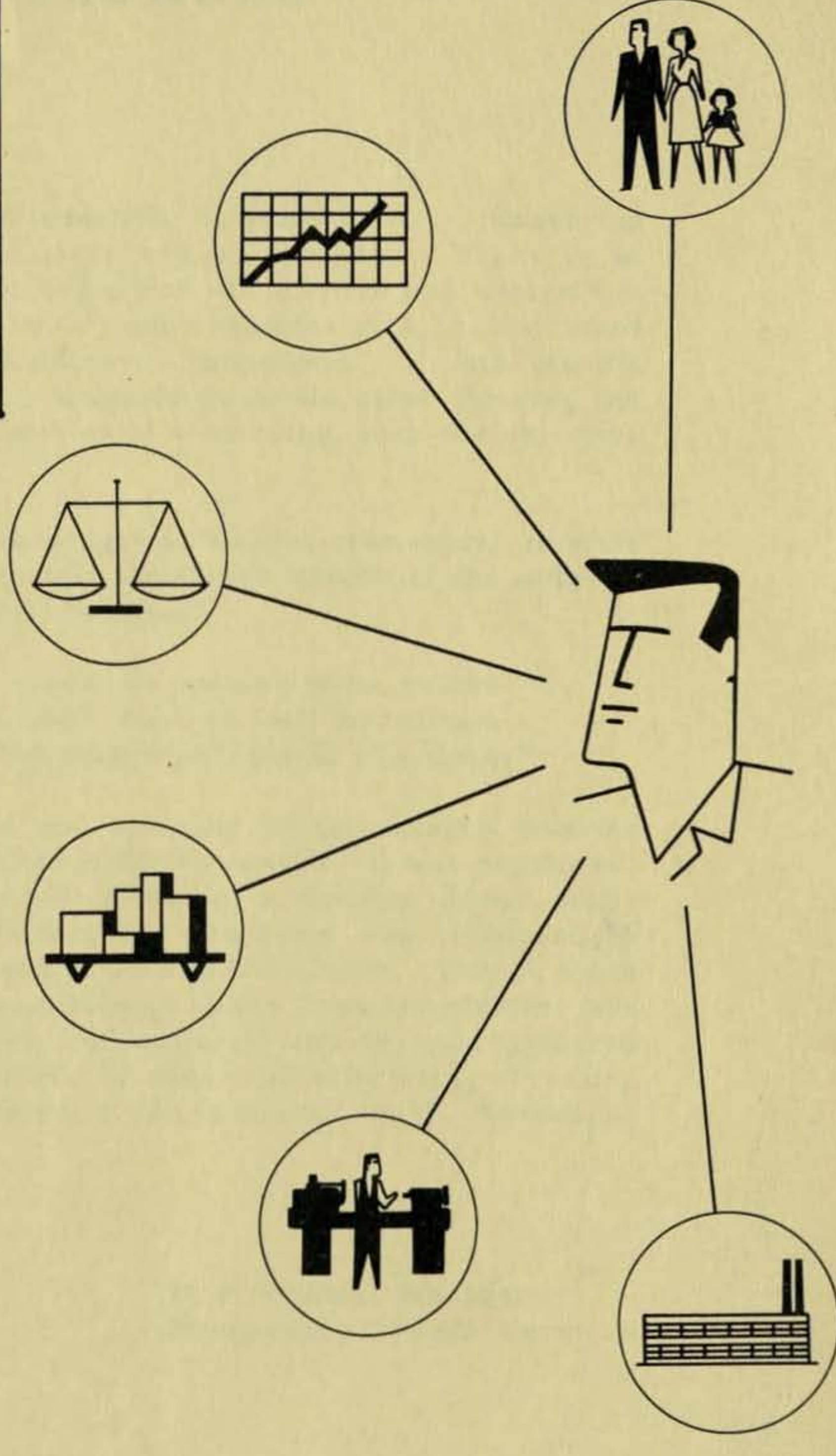
Dynamic PRODUCTION SCHEDULING



Production Control Services

GENERAL ELECTRIC

FOR INTERNAL USE

PRINCIPLES

PROCESSES

PRACTICES

FOREWORD

"Dynamic Production Scheduling" is a pioneering effort in an area where there are no panaceas. There is an unquestioned need for an organized compilation and analysis of scheduling techniques since so much remains to be accomplished before we achieve satisfactory competence. If this Manual succeeds in stimulating individuals to devote clear thinking and effective action to the function of scheduling, then our objective has been attained.

We were encouraged to publish this study, in spite of the broad and inadequately developed nature of the subject, by this thought of Cardinal Newman:

> "A man would do nothing if he waited
> until he could do it so well that no one
> would find fault with what he has done."

The concept and planning of this Manual was the work of the Production Control Services staff. It was organized, directed, and edited by Mr. B. Grad, a member of our staff. The greater part of the text and problems was composed by Professor R. E. McGarrah of Cornell University. Though much of the credit for the cases belongs to the Departments who are identified with each case, the material was actually gathered through the capable efforts of three Manufacturing Training Program students, Messrs. R. A. Budinsky, T. F. Kavanagh, and D. G. Ransom.

H. F. Dickie, Manager
Production Control Services

April, 1955

PRINCIPLES

PROCESSES

PRACTICES

PREFACE

Look ahead ten years --- Picture the impact of Cybernetics, Computers, and Automation on Production Scheduling. In this era of increasing productivity, extensive progress in our scheduling techniques is needed to keep pace with advancing manufacturing methods.

Accurate scheduling lubricates the wheels of business --- Employment is stabilized --- Costs are reduced --- and business grows. The schedule is the timetable which guides manufacturing operations; it is the plan by which our customers are satisfied and retained.

Once a stepchild of managerial attention, new concepts in programming production have focused the spotlight on scheduling --- the spotlight it so richly deserves. Fostered by management interest, a whole new technology is growing, rooted in scientific research.

The solution to our problem is vital --- we must master new concepts of Dynamic Production Scheduling.

THE CONTENTS

part one PRINCIPLES

PRINCIPLES PROCESSES PRACTICES

part two PROCESSES

chapter 5 - Methods of Handling Scheduling Data

chapter 6 - How to Size Up Your Scheduling Problems

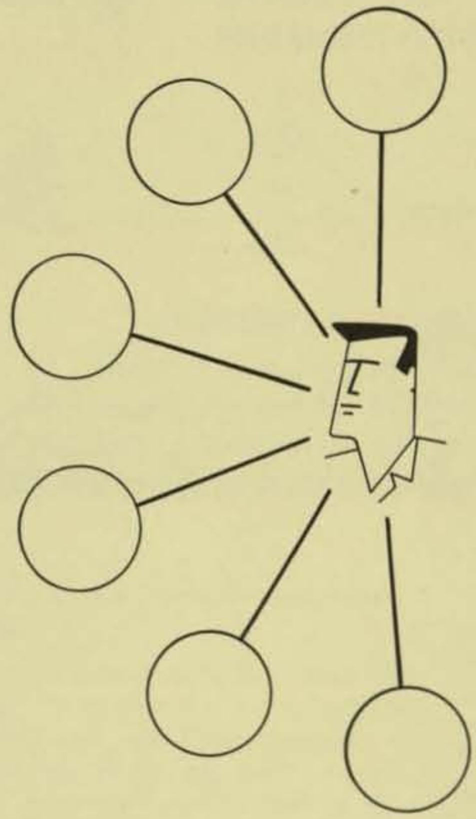
part three PRACTICES

chapter 7 - About These Cases

PRINCIPLES

PROCESSES

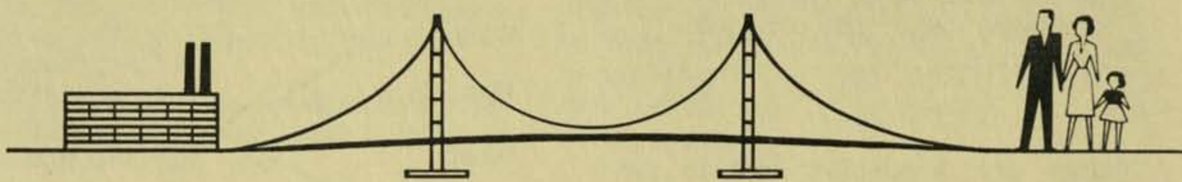
PRACTICES



PART ONE

Some basic principles involved in Production Scheduling

CHAPTER I - WHAT IS PRODUCTION SCHEDULING



PRODUCTION SCHEDULING CONSTRUCTS THE TIME BRIDGE CONNECTING THE CUSTOMERS' WANTS WITH THE FACTORY'S ABILITY TO PRODUCE

A NEW LOOK AT SCHEDULING IS NEEDED

Two production schedules, both for the same plant, both for the same month, both specifying the same total number of products, and the same number of components to be manufactured -- though different, both schedules may be feasible! Yet, the monthly profit derived from manufacturing to the first schedule could be twice the profit resulting from using the second schedule. Why? Because the timing of the first schedule is twice as good as the second...in-process parts move toward the customers on the right day, the right hour, in the first schedule, but in the second, machines are utilized inefficiently, customers are kept waiting, and materials within the shop do not "flow" smoothly. No sales dollars are collected while inventory is piling up around the factory. This is why the profits are different. TIME makes the difference! Time is the all important fourth dimension of the production schedule. It is the means for controlling manufacturing activity. Though it now takes only 12 hours to cross the Atlantic, Columbus needed over two months; similarly, where factories in the past were run on a monthly basis, today they require scheduling right to the minute. Indeed, progress itself has been measured by the increased "mastery" of time.

Most production control personnel in General Electric manufacturing departments have a good idea of the importance of scheduling. But this realization may become vague under the pressure of day-to-day routine--"putting out fires"--material shortages--breakdowns--manufacturing delays--engineering changes--and on, and on, and on! Perhaps the situation reaches the point where a person "can't see the woods for the trees". However, there is an orderly pattern to all this activity--to these systems and paperwork procedures, which make up the environment of the production scheduling job. Once this pattern is discovered, the function of production scheduling becomes orderly and productivity increases with no added effort.

A big share of the responsibility for boosting manufacturing productivity rests squarely on those who make "time" their business-production schedulers. Industry cannot expect to meet its growth predictions solely by the development of better machine tools and materials handling equipment. Here are just a few of the reasons:

- There isn't a sufficient supply of investment capital available.

- There aren't enough technically trained people to design all the better machine tools and factories which would be needed.

- There is a future trend toward a relative reduction of work force, because of earlier retirement, longer life expectancy, etc.

Things are happening fast in the electrical manufacturing industry. New products are being developed for the market at a faster rate than ever before—not just military products, but consumer goods as well. For instance, the home television receiver industry grew into a "big volume" business a lot faster than automobiles. Take a look at the increasing number of new competitors in the electrical manufacturing industry and it's easy to see that, even with the progress already made, the business is really just beginning to grow. Even to hold its traditional share of the market a company must accelerate its annual rate of increase in output. This is why manufacturing productivity at General Electric must go up at an increasing rate in the future.

If realization of our necessary growth is not possible through better machine tools and factories alone, obviously the one remaining recourse is improved utilization of available facilities. This means we must improve the production scheduling job now being done. We can't schedule the shops just to keep them busy; if we do, we will have inventory piled all over the place--not moving out the back door. On the other hand, we can't release to the shop just a stack of manufacturing orders (labor vouchers, material withdrawal slips, routing instructions, etc.) and hope the foreman will somehow fabricate and assemble the products in time to meet the customer delivery promises.

Consequently, it is NOW time to take a new and careful look at PRODUCTION SCHEDULING.

PRODUCTION SCHEDULING DEFINED

A Production Schedule is a plan showing:

When
How Many
What
Where

→ of the products and materials you're going to buy and make.

A Production Schedule may be expressed in terms of:

- quantities of products to be shipped "out the back door" per day or week
- pounds of material to be processed per day or week
- man-hours to be utilized at each work center per day or week
- machine hours to be expended at each station per day or week

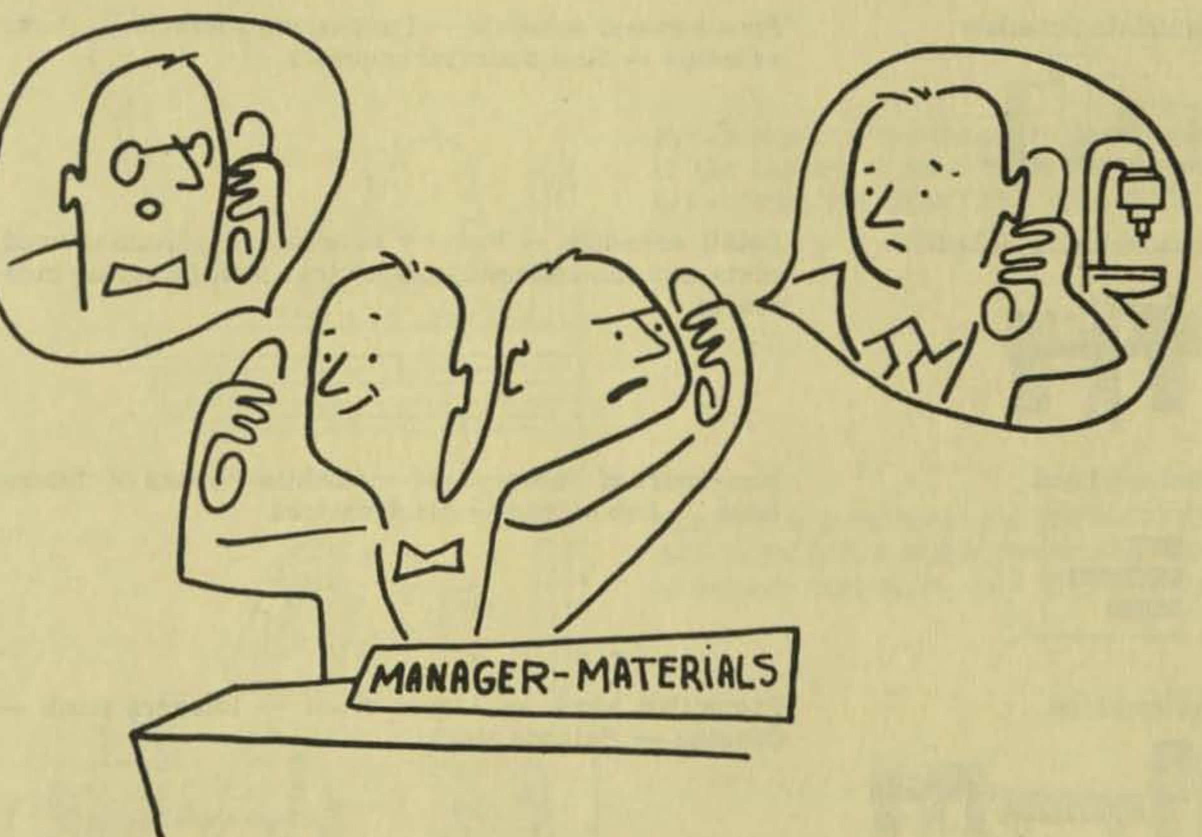
A production schedule is required for the plant as a whole, for each section within the plant, for each unit within the section, and so on. Whether or not the schedule is issued as a formal, official document, important scheduling decisions are made throughout the factory--even when the floor foreman or dispatcher answers the machine operator's question--"What'll I do now?".

Obviously, a production schedule which ignored the capabilities of the factory just wouldn't make sense. The inside works of a factory don't respond like a hand organ which plays music faster or slower, depending on how fast you turn the crank. In a changing market a certain amount of "slippage" takes place before the factory's output of products to the market is "geared" directly to the input of customers' orders. Due allowance must be made for time to perform all the necessary operations; otherwise the manufacturing sections cannot meet the deadlines for delivering the product.

On the other hand customers have to be satisfied. They demand prompt delivery service and promised delivery dates must be kept--otherwise your customers are apt to become somebody else's.

So, in making the production schedule one has to "wear two hats" -- the first to think about the problem of losing a customer because of failure to deliver on schedule and the other to think about the problem of losing the Company's shirt because of too much inventory! Scheduling is concerned with TIME PERFORMANCE, just as finance is concerned with cost performance.

**PRODUCTION SCHEDULING
CONSTRUCTS THE TIME BRIDGE
CONNECTING THE CUSTOMERS' WANTS
WITH THE FACTORY'S ABILITY TO PRODUCE**



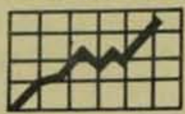
Constructing the "Time Bridge"

AN UNDERSTANDING OF TERMS . . .

To get our names straight - - - let's make sure that we agree on the meaning of a few terms we'll be using. It's really surprising to hear the different names production people in the various departments of General Electric give to the same thing. This can be very confusing!

TERM USED IN MANUAL	SOMETIMES KNOWN AS

Market Forecast

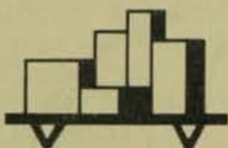


Sales forecast -- Sales budget -- Proposition list

Master Schedule

Production forecast -- Factory load chart -- Production budget -- Final assembly schedule -- Factory program -- Finished product schedule -- Broad load

Materials Schedule

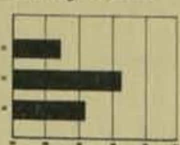


Procurement schedule -- Purchasing schedule -- Parts schedule -- Raw material requests

Manufacturing Schedule

Detail schedule -- Factory schedule -- Manufactured parts and sub-assembly schedule -- Manufacturing rate sheets

Factory Load

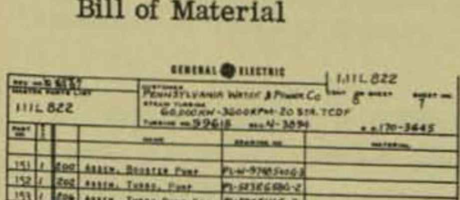


Man-hours of future load -- Machine hours of future load -- Labor load -- Machine load

Buffer Stock

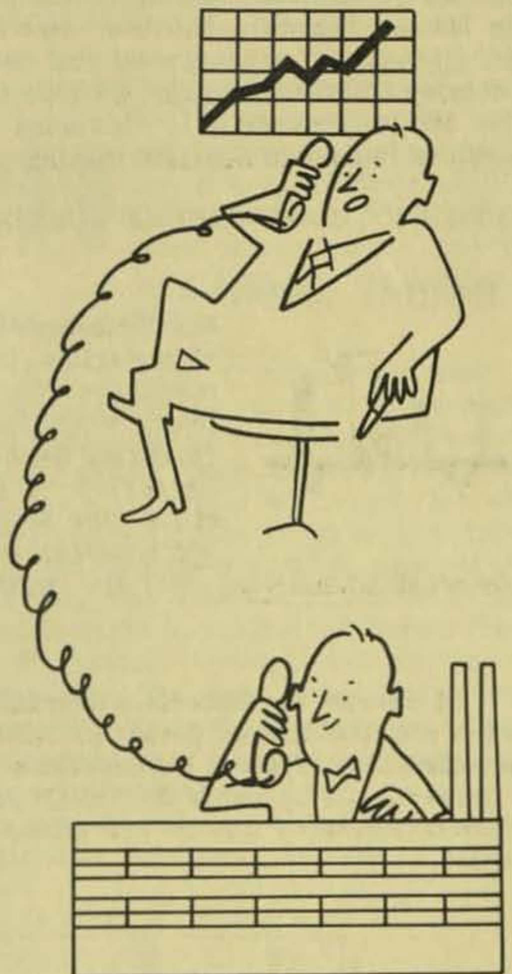
Protective stock -- Liquid stock -- Reserve stock -- Cushion -- Balance stock

Bill of Material



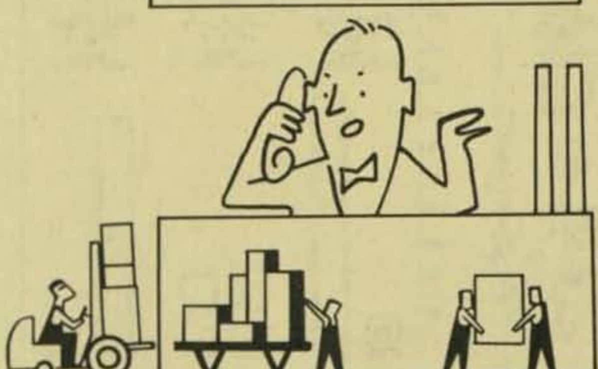
Parts list -- Materials list -- Drawing list -- Requirements list

HOW SCHEDULES ARE DEVELOPED



Marketing transmits the market forecast or customer's order to the factory.

Production surveys the over-all capacity of the factory to meet the forecast and determines the MASTER SCHEDULE.

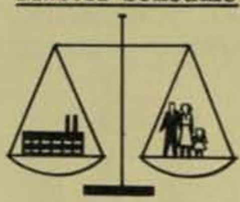


Production then develops the MATERIALS SCHEDULE which controls the flow of vendor materials into the factory.

Production finally sets the MANUFACTURING SCHEDULE which directs the work activity in the factory.

