9	98	3	1	1 - 9	98					-	-	1 - 9	
10	2	-	1 - 10		1	1	1 - 10						1	2	1 - 10	98
Over	17	2	Over	100	6	2	Over	100					1	2	Over	100
SUB TOTAL:	763				284				11				52			

Table 3-B

ORIGINAL CONTINUOUS FORMS SYSTEM

Cummulative Breakdown
(Other, Rush, MG Rush & In-House Rush)

TOTAL ORDERS: 848

DAYS IN ORDER ENTRY	OTHERS				RUSH				MANAGEMENT GROUP RUSH				IN-HOUSE RUSH			
	ORDERS	%	CUMULATIVE DAY	CUMULATIVE %	ORDERS	%	CUMULATIVE DAY	CUMULATIVE %	ORDERS	%	CUMULATIVE DAY	CUMULATIVE %	ORDERS	%	CUMULATIVE DAY	CUMULATIVE %
1	-	-	0 - 1	-	-	-	0 - 1	-	-	-	0 - 1	-	-	-	0 - 1	-
2	12	2	1 - 2	2	8	4	1 - 2	4	3	16	1 - 2	16	13	19	1 - 2	19
3	34	6	1 - 3	8	24	13	1 - 3	17	7	37	1 - 3	53	17	25	1 - 3	44
4	126	22	1 - 4	30	64	33.5	1 - 4	50.5	4	21	1 - 4	74	11	16	1 - 4	60
5	118	21	1 - 5	51	39	20	1 - 5	70.5	2	10.5	1 - 5	84.5	8	12	1 - 5	72
6	96	17	1 - 6	68	27	14	1 - 6	84.5	2	10.5	1 - 6	95	5	8	1 - 6	80
7	57	10	1 - 7	78	14	7	1 - 7	91.5	1	5	1 - 7	100	4	6	1 - 7	86
8	46	8	1 - 8	86	7	4	1 - 8	95.5					3	4	1 - 8	90
9	34	6	1 - 9	92	5	3	1 - 9	98.5					2	3	1 - 9	93
10	13	2	1 - 10	94	2	1	1 - 10	99.5					2	3	1 - 10	96
Over	35	6	Over	100	1	.5	Over	100					2	4	Over	100
SUB TOTAL:	571				191				19				67			

Table 4-A

REVISED CONTINUOUS FORMS SYSTEM

Commulative Breakdown
(Other, Rush, MG Rush & In-House Rush)

TOTAL ORDERS: 855

DAYS IN ORDER ENTRY	OTHERS				RUSH				MANAGEMENT GROUP RUSH				IN-HOUSE RUSH			
	ORDERS	%	CUMULATIVE DAY	CUMULATIVE %	ORDERS	%	CUMULATIVE DAY	CUMULATIVE %	ORDERS	%	CUMULATIVE DAY	CUMULATIVE %	ORDERS	%	CUMULATIVE DAY	CUMULATIVE %
1	145	26	0 - 1	26	94	50	0 - 1	50	14	58	0 - 1	58	46	58	0 1	58
2	248	44	1 - 2	70	81	43	1 - 2	93	9	38	1 - 2	96	30	38	1 - 2	96
3	144	26	1 - 3	96	10	5	1 - 3	98	1	4	1 - 3	100	2	2	1 - 3	98
4	20	3	1 - 4	99	1	1	1 - 4	99					1	1	1 - 4	99
5	6	1	1 - 5	100	2	1	1 - 5	100					1	1	1 - 5	100
SUB TOTAL:	563				188				24				80			

Table 4-B

APPENDIX D

Four-Day Delivery Comparison

Brokendown between "Other" and Combined Rush

With cumulative percentages

Four-Day Delivery Comparison

Total Orders: 1114

ORIGINAL UNIT SET FORMS SYSTEM

DAYS IN ORDER ENTRY	ORDERS	CUMULATIVE				
		DAY	OTHER		RUSH	
			ORDER	%	ORDER	%
1	-	0 - 1	-	-	-	-
2	17	1 - 2	4	=	13	3
3	97	1 - 3	37	6	60	19
4	194	1 - 4	91	18	103	46
	308		132		176	

Table 5-A

Total Orders: 1110

REVISED UNIT SET FORMS SYSTEM

DAYS IN ORDER ENTRY	ORDERS	CUMULATIVE				
		DAY	OTHER		RUSH	
			ORDER	%	ORDER	%
1	42	0 - 1	24	3	18	5
2	313	1 - 2	188	28	125	41
3	376	1 - 3	257	62	119	75
4	242	1 - 4	193	87	49	89
	973		662		311	