Production scheduling begins when information is received as to how many of which products customers will want during a future period. Dealing with production scheduling problems, we must be careful not to use a sledge hammer to drive a tack. In selecting a specific method to use, the magnitude of the problem should always be considered. For example, there are many stages which require scheduling decisions---from the proposition to the final detailed manufacturing schedule. To schedule propositions in terms of the detailed parts and machine requirements may often be in the sledge hammer category. It usually makes more sense to use some sort of approximation technique such as equivalent units.

DETERMINE THE MASTER SCHEDULE



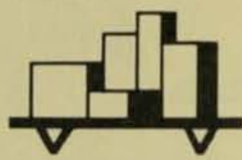
Master Schedule -- Specifies how many finished products (by type or model) are to be completed by the factory during a certain future period.

The Master Schedule cannot be made just by knowing the market forecast information. The scheduler must also consider the restrictions of the factory facilities, such as:

- Manpower -- is there enough skilled help available.
- Machines -- are there enough of the right machines to do the work?
- Materials -- can we get the necessary materials on time?
- Money -- can we afford to run overtime--should we increase our inventory?

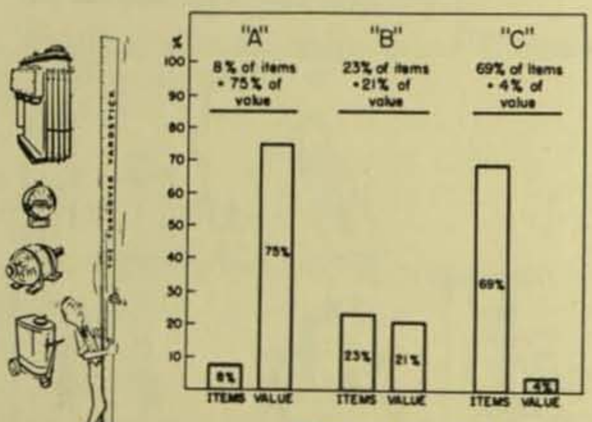
Only after weighing the effects of fluctuating market demand upon the production facilities, can the scheduler determine the Master Schedule. It's called the Master Schedule because once it is set, all material procurement and manufacturing activities are tied directly to it. The Master Schedule is therefore the result of important decision making.

DEVELOP THE MATERIALS SCHEDULE



Materials Schedule -- Sets forth quantities of materials to be purchased for delivery to the factory during the coming period--it specifies how many of which materials are to be received and when they are required.

Of course the Materials Schedule is tied in with the Master Schedule. Materials scheduling involves big decisions too; it is the means by which the "ABC" principles of Inventory Control are often first applied.



ABC Pattern of an Average Product.

By ordering "A" items in quantities proportional to the quantities contained in the Master Schedule, with due consideration for buffer stocks, we take a first important step toward efficient inventory control. Order "B" items in economical order quantities, say up to 2 or 3 months' supply; for "C" items, order 6 months' to a year's supply and "forget" them.

DETERMINE THE MANUFACTURING SCHEDULE

Manufacturing Schedule -- Sets forth the plan of work for each manufacturing sub-section and unit, specifying the quantity of parts to be manufactured or assembled, and the time sequence for performance.

Just to hand a foreman a stack of planning papers for parts to be manufactured during the next month is not scheduling his work. These have to be expanded in terms of hours of work and then arranged as to sequence of job so as to minimize set-up changes and in-process inventories. The scheduling problem of one foreman might be entirely different from that of another -- though both are in the same plant. The point is that a manufacturing schedule is not the same as a parts requirement list. It is a plan for work activity -- specifying the time sequence of doing each machine or assembly operation required to make each component.

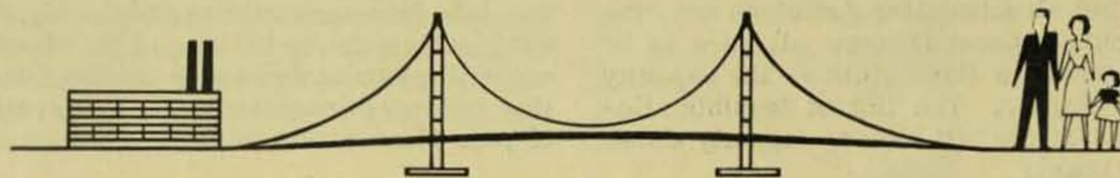
SUMMARY

- Production Scheduling involves a vast complex of decision-making-- important decisions which can "make or break" a department. The complexities can be reduced if the problem is viewed from an over-all pattern concept. This is why production scheduling must be given a new and careful look.
- Master Schedule -- Specifies how many of which products are to be shipped "out the back door" during the next schedule period.
- Materials Schedule -- Specifies how much material is to be received from vendors and when it is required to support the needs during the next schedule period.
- Manufacturing Schedule -- Specifies what parts and assemblies must be made, and the time sequence of doing them during the next schedule period.

PROCESSES

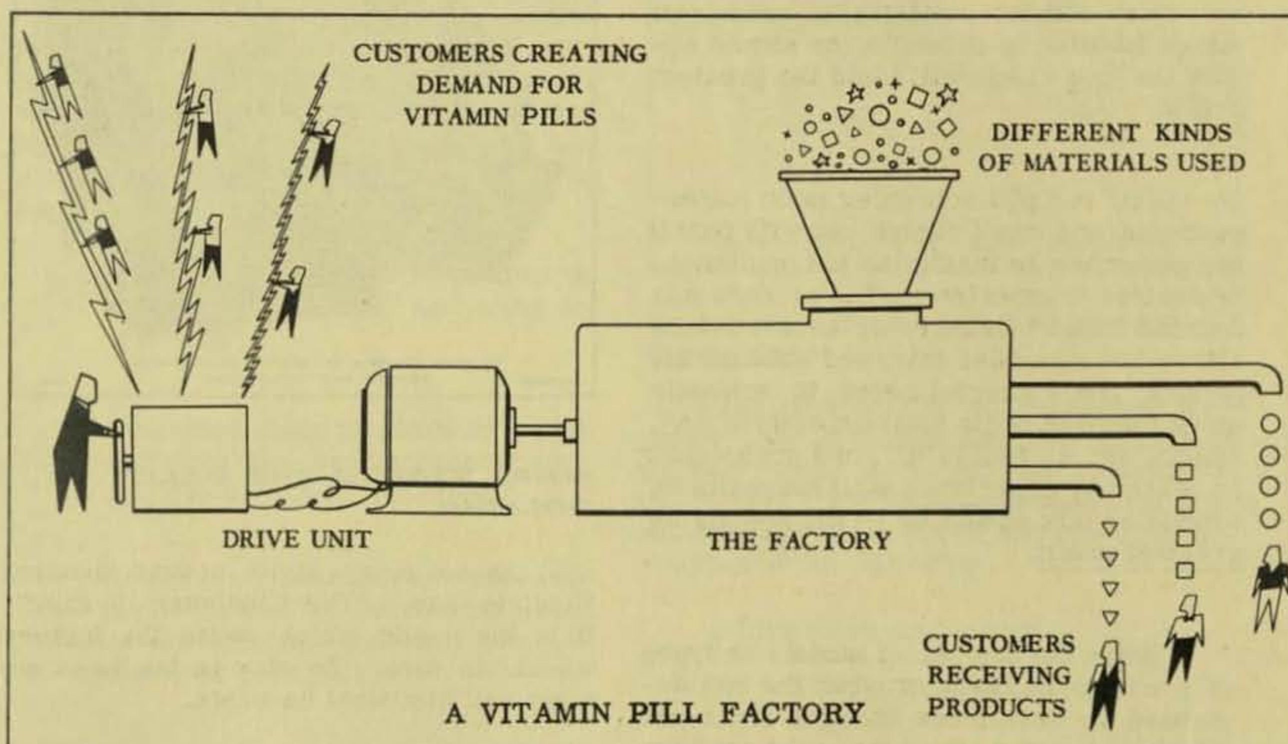
PRACTICES

CHAPTER II THE MASTER SCHEDULE



THE FACTORY SYSTEM - SCHEDULING A VITAMIN PILL FACTORY

The factory is a complex mechanism with the large numbers of employees, machines, materials, and organizational activities involved in running it. For the time being however, let us simplify our picture of the factory so we can more readily develop a few ideas about master scheduling decisions.



A VITAMIN PILL FACTORY

The little man at the motor control has got to be on his toes. He has a machine producing three types of vitamin pills---and the total pill producing capacity is fixed. If the market demand for type "A" pill takes 80% of his capacity and if the respective market demands for pills "B" and "C" require 25% and 10% machine capacity, "something has got to give". The pill factory just cannot be operated at 115% capacity. What does our pill scheduler do? He can allocate his pill machine capacity in a number of ways:

Choice	% of Machine Capacity Devoted to --		
	A	B	C
1	80	20	0
2	65	25	10
3	75	20	5
4	70	20	10
etc.			

As you can see, there is a large number of feasible ways of trying to fit the demand to the limited capacity of the system. But all scheduling decisions are "interlocking" because they all have to be made under a fixed limit -- the capacity of the factory. The list of feasible allocations of the pill factory capacity shows this clearly.

Whatever his choice, the pill scheduler knows he is utilizing his factory 100%. But is this a satisfactory answer? Obviously not, because the profits in pill making are not necessarily the same for every scheduled "mix" of pills manufactured. So, from almost an infinite number of mixes feasible to schedule, he should select the one which will yield the greatest profit.

But, our pill scheduler is no mathematician and can't figure out with pencil and paper how to maximize his profits, so he decides to experiment. His product mix demand doesn't change, so each week he alters his scheduled mix, and watches his profits. He's careful never to schedule more than 80% of his total capacity to "A", 25% to "B", or 10% to "C"; and pretty soon he learns by experience what his optimum scheduled mix should be -- the one giving greatest profit.

When the number of models or types of products is large or when the mix demanded by customers changes from one month to the next, the scheduling problem becomes complex indeed. Each different mix places a different sort of workload on the production facilities--men, materials, machines. One month the bottleneck may be in assembly manpower--so a second shift is hired or the assemblers work overtime. Next month the bottleneck is in the machining section, so machine operators work overtime; and the very next month you are caught short of materials, so you authorize the vendor to work extra hours so he can get the materials to you on schedule. As a matter of fact all these bottlenecks can crop up in the same month!

Does this mean that we have to give up? Certainly not. Today there are ways of scheduling your factory by which you can take into account many of the significant factors. In the balance of the chapter we will try to analyze with you the things that you may consider in the preparation of your Master Schedule.

"Gentlemen, I'm afraid we'll have to revise our basic idea that there's one born every minute."

NEW YORKER

WHAT STARTS THE BALL ROLLING

As so many signs around General Electric say, "The Customer is King"; it is his needs which cause the factory wheels to turn. To stay in business we must sell him what he wants.

In scheduling, the customer's demands are received as Propositions, Requisitions or Market Forecasts. While the first two are direct communications indicating specific wants, the Market Forecast is only an estimate of what customers will buy. If the final sales are not realized a new Market Forecast will soon have to be prepared.

Frequently, extensive cost and planning data is needed before an order can be accepted for delivery. In other departments all that appears to be required is a glance at standard Stock and Shipment sheets. Regardless of which method is used, every time a promise is given to deliver a product on a certain date, it must be added to the factory load and deducted from available factory capacity for that time period.

FACTORY CAPACITY - DO YOU KNOW WHAT YOURS IS

Factory capacity is a nebulous term. Capacity is not what your plant turned out during the last peak production period -- running three shifts, 6 days a week. It is what the plant can do during the next quarter -- or next month -- or week -- or whatever your master scheduling period is. To know what your capacity will be, means you have to answer questions like the following:

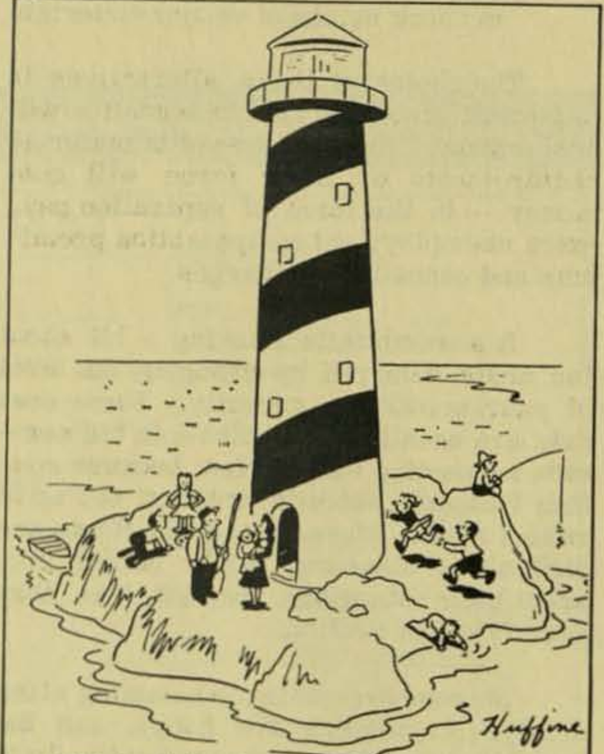
. How well de-bugged is production of the new product, just being introduced?

. How much more production can we get when the new broaching machine is installed next week?

. Now that we make our own die castings, instead of purchasing them on the outside, how will our capacity be changed?

. Since we've hired 10 additional bench assembly operators, how much more production can we expect to get?

Capacity is dynamic -- always changing. Just because your plant took 21 days to produce and ship the first 500 units of a new product -- doesn't mean it will take 21 days to ship the next 500 units. Maybe it should take only 16 days. But, if you have another big job in the shop at the same time as the second order -- it may require more than 21 days!



"Well, it wouldn't hurt for you to ask for a bigger lighthouse"

WAYS OF CHANGING FACTORY CAPACITY

The comparison of Demanded Capacity with Available Capacity tells you whether or not to recommend a change in the factory's ability to produce. What kind of a change? It could be any one or combination of the following:

. hire more employees

. lay off some employees

. authorize 1000 man-hours of overtime

. cut back to a 3-day work week

. sub-contract parts manufacturing

. lease additional storage space

. buy additional machinery

. sell surplus machinery

. increase stocks of vendor materials

- cut back stocks of vendor materials

The choice of these alternatives is important since any recommendation will cost money. Even cut backs in material requirements or labor force will cost money -- in the form of separation pay, extra unemployment compensation premiums and cancellation charges.

It's worthwhile thinking a bit about the costs incurred by changing the level of your productive capacity. These cost data are usually not available in the common accounting summaries, because routine financial records are not set up to report them. Moreover, some items are difficult to measure, while others may seem quite intangible. Nevertheless, they greatly affect profits.

Suppose everything is humming along nicely. Customers are happy, and the monthly output hasn't changed radically in almost six months. All of a sudden Marketing sends through an order which requires a 15% boost in production. What are the costs of disturbing the "peaceful equilibrium"? Some possible costs resulting from boosting productive capacity are:

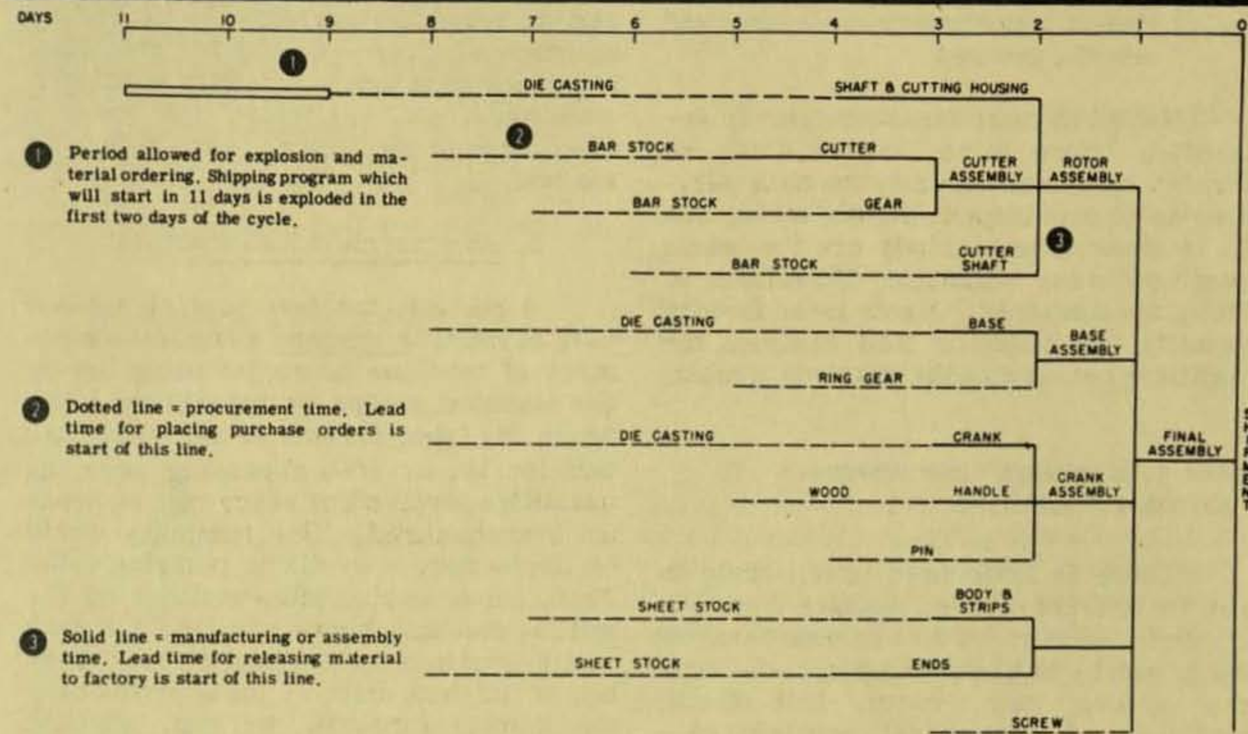
- more phone calls by buyers in purchasing
- more overtime paperwork by order clerks
- more work in materials receiving, inspection, and stocking
- extra costs from authorizing overtime work by vendors
- extra costs of sub-contracting some of the work now being done
- overtime premiums and/or shift premiums to direct and indirect labor force
- make-up pay for new employees
- cost of recruiting (newspaper ads, etc.)
- cost of physical examinations
- security checks
- costs of training new employees
- additional spoilage and rework costs
- additional factory service (tool and plant maintenance, etc.)
- cost of added materials expediters
- stockroom space and personnel
- calculation of new order quantities and reordering points
- making additional factory load analyses; revising schedules

The costs of decreasing productive capacity are real too. Cancellation charges by materials vendors, possible separation pay for clerical and direct labor employees, the risk of bad plant-community relations, and poor employee morale are only a few of these. Probably the most critical item is the "stickiness" of many overhead accounts --- so that costs such as depreciation and managers' salaries will not decrease even though business has dropped. Naturally, this makes it even tougher to earn an adequate profit on sales.

However, with all these costs of changing the status quo it becomes essential to define operating capacity in a rigorous hard-headed manner. It isn't enough to say that there is sufficient capacity to produce 10 units a month or 100 units per week or 1000 per day. Quantity alone is not enough; the second concept necessary is that of lead time--the number of time periods prior to final shipment when each of the various key operations must be performed. For example, it may be necessary to have engineering complete 16 weeks prior to actual shipment and purchase orders written 12 weeks before the delivery date.

TIME IS THE COMMON DENOMINATOR

TYPICAL TIME CYCLE CHART USING PENCIL SHARPENER AS EXAMPLE



The Time Cycle Chart illustrates a fine method for showing the time interrelationships of your product. This particular chart shows a total of 11 days required. Suppose a pencil sharpener customer won't wait 11 days for his purchase--since a competitor can give him one in 8 days. Let's look at what prevents our being able to meet this shorter cycle:

. Explosion and Ordering	2 days
. Procurement and Manufacturing	
Shaft & Cutting Housing	9 days
Cutter, Base, Crank, and Ends	8 days
Gear, Body & Strips	7 days

The time cycle chart, therefore, can be used by production in fulfilling two important functions:

1. To assist in directing the efforts of methods, tool, and procedures planners toward areas logically needing methods improvements.

2. To indicate how much buffer stock should be carried at what stages to maintain good customer service.

THE IMPORTANCE OF THE TIME CYCLE

It is absolutely necessary to the factory that there be a certain portion of the future scheduling period which is fixed--"come hell or high water". This is a period of time during which the costs of revising the master schedule would be prohibitive. There has to be:

. time to design the product

. time to set up the facilities for manufacture

- time to determine manufacturing and purchasing requirements

- time to procure purchased materials

- time to manufacture, assemble and test the product

Not all of these times are purely sequential. Since some functions can be carried on simultaneously the time periods can be overlapped. What's more, not all of these time periods are the same length in every situation. Therefore, in fitting the customers' wants to the factory capacity, an effective load analysis for each time period into the future is a must.

HOW TO ANALYZE THE FACTORY LOAD

There is little need to elaborate on how the market demand changes from one month to the next. Total volume changes; the product mix changes; special customers' orders, rush orders, last minute revisions of customers' requisitions--these things are all too familiar to the production man.

When the market forecast (or a customer's requisition) is received, what can be done before committing the factory to a promised delivery date on a master schedule? This is a crucial time for the production scheduler--his time for deciding the course of action to be taken -- whether to cut back on manpower, to increase manpower, to plan for overtime, etc.

1. A complete, detailed factory load analysis

If there is sufficient lead time a load analysis can be made by summarizing direct labor dollars or machine hours. This involves computing the detailed parts requirements, then using planning time estimates or cost accounting data to determine machine hours by type or area, and labor dollars by skill or station. The result is an accurate estimate of the factory load for certain future periods. The hours (dollars) of load are then compared with hours (dollars) of available machine and manpower capacity. The relationship will indicate the course of action to be taken, and the scheduler can make the necessary recommendations---to plan for overtime, to cutback on manpower, to hire additional employees, etc. --- before the need is discovered in the factory, when it may be too late.

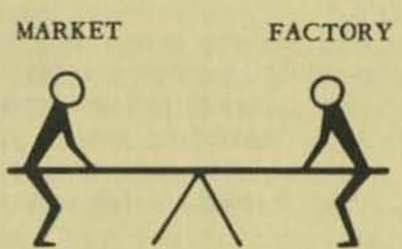
2. An equivalent load analysis

A quicker, but less precise method is to prepare in advance a complete summary of machine hours including set-up (by machine groups or types), and labor hours (by labor classes or skills) for one unit (or 10, or 1000 depending upon the quantities involved) of every type of product manufactured. This summary would be derived from available planning data. Then, for example, after multiplying the milling machine hours required for each unit of products A, B, C and D by the number of finished units of these products in the market forecast, we can, through summarizing, obtain the total milling machine hours in the factory load. A comparison of this load with the available hours of milling machine capacity indicates the need for adjusting capacity or schedule. Similarly this procedure can be followed for all machines, labor classes or skills. This can even be done quite readily on a desk calculator in a short time, and again, action can be taken in advance.

3. A spot check of key bottleneck situations

From past experience, certain "key bottlenecks" have occurred. For example, you may have recalled that each time more than 500 units of product X were scheduled, the screw machine unit had to work overtime, or you had to call the vendor to expedite delivery of a certain casting, or you had to dream up a lot of excuses for your customers. If this experience is recorded somewhere in a "little black book", you gradually can build a good check list on where key bottlenecks exist for certain product mixes scheduled in the factory. By referring to such a list, you can anticipate where the bottleneck situation is likely to be -- that is, you have "isolated" the most likely trouble spots. Then, load analysis of only these trouble spots is needed, and the work of "exploding" the entire proposed schedule is eliminated. Of course, this is only a rough approximation, but it's considerably better than using a fresh crystal ball every month!

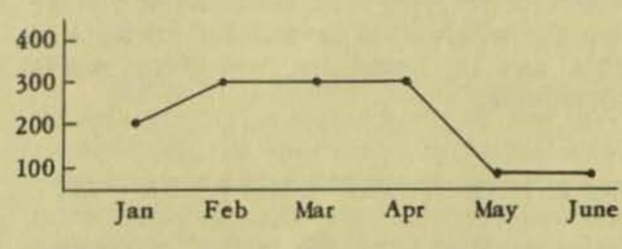
LEVELED PRODUCTION



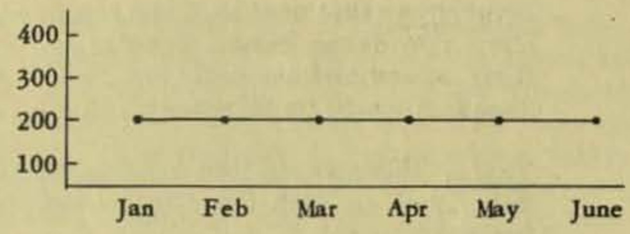
LEVEL PRODUCTION

Production is leveled when this happy state of affairs exists: materials coming in one door and products moving out the other at a steady, smooth-flowing rate. Payrolls are relatively constant, week-in, week-out. Neither the total weekly scheduled volume nor the mix of products changes substantially from one week to the next. The production man, who has had the time to "put out the fires", thinks things are fine. But are they?

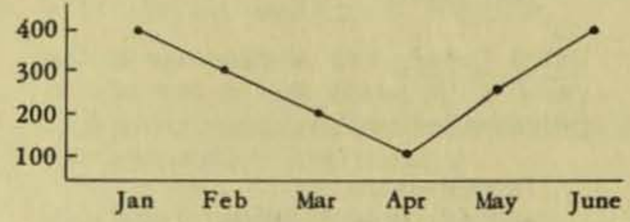
What about finished goods inventories? If sales to the customers are like this:



And during the same period, production output has been like this:



The finished goods inventories will look like this:



The question then is: Is it more profitable to level production, thus incurring added inventory carrying costs? Or is it more profitable to change the level of production capacity frequently and thus incur added costs of hiring and laying off employees? A big question requiring a big decision.

The cost of carrying inventory will generally consist of four basic factors:

(1) Possession Costs
(2) Value Losses
(3) Return on Investment
(4) General Business Influences

Possession Costs are those costs chargeable to inventory which are normally considered part of overhead; they can be divided into the following:

- Space - space made available by reducing inventory would be utilized for increased output.

- Equipment - cranes, vehicles, bins, and racks that could be sold if inventory were reduced.

- Handling - handling labor is proportional to the inventory level. Cost chargeable to inventory is the sum of all material handling labor expense.

. Insurance - this cost is of two types: one, the costs based directly on floor space, and secondly, the costs based directly on inventory value.

. Taxes - these costs, like insurance, are based on both floor space and inventory level.

. Taking Physical Inventory - this cost depends directly on the inventory level.

Value Losses are a decrease in the value of inventory due to one of the following factors:

. Obsolescence
. Natural Deterioration, Loss and Damage

Return on Investment is the net profit earned expressed as a percentage of the investment.

General Business Influences include the following:

. Cost Improvement - reduction in costs due to technological improvements.

. Value of the Dollar - inflationary or deflationary trend.

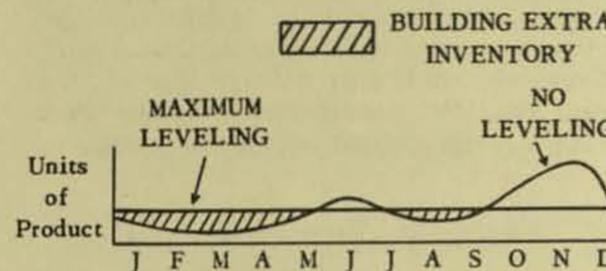
These costs are often as difficult to measure as the costs of changing production level. But they are just as real.

HOW TO DECIDE ABOUT LEVELING PRODUCTION

The Problem: Should production capacity be leveled?

If so, how should we go about doing it?

1. Make a statistical analysis of the historical sales pattern or determine the expected sales curve, using market research. The data used should be in terms of sales to the ultimate customer, if possible. This could be a plot of the average monthly unit sales over the previous five years. For example, take a small household appliance. Since small appliances make fine wedding and Christmas gifts, the graph of the data might appear something like this:



2. The picture shows two extreme production programs: (a) production varies in precise accordance with fluctuating sales; (b) production proceeds at a uniform rate throughout the entire year.

3. The shaded area represents the additional units added to finished goods inventory, because of the leveling plan. The cost of storing these additional units during the months shown, comprises the major portion of the cost of leveling.

4. The cost of changing production levels can be obtained by a careful review of the historical costs incident to changes in the production level. The cost accountant can assist in evaluating these costs.

The solution requires comparison of costs of leveling with the costs of changing the production level. An example of this can be found in Part Five under Problems.

THE PRINCIPLE OF FEEDBACK

Another problem is that of knowing the status of your manufacturing capacity; this deals with the principle of "feedback".

What is "feedback"? Take a simple example--a thermostat for controlling the heater in the house. The thermostat, the heater, and the temperature of the air make up the system. The housewife sets the thermostat at 72° Fahrenheit. The actual temperature of the room being, say 68°, causes the thermostat to close the electric circuit which starts the heater warming the room. As the room temperature rises (feedback of information) the thermostat prepares to open the electric circuit, and finally at 74° F., the circuit is opened and the heater is turned off.

There is an analogy to be drawn here. Fundamentally the business system is made up of the customer, production, purchasing and manufacturing organizations. The customer is analogous to the housewife who causes the system to act. The production unit (thermostat) interprets the customer's requisition (temperature setting) into the production schedules (electrical impulses) and transmits or releases the schedule to the purchasing and manufacturing units (heater). The purchasing unit procures the materials (fuel), the manufacturing unit works on the materials to make finished products (heat). As these actions take place, the production group follows the progress by obtaining various reports (temperature feedback) from expediters, dispatchers, etc. These reports spotlight the troubles being encountered in meeting the schedule.

Without the feedback of information to the thermostat there would only be a one-way circuit -- from the thermostat to the heater, and the thermostat would keep telling the heater to "warm up the room". The feedback circuit completes the system, enabling the thermostat to tell the heater when to "stop heating".

Without feedback knowledge of the manufacturing problems being encountered there would be only a one-way communication network between the production and manufacturing units. Production schedules could not be realistic, and would rarely, if ever, be fulfilled in the time allotted. Obviously, feedback communication of shop information is essential. The production scheduler needs this progress information just as vitally as he needs the market forecast, for it is the feedback communication circuit which tells him the status of available manufacturing capacity. With better knowledge of restrictions in the manufacturing facilities, the production scheduler is able to recommend action (run overtime, extra shifts, cutback, etc.) which eliminate bottlenecks before they occur. Through feedback, production schedules are made more realistic.

SCHEDULING PRODUCTION OF A "STANDARD" PRODUCT

Products that are being manufactured as part of the "standard line" have definite established time cycles which can be used in the basic scheduling decisions. It is of prime importance that continual effort be extended to reduce time cycles. How do we accomplish this objective?

1. Improve methods

The production man's first step is to determine the extent of potential methods improvements. Since improvements shorten the time requirements, manufacturing allowances and planned cycles can be reduced accordingly. In addition, improvements can often be passed along to the customer in the form of better service.

Referring to the time cycle chart of the pencil sharpener, there are three basic areas of methods improvement which could bring about the net reduction of the time cycle from 11 to the desired 8 days.

(a) Improve the scheduling system:

- methods of exploding the schedule into detailed requirements
- methods of materials ordering
- procedures for reproducing necessary production control paperwork

(b) Improve the materials procurement system:

- procedures for reproducing purchase order information
- methods of contacting vendors
- procedures for routing incoming traffic

(c) Improve the manufacturing and assembly methods:

- improved tool designs
- combine manufacturing operations
- simplify machine set ups
- reduce materials handling between work stations

A reduction in time cycle resulting from simplifying methods should be viewed as the ideal solution--for, in addition to the benefits mentioned above, buffer stocks can frequently be reduced.

Hence, in using the time cycle chart, the production man should first investigate with methods men,and procedures analysts the possibilities of systems improvement.

2. Build up strategic buffer stocks

If methods improvements cannot reduce the cycle, the production man should next consider creating buffer stocks. Further examination of the chart indicates that the cycle time for the pencil sharpener could be reduced two days if:

- two days' supply of die castings for the Shaft and Cutting Housing were stocked
- one day's supply of Base and Crank die castings were stocked
- one day's supply of sheet and bar stock for the Cutter and Ends of the pencil sharpener were stocked

The effect of this "strategic" build-up of buffer stocks of these items should reduce the total time cycle from 11 to 9 days. This specific build-up of buffer stocks is "strategic", because the time cycle chart shows clearly where the stocks should be created, and how much stock should be carried. In other words, the time cycle chart is an invaluable tool in solving the problem of determining where and how much buffer stock should be carried to meet customer demands for prompt delivery.

HOW TO DEAL WITH A LARGE, VARIED PRODUCT MIX

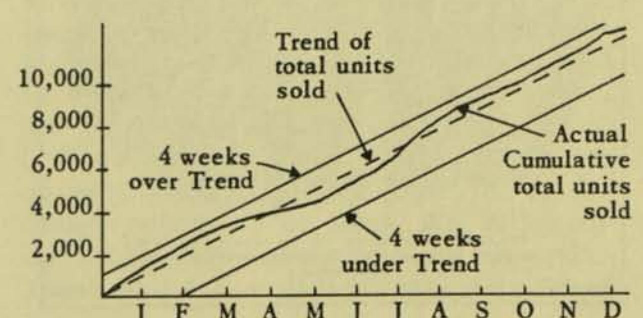
We know of one department in General Electric which lists in its catalogue so many model numbers, that with all of the possible combinations of special features, over a million different devices could conceivably be ordered. Actually, over 20,000 different devices are ordered each year, in what were thought to be purely random quantities and frequencies. The paperwork was overwhelming--handling 125,000 different orders annually—increasing and decreasing order quantities --cancelling orders, and so on. Labor turnover was excessive because the department was always trying to keep pace with widely fluctuating order rates. Certainly the problems inherent in dealing with a large, varied product mix were present in this situation. In spite of this rather hectic state of affairs, the situation was remedied. What was done?

The first step was to study the composite bills of material and parts lists for all the models. This was done by the very simple, logical step of making a large spread sheet with the model numbers listed across the top, and the component part numbers in a column down the left hand side of the sheet. For example:

Part Name	Parts comprising Product Family A				
	A1	A2	A3	A4	A5
Casing Assembly	C500^{1}	.	C495^{1}	.	.
Top	C501^{2}	.	.	.	.
Bottom	C502^{1}	C509^{4}	.	.	.
Sides	C503^{2}	.	C383^{2}	.	.
Door	C504^{1}	.	.	.	.
Rivets	C505^{1}	.	.	.	.
Coil Assembly	E300^{1}	.	.	.	E293^{2}
Spool	E301^{1}	.	.	E485^{1}	.
Wire	E303^{1}	.	E501^{1}	.	E486^{1}
Plunger Assembly	P484^{1}	P485^{2}	.	.	.
Laminations	P427^{10}	P438^{20}	.	.	.
Rivets	P432^{4}	P495^{2}	.	.	.

In this chart, the dots mean that the same part is used on several different model numbers; in effect a dot is a horizontal ditto mark. The numbers in the upper right hand corner of the boxes indicate quantities used. When a spread sheet contains large areas of dots, the model numbers are said to be arranged according to the engineering design logic. The chance or deliberate deviations from a pattern, clearly revealed within the dotted areas, were glaringly exposed. Engineering was thereby prompted to make further moves toward standardization and the use of standard components. The results of this analysis showed essentially 130 "families" of models having basically identical parts.

The second step was to plot the cumulative total monthly unit sales of each family of models:



These charts showed that despite the apparent random sales pattern thought to have existed, the cumulative total sales were built up during the year in definite patterns, not at all random. In the case of this department, the actual cumulative total monthly unit sales by family, plotted over a one-year period stayed within the limits of plus or minus four weeks' estimated average sales. This pattern became an extremely valuable yardstick for the marketing section. For the first time, they were able to project market forecasts with a measured degree of confidence.

After these analyses, step three consisted of making a bill of material usage index from which stock control points, economical ordering quantities, and bin reserve quantities could readily be calculated. This usage index notebook contained a complete "parts list" for each family of models:

Bill of Material Usage Index Product Family A	
Part Number	Number of Parts used per Model in this Family (Usage Index)
C495	.400
C500	.600
C501	1.000
C503	.800
P438	16.000
P485	.800
P495	.800

The bill of material usage index for each part number is calculated as:

> Total Quantity of Parts required for all Models in the family divided by the Total Number of Models in the family.

Having the bill of material usage data, the total parts requirements for a particular scheduling period is readily determined. First, the estimated number of units to be sold during the next period is determined from the unit sales curve derived in Step 2 above. For example, for Product Family A, during the six month period--January to June, 5000 models should be required -- as read from the trend curve. Then total usage is calculated for each part:

Total requirements = (estimated models required) x (usage index for the part)

Thus for part number C503, the total requirements are calculated as 5000 x .800 = 4000 pieces.

In the same manner, the total requirements for all parts and raw material items are calculated. Based on these requirements, quantities are either manufactured or purchased, in accordance with the "ABC" principles of inventory management.

What does all this have to do with the problem of a large, varying product mix? The answer lies in the effort to discover the pattern or "family grouping" of the models -- the unit sales pattern and the parts usage pattern. Once these patterns are discerned, and common sense tells you they must exist to some degree, long-range requirements can be predicted in advance. Thus, the master scheduling problem can be approached in an orderly manner.

Moreover, machine and sub-assembly schedules can be set more efficiently and effectively. In the case of this particular department, parts were divided into three inventory classes:

"A" - Those parts manufactured every month

"B" - Those parts manufactured every other month

"C" - Those parts manufactured every six months

Schedules could then be established well in advance, and since most of the manufacturing activity is pre-planned, the drastic short-run variations in factory load are effectively washed out by scheduling patterned families of models, instead of each individual model.

This previous description is based substantially on work originally published by Mr. M. L. Hurni, Senior Consultant - Operations Research & Synthesis, and Mr. W. H. Bloodworth, Project Consultant, both of the Management Consultation Services Division.

HOW TO SCHEDULE PRODUCTION OF A BRAND NEW PRODUCT

If your factory is producing custom-designed products--for example, military electronic equipment -- the scheduling problem is a much broader one. The date for shipping the product to the customer is still the bench mark, but in this situation, the time for engineering design and development work must be scheduled.

"I hate to put pressure on you men, but we're in a dog-eat-dog situation. We've got to come through with another wonder drug, and damned fast."

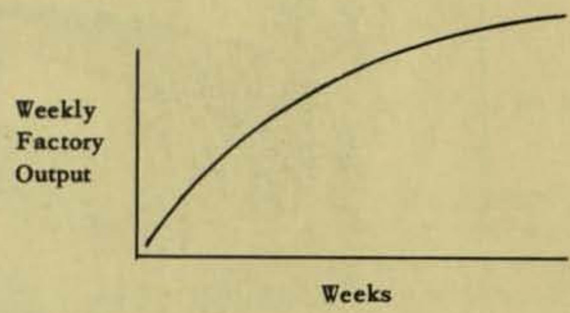
NEW YORKER MODELL

A new set of engineering specifications must be drawn for each customer's order. Even though shipping dates may be twenty-four months in the future, the "heat is on" engineering to set the materials specifications so that procurement can begin. Drafting work goes on during materials procurement, so that when the materials do arrive, the shop drawings will be available. New jigs, tools and fixtures must be designed and made so that the rate of manufacturing can be built-up to say five hundred units per month. This, of course, involves additional time in the planning stages.

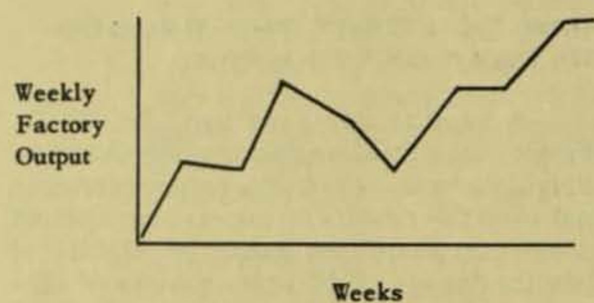
Here is a situation in which the proposition schedule is the result of "pooling" the experiences of the:

- . Design Engineer
- . Manufacturing Engineer
- . Production Scheduler
- . Sales Engineer
- . Cost Estimator

Usually the marketing section will transmit the customer's proposition, which includes his desired shipping date, to this group. At meetings, each of these persons, roughly in the order listed, will interpret the proposition into terms of their particular planning function, estimating the time required to accomplish each phase of the work. Next there are discussions concerning problems of overlapping time cycles-- and finally, by negotiation, the schedule is agreed upon and adopted. From this point, the Production man becomes the key man or "quarterback" of the factory team. He coordinates all efforts to meet the established schedule; he does the follow-up work necessary to accomplish the goals. These are the organizational aspects of master scheduling--Production has a key role. The goal is to schedule for a smooth build-up of the factory output so that it appears like this:



And not like this:



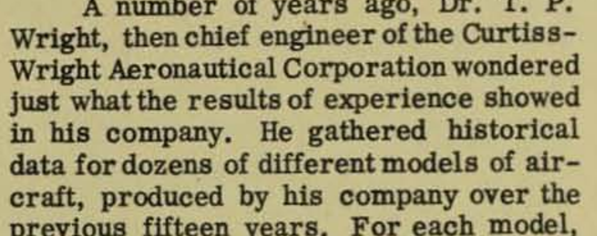
WHAT DOES EXPERIENCE TEACH

The fact that your plant has been given the job of producing a product which nobody has ever produced before, is not just a bolt out of the blue. A customer with a new application for a turbine, or a new type of radar equipment comes to you because he knows that you have had experience in producing products something like the one he has in mind. The meaning of the word "new" is relative. There can be new models of "old" products, produced by an old factory organization, just as there can be "old" products, being manufactured for the first time by a "new" factory organization.