Table 5-B

Four-Day Delivery Comparison

Total Orders: 848

ORIGINAL CONTINUOUS FORMS SYSTEM

DAYS IN ORDER ENTRY	ORDERS	CUMULATIVE				
		DAY	OTHER		RUSH	
			ORDER	%	ORDER	%
1	-	0 - 1	-	-	-	-
2	36	1 - 2	12	2	24	9
3	82	1 - 3	34	8	48	26
4	205	1 - 4	126	30	79	65
	323		172		151	

Table 6-A

Total Orders: 855

REVISED CONTINUOUS FORMS SYSTEM

DAYS IN ORDER ENTRY	ORDERS	CUMULATIVE				
		DAY	OTHER		RUSH	
			ORDER	%	ORDER	%
1	299	0 - 1	145	26	153	53
2	368	1 - 2	248	70	120	94
3	157	1 - 3	144	96	13	98
4	22	1 - 4	20	99	2	99
	846		557		289	

Table 6-B

APPENDIX E

Combination of Unit Set Forms and Continuous Forms Systems. Breakdown - Other and Combined Rush.

Total Orders: 1962

ORIGINAL COMBINED FORMS SYSTEM

DAYS IN ORDER ENTRY	ORDERS	CUMULATIVE				
		DAY	OTHER		RUSH	
			ORDER	%	ORDER	%
1	-	0 - 1	-	-	-	-
2	53	1 - 2	16	1	37	6
3	179	1 - 3	71	6	103	22
4	399	1 - 4	217	23	182	50
5	375	1 - 5	252	42	123	69
6	328	1 - 6	239	60	89	83
7	205	1 - 7	156	72	49	90
8	154	1 - 8	126	82	28	94
9	93	1 - 9	77	88	16	96
10	52	1 - 10	45	92	7	97
Over	124	over	104	100	20	100
	1962		1303		659	

Table 7-A

Total Orders: 1965

REVISED COMBINED FORMS SYSTEM

DAYS IN ORDER ENTRY	ORDERS	CUMULATIVE				
		DAY	OTHER		RUSH	
			ORDER	%	ORDER	%
1	341	0 - 1	169	13	172	27
2	681	1 - 2	436	46	245	65
3	533	1 - 3	401	76	132	86
4	264	1 - 4	213	92	51	94
5	71	1 - 5	51	96	20	97
6	11	1 - 6	8	97	3	97.5
7	19	1 - 7	15	98	4	98.5
8	7	1 - 8	7	98.5	-	
9	10	1 - 9	7	99	3	99
10	4	1 - 10	2		2	
Over	24	over	17	100	7	100
	1965		1326		639	

Table 7-B

APPENDIX F

Combination of Cumulative Unit Set Forms and Continuous Forms System.

Total Orders: 1962

ORIGINAL COMBINED **FORMS SYSTEM**

DAYS IN ORDER ENTRY	ORDERS	%	CUMULATIVE	
			DAY	%
1	-	-	0 - 1	-
2	53	3	1 - 2	3
3	179	9	1 - 3	12
4	399	20	1 - 4	32
5	375	19	1 - 5	51
6	328	17	1 - 6	68
7	205	10	1 - 7	78
8	154	8	1 - 8	86
9	93	5	1 - 9	91
10	52	3	1 - 10	94
Over	124	6	over	100

Table 8-A

Total Orders: 1965

REVISED COMBINED **FORMS SYSTEM**

DAYS IN ORDER ENTRY	ORDERS	%	CUMULATIVE	
			DAY	%
1	341	17	0 - 1	17
2	681	35	1 - 2	52
3	533	27	1 - 3	79
4	264	13	1 - 4	92
5	71	4	1 - 5	96
6	11	1	1 - 6	97
7	19	1	1 - 7	98
8	7	-	1 - 8	
9	10	1	1 - 9	99
10	4	-	1 - 10	
Over	24	1	over	100

Table 8-B

APPENDIX G

Computation of the Mean and Standard Deviation for the data -- and graphic illustrations. -- Unit Set Forms.