"So far so good. From here on, it's engineering's baby."

HOW TO CHART THE RECORD OF PAST EXPERIENCE

A number of years ago, Dr. T. P. Wright, then chief engineer of the Curtiss-Wright Aeronautical Corporation wondered just what the results of experience showed in his company. He gathered historical data for dozens of different models of aircraft, produced by his company over the previous fifteen years. For each model, he made a plot something like this:



Now at first glance, there doesn't seem to be anything remarkable about this. But a second look shows that all these plots have the same degree of curvature. What does that mean? In Curtiss-Wright's case the data showed that with every new model of airplane built, as the number of planes produced was doubled, the direct labor hours per plane was reduced by 20%. This means that production of the eighth plane cost only 80% of the fourth plane produced; the sixteenth plane took only 80% of the man-hours required by the eighth plane--and so on. Thus it is called an "80% Progress Curve". Later, during World War II, the record of all the other airplane manufacturers fell into a pattern very similar to that of Curtiss-Wright. Remember, during the War there were many different plants, most of them completely new, freshly organized, and just tooled up --turning out many different airplanes. Nevertheless, the progress curves of different plants and different companies compared directly with one another and therefore could be effectively used by the War Production Board in controlling manpower within the aircraft industry.

WHAT THE MANUFACTURING PROGRESS CURVE CAN SHOW

The Progress Curve or "Learning Curve", as it is sometimes called, is a powerful planning tool, now being used throughout the aircraft industry and by the Department of Defense. Other industries, including automobiles and appliances are finding it useful in their production planning in a variety of ways. For example:

- A manufacturer can plan his manpower requirements merely by knowing how many man-hours were required to build the first prototype model and how many units of product he is to ship to his customers each month.

- By plotting cumulative average man-hours per unit against the rate of production (number of units per month) similar results are obtained. This gives the manufacturer, planning information on how fast he should build-up his labor force to achieve the production goal.

- A plot of cumulative average manufacturing cost dollars per unit against the cumulative number of units produced provides a valuable aid in financial planning--particularly for working capital requirements. For, by knowing (1) how much the first prototype unit costs and (2) that a total of say 1000 units are to be produced, the cost of the 1000th unit can be estimated with reasonable accuracy.

This brief discussion of the "Progress Function" is merely to stimulate interest in the possibility of applying a similar technique to your problems---planning new products, building up production, fulfilling the contract. There is no known mathematical logic to developing a new technique. For example, psychologists have been charting "learning progress" data on performance of groups of people for years. The same concept has been applied to a whole factory system, using input and output data from past experience. A pattern is discovered; it is tested, and found to fit over and over again, with each new job tackled by the manufacturing team. About all you can say is that, intuitively, it makes sense that the factory organization learns by experience--and the Progress Curve shows how fast the learning takes place--on an over-all, aggregate scale. Most important, the curve is a valuable yardstick for control because it shows on a single graph, the dynamic characteristics of the period when "de-bugging" of manufacturing takes place. One word of caution, however, before you use it. Make a thorough study, using your own experience data. Don't expect airplane progress curves to necessarily fit radar systems.

SUMMARY

In this chapter we have tried to show that:

1. Master scheduling decisions are not just routine, but are important and complex enough to be given the best analytical thinking. Decisions must be made in a limited time. Yet these decisions result in the commitment of large sums of working capital. The procedures for determining patterns within large, varied product mixes, the importance of feedback of information on manufacturing capacity limitations, and methods of analyzing the factory load have been described.

2. The time cycle chart is an invaluable aid in discovering "bottleneck" activities in the manufacturing program for a product. Once these bottleneck activities are isolated, two courses of action can be taken to decrease and thus improve the time cycle:

    a. Work simplification or methods improvement of scheduling procedures, materials procurement procedures, manufacturing and assembly techniques.

    b. Establishing buffer stocks at strategic points in the time cycle, where such stocks enable a foreshortening or overlapping of the events within the over-all time cycle.

3. The costs of changing production levels and the costs of maintaining production levels are neces-

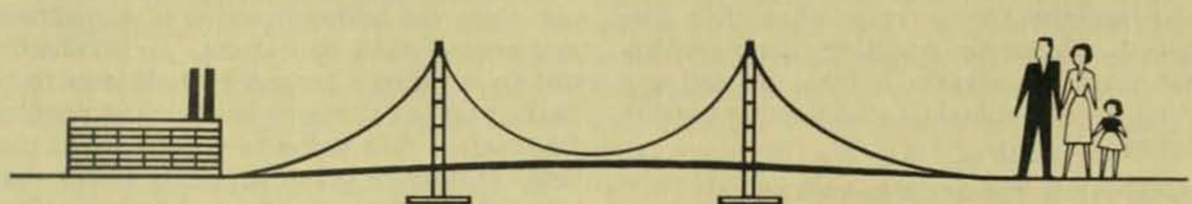
sary parameters which must be used before deciding which of two basic approaches to follow in formulating the master scheduling program:

. Maintaining leveled production, with fluctuating finished stock inventories, carried at a higher average level.

. Manufacturing at rates synchronized with the current rate of customers' requisitions--resulting in changes in production levels, but a relatively lower, more stable average level of finished stock inventories.

4. There is an experience pattern developed by the factory organization which deals with projects involving the manufacture of new products. This pattern is known as the progress curve. The progress curve can be used to schedule the build-up of deliveries to customers, to schedule the build-up of manpower required and to control the production program as manufacturing approaches its ultimate output rate.

CHAPTER III THE MATERIALS SCHEDULE



Like the weather, material leadtimes are always changing. It's not enough to set a Materials Schedule once and then forget it. In contrast to Master and Manufacturing Schedules, which are primarily limited by internal, controllable factors, the Materials Schedule is dependent upon external conditions over which we exercise little or no control.

In the shop, for example, cycles can be shortened and capacity increased by introducing better machines; but with purchased items, it is the competitive market conditions which regulate procurement cycles and the availability of materials.

"Joe sure has it easy since he got an oil burner"

This dynamic characteristic emphasizes the importance of having efficient techniques for calculating and recalculating materials requirements, as well as the need for continual re-evaluation of the market situation.

HOW TO ESTABLISH THE MATERIALS SCHEDULE

The time cycle chart shows that the Materials Schedule is the first one to be committed to action. Ideally, it would seem that we should procure all materials only when they are really needed to support manufacturing and assembly operations; but to be more practical, in order to keep our shop running, we must have the materials to work with when they are needed. Even though we may buy many of our items from within our own Company, it is still vital to maintain inventories to avoid starving ourselves out of business. For example, even though we get a part from a machine shop down the block, there may suddenly be a substantial demand increase so that we have to wait 4 weeks for replenishment instead of the usual two days. Another factor is the price discount offered by many vendors to encourage the purchase of economic quantities; furthermore, some items cannot even be obtained unless minimum quantities are ordered. These are some of the reasons for carrying stock inventory; stock is not, as many believe, just an evil to be avoided wherever possible; there are many places where carrying inventory is the least expensive and most effective way of maintaining good material control and efficient materials scheduling.

But the first essential is to know what you need and when you need it. Remember, scheduling is always a two-pronged problem:

- how much is required
- when is it required

EXPLODE THE MASTER SCHEDULE

Naturally, the Master Schedule is the document which begins the explosion process. It is combined with the Bill of

Materials to determine the gross requirements, and then with the time cycle charts to determine the time when they are needed. These are starting figures which need further analysis before preparing a procurement schedule and placing vendor orders.

COMPARE REQUIREMENTS TO INVENTORIES

It isn't just idle curiosity that prompts us to determine the time when materials are needed. Just comparing total gross requirements with initial inventory won't do the job. What must be done is to make this comparison for each time period in the future. For instance, take the starting inventory as of May 1st; subtract the requirements during the month of May and add to this any open orders due during the month to obtain the closing inventory balance. Now, you can decide whether to order more, cancel part of the order or just sit tight.

This same type of analysis should be followed for each succeeding month, out at least as far as the procurement cycle and often for the full master scheduling period. To make these computations for all purchased items amounts to a lot of clerical work; but if the Materials Schedule is to be a valid one, and inventories are to be controlled, there is really no other effective way.

In using procurement cycles, the transportation component of delivery time is often overlooked. Traffic is a scheduling problem all its own; its variability and predictability are directly connected to the method of shipment, season and product. Just because a vendor promises to ship on December 15th doesn't mean that we'll always get delivery two days later. Other elements to be considered in the procurement cycle include incoming inspection, laboratory analysis of raw materials and sample approval of castings.

RECOUNTS ARE PART OF BETTER CONTROL

In speaking of inventory balances, we often think of the stock records which are kept as to withdrawals, receipts, spoilage and so on. But these records usually do not show the midnight raids of expediters and second shift operators. An invaluable aid in verifying inventory balances is to make planned physical recounts at regular intervals. This helps to create and maintain confidence in the accuracy of the data used in order quantity determination. Some departments even go so far as to depend entirely on recounts instead of records. Still another way to avoid this onerous posting activity, is by maintaining bin reserves with a packaged quantity which indicates when to reorder.

The prime value of recounts then, is its auditing feature; but there's more to it. The mere fact of keeping your records up-to-date and accurate provides you with a self-compensating device to correct the new order quantity for the allowances that you estimated for spoilage, shrinkage and other variations. Physical inventory once a year isn't enough for most items. A planned system of recounting, based on the relative value of a part over the year, will often pay big dividends.

NEW YORKER "Know what I dread? Inventory." DAP

REMEMBER YOUR "A B C's"

To apply the principle of "ABC" control of materials inventory it is necessary to:

- compute the total cost per year for each item purchased (cost per unit times annual usage).

- arrange these items in sequence by their total cost; they can then be conveniently divided into three categories.

- "A" items--large percent of total cost, small number of items.

- "B" items--moderate percent of cost, moderate number of items.

- "C" items--large percent of items, small portion of total cost.

This leads to an effective tool for guiding scheduling efforts. Obviously, "A" items must receive prime consideration, while "C" items are handled on a rapid, inexpensive basis. Following this lead, many plants have found it advantageous to separate their materials into:

- Rate Items

- Lot Items

HANDLING RATE ITEMS

- Rate Items are procured at scheduled intervals (daily, weekly, monthly) or to specific customer's order in the quantity required for immediate use. They will consist chiefly of "A" items with some "B" items thrown in where it is desirable to strengthen control and improve turnover.

A rate item should be scheduled for receipt close to when it's needed in the manufacturing cycle. For these items it's hard to justify tying up inventory dollars in materials which are not moving toward the back door as finished products. For example, if explosion of the Master Schedule indicates the need to purchase 1600 motor castings during the next four weeks, it may be better to have the vendor deliver 400 castings each week--or even 200 castings twice a week--instead of ordering all 1600 for a single delivery. Stock records are reduced, stockroom space minimized, and the only data necessary is the status of vendor orders and a record of spoilage. The toughest decision is determining just how much protective time will be allowed in the procurement cycle, considering your own manufacturing cycle variance as well as the reliability of each vendor's delivery promises. Data on actual past procurement can be averaged to calculate the most probable procurement time required and the likelihood of wide deviations.

HANDLING LOT ITEMS

- Lot Items are purchased in quantities sufficient to cover the needs over an extended future period. They will consist chiefly of "C" items and the balance of "B" items where it is not critical to exert such close control and maintain so high a turnover.

While more and more plants are stocking "C" items directly at the point of usage, some still find it necessary to store lot items in stockrooms. Regardless of where they are located, it is generally unnecessary to keep elaborate stock records for these parts. Frequently, a simplified bin reserve system is all that is required. After all, a "C" item is one that is so relatively inexpensive that you can order enough to last three months, six months or even a year--and "forget it". The amount in the bin reserve is, of course, sufficient to cover the needs during stock replacement including a protective reserve. When the bin reserve package is broken, a replenishing order is sent to purchasing.

While these principles serve as a good general guide for lot items, they still don't really tell you how much to order. The whole subject of economical order quantities has been explored for many years and a number of different formulas and slide rules have been devised. The following formula, while originally designed for use with internally manufactured parts or purchased items on which there is no discount, can be adapted for calculating order quantities for items obtained from contributing departments:

$$n = \sqrt{\frac{2U\ (S + P)}{CI}}$$

n = economical order quantity

U = anticipated yearly usage

S = vendor's fixed costs per order

P = cost of processing an order

C = variable part cost

I = cost of carrying inventory ratio

The only really different idea is the definition of "S" and "C".

C = difference in total price for two different quantities divided by difference in quantities

S = total price minus the product of quantity times "C"

To mathematically determine order quantities where there is a step discount structure requires actual analysis of total cost at each price breaking point and then the selection of that quantity which produces the lowest over-all cost. It should be remembered however, that order quantity formulas are not a substitute for the good judgment which your organization has built up over its many years of experience.

An interesting sidelight to this type of approach is the classification of parts into order quantity ranges by ABC value. For instance, one department set up the following table:

A items:	1 day to 4 weeks
B items:	2 weeks to 10 weeks
C items:	6 weeks to 26 weeks

Another difficult-to-handle consideration in the control of lot items is the determination of buffer stocks. Their size depends on the variability both in predicted usage and vendor delivery promises. If it were absolutely certain that fifty parts were to be used each week for the next four weeks and that the vendor would deliver the order exactly twenty-eight days from now, there would be no question of carrying buffer stocks; all you'd have to have on hand would be 200 pieces (unless there was chance of deterioration or spoilage). However we very seldom see this ideal condition; we constantly deal with seemingly unpredictable factors. This complicates our job and is the main reason why buffer stocks are carried. They normally are not designed to provide 100% insurance, but rather to minimize the number of times when special expediting will be needed.

USING FEEDBACK INFORMATION

Without adequate feedback, materials scheduling activities are often hectic and poorly integrated.

"Now, if I may have your undivided attention . . ."

There's nothing quite as damaging as sending workers home when there are orders to be filled, but no material to work with. Since the Materials Schedule is the first one committed to action, nothing else can start until adequate flow has been established. On the other hand, however, too much material can also be embarrassing especially when there's no place to put it. To keep the materials supply situation well balanced requires careful juggling.

We've got to keep posted on:

- Master Schedule changes
- Anticipated design changes
- Price change predictions
- Status of open orders
- Procurement cycle variation
- Vendor performance records

SUMMARY

Good materials scheduling and good inventory management go hand in hand. Without one, the other is impossible. Certain rules were developed to guide materials scheduling:

1. Explode the Master Schedule into its detailed materials requirements. This needs to be done accurately -- far enough in advance.

2. Classify all material items -- raw stocks and purchased parts--carefully, according to the ABC plan. In other words, determine the logical "value pattern" for approaching your materials scheduling.

3. Further classify the items as either "Rate" or "Lot". Rate Items comprise all the "A" items and some "B" items; schedule their procurement in quantities only sufficient for immediate needs. Lot Items include all "C" items plus the balance of the "B" items; these can be purchased to replenish stocks--enough to fill the needs for several future time periods.

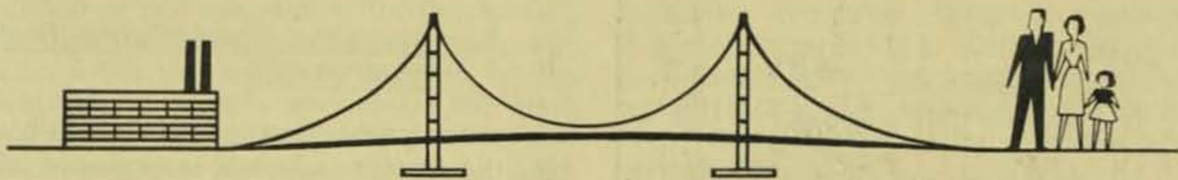
4. Keep the stock record clerical routine as simple as you can, even to having no stockroom at all. Stocks can often be kept right on the factory floor at the point of use, so materials handling efforts are minimized and automatic replenishment encouraged.

5. Maintain a rapid and reliable communication system so that feedback information on changing materials requirements is readily available.

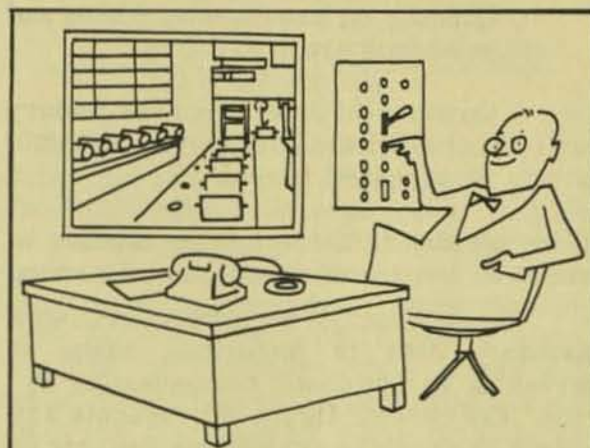
PROCESSES

PRACTICES

Chapter IV THE MANUFACTURING SCHEDULE



In the perfect, automated, push-button factory, once the Master Schedule was set the scheduling job would be over. We would just push a button and watch the products flow out the back door.



The new "Life of Riley"

But we don't have 100% automated factories -- yet. Present plants are mostly made up of lots of little factories, each of which turns out "products" to its own "customers" -- the work center responsible for doing the next operation. Therefore, each of our "little factories" has to be scheduled in terms of the work it performs. This results in many manufacturing schedules, one for each shop activity -- all tied to the Master Schedule.

THE MASTER SCHEDULE STARTS THINGS GOING

Here, as in the material scheduling area, it is the Master Schedule which serves as the guide for coordinating all internal scheduling activities. After the Master Schedule is exploded and the various parts requirements consolidated, the nature of the shop processes dictates what the Manufacturing Schedule will look like--

. Lead Time
. Buffer Stock
. Setup and Running Time
. Shop Layout
. Operation Sequence
. Tools and Methods

WHAT KIND OF DATA DO YOU NEED?

There's an old story about a dairy farmer who owned only one cow. He started keeping so many records -- such as height of grass eaten, distance walked, etc. --- that he was forced to sell the cow to pay the overhead.

The fault was not with the cow, nor in fact, was the fault with the records themselves; rather, the cause of "liquidation" was the failure to use the records properly. No one wants to go broke keeping records, but to remain competitive we must accumulate and use certain historical statistics about our business. The use of these data to improve operation and cost position has always been a critical problem, but now the new scientific exproach to data analysis permits more effective application of the figures available.

Who supplies the basic information? Every function of the business:

Marketing

. market forecast
. warehouse stock position

Engineering

. bills of material
. expected obsolescence
. anticipated product life
. engineering lead times

Factory

. manpower availability
. employee training time
. cycle time performance
. bottleneck points

"I'm tooling up, dear; production will start in just a few minutes"

Purchasing

- buffer stock recommendations
- procurement cycles
- prices for economic order quantity

Manufacturing Engineering

- operational planning--sequence and time
- capacity--work stations and groups
- part and product flow
- alternate manufacturing methods

Tools and Maintenance

- tool and die life
- preventive maintenance schedules
- machine breakdown statistics

Quality Control

- manufacturing losses
- test and inspection times

Employee Relations

- absenteeism statistics
- labor availability

Finance

- cost of carrying inventory
- cost of changing production levels
- cost data for "ABC" analysis

PROCEDURE FOR ESTABLISHING MANUFACTURING SCHEDULES

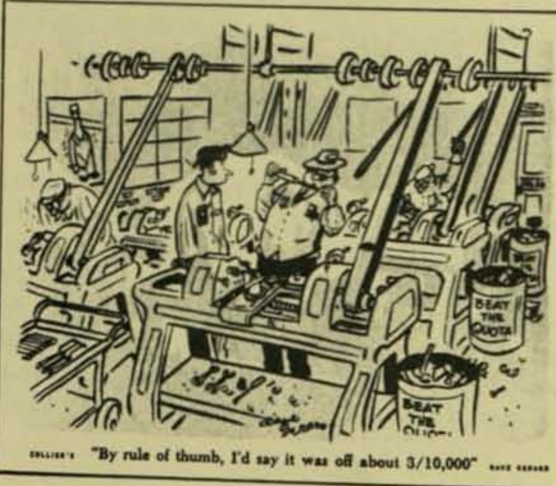
1. Determine Manufactured Parts Requirements

As in preparing the materials schedule, the master schedule is exploded into the gross fabricated parts requirements -- sub-assembly and detail parts. The net quantity of parts needs is determined by subtracting from the gross parts requirements:

- Quantity on hand in stockrooms and sub-stock areas
- Quantity on order from the factory to be finished before the schedule requirement period.

This quantity is the minimum number of parts to be manufactured in the shop.

The accuracy of the current available inventory data is important, since it serves as an automatic compensating device. The current figure will indicate any errors in previous projections because of scrap loss, spoilage and other shrinkage factors which were incorrectly estimated in ordering the original quantity from the shop. In other words, if the allowance for spoilage was insufficient in the past, extra quantities will now be ordered to make up for this shortage; if the allowances were too liberal, then there now will be higher inventories and, therefore, fewer parts ordered.