COMPUTATION OF THE VARIANCE

Original Unit Set System

X	F	XF	X^2	FX^2
1	0	0	1	0
2	17	34	4	68
3	97	291	9	873
4	194	776	16	3104
5	208	1040	25	5200
6	198	1188	36	7128
7	129	903	49	6321
8	98	784	64	6272
9	52	468	81	4212
10	35	350	100	3500
11	23	253	121	2783
12	20	240	144	2880
13	17	221	169	2873
14	14	196	196	2744
15	9	135	225	2025
16	3	48	256	768
136	1114	6927	1496	50751

Figure 11

COMPUTATION OF THE VARIANCE

Revised Unit Set System

X	F	XF	X^2	FX^2
1	42	42	1	42
2	313	626	4	1252
3	376	1128	9	3384
4	242	968	16	3872
5	62	310	25	1550
6	11	66	36	396
7	19	133	49	931
8	7	56	64	448
9	10	90	81	810
10	4	40	100	400
11	13	143	121	1573
12	10	120	144	1440
13	1	13	169	169
91	1110	3735	819	16267

Figure 12

LARGE SAMPLE DATA - Original System
Unit Set Forms

MEAN:

$$\bar{x} = \frac{\Sigma XF}{\Sigma F}$$

$$\bar{x} = \frac{6927}{1114}$$

$$\bar{x} = 6.2$$

STD. DEV.:

$$s = \sqrt{\frac{n\Sigma fx^2 - (\Sigma fx)^2}{n(n-1)}}$$

$$= \sqrt{\frac{1114(50751) - (6927)^2}{1114 \times 1113}}$$

$$= \sqrt{\frac{56536614 - 47983329}{1239882}}$$

$$= \sqrt{\frac{8553285}{1239882}}$$

$$= \sqrt{6.89846695}$$

$$= 2.6$$

Figure 13

LARGE SAMPLE DATA - Revised System
Unit Set Forms

MEAN:

$$\bar{x} = \frac{\Sigma XF}{\Sigma F}$$

$$\bar{x} = \frac{3735}{1110}$$

$$\bar{x} = 3.4$$

STD. DEV.:

$$s = \sqrt{\frac{n\Sigma fx^2 - (\Sigma fx)^2}{n(n-1)}}$$

$$= \sqrt{\frac{1110(16267) - (3735)^2}{1110 \times 1109}}$$

$$= \sqrt{\frac{18056370 - 13950225}{1230990}}$$

$$= \sqrt{\frac{4106145}{1230990}}$$

$$= \sqrt{3.3356444}$$

$$= 1.8$$

Figure 14

Unit Set Forms

$$\text{Fisher Behrens "t"} = \frac{\bar{x}_o - \bar{x}_n}{\sqrt{\frac{S_o^2}{n_o} + \frac{S_n^2}{n_n}}}$$