"By rule of thumb, I'd say it was off about 3/10,000"

Next, the parts requirements are sorted according to the particular subsection or unit responsible for performing the first operation (starting the job). For example, in making pencil sharpeners, the detail parts might be sorted into two main categories: punch press parts and screw machine parts. Hence, the foremen of the punch press and screw machine units would each receive sets of manufacturing order paperwork (planning sheets, labor vouchers, raw material withdrawal slips, etc.) for parts each is to produce in his section during the next week.

2. Schedule the Work Sequence -- The Big Problem

Many times all that the shop receives from the production office is a pile of manufacturing order paperwork, or a list of parts requirements. But manufacturing scheduling shouldn't stop here. Production, using appropriate planning records, may convert these orders into hours of machine or assembly time within each area. Then these hours need to be "loaded" onto the machines in some feasible and desirable sequence. In doing this the dispatching function really makes important scheduling decisions.

Reading between the lines, one is prompted to raise a lot of questions. For instance, you may well have asked:

- We have several work centers -- heat treating, drilling, milling, plating, grinding, painting, etc. -- which might be classified as "secondary operation" areas. What about the schedule of work for these activities? Do these groups just idly wait until the primary operations are completed -- and then have their work load come to them in one great big slug?
- How does the dispatcher in the "primary" work sub-section decide what a "desirable load sequence" is to be? In his own little activity, should he strive to load the work to each machine so that the number of machine setups is minimized?

To illustrate these problems, take for example, a six-spindle automatic screw machine. The setup changes are reduced if part number 1234 is dispatched before part number 5678. But, suppose part number 5678 is really needed first, from the over-all viewpoint, since it is used at an earlier assembly work station.

As a result of a decision based on setup time alone way back in the screw machine unit, we would have a batch of part number 1234 completed first. These would just be lying around until needed on the last operation in assembly.

Therefore, is it wise to let the shop do all its own scheduling in a case like this?

In a sense, this is our dilemma: To what degree should the central production office try to issue to each work area a schedule which specifies in detail the time at which each operation on every job should be performed?

Should the basic scheduling and dispatching decisions be centralized or should they preferably be decentralized?

This is a very important question-- one with wide implications--and certainly worth our best thinking. Let's discuss the alternatives in some detail.

HOW MUCH CENTRAL CONTROL

The production office is concerned with the performance of each work center only as it relates to the achievement of the ultimate goal -- to ship finished products to customers on time. It is also concerned with keeping inventories turning over. These are of course identical to the objectives of the entire factory system. The Central Dispatch Coordinator in the production office is in a unique position to view the whole plant and all of its related manufacturing components -- if there are adequate communications.

The screw machine foreman may claim that his scheduled load is best when the cost of machine setup charges and machine "down time" is at a minimum; however, the Central Dispatch Coordinator is in a better position to more accurately evaluate the total operating cost of scheduling and dispatching work on this basis. The over-all costs may be too high because:

- excessive in-process inventories are piled around the shop, waiting further operations or assembly.
- too much overtime in work centers performing "secondary operations" on "screw machine" parts -- or too much idle time in these work centers.

In other words, the production office can measure the true costs of the sub-optimum program being proposed by the screw machine foreman. If decentralized scheduling results in costs that are too high, then the production office--on a justifiable basis--should determine the rules for scheduling the screw machine area.

If any emergencies should arise -- vendor delays, machine breakdowns, inspection delays, etc., the production office is in a position to establish the next best schedule--which parts should be run, what "off-specification" dimensions might be accepted, whether overtime is necessary. The next best schedule from the viewpoint of a small part of the shop, may not be the next best schedule from the viewpoint of the over-all manufacturing program.

The centrally issued schedule often has more authority and is psychologically more effective with factory personnel than one issued locally. The central schedule appears to have the "stamp of approval" of top management affixed to it. Therefore, it is more likely that the central schedule will be adhered to than a local one; this normally results in more effective integration of parts completion.

There are, of course, many drawbacks to centralized decisions and corresponding advantages to decentralized decision-making:

- A communication network is needed to keep the Central Dispatch Coordinator informed so that he can make the proper decisions, bearing in mind all the salient facts. One company has gone so far as to have a telephone at each work station connected into a Central Dispatch Office, where all the basic scheduling decisions are made. It has even been suggested that a TV camera be placed at each machine or group of machines and, thereby, the Central Dispatcher could, by switching his receiver, look at each station. Obviously, nothing this complex may really be necessary, but you should remember that there is bound to be some loss of detail in transmission which may lead to misinterpretation and hence, incorrect decisions.

Tight Scheduling
Provides Worker Incentive

NEW YORKER

PRICE

- If operation were attempted on the feedback of "exception" data, a very difficult problem of determining what should and should not be communicated arises. It's quite a task to predict in advance what fact or group of facts will influence a future decision. In other words, there is no real substitute for the detailed knowledge of particular conditions possessed by the foreman and dispatcher for their specific work area.

- Even assuming that enough of the right information concerning conditions can be rapidly transmitted to the Central Dispatch Coordinator, there is still the problem of whether it can be grasped effectively by one individual and properly weighted in making future scheduling decisions.

  The importance of this point is dependent upon:

  . complexity of the product being manufactured

  . number of different work areas which have to be dispatched

  . variety of finished products that can be produced

  . frequency of change in demand

  . length of operation time for each job

- Central control has one additional undesirable feature in that it takes away from the local foreman and dispatcher, the feeling of responsibility that goes along with making the detailed scheduling decisions. When they, themselves, have decided what to do, they naturally have a greater interest in seeing to it that the decisions are carried out properly.

THE BEST CONCEPT OF A MANUFACTURING SCHEDULING PROGRAM

The disadvantages listed above should serve as strong warnings against too hasty adoption of a centralized control plan, but there are methods of minimizing these objections so that a proper degree of centralization can be established. Generally, it has been found that the greater the amount of sensible centralization, the more effective the operation. However, the amount of control exerted centrally must be limited by:

. effectiveness of the communications plan

. amount of authority which can properly be delegated to individual dispatchers and foremen

. size and complexity of the business

. availability of mechanical and electronic aids

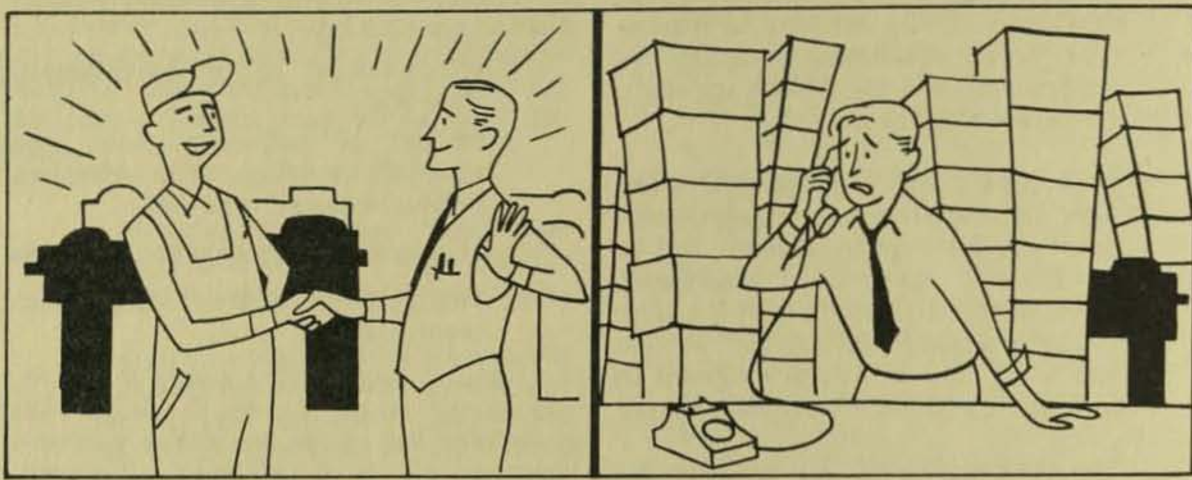
Back in the 1920's Henry Ford, Sr. was quoted as saying he would give his customers any color Ford they wanted--"just so long as it is black". However, Henry's competitors soon made him change his tune. By setting up an effective production dispatching and communication system throughout the entire body assembly plant, cars are now painted almost any color of the rainbow. Think of the tremendous variety of accessories an automobile customer can order these days, for delivery within a few weeks--fresh from the factory. This could not have been accomplished without effective central control and direction. A system has been set up so that every single conveyor hook or fixture carrying fenders, wheels, etc., is "loaded"--(designated as to what specific item it will carry) from a central dispatching point. This is scheduling and dispatching in "high gear". Centralized control insures that all production work is being directed to meet the main objectives of the entire plant:

- to produce and ship to customers on time
- to keep all factory inventories turning over
- to keep machine-down time at a minimum
- to keep man-hour idle time at a minimum

The key is, what's good for one manufacturing sub-section, may be bad for the plant as a whole. Manufacturing activities must be coordinated toward a single set of over-all objectives; the central production office must be singularly responsible.

PROCESSES

PRACTICES



A schedule that's good for one area may be a headache to the next.

Having accepted the concept of strengthened centralized scheduling and dispatching, your next question will probably be: "How do I go about it in my particular case?" Like all new procedures and systems, you just can't "take the plunge" and make the complete change overnight. There has to be gradual adoption--otherwise the system would "never get off the ground"; it just wouldn't operate on a successful, paying basis. Here are some recommended steps on how to develop an effective centralized scheduling and dispatching plan:

1. Select the manufacturing unit

The manufacturing unit selected should be one which is somewhat "self-contained" -- responsible for both "primary" and "secondary" operations on a product or its components. Within this unit, there should be a fairly uniform operational sequence. One way to identify this is to actually trace on a floor layout the lines of flow for a representative sample of the jobs which are routed through this area. The dense lines, of course, indicate the main flow patterns. By repeating this for several different manufacturing units, the most logical choice can be made. Often, assembly areas are the best to select, because flow patterns are quite easily discerned.

2. Set your specific objectives

For example:

- To reduce floor inventories and increase turnover by 20%--both within this unit and in manufacturing units preceding and following this unit
- To assure closer control of manufacturing operations in the selected area
- To control the input and output of work to and from this unit

3. Get all the facts about the manufacturing activity in the unit

Investigate the various delay factors: material shortages, machine setup, rework, maintenance, repair, etc. Check on how manpower is deployed: are operators shifted from one work station to another, or are they able to remain in one location? Note the work stations where the largest backlogs occur. All these items are often very revealing, for they indicate the really critical factors controlling production within the area; for instance, is it the foreman's close supervision, the group incentive pay plan, or morale of the individual operator that causes work to be done. Locating the largest backlogs, indicates the bottlenecks which are logical points for measuring the production output via the feedback reporting procedure.

4. Design your centralized dispatching system

In what terms will the schedule be dispatched to each unit--sequence of manufacturing individual parts, lots of parts or sub-assemblies? Will the man-hours of work at each work station be scheduled, or can you merely specify the sequence of work input (i.e., the order in which parts or sub-assemblies are to be run) to the manufacturing unit? How frequently will the workload be dispatched? Daily? Weekly? What sort of "feedback" of information on the progress of work do you desire? Do you want to know when every job is completed, or do you want to be informed only when something goes wrong? At what points within the area do you want to measure the output?

How do you want to specify schedule dates: when to start, due complete, or by intermediate check points? What communication media should you use? Paper forms, punched cards, telephone, TelAutograph, punched tape, facsimile transmission, etc..

5. Test out the system

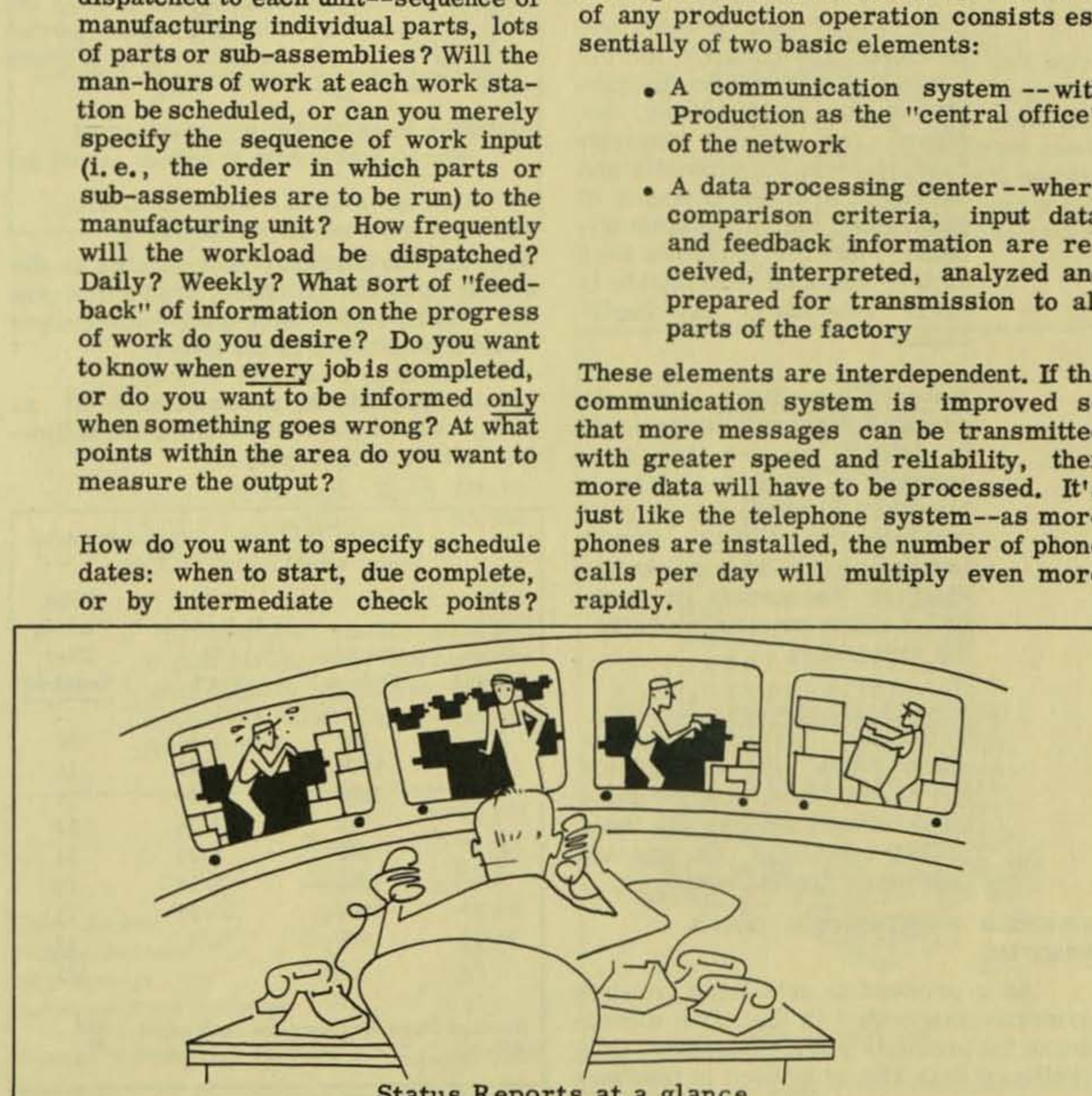
Sell the system to management and to the employees who will be operating it. Consult with the manufacturing people about your proposal. Give it a fair trial.

LOOK AT YOUR SYSTEM CRITICALLY

Looking at the facts in a little different light it can be seen that the hard core of any production operation consists essentially of two basic elements:

- A communication system --with Production as the "central office" of the network
- A data processing center--where comparison criteria, input data and feedback information are received, interpreted, analyzed and prepared for transmission to all parts of the factory

These elements are interdependent. If the communication system is improved so that more messages can be transmitted with greater speed and reliability, then more data will have to be processed. It's just like the telephone system--as more phones are installed, the number of phone calls per day will multiply even more rapidly.



Status Reports at a glance

But a communication system has to be maintained and repaired, and the "customers" served by the system are a dynamic group. So we can't just set up one kind of service network and then expect it to last forever. The Indian runner was replaced by Pony Express, which has since been replaced by wireless, teletype, and other advanced communication networks. What can we do to insure that our communication system is up-to-date and operating most effectively?

A reappraisal of the media used and comparative evaluation of their effectiveness will often pay big dividends:

- Paperwork forms: Is there unnecessary information on the forms? Are the forms distributed to the right groups, designed for quick, accurate reading, sent out promptly and quickly? Are the methods of generating the information adequate? Are reproducibles used so that common information is never rewritten, just duplicated?

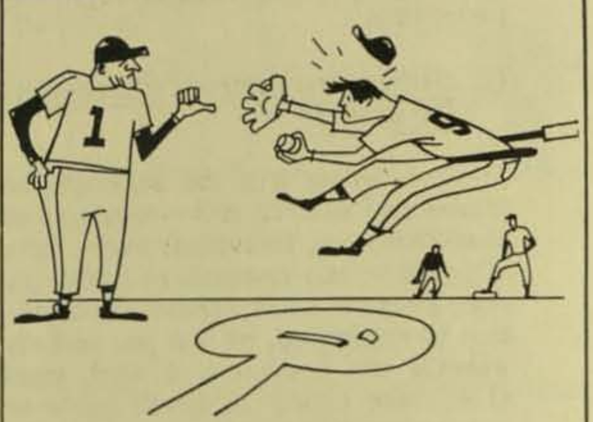
- Material expediters: Are their areas of responsibility logically defined, or are they constantly duplicating each other's work? Do we have too many or too few expediters? Should movemen (truckers, materials handling personnel) be made a part of the materials expediting system?

- Electrical and mechanical aids: Telephone, telegraph, pneumatic tubes, two-way radios are here to stay. Are we using these newer devices to their fullest advantage or are we still using "Indian runners".

MAKING FEEDBACK DATA USEFUL

As a production scheduler, you are primarily interested in the time dimension of the products you manufacture. Only significant data should be used in feedback reports; it must be received promptly and accurately so that proper corrective action can be taken in time.

In baseball, a good manager is usually one who "plays the averages". He schedules his pitchers so that the chances of winning are greatest--taking the entire baseball season into account.



"That's it, Lefty. With your E.R.A., we can't take any more chances."

With all the data that accumulates in the average production office, production men can also do a lot with playing the averages - and it's well worth the effort.

For example, you can look at an order record card and extract the following historical information:

Ordering lead time – 20 working days
Buffer stock – 30 days' Usage

Date Ordered	Quantity Ordered	Date Delivered To Stock	Total Working Days Required
2/6	500	3/2	18
4/5	1000	4/26	16
5/18	2000	6/10	19
7/12	500	7/26	12
8/2	800	8/20	14
9/6	3000	9/25	15
10/10	1000	10/25	13
11/15	800	12/5	15
			122

Average Days Required for each order $= \frac{122}{8} =$ 15.2 days

The recorded experience shows that the 20 days allowance per order is too much since the shop has consistently delivered in less than 20 days; beyond this, a 30 days' buffer stock has been maintained--just in case the shop couldn't deliver the parts in 20 days. All this indicates that inventories have been too high for this part. Obviously, you would cut back on the buffer stock and change the lead time for each order.

This is nothing more than a case in simple applied statistics. In other words, if we can boil the facts down into numerical terms, the scheduling job can be done more rationally--because much of the guess work is eliminated.

Here are more examples of scheduling facts, stated in numerical terms:

- The last 3 times we ran an order of more than 50,000 pieces of part number 5678, we had to stop the press, take out the die and grind it. Orders for 30,000 pieces or less required no die changes for the past 10 orders.

  Action Indicated: Keep future order quantities at 30,000 pieces or less.

- The machine maintenance and repair history over the past two years (4500 operating hours) shows the following down-time for repairs:

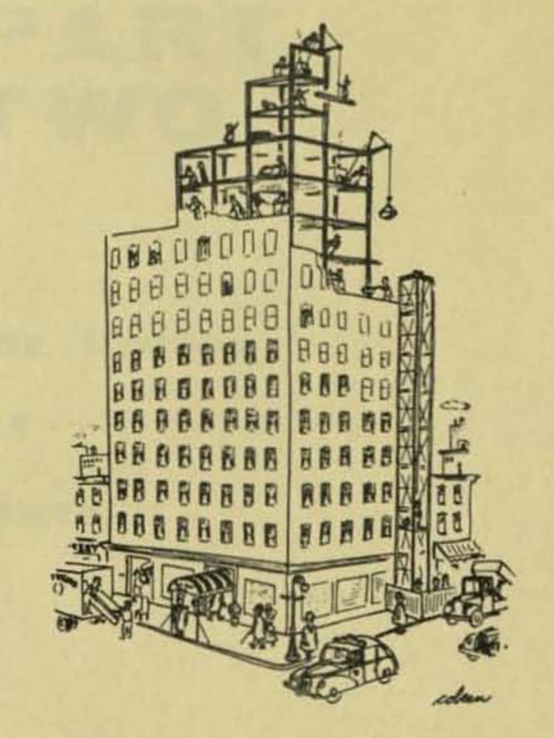
	Repair Hours	% of Total Operating Hours
Turret Lathes	25	.59
Milling Machines	15	.33
Drill Presses	30	.67
Automatic Screw Machines	50	1.11

Average % Down-Time for Repairs = $\frac{2.70}{4} = 0.675\%$

  Action Indicated: Since, on the whole, machines are shut down for repairs less than 1% of the time, we will not maintain buffer stocks solely to cover risk of machine breakdown while an order is in process.

- Over the past year, $175,000 of overtime premiums has been paid to assembly workers--as shown by accounting records. 11% of this overtime was planned. 78% was caused by delays in delivering parts to the assembly area.

  Action Indicated: We will analyze our assembly shortage lists over the past year and pick out those parts listed most frequently. Then we will establish buffer stocks of these parts to guard against assembly overtime.



Scheduling for maximum profit

NEW YORKER COBEAN

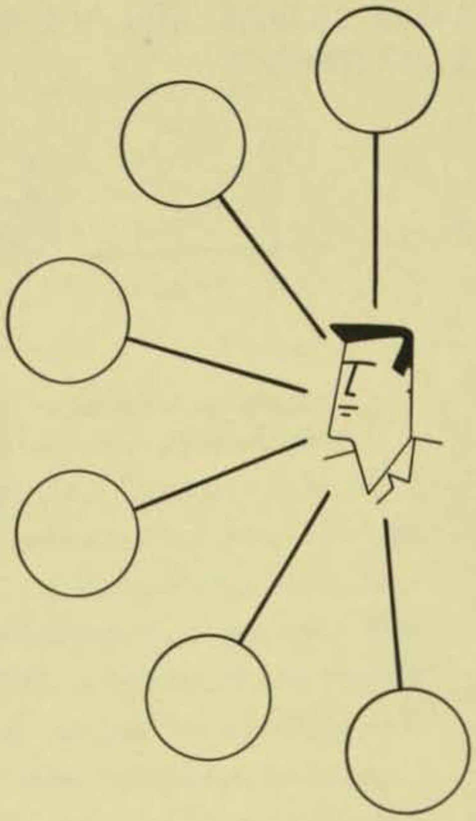
SUMMARY

1. Manufacturing Schedules direct the timing of factory operations, by specifying the sequence of job performance.

2. It is important to have an effective degree of centralized scheduling and dispatching in the production office. This is needed to coordinate all manufacturing activities so as to accomplish the ultimate goal of the entire factory -- to ship the products to the customers on time and to keep inventories turning over.

3. Scheduling involves (1) a communication system and (2) a data processing center, both of which operate in a dynamic environment. Therefore, unless scheduling systems and practices are "maintained", they will very soon go into a state of disrepair.

4. Much of the follow-up record and experience of manufacturing performance is filed away as soon as a job has been completed. Instead, these data should be used in analyses which make rational scheduling decisions possible, because they are founded upon experience.

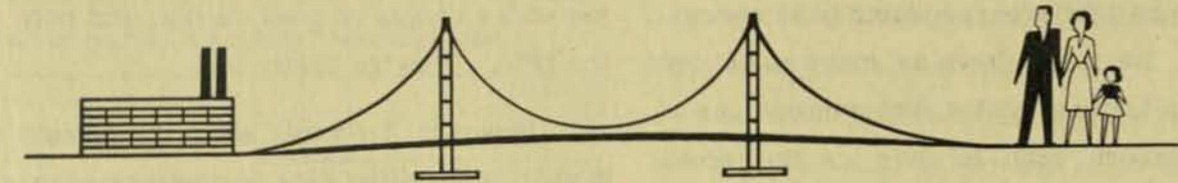


PART TWO

Some ideas for better processing of Scheduling Data

PROCESSES
PRACTICES

CHAPTER V METHODS OF HANDLING SCHEDULING DATA



WHY THIS CONCERN FOR METHODS OF SCHEDULING?

In Part One some ideas were developed on what production scheduling is - the master schedule, the materials schedules, and the manufacturing schedules. Now let's take a look at how scheduling may be accomplished. Unless we carefully calculate the amount of clerical time involved in scheduling, we might well find ourselves in the position of having to schedule the work of the schedulers themselves! This could go on and on - to absurdity.

You may have heard the rhyme:

"Big dogs have big fleas
Upon their backs to bite 'em!
Big fleas have little fleas
'n so on, ad infinitem!"

HOW TO DETERMINE PARTS REQUIREMENTS

We are all aware of the large quantities of manufacturing data used in determining production schedules. Take the parts requirements for the final assembly section -

Master Schedule
Period 12

Prod. Type	Ship
X	3000
Y	6000
Z	2000

X

Product X
Parts List

Part #	Use
1001	3
1002	2
1003	6

Product Y

Use
2
-
1

Product Z

Use
1
2
4

=

Parts Requirements
Period 12

Part #	Tot. Req'd.
1001	23,000
1002	10,000
1003	32,000

Suppose we had a factory which stocked 6000 different material items, used on 10 different products to be assembled. We might have as many as 60,000 multiplications and 6,000 summations of 10 numbers each to give us the gross parts requirements. Now to get the net requirements to be processed or purchased from outside vendors, we must review the current status of our stock. This means 6,000 subtractions. The total job requires 72,000 arithmetic computations. Quite a task!

SIMPLIFIED MANUAL SYSTEM

If, in our example, we had firm master schedules issued to us quarterly (every three months), we might find it entirely feasible to do the job manually-if the engineering designs of our 10 products are pretty well "de-bugged" - if we receive our firm master schedule about ten weeks in advance of the start of the quarter. It's a good bet that we could do the job with a couple of good clerks. But note the IF's. They're pretty big.

However, let's talk about the manual system of handling data on parts requirements. We take the parts list for each model of finished product, and for each part, multiply the quantity of parts per model times the number of models scheduled. With a moderately long parts list of, say 10 pages for each model, and a mix of 10 models, it's easy to see that lots of paper shuffling occurs. And there are a lot of chances for errors, too.

There are ways of simplifying manual methods for doing this job. For example, the "spread sheet" technique is simple and effective. Using this technique, we made a permanent spread sheet summary parts list:

Part No.	Number of Parts Used in Each Type of Product									
	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H	Model I	Model J
1001	3	1	-	2	2	1	3	3	2	1
1002	2	1	2	2	5	4	2	6	4	3
1003	8	1	3	5	6	2	4	1	3	3
--	-	-	-	-	-	-	-	-	-	-
–	-	-	-	-	-	-	-	-	-	-
6000	5	1	2	6	3	4	5	1	4	4

Then we made a cardboard strip which contains the number of finished units of each type of product during the next scheduling period (monthly, weekly, etc.):

No. of units to be assembled	A	B	C	D
	300	200	500	50

Aligning this strip over the spread sheet in the proper column and using a desk calculator, we proceed to multiply the number of finished products by the number of parts per product. By accumulating these extensions as we go, we determine the total requirements for each part. Our example would take only about 16 man-hours, using the spread sheet technique.

Another manual method, the so-called "peg board explosion" is quite similar to the spread sheet method described, but permits level by level explosion and summation.

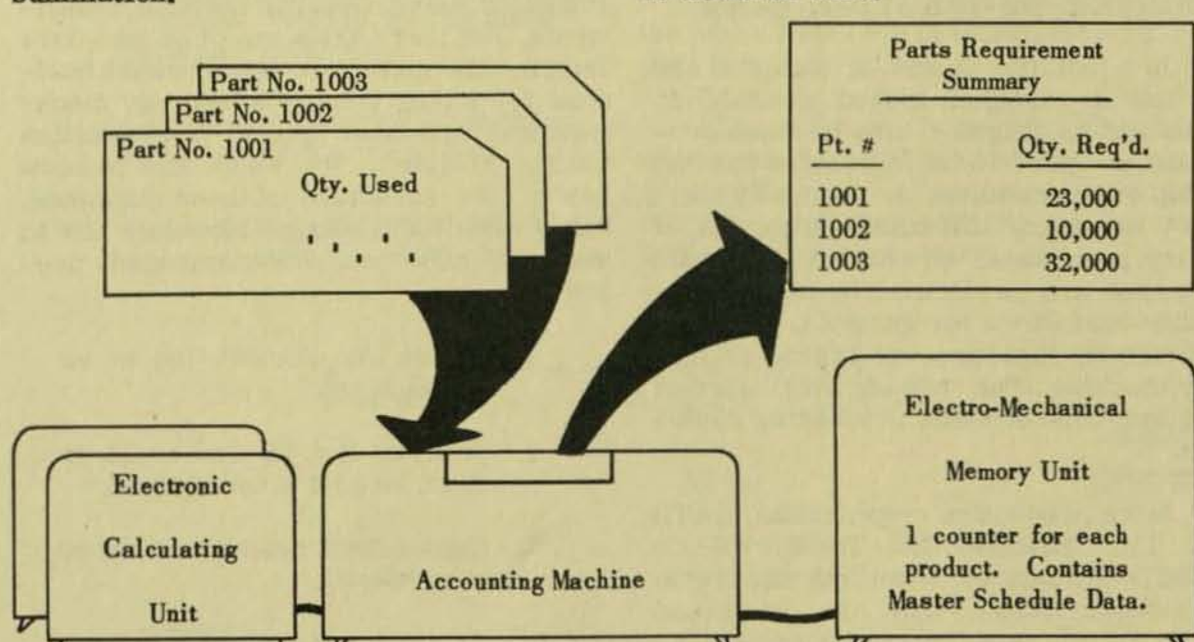
WHEN TO USE MANUAL TECHNIQUES

In general, manual handling of scheduling data is most useful where the following circumstances prevail:

1. The number of parts is not large.
2. The mix or variety of products is small.
3. The period for making the computations is adequate - i.e. you receive the master schedule well in advance of the lead time required for purchasing and manufacturing.
4. The master schedule is reasonably firm.
5. The number of parts used on each model is not subject to frequent changes.

PUNCHED CARD SYSTEM FOR DETERMINING PARTS REQUIREMENTS

In a punched card system, the parts requirements in our example could be determined in about one hour. Using an IBM Card Programmed Calculator, here's how it would be done:



SCHEME FOR CARD PROGRAMMED CALCULATION OF PARTS REQUIREMENTS

The master schedule information is fed into the electro-mechanical memory unit of the Card Programmed Calculator. Then, usage index cards, one for each part, punched as to the quantity of parts for each type of product are fed into the connected Accounting Machine. The Calculator extracts the scheduled quantity of each product-type from memory storage and multiplies it by the parts per type of product and then prints the requirements on a parts requirement summary sheet.

The memory storage capacity of the Card Programmed Calculator is somewhat limited. There are other calculators, however, with more adequate memory storage. These include, among others, IBM 650 and Rem. Rand Speed Tally.

The machine method certainly has many advantages over the manual system for determining parts requirements. The benefits of speed and accuracy are obvious, but it's not our purpose to sell punched cards, or any particular kind of mechanization. Rather, we should take a closer look at scheduling practices so we can better decide where machines can make our work more effective.

THE BEST APPROACH TO HANDLING SCHEDULING DATA

In a factory, pieces of material are cut, heated, stamped, moved, assembled, tested and packaged -- and by these processes we get a finished, usable product to ship to our customers. Basically there aren't too many different categories of factory processes. In some factories the processes are performed by hand -- assembly operations for example. In other factories the same process is done entirely by machine. But, nobody ever heard of a factory without some processing equipment.

In the production organization, DATA ARE THE MATERIALS TO BE PROCESSED. By data we mean both alphabetic and numeric facts. Data are processed into materials requirements summaries, labor load reports, manufacturing schedules ... to name just a few "finished products" which are turned out by production. Fundamentally, there aren't too many different data processing operations. All the "products" of the production section are processed by various combinations of sorting, filing, posting, checking, summarizing, tabulating and computing (adding, subtracting, multiplying, dividing). If we think of manufacturing and marketing data as materials, and the various clerical routines as processes, we can now accept the idea that we operate a DATA PROCESSING FACTORY!

Some of the data processing can best be done by hand. But, our factory must have some kind of data processing machinery -- even if it's only an adding machine. (Remember, a factory isn't a factory without equipment!)

WHERE AND WHEN SHOULD MACHINES BE USED IN SCHEDULING SYSTEMS

In General Electric we have all been made aware of some of the fantastic accomplishments of so-called electronic brains. We know that production control functions have been more or less mechanized in some General Electric departments. But there are some of us who have been in this materials management business for a long time -- before any mechanization had been applied to production control routines. We would like to know how to take advantage of these machines, but we don't quite know where or how to start. Here's one recommended procedure:

1. Select the clerical job to be mechanized.

2. Analyze the job and break it down into its elements.

3. Decide how much you want to mechanize.

4. Analyze and compare several different machine methods.

Step 1. SELECT THE CLERICAL JOB TO BE MECHANIZED

Which routines require the greatest clerical effort in your production control organization? On which routine do your clerks spend the most time to perform the job with the required accuracy? Or, an even better question to ask -- what jobs should we be doing to improve the schedule, but which we can't afford to do manually? Some tasks which might be considered for mechanization are:

- Determining materials requirements from the master schedule and bill of materials.
- Processing customers' orders placed on the factory (requisition service); preparing shipping papers, etc.
- Keeping stock records.
- Scheduling material procurement.
- Computing labor and machine loads.
- Preparing the production paperwork for release to the manufacturing sections.
- Compiling material expediting reports and shortage lists.
- Summarizing dispatch records and load status reports.

Step 2. ANALYZE THE JOB AND BREAK IT DOWN INTO ITS ELEMENTS

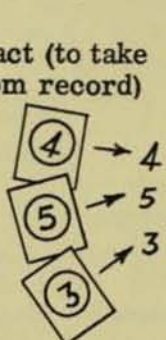
After factory management has decided to mechanize a manufacturing operation, the manufacturing engineers and tool engineers are called in. The first thing they do is to study the job in detail. This step is important. If a stock record posting job is going to be delegated to a machine, you can't just tell the machine to go and sort the day's withdrawal slips, as you could instruct a clerk. A machine has no ability to understand generalities. Your instructions must be specific. The job has to be clearly defined and the machine set up to do exactly what it's supposed to do. This involves making a detailed flow chart of all the elements of the routine job which is to be mechanized.

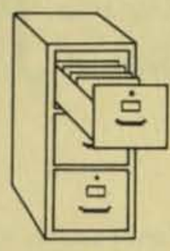
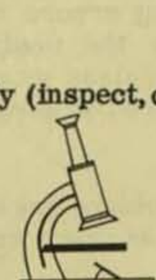
These basic job elements are necessary specifications used by the "programmer" in preparing the job for the computer. Such a "programmer" is a person who knows how to specify the various instructions which control computer operating sequence and take the right data from the right memory source. He doesn't necessarily know how to mechanize your particular clerical routine. Conversely, a production supervisor doesn't have to know how to program the clerical job for a computer, but he must be able to define the job in terms which enable the programmer to take over.

The following suggested list of elements can be used to describe any clerical routine. The programmer must spell out the job in these terms so that it can be set up for a computer.

A TABLE OF BASIC DATA PROCESSING ELEMENTS

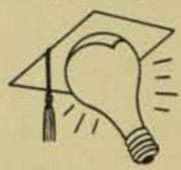
Function		As In:	Done By Machine?
Add	+	Adding number of customers' orders for each type of product.	Yes
		Adding requirements for parts or materials used on all products, etc.	

Function	As In:	Done By Machine?
Bring (Move, Transmit)	Bringing a report of current load status of machines in shop.	Yes
	Bringing engineering design data on number of pieces per standard length of bar stock.	
	Bringing data on availability of tools for future schedules.	
	Bringing data on operation times for computing machine loads.	
	Bringing reports from district warehouses on current balances of stocks, etc.	
Compare (for: equality, greater than, less than).	Comparing current stock balances with future requirements.	Yes
	Comparing machine hour requirements with machine hours of capacity.	
	Comparing scheduled time allowed to complete a job with actual time taken to complete a job, etc.	
Divide	Dividing total products required by number of weeks in the scheduling period.	Yes
	Dividing number of parts required in scheduling period by number of weeks in scheduling period to get weekly rate, etc.	
Extract (to take from record)	Extracting from stock records the current stock balances of parts available.	Yes
	Extracting data from parts lists to ascertain those products requiring a particular part.	
	Extracting machine specifications from planning record file to obtain machine load analyses, etc.	

Function	As In:	Done by Machine?
File 	Filing stock record cards.	Yes
	Filing machine load record cards.	
	Filing parts lists, bills of material, etc.	
Multiply 	Multiplying pieces per unit times number of units scheduled to ascertain gross parts requirements.	Yes
	Multiplying hours per piece times number of pieces ordered to determine total machine time, etc.	
Reproduce (to write, or print) 	Reproducing production paperwork data for labor time tickets, materials withdrawals, cost records, dispatch tickets, etc.	Yes
	Reproducing blueprints.	
	Reproducing sales order data onto factory order forms, etc.	
Subtract	Subtracting current stock balance from gross requirements to obtain net requirements of materials.	Yes
	Subtracting man-hours required from man-hours of labor available to determine whether overtime or layoff is necessary.	
	Subtracting number of days to manufacture from promised shipping date to determine starting date, etc.	
Verify (inspect, check) 	Verifying accuracy of input data.	Yes
	Verifying computations of net parts requirements, etc.	

PRACTICES
PRELUDE
PROBLEMS

Function	As In:	Done by Machine?
Originate (to create, to set an objective)	Originating the program or system of handling scheduling data. Originating the criteria for the classification of ABC inventory items, etc.	NO



Some of these terms may sound awkward. But remember, an electronic computer cannot be "told" simply "to sort" all the stock withdrawals into part number order. It must be set up to bring, extract, compare and file the withdrawals, by part number. It can "summarize" by (1) bringing data from several sources, (2) extracting desired data, (3) adding together the figures and (4) reproducing the data in summarized form.

Step 3. DECIDE HOW MUCH YOU WANT TO MECHANIZE

The basic elements used to describe the clerical routine depend upon how much you desire to mechanize. For example, let's take a job of posting stock withdrawals:

- A bookkeeping machine is used to mechanize the subtraction of amount withdrawn from the old balance, and prints the new balance on the card -- all the rest is manual.
- A punched card system can mechanically: sort all the withdrawal cards by part number; collate these cards with "previous balance cards"; subtract amount withdrawn; punch the new balance on new cards (used to repeat the cycle); and print the new balance on a facsimile posting ledger card. The manual work consists of getting decks of cards from the file and feeding them into the various machines.
- An electronic digital computer system has its own file (memory storage) and one feeding of the withdrawal quantities is all that's necessary -- without any sorting by part numbers. So virtually all the manual work is eleminated.

Programming the job becomes more complex as more of the job is done by the machine. Hence, the job descriptions must be made more and more detailed as you desire the machine to take over more and more of the clerical work.

Step 4. ANALYZE AND COMPARE SEVERAL DIFFERENT MACHINE METHODS

Although it's not our purpose to describe in detail the various mechanized systems now available, the following ideas and suggestions may help you in attaining more satisfactory results:

A. Review your entire present production control system very carefully before deciding the clerical routines to be mechanized. Remember, each routine is a link in a long chain. The apparent weak link may be due, not to that link itself, but to some other link further up the line! For example, stock record posting errors can be caused, not by the posting clerk, but by a careless stockkeeper whose writing on withdrawal slips isn't clear.

B. Data processing machines are expensive. Plan to get as much work as possible out of these machines. If your section is already using machines, try to mechanize even more of your routines. Choose your mechanized system with an eye to the future. The designs of these machines are changing fast.

C. If a cost reduction study shows you cannot justify purchase of a mechanized system solely for your use in production control, you might share a machine with payroll, accounting, quality control, or engineering. If another group already has mechanized equipment perhaps you can use it to "experiment" on your computing problems.

A CHALLENGE TO MATERIALS MANAGERS

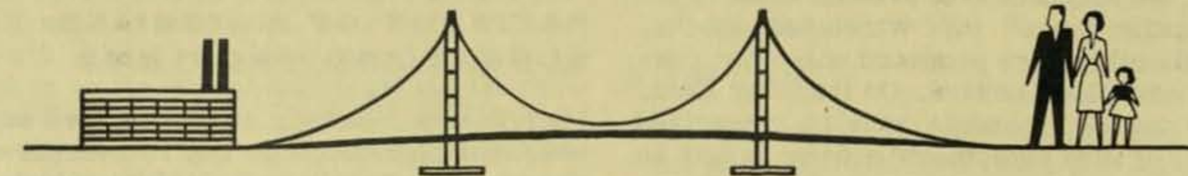
According to the Department of Commerce, there has been in the past 35 years, in the United States, an increase of 20% in the population, while office and clerical employees have increased 100%! Materials management clerical personnel have contributed significantly to this 100%. Not an impressive record of administrative productivity! The good record of the factory is due chiefly to more and improved mechanization of more jobs. This then is the challenge for all of us concerned with production scheduling and materials management. Just as the shops have learned to process more materials into more and better products in less time and with less effort -- so the production office can process more manufacturing data into more accurate production schedules in less time and with less effort.