$$= \frac{6.2 - 3.4}{\sqrt{\frac{2.6^2}{1114} + \frac{1.8^2}{1110}}}$$

$$= \frac{2.8}{\sqrt{.0060682 + .0029189}}$$

$$= \frac{2.8}{\sqrt{.0089871}}$$

$$= \frac{2.8}{.0948003}$$

$$\text{"t"} = 29.53$$

Figure 15

POLYGON - UNIT SET FORMS

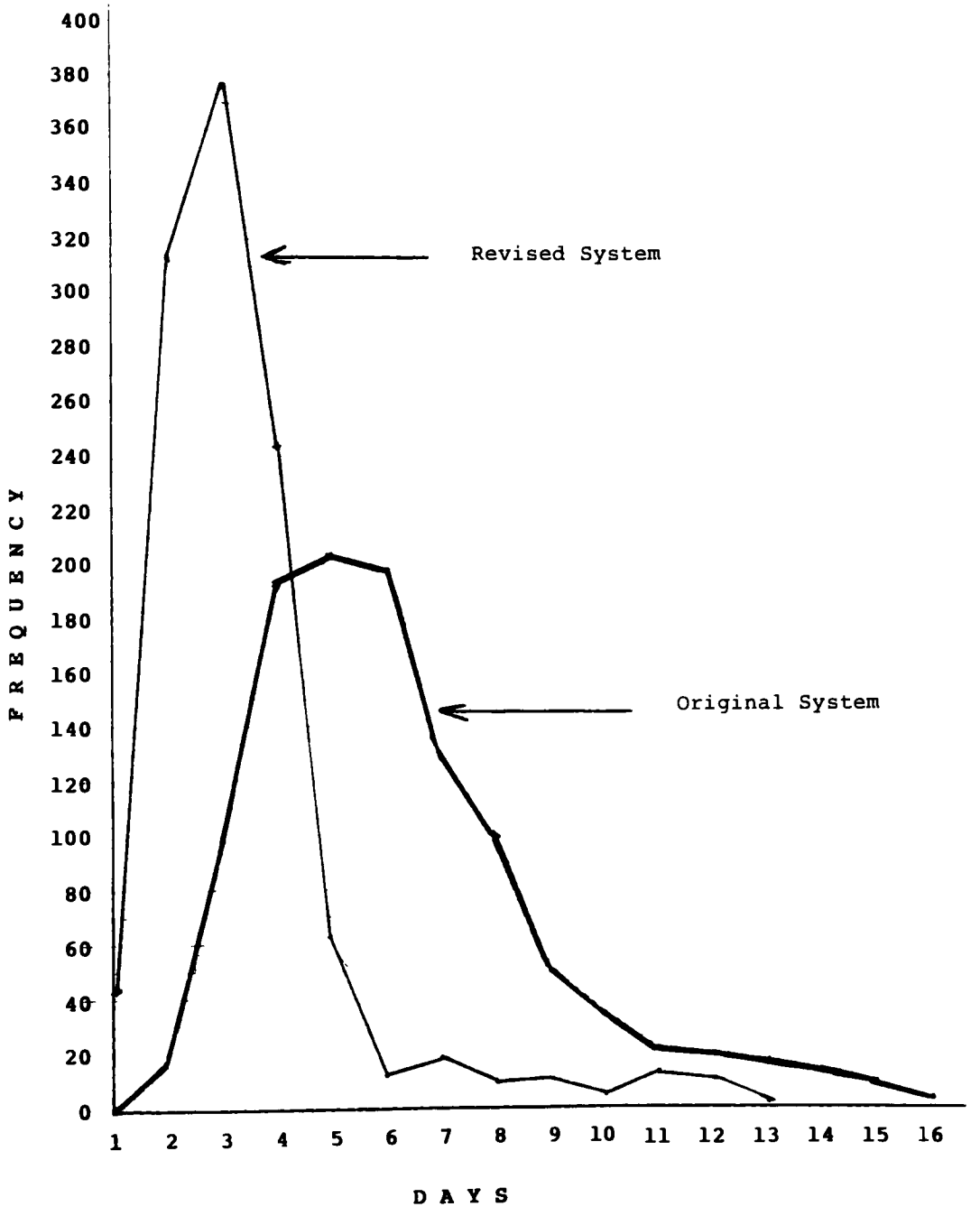


Figure 16

UNIT SET FORMS

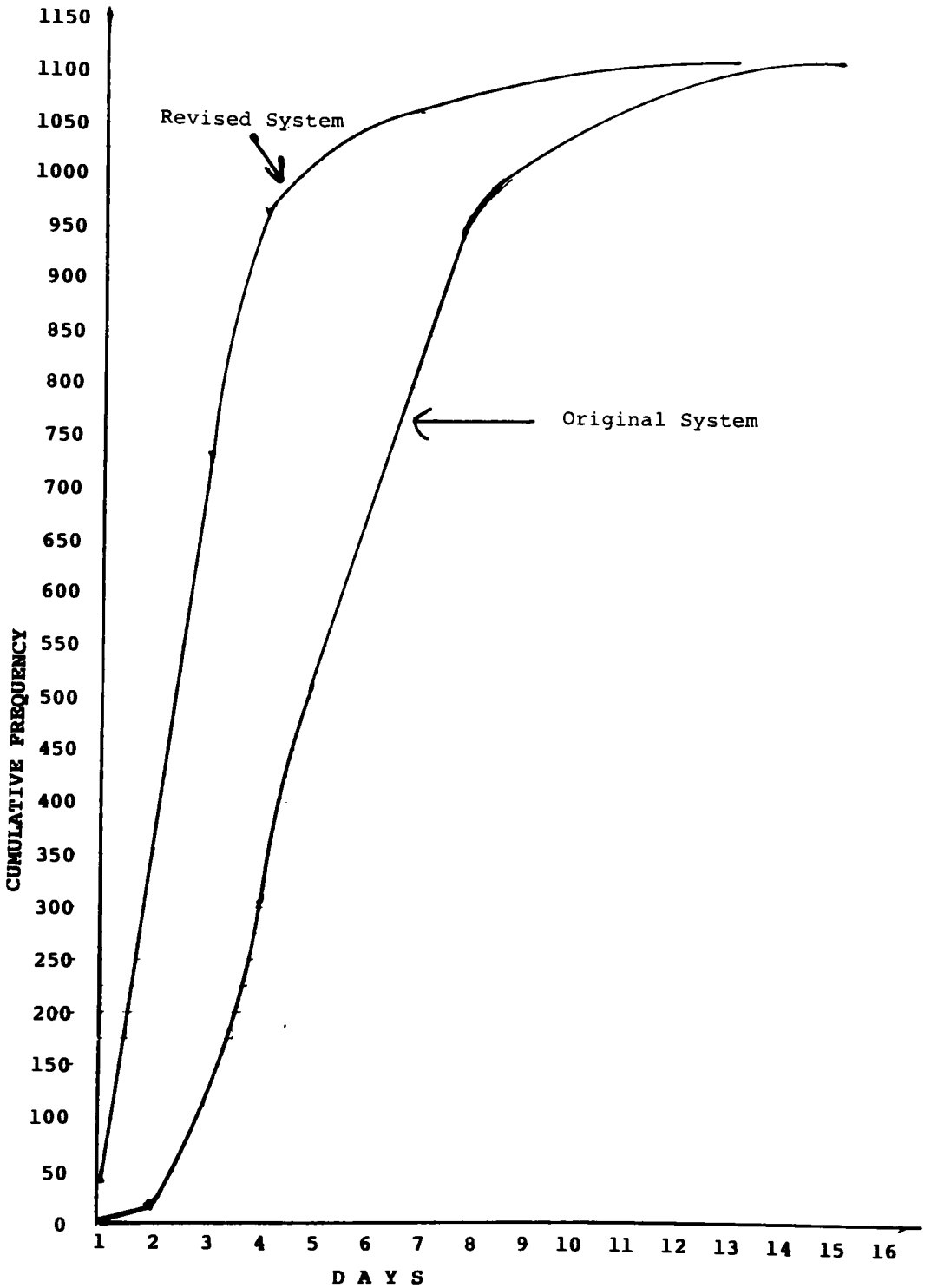


Figure 17

APPENDIX H

Computation of the Mean and Standard Deviation for the data -- and graphic illustrations.-- Continuous Forms.

COMPUTATION OF THE VARIANCE

Original Continuous Forms System

X	F	XF	X^2	FX^2
1	0	0	1	0
2	36	72	4	144
3	82	246	9	738
4	205	820	16	3280
5	167	835	25	4175
6	130	780	36	4680
7	76	532	49	3724
8	56	448	64	3584
9	41	369	81	3321
10	17	170	100	1700
11	15	165	121	1815
12	11	132	144	1584
13	9	117	169	1521
14	3	42	196	588
105	848	4728	1015	30854

Figure 18

COMPUTATION OF THE VARIANCE

Revised Continuous Forms System

X	F	XF	X^2	FX^2
1	299	299	1	299
2	368	736	4	1472
3	157	471	9	1413
4	22	88	16	352
5	9	45	25	225
15	855	1639	51	3761

Figure 19

LARGE SAMPLE DATA - Original System
Continuous Forms

MEAN:

$$\bar{x} = \frac{\Sigma XF}{\Sigma F}$$

$$\bar{x} = \frac{4728}{848}$$

$$\bar{x} = 5.58$$

STD. DEV.:

$$s = \sqrt{\frac{n\Sigma fx^2 - (\Sigma fx)^2}{n(n-1)}}$$

$$= \sqrt{\frac{848(30854) - (4728)^2}{848(847)}}$$

$$= \sqrt{\frac{26164192 - 22353984}{718256}}$$

$$= \sqrt{\frac{3810208}{718256}}$$

$$= \sqrt{5.3048049}$$

$$= 2.30$$

Figure 20

LARGE SAMPLE DATA - Revised System
Continuous Forms

MEAN:

$$\bar{x} = \frac{\Sigma XF}{\Sigma F}$$

$$\bar{x} = \frac{1639}{855}$$

$$\bar{x} = 1.92$$

STD. DEV.:

$$s = \sqrt{\frac{n\Sigma fx^2 - (\Sigma fx)^2}{n(n-1)}}$$

$$= \sqrt{\frac{855(3761) - (1639)^2}{855(854)}}$$

$$= \sqrt{\frac{3215655 - 2686321}{730170}}$$

$$= \sqrt{\frac{529334}{730170}}$$

$$= \sqrt{.7249462}$$

$$= .85$$

Figure 21

Continuous Forms

$$\text{Fisher Behrens "t"} = \frac{\bar{x}_o - \bar{x}_n}{\sqrt{\frac{s_o^2}{n_o} + \frac{s_n^2}{n_n}}}$$