PRACTICES

PRELUDE

PROBLEMS

CHAPTER VI HOW TO SIZE UP YOUR SCHEDULING PROBLEMS



We have often heard someone say, "Don't tell me your problems, I've got enough of my own!" Sometimes we become so engrossed in day-to-day headaches of materials management we think that our particular problems are unique among all the manufacturing departments of General Electric! Why not look at the other side of the picture -- what do we have in common -- what problems do we share? Basically --

- Getting the right products out the back door on time!
- Keeping inventories turning over!
- Getting part PDQ 8080 up to assembly right away, before the line shuts down!
- Keeping the cost of running the production section within the budget!

This may not be the precise way of stating your particular production problems, but you get the idea. Let's discuss how some departments meet these problems. Then if you find something in common with another department, you might find a way to help each other -- a sort of mutual aid society for better production scheduling. It is for this reason that case studies describing production scheduling at a variety of General Electric product departments are included in Chapter VII.

What are the basic patterns of materials management situations which determine the kind of scheduling problems faced? The discussion of this question will be divided into three parts:

- Master Scheduling
- Materials Scheduling
- Manufacturing Scheduling

PATTERNS OF MASTER SCHEDULING PROBLEMS

The type of problems encountered in master scheduling will depend upon the nature of the business. Are the products:

1. Custom designed.
2. Standard components assembled to make a large mix of finished products.
3. Standard components assembled to make a small mix of finished products.

CUSTOM DESIGNED

When products are custom designed, the master schedule is determined solely by the number of customers' orders or proposition commitments on hand. These orders are firm. But in our master schedule, we must allow time for design engineering work, in addition to the time for materials procurement and manufacturing. When completed, the finished product is shipped directly to the user. The key factor, therefore, is that no finished goods are warehoused, and the master production schedule is always the same as the backlog of firm customers' orders.

STANDARD COMPONENTS Assembled to Make a Large Mix of Finished Products

When standard sub-assembly components are assembled in many different combinations, very likely there is a large mix of finished products. Some of these may be quite popular sellers; others may be sold only once in a blue moon. So in determining our master production schedule, we may decide to produce some of the "popular types" for warehouse stocks, while others are produced only when customers place orders. On the other hand, the master schedule may be comprised only of firm customers' orders; it may be too risky or too costly to produce even one type for finished stock. Generally, the important distinction is that some component parts have been previously fabricated in anticipation of orders. Since product design work is virtually complete and standardized, the master schedule need not include consideration of time required for engineering or standard parts procurement.

STANDARD COMPONENTS Assembled to Make a Small Mix of Finished Products

When the factory produces a product of standard design in a small mix, all finished products are usually assembled and shipped to various warehouse stocks for further distribution to the customers. Because of design standardization, there is less risk in producing before the actual sale to the ultimate customer; therefore stocks of finished goods can be kept in nearly all the marketing areas. Based on past experience we can usually measure accurately the amount of risk involved.

There are lots of implications to this classification of master scheduling problems.

As we consider these concepts in sequence, we see:

- An increasing volume of sales for each design of the finished product.
- A decreasing variety or number of types of products manufactured and sold.
- An increasing stability of product mix. In other words, we find that there is more and more assurance that the entire mix of products will be sold during each scheduling period.
- An increasing necessity for controlling finished goods inventories.

PATTERNS OF MATERIALS SCHEDULING PROBLEMS

Materials schedules, of course, tell us when and how much to buy of each purchased item. Recalling the "ABC" principles of inventory control, we know that, "A" items are generally purchased only as needed, "B" items every so often, and "C" items even less frequently. So, the type of materials scheduling problems will depend upon whether items are procured:

1. to scheduled (real, immediate) needs in manufacturing.
2. to stock in anticipation of future factory requirements.

Very likely, if the "ABC" principles are being properly executed, the materials schedule will always include some "rate items" and some "stock items".

PATTERNS OF MANUFACTURING SCHEDULING PROBLEMS

Scheduling the activities of the various sections or units producing parts or subassemblies for our product brings us to the consideration of the arrangement of manufacturing facilities. The physical layout of the factory floor has a lot to do with the kind of scheduling problems you will have to solve. There are essentially only two basic classifications of work station arrangement, but even within a single factory both types are usually found. The equipment for a parts manufacturing section might be arranged one way and the product assembly stations another. To describe these two arrangements the following terms are frequently used:

- Job Shop
- Flow Shop

JOB SHOP

Machines are arranged essentially according to their particular kind of processing function. For example, all punch-presses are placed together in one area, all screw machines are placed in another, all milling machines in a third, and so forth. Relatively little consideration is given to the flow of individual items. Machines are usually general purpose and, in the course of a week, a single machine might be tooled up many times to produce many different products. Perhaps the simplest example of the job shop arrangement is in a home workshop where there is a drill press, a circular saw, and a wood lathe. Since the "products" made may consist of anything from a birdhouse to a picnic table, very little consideration can be given to the flow of individual products.

WHY DO WE HAVE JOB SHOPS?

One of the most common errors made in talking about America's great productive capacity, is to picture all American factories as automobile assembly plants -- products pouring out the back door in one great stream. Nothing could be further from the truth. In fact, those plants arranged as job shops greatly outnumber the others.

There are two principal reasons for having job shops:

- Where each product must be designed and made entirely to the customers' specifications, the methods of manufacture will change from one product to the next. Hence, we must use machines which can be tooled for any kind of job; frequently there is little or no fixed pattern to the sequence of operations performed.

- Where the volume of production is not high enough, it may be uneconomical to assign a work station to make only one part. Take a small punch press, for example. If 6000 of a certain part were required per week and these pieces could be banged out in one hour, wouldn't it be a waste to leave this press idle for 39 hours per week!

FLOW SHOP

The other extreme in the arrangement of work stations, is the flow shop. It is sometimes called streamlined, mass production, continuous, or product-line type of manufacturing layout. With this arrangement, the machines and assembly work stations are carefully selected to do only one operation. The manufacturing engineer determines how the product will be machined or assembled; he then designs a production line with the necessary work stations to produce the desired volume of products with a smooth uninterrupted flow of materials. It's almost like the hydraulic engineer who designs the city water supply system by specifying a certain diameter of pipeline to deliver the water from the reservoir. Obviously, for the production line flow of materials, the sequence of operations to be done and the rated capacity of each work station must be studied in minute detail. Extensive analyses are required to insure balanced flow. In the automobile business, the transmission, body stampings, engines, chassis -- virtually all the basic standard components of the car -- are produced and assembled on a product-flow basis.

There has been a lot of discussion about the automatic factory, the push button factory, lately. This is really the ultimate in product-flow manufacturing. The chemical and oil industries have been operating "automatic factories" for years. But in manufacturing, where products have to be cast, molded, machined, etc., the problem is much more complex. You can pump a liquid from one tank to another through a pipe, but pumping refrigerator motors is a little more difficult! But if your product or any of its parts are being manufactured in large quantities, if the basic method of manufacture and assembly are quite free from "bugs", then you might seriously consider rearranging your facilities for product-flow. To do so is to rid yourself of a raft of production scheduling headaches.

It's not appropriate to discuss the pros and cons of the two types of manufacturing arrangements at this time. Each has its own advantages and disadvantages. Our purpose in mentioning them is to provide some basis for describing the manufacturing scheduling problems which seem to fall within each type. Now let's compare some of the characteristic production scheduling problems in the job shop and flow shop arrangements.

COMPARISON OF JOB SHOP AND FLOW SHOP SCHEDULING PROBLEMS

IN THE JOB SHOP

1. The over-all cycle from receipt of an order to final delivery may be quite lengthy as in the case of custom designed products. In fact, it is sometimes necessary to schedule product engineering (design, specifications, drafting) as well as planning, procurement, and manufacturing.

2. Precise processing instructions for material routing through each operation are required.

3. Relatively complete scheduling of each operation is needed.

4. Efficient machine and utilization set up reduction necessitate consolidation of orders for similar parts.

5. Because of the large variety of parts and operations it is often difficult to make a detailed load versus capacity evaluation. It is not sufficient to speak of 6,000 units per week capacity for a section; measurements must be in terms of some common denominator such as hours or labor dollars for each work area.

6. As the product mix changes, the limiting operations are continuously shifting. This, of course, magnifies the difficulty of scheduling without adequate load analysis.

7. Since feedback information is difficult to obtain, it's hard to know when trouble has occurred.

IN THE FLOW SHOP

1. Much of the manufacturing scheduling job is done in the preplanning phase. This highlights the importance of materials personnel being tied in with the original layout of the production line.

2. We have mentioned the analogy of the water pipe in describing product flow manufacturing. If there are no rough spots on the inside of the pipe, the water flows smoothly. All we have to worry about is keeping the pipe full. It's the same way in flow shop manufacturing. Because we have designed our production lines to feed smoothly into the main assembly line, all component units are well balanced. The work is done as the product moves past each station, and we know products will flow out in the order in which materials are put into the system.

3. Deviations from schedule are much more critical as they can cause line shutdowns which destroy in hours, months of scheduling effort.

4. The need for leveling is emphasized by the relative inflexibility of a production line which makes it difficult to change operating rates.

ONE KEY TO MANUFACTURING SCHEDULING

In all the departments of General Electric, there are very few whose manufacturing units are all "job shops", or all "flow shops". Assembly work is frequently manual and requires comparatively few machines; here it is often easier and more economical to arrange the work stations in order of the sequence of operations on the product being assembled. Hence, assembly work is more often done on a product flow basis than machining work. The key to the problem is that a manufacturing schedule must be "tailored" to suit the needs of each activity. At the same time, all manufacturing schedules must be tied directly to the master schedule.

SUMMARY

It's profitable to "take a look at what the other fellow is doing" in production scheduling. There are patterns to the problems. Classification of these problems is possible:

Master Scheduling

1. Are products completely custom designed, or is all production strictly for orders already on the books ?

2. Are products assembled in large mix, some types shipped to warehouse stock, others produced strictly for booked orders ?

3. Are products of standard design, small mix where all production is to replenish finished warehouse stocks ?

Materials Scheduling

1. Are most materials purchased in quantities needed to fill customer requirements only.

2. Are most materials purchased for stock replenishment.

Manufacturing Scheduling

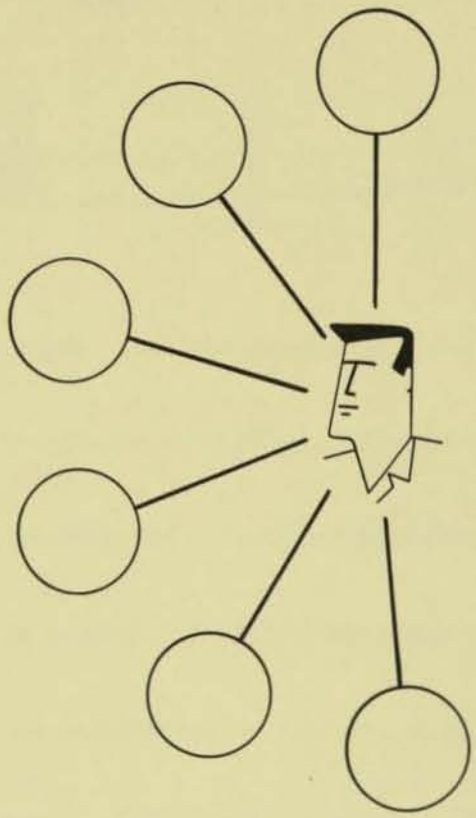
1. Are the machines in a job shop arrangement?

2. Are the machines placed for product flow?

PRACTICES

PRELUDE

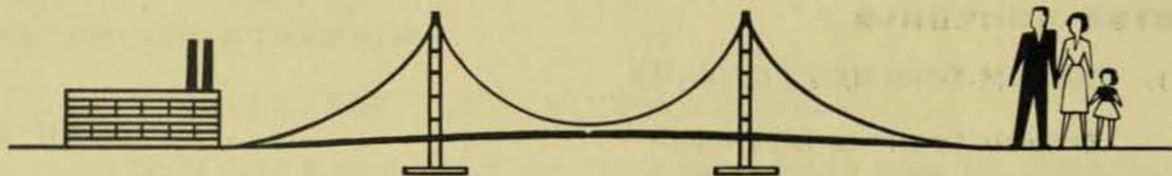
PROBLEMS



PART THREE

Some selected case studies illustrating Current Practices

CHAPTER VII ABOUT THESE CASES



This chapter consists of a series of cases which illustrate how various operating departments of the General Electric Company are meeting their scheduling problems. These cases were selected not only because they are examples of good scheduling practice, but also to describe certain basic patterns of materials management situations. Naturally, not all departments of General Electric share identical problems, but there are definite patterns of similarity in many of them.

The write-ups of these cases are, of necessity, short -- just enough to give you the main facts. Those who wish to look further into some of these examples may contact the departments directly or obtain assistance from the Production Control Services Section.

A special case index, prepared in accordance with the scheduling framework developed in Chapter VI, has been included to assist you in locating cases dealing with specific phases of the scheduling problem which parallel your own operations.

INDEX TO CASE STUDIES

MASTER SCHEDULE

MATERIALS SCHEDULE

SCHEDULED NEEDS AND ANTICIPATED NEEDS

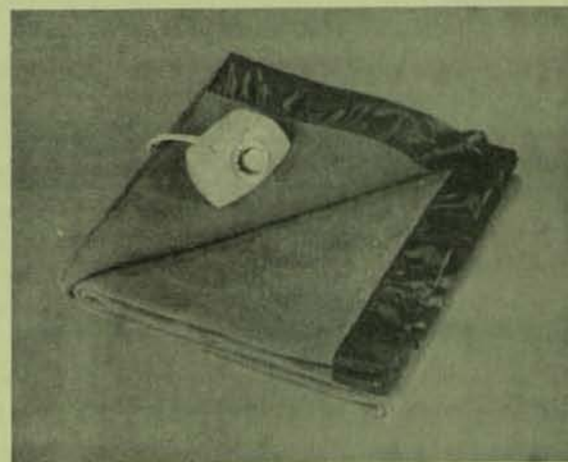
Cases have been included here under one category since the distinction between "scheduled" and "anticipated" needs most often depends on the quantity and nature of the components themselves rather than the "nature" of the product department's business.

PRELUDE PROBLEMS PROVOCATIVE

MANUFACTURING SCHEDULE

AUTOMATIC BLANKET DEPARTMENT

ASHEBORO, NORTH CAROLINA



SCHEDULING IN BRIEF

MASTER SCHEDULE

KEY FACTORS - - - -

. Volume: 400,000 blankets per year.

. Small Mix: 6 colors, 3 models.

. Highly seasonal market.

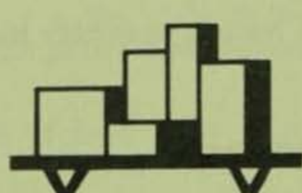
. Blankets are manufactured for factory warehouse stocks.

HOW IT'S DETERMINED - - - -

. Market forecast covers entire calendar year.

. Manager - Materials sets the master schedule for the year, broken down by quarters and months. The 12 month Master Schedule is leveled at a uniform output rate per week. This gives a planned leveled production rate to be held for the year.

MATERIALS SCHEDULE



KEY FACTORS - - - -

. 315 different vendor items purchased, mostly for stock.

. Strict application of ABC principles of inventory control - aggregate annual turnover = 20.

. Deliveries of blanketing - - the big "A" items are received daily by truck - two (2) to three (3) days' supply may be on hand at the factory.

HOW IT'S DETERMINED - - - -

- Quarterly schedule exploded into detail procurement requirements is given to Purchasing 3 months in advance.
- Blanket mill given quarterly requirements to facilitate scheduling of coloring and cutting runs.
- Stock records kept according to inventory turnover bogeys.

"A" items - 1 week stock balance at current usage.
"B" items - 2 weeks stock balance at current usage.
"C" items - 8 weeks stock balance at current usage.

MANUFACTURING SCHEDULE

KEY FACTORS - - - -

- Single story factory building.
- Chiefly assembly work on two parallel product flow lines:

  Assembly of wire into blanket - 2 hrs/unit
  Assembly of blanket controls - 2 hrs/unit

- Light punch press work on parts for controls - a job shop arrangement.

HOW IT'S DETERMINED - - - -

- Quarterly requirements of the master schedule are sub-divided into months, and the months into weekly requirements.
- Weekly mix for final assembly then released to manufacturing.
- Punch press unit is issued a schedule of monthly requirements of individual parts.
- The heating wire is produced from a schedule of average weekly usage over the next four months' period.
- Molded parts are scheduled weekly - geared to the "control assembly line."

OUTSTANDING FEATURES

* Twice a week teletype summaries of latest sales data facilitate better control of finished warehouse stocks at the factory. In turn, these data provide better control of the weekly schedule of product mix in the assembly units.

* Leveled production schedule provides for stabilized employment. Interim fluctuations in workload are easily handled because employees are trained to do several jobs. Labor productivity is closely controlled.

* Simplified feedback communication system, enables close control of assembly progress. Daily counts are made by the following:

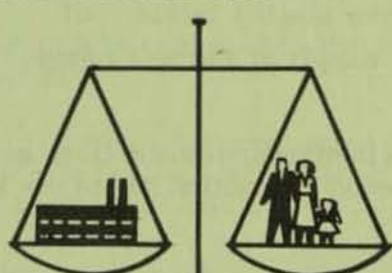
  Cutters at the beginning of the blanket assembly line.
  Packers at the end of the assembly line.
  Finished stock tally man.

* The forecast for the year enables better materials scheduling and procurement - - better prices on blanketing can be obtained through longer term contracts.

* Daily receipts of blanketing via special truck, supplies enough to fill daily assembly needs. The supply of blanketing at the factory rarely exceeds three days' usage. This means high turnover, little chance for soiling the blankets - - costs are down.

FULL DRESS VERSION

MASTER SCHEDULE



EXAMINE Market Demand - - - -

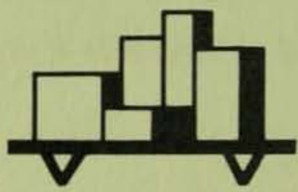
A yearly forecast is developed by the Marketing Section as to the total quantities and models of blankets required to satisfy customers' demands. From this forecast the Manager - Materials establishes his yearly Master Schedule on a quarterly basis by months. This Master Schedule is a reflection of the sales estimates. Mixes of colors are changed frequently, therefore the schedule must be somewhat flexible. To get a more realistic forecast of anticipated demands for various colors, an outside consultant is employed to survey customers' choices. The percentage figures of color choice are reviewed by the Manager - Materials and compared with historical records to establish trends of color preference. The purpose of this long-range scheduling is to enable better materials procurement. Wool blanket prices are subject to variations. With knowledge of long-range requirements, better vendor price agreements are possible.

A quarterly schedule is issued to the Production units each month three months prior to the start of the quarter. This may reflect changes in market demand and shows the production necessary to meet these changing conditions.

FEEDBACK of Sales Data - - - -

Twice weekly teletype information as to orders received from distributors is available to Production. This gives an up-to-date picture of the sales of various models and colors. With this late data on changes in the forecasted mix, production can modify the schedule to keep up with the required demands. This also helps to maintain a better control over the level of inventory in the warehouse.

MATERIALS SCHEDULE



DETERMINE Materials Requirements - - - -

Each production unit manually makes an explosion of the quarterly schedule, received from the Manager-Materials. Requirements are checked against stock record cards containing data on current stock balances, orders outstanding, and current usage rates.

USE The ABC's of Inventory Control - - - -

All Vendor materials are classified according to the ABC principles. For purposes of controlling stock levels scheduled quantities are limited:

"A" Items - a limit of one (1) week's supply at current usage. These are "Rate items".

"B" Items - a limit of two (2) weeks' supply at current usage. These are also "Rate items".

"C" Items - a limit of eight (8) weeks' supply at current usage. These are "Stock items".

Monthly reports of actual stock balances in standard cost dollars and "bogey" balances in standard cost dollars are submitted by each production unit to the Manager - Materials.

Bogey balances = \$ standard cost/unit x Allowed number of units in stock, according to ABC limiting quantities, described above.

This report shows the performance of each production unit with respect to its ability to control material inventories.

Blanket materials are scheduled quarterly as to quantity, size and color, for daily delivery. With a three-month advance notice, the blanket supplier can make economic runs in his weaving and dyeing facilities. On the other hand, the daily receipt of blanketing materials means high turnover and small chance for soiling. Daily, the truck backs up to the assembly line and feeds a day's supply of blanket material. A maximum of two (2) or three (3) days' supply of blanketing is carried at the factory.