$$= \frac{5.58 - 1.92}{\sqrt{\frac{2.30^2}{848} + \frac{.85^2}{855}}}$$

$$= \frac{3.66}{\sqrt{.0062382 + .000845}}$$

$$= \frac{3.66}{\sqrt{.0070832}}$$

$$= \frac{3.66}{.0841617}$$

$$\text{"t"} = 43.49$$

Figure 22

POLYGON - CONTINUOUS FORMS

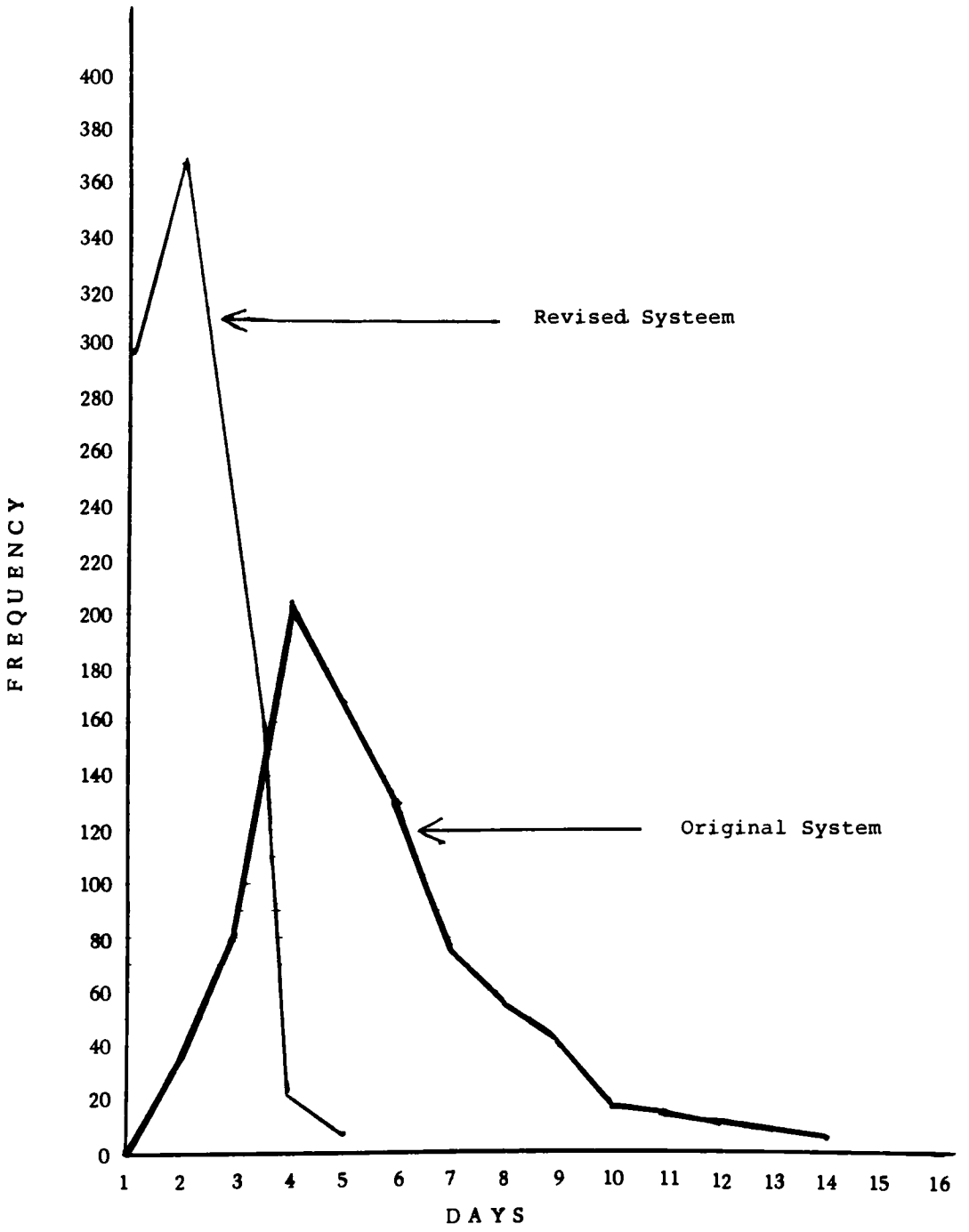


Figure 23

CONTINUOUS FORMS

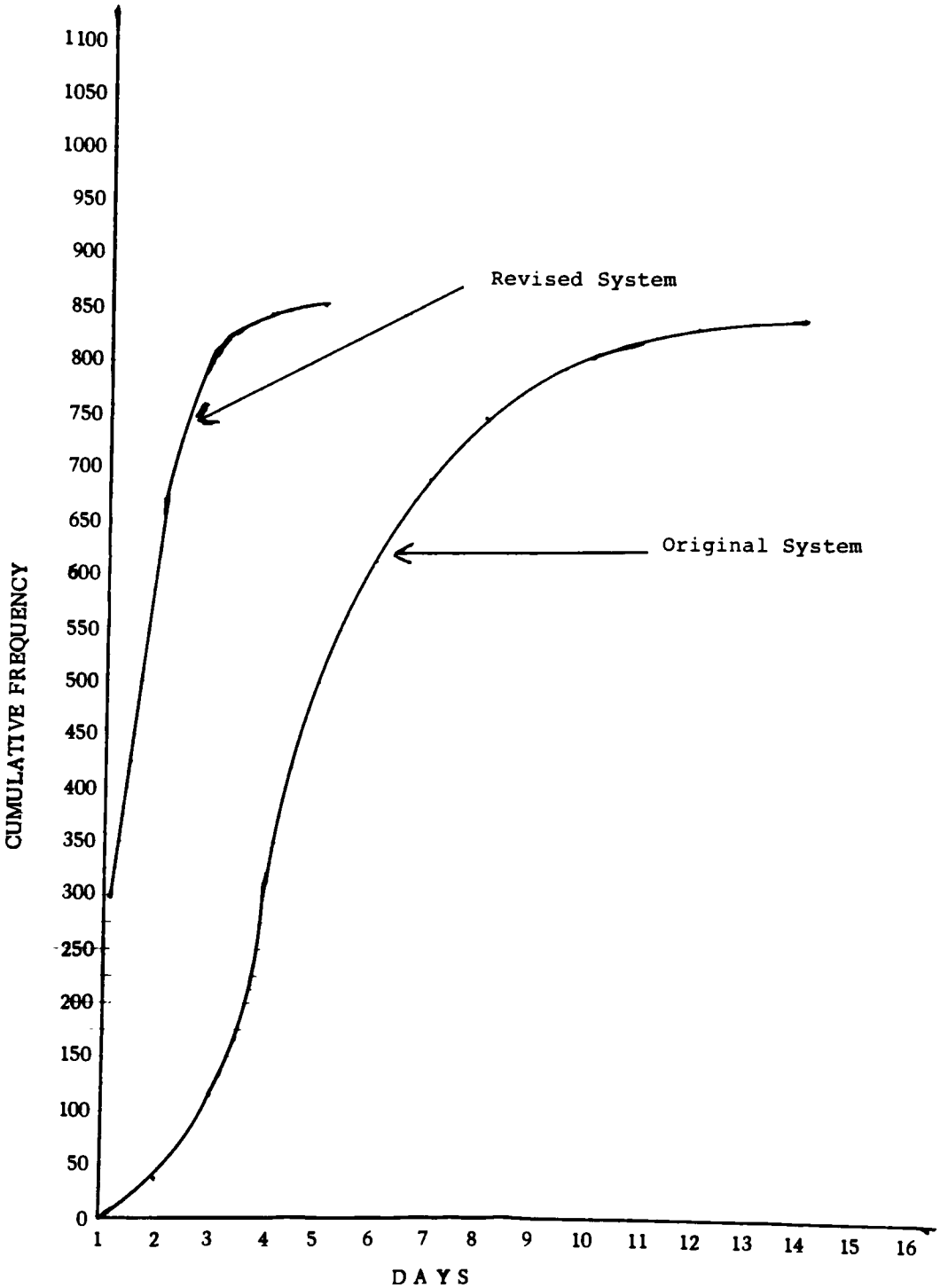


Figure 24

APPENDIX I

Combined data for Unit Set and Continuous Forms and graphic illustration.

COMBINED UNIT SET & CONTINUOUS FORMS
DATA

Original System

X	F
1	0
2	53
3	179
4	399
5	375
6	328
7	205
8	154
9	93
10	52
11	38
12	31
13	26
14	17
15	9
16	3
136	1962

Figure 25

COMBINED UNIT SET & CONTINUOUS FORMS
DATA

Revised System

X	F
1	341
2	681
3	533
4	264
5	71
6	11
7	19
8	7
9	10
10	4
11	13
12	10
13	1
91	1965

Figure 26

POLYGON - COMBINED UNIT SET & CONTINUOUS FORMS

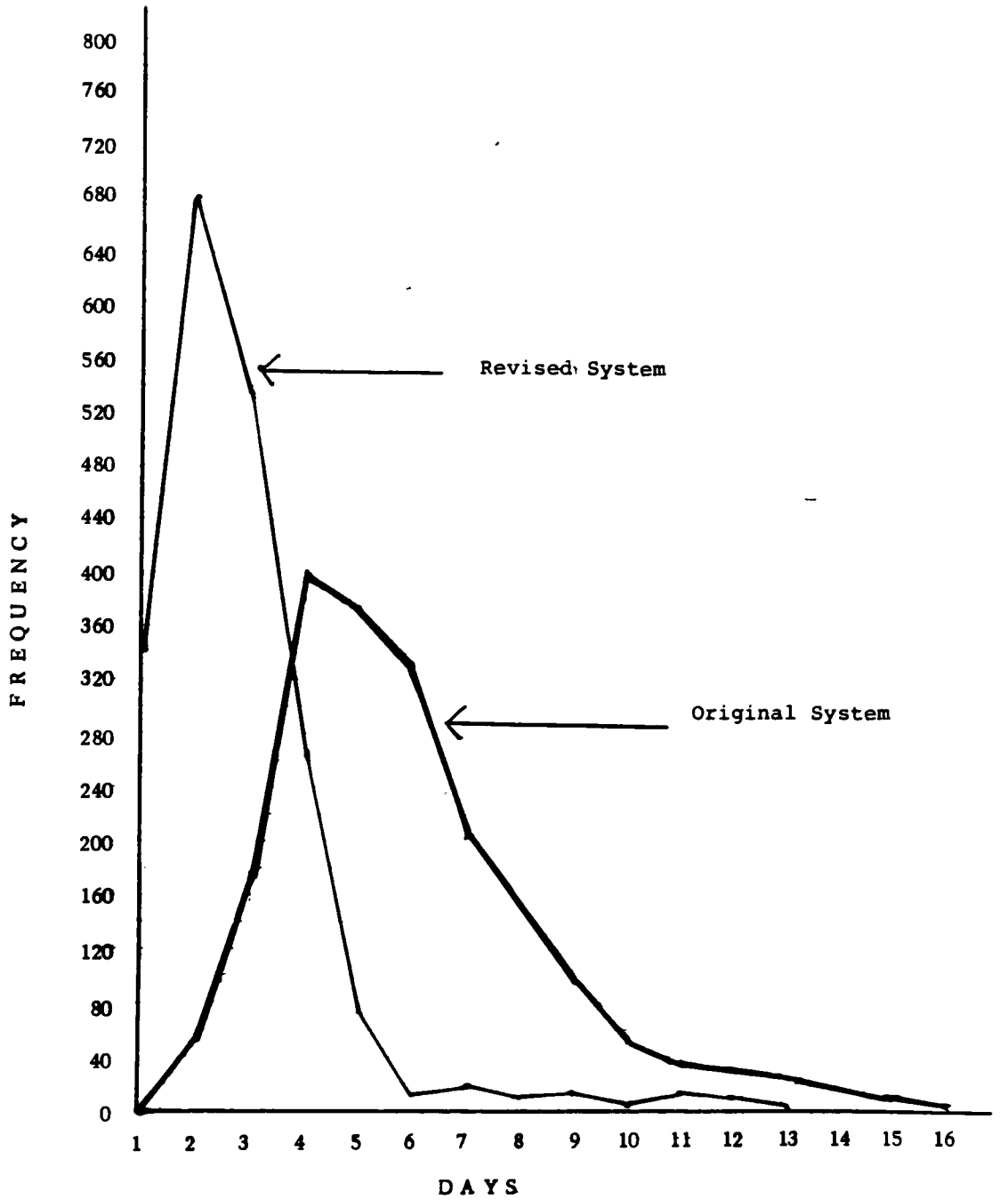


Figure 27

BIBLIOGRAPHY

BIEGEL, JOHN E., "Production Control" 2nd ed. (Englewood Cliff, NJ: Prentice-Hall, Inc., 1971), pp. 1-6, 7-89, 153-249.

BUFFA, ELWOOD S., "Readings in Production and Operation Management" 2nd ed. (New York: John Wiley & Sons, Inc., 1966), pp. 132-137, 157, 159.

GAVETT, WILLIAM, "Production and Operation Management" (New York: Harcourt Brace and World, Inc., 1968), pp. 133-137, 166-171.

GREEN, JAMES HARNSBERGER, "Operations Planning and Control", (Homewood, ILL: R.D. Irwin, 1967), pp. 12-14, 17-18.

HOPEMAN, RICHARD J., "Production--Concept Analysis Control" 2nd ed. (Columbus, Ohio: Charles E. Merrill Publishing Co., A Bell & Howard Co., 1971), pp. 3-31.

PLOSSL, GEORGE W., "Manufacturing Control", (Reston, Virginia 22090: Reston Publishing Company, A Prentice-Hall Company, 1973), pp. 1-36.

RICKMERS, ALBERT D., TODD, HOLIS N., "Statistics--An Introduction", (NY: McGraw-Hill Book Company, 1967), pp. 13-18, 25-34, 119.

VEMON, IVAN R., "Introduction To Manufacturing Management" Vol. 1, (Dearborn, Michigan: American Society of Tools & Manufacturing Engineering, 1969), pp. 141-157.

SCHEELE, EVANS D., WESTERMAN, WILLIAM L., WIMMERT, ROBERT J., "Principles and Design of Production Control System", pp. 1-3, 35-39, 266-307.

WEINBERG, GEORGE H., SCHUMAKER, JOHN A., "Statistics -- An Intuitive Approach" 3rd ed. (Monterey, CA: Brooks/ Cole Publishing Co., A Division of Wadsworth Publishing Company, Inc., 1974), pp. 80-81, 330.