MANUFACTURING SCHEDULE

The manufacturing function consists of making components such as heating wire, punch press parts, molded parts, and cord sets. Sub-assemblies and final assemblies for blankets and controls are made on two (2) separate parallel product flow lines.

TRANSMIT Assembly Mix to Manufacturing - - - -

Production uses the quarterly schedule to determine weekly rates. The blanket assembly foreman is then notified as to the quantity, style, and color he is to produce for that week. The sequence of models and colors to be produced is specified by Production. The blanketing is received daily from the vendor and placed at the beginning of the assembly line. The shearing to size, assembly, inspection and packaging are performed on the assembly line and the completed blankets are sent to the warehouse.

A weekly schedule as to the quantity and mix of controls required is issued to the control foreman. The controls are assembled on a Product-Flow basis, packaged separately and delivered to the warehouse independent of the blanket assembly.

DETERMINE Component Requirements - - - -

The major components are the heating wire, molded parts, cord sets, and punch press parts for the control assembly.

The wire usage by weeks for the next four (4) months' period is issued to Manufacturing as authority to make. Small stocks of wire are maintained so as to make certain the assembly line is supplied as required.

The molded plastic parts are produced in the plant's own mold room. A weekly schedule is issued to the foreman and production is geared very closely to the assembly line.

Many of the component parts of the controls are produced in the punch press unit which is issued a schedule of monthly requirements of each individual item that must be produced. Small reserve stocks of component parts are maintained.

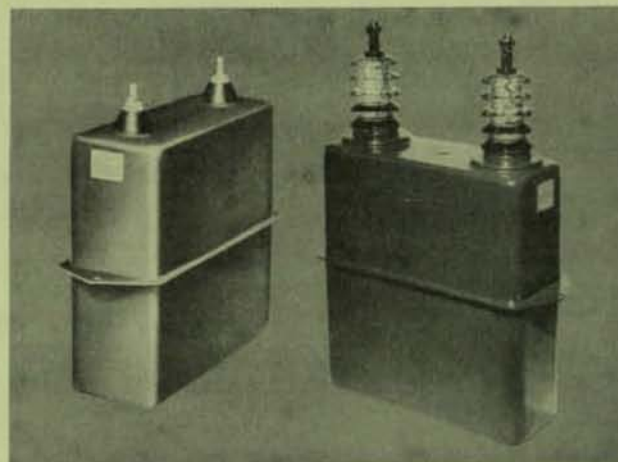
FEEDBACK Report of Performance - - - -

Cutters and inspectors at the beginning of the line maintain a starting count for the day. Another count is made by the packers at the end of the line. A final count is made by the tallyman in the warehouse when packed blankets are received via conveyor belts. This count is the quantity actually ready for shipment and is sent daily to the Manager - Materials for inventory purposes.

CAPACITOR DEPARTMENT

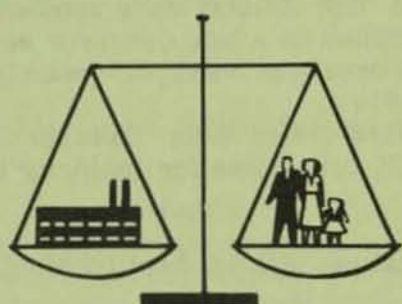
LARGE CAPACITOR MANUFACTURING

HUDSON FALLS, NEW YORK



SCHEDULING IN BRIEF

MASTER SCHEDULE



KEY FACTORS - - - -

- 2000 units produced per week.
- 5 major classes composed of 1000 variations.
- Finished products are of great variety but consist largely of standard components.
- 50% of output for warehouse stocks at factory and in districts.
- 50% of output sold direct to customer.

HOW IT'S DETERMINED - - - -

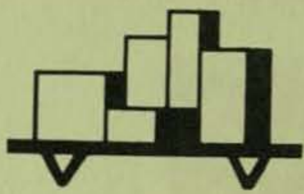
- Market forecast is issued quarterly based on:

  1. A projection of finished warehouse stock requirements to meet forecasted sales.
  2. A forecast of customers' orders for non-stocked items.

- A proposed Master Schedule by weeks, for the next six (6) weeks, is issued to Manufacturing.

PRELUDE
PROBLEMS
PROVOCATIVE

MATERIALS SCHEDULE



KEY FACTORS - - - -

- Most items purchased.
- Variation of ABC principles of Inventory Control used - materials divided into two (2) groups, A & B.
- Few in-process stocks carried - mainly for accumulation.

HOW IT'S DETERMINED - - - -

- Material breakdown of six (6) weeks' requirements made by punched card setup.
- Materials are purchased to anticipated needs (stock inventories).

MANUFACTURING SCHEDULE

KEY FACTORS - - - -

- 3 story building.
- About 85% of total units produced are assembled on a belt conveyor serviced by an overhead conveyor - mainly Product-Flow.
  Standard times quite uniform for assembly operations for majority of output.
- Other manufacturing - light press work, surface treating, plating, heat treating, etc. - a Job Shop arrangement.

HOW IT'S DETERMINED - - - -

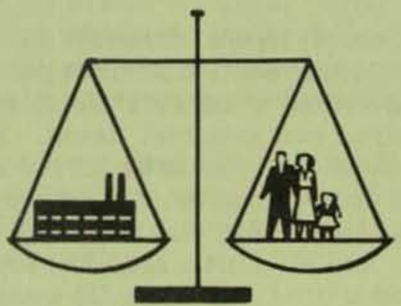
- Production dispatches a daily load to each component line and the assembly line. This controls input to and output from final assembly conveyor.

OUTSTANDING FEATURES

* Production through central dispatching details sequence of work to be performed by a daily schedule. Through central dispatching the unnecessary accumulation of in-process inventories is prevented.
* Punched card setup used in exploding material lists.
* Manufacturing is issued information as to the labor dollars necessary to produce the proposed six (6) weeks' output. They are given the opportunity at this time to examine labor and facilities and to make any changes that may be required.
* A two (2) weeks' period is kept "fixed" as much as possible during which time the factory loading is not altered.

FULL DRESS VERSION

MASTER SCHEDULE



EXAMINE Market Forecast - - - -

The Marketing Section prepares a quarterly forecast as to the quantities of items that will be needed to satisfy customer requirements. This is submitted to Production a few weeks before the beginning of the quarter. Marketing gathers this information from stock status reports from the district warehouses and an analysis of business conditions. The finished products manufactured for the district warehouses account for about 50% of the volume of output. The other 50% is accounted for in sales direct to the customer. These forecasts are reviewed periodically and revised up or down as business conditions change. Each district warehouse has a definite maximum and minimum level of inventory for each item, depending on its anticipated sales. Finished products are stored at the factory and shipped to the warehouses when warehouse stocks reach a certain minimum.

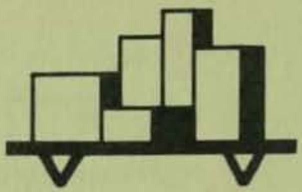
CONSOLIDATE Requirements - - - -

Production uses the market forecast together with the consolidation of customer requisitions to prepare factory loading by quantities of the various models and types of finished products. The capacity of the shop as to total quantity of finished products that can be produced is known. At present the shop is averaging an output of 2000 units per week. When the shop is being loaded certain mix restrictions are recognized. The quantities of some types of units must be balanced correctly with the rest of the mix so that no bottlenecks will occur in the sequence of operations.

Once a month, Production notifies the Manufacturing Superintendent of the proposed final assembly schedule. This schedule is for the next six (6) weeks' period and is divided into weekly production by classes and types of units. Allowances are made in these quantities for incoming orders which are anticipated at a later date. The labor load imposed by the proposed schedule is also submitted to Manufacturing so that any changes that might be necessary can be made before the scheduled starting dates. If Manufacturing feels that the schedule can be met, then it is returned to the Production supervisor for release. After the schedule has been released, Production attempts to have a two (2) weeks' period during which no changes in the load are to be made. This period is used for two reasons: (1) The manufacturing cycle averages close to two weeks. (2) This period of time is necessary before any shifting, hiring, or lay-off of employees can be accomplished effectively.

Copies of this schedule are sent to the foremen so that they may evaluate the detailed labor and facilities required.

MATERIALS SCHEDULE



DETERMINE Material Requirements - -

The six (6) weeks' forecast is submitted to the order section where a punched card setup makes a material breakdown of the required raw material items. From this breakdown the requirements are checked with the stock records to be sure that all material will be available. The purchased items are divided into two (2) groups, "A" and "B" (this being a variation of the "ABC" principles of inventory control). The "A" items which consist mainly of the outside cases, paper, and aluminum foil, are ordered to a predetermined order point and order quantity so that a two (2) to three (3) weeks' supply is always on hand in reserve. These "A" items account for about 80% of the material cost. The "B" items, being the other 20% of material cost, are ordered less frequently and the supply varies upward from a six (6) weeks' supply.

MANUFACTURING SCHEDULE

TRANSMIT Daily Mix to Manufacturing -

A daily schedule is developed by Production five (5) days prior to the scheduled date. This is determined from the six (6) weeks loading that was released. At the time this daily schedule is prepared another check on available material is made to be sure that all necessary vendor-finished materials are or will be available.

A central dispatching procedure is set up to meet these daily schedule requirements. The schedule shows the quantity of finished units to be off the assembly line at the end of the shift on the scheduled date. The various sequence of types and models will be determined by the Central dispatcher. There are two main components that must be considered: (1) the covers and (2) the windings. The covers must be started a certain number of days before the assembly schedule date. This component may require punch press work for special features and/or plating as well as the assembly of glass or porcelain resistors. The windings must in turn be started a predetermined time before the scheduled assembly date. This component consists of the winding of paper and foil into "rolls" of the required size.

The dispatching units are responsible for the required material being available at the work stations at the proper time. This is coordinated by the central dispatcher who also schedules the movement of components into the assembly area. The central dispatcher receives feedback information from all areas so he knows immediately if any bottlenecks are developing. By this rapid relay of information all areas including assembly can be adjusted accordingly. Various other components such as insulation and hardware are accumulated to go on an overhead conveyor which leads to the assembly area. All component parts except the windings are set on trays on the overhead conveyor at a predetermined time so as to be at the assembly area as scheduled. The windings are set on moveable carts and rolled to the assembly area. All parts are then placed on a belt conveyor where operators perform the few assembly operations.

FEEDBACK Information on Finished Items - - - -

After the assembly is completed, the number of completed items is reported daily to the Production office. At this time a treating operation is performed which takes two (2) to four (4) days. After treating, the units are tested, painted and packed for delivery either to factory storage awaiting requests from the district warehouses, or direct to shipping to fill a customer's order. The quantity of items through "paint and pack" is also sent to Production for record purposes.

A constant check is made by Production and Marketing of the movement of items to the district warehouses. If the warehouses are not ordering as was anticipated, or a greater quantity is being called for, the reasons must be determined and schedules adjusted accordingly.

Reports of defective items are made weekly with the exception of electrical test rejects which are reported daily.

CHEMICAL MATERIALS DEPARTMENT

PAINT MANUFACTURING SUB-SECTION

SCHENECTADY, NEW YORK

SCHEDULING IN BRIEF

MASTER SCHEDULE

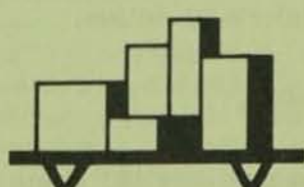
KEY FACTORS - - - -

- 360 catalog numbers of paints.
- Up to 40, 000 gallons can be produced per week.
- Paints are produced and shipped to customers' orders.

HOW IT'S DETERMINED - - - -

- Weekly consolidation of customers' orders.

MATERIALS SCHEDULE



KEY FACTORS - - - -

- 400 purchased raw materials.
- ABC principles of Inventory Control used.
- Materials purchased to anticipated needs (stock inventories carried).

HOW IT'S DETERMINED - - - -

- Raw material records posted by IBM unit.
- Predetermined minimum quantity tells when to check for reordering.

PRELUDE
PROBLEMS
PROVOCATIVE

MANUFACTURING SCHEDULE

KEY FACTORS - - - -

. Primarily "Batch Control".

. Three story building.

. 40 mills of three types for paint manufacturing.

. One operation process - produced in mills in cycles of 24 or 36 hours.

HOW IT'S DETERMINED - - - -

. Paint Schedule Board shows when and where paints are to be produced.

. Schedule Sheet issued weekly to shop showing:

1. Catalog numbers to be produced
2. The mills to be used

OUTSTANDING FEATURES

* The use of the Paint Schedule Board - a Visual Aid to scheduling, enabling fast interpretation of the paint shop load, easy to maintain. Every change in the shop is reflected daily on the Paint Schedule Board by means of an effective method of feedback.

* Each foreman has a Performance Chart which indicates the status of all orders in process. This enables him to take quick, accurate follow-up action.

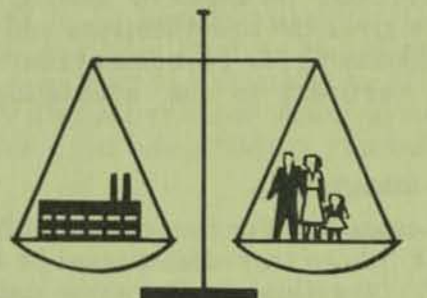
* A physical inventory of all A-items is taken once a week.

* Effective controls of materials inventories. Even though only 400 items of raw materials are involved, a punched card system enables more rapid stock status reports so that:

  It is possible to reduce transportation costs by ordering in full truckload shipments from each vendor. Inventory turnover is averaging 29, while customers' orders are rarely, if ever, delayed because of lack of raw materials. Close surveillance of stock control points -- maximum and minimum quantities - is maintained.

FULL DRESS VERSION

MASTER SCHEDULE

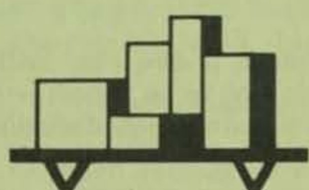


EXAMINE Incoming Orders - - - -

Orders are sent to Production Scheduling by the Customer Service group. These contain the order number, date written, catalog number identifying the items on order, quantity, requested delivery date, and packaging instructions.

The scheduling clerk examines all orders when received in order to catch any rush items or extra large orders requiring scheduling in advance so that the delivery date can be met. Items ordered for shipment within the following 2 1/2 weeks are consolidated once a week. Orders which bear the same catalog number are grouped and quantities are totaled.

MATERIALS SCHEDULE



DETERMINE Raw Material Requirements

From information received from the Marketing Section, Purchasing is able to make long-range plans concerning the purchase of some of its raw materials. "A" items (the ABC system of inventory control is used) are contracted for future delivery released only by firm orders from Production in quantities actually required by the current schedule. Vendors are contacted concerning future purchases of "B" items but no firm contracts are made.

So that material will be available at the time the order is scheduled into the shop, the material clerk prepares a breakdown list when the customer's order is received. This list includes the catalog numbers and other pertinent information for paints to be processed within the next 2 1/2 weeks. This list is sent to an IBM tabulating unit where a reserve deck from a master deck is key punched for the purpose of reserving (or "mortgaging") raw materials for the scheduled orders. The material reservation is posted to a stock card which also indicates the balance on hand. When a predetermined minimum is recorded, the card is forwarded to the Production group for reordering. Items are examined carefully, considering amount on order and both previous usage and anticipated usage before placing an order for an economical quantity. The order cards contain all information such as vendors and prices for various ordering quantities. Usually once a month all order cards for items purchased from a particular vendor are checked so that economical shipments, such as full truckloads, can be realized.

All "A" items are checked very closely and a physical inventory of these items is taken once a week. A visual chart is used to show the status of all "A" items as to: amount on hand; amount on order, and amount "mortgaged" for manufacturing orders.

MANUFACTURING SCHEDULE

DETERMINE Facilities Required - - - -

The clerk, after consolidating the incoming orders, refers to a book of Engineering Instructions arranged by catalog number which gives the specifications and method of processing for each item ordered. The data pertinent to the scheduling clerk are:

1. Type of mill (rolling, pebble, chrome-manganese).
2. Ratio of standard batch output to mill capacity. For example, 150:200- in a 200 gallon mill only 150 gallons of paint, whose ingredients must be in proper proportions, can be processed. If 170 gallons of the same paint were processed in the 200 gallon mill, the mill base of the paint would not be satisfactorily ground and, therefore, the paint would fail to meet Engineering Specifications.
3. Color.
4. Number of hours to grind - either 24 hours or 36 hours per batch. The type of equipment having been specified, the clerk must then decide what capacity mill or mills to use. The objective is to use that size mill or mills which will produce the order by using the fewest mills. The choice of capacity may be limited because a certain type of mill specified in the instructions may be available in only one or two sizes.

REFER To Present Load Conditions - - - -

The present load on the shop must be examined to see what mills are available during the week in which the manufacturing orders are to be scheduled. The up-to-date Manufacturing Schedule is in the form of a Paint Schedule Board which takes up the space of one wall in the Production Office.

WEEK ENDING 1-16 PAINT SCHEDULE BOARD						
MILL NO.	GALS. TYPE	MON. 1 2 3	TUES. 1 2 3	WED. 1 2 3	THURS. 1 2 3	FRI. 1 2 3
1	200 PM	1 A50 120 5 GALS.		1 A51 120 5 GALS.		A52 120 5 GALS.
2	200 PM		2 A12 150 5		2 A13 150 5 GALS.	
3	200 PM	3 A64 140 DRUMS		3 A65 140 GALS.		3 A63 140 DRUMS
4	200 PM	4 A24 180 QTS.			4 A25 180 QTS.	
5	200 PM					
6	200 PM	6 A17 210 DRUM		6 A15 100 5 GALS.		
7	200 PM	7 A4 75 GALS.			7 A42 160 DR.	

This shows the present load on the shop, reflecting all open orders. The Paint Schedule Board has the "capacity" and "type" of mill listed in the left hand column. The remainder of the board is divided into days which are listed across the top. If mills of the desired capacity aren't available during the scheduled week, the order may have to be broken into several batches and smaller capacity mills selected. Or, the order may have to be scheduled earlier or later in mills having the desired capacity. Choice may also be influenced by the color of paints previously processed in the mill. A totally dissimilar color would necessitate the washing and rinsing of the mill. Scheduling with color compatibility in mind increases machine productivity.

RELATE To Master Schedule - - - -

After selecting the mill the clerk prepares schedule tickets (colored strips 3" x 1-1/4" - the color denoting the color of paint) on which the scheduling information is written. These tickets are inserted on the Paint Schedule Board. By looking at the Schedule Board the schedule clerk easily avoids the possibility of scheduling incompatible paints in a mill without first considering the time for washing and rinsing the mill. The length of one ticket extends across the period of one day. Only one ticket is inserted in the Board for each batch regardless of the hours that the batch is scheduled to be normally processed.

TRANSMIT Schedule to Shop - - - -

The information on the Paint Schedule Board is transferred to a Paint Schedule Sheet which is prepared the Friday before the scheduled week. It reflects a realistic loading for the coming week, based upon the status of orders in process at the time the schedule is drawn up. The numbers of the mills are listed across the top of the schedule and the days of the one week period for which the breakdown list has been prepared are listed in the left column. The schedule clerk also prepares a "Batch Card" which is preprinted for each catalog item. Information is printed on these cards from the Engineering Instructions.

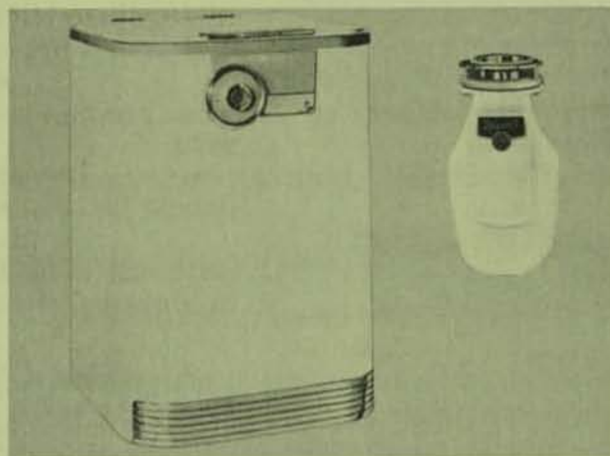
The Paint Schedule Sheet and the Batch Cards are taken to the foreman early Monday morning of the scheduled week. The Batch Cards accompany the work-in-process for purposes of identification.

FEEDBACK Information on Actual Progress - - - -

A Paint Mill Performance Chart is posted on a board in the foreman's office. This chart indicates the status of all orders in process with symbols designating loading times, grind times, miss grinds, mix-off time, and emptying time. From the status of orders reflected on this chart the foreman prepares, late every afternoon, a Mill Loading Schedule. This schedule indicates available mills, status at 4:00 p.m., wash or rinse mills, catalog and batch numbers plus other information concerning orders to be processed or in process. From this foreman's schedule the schedule clerk in the production office gets the current status of batches in process and changes the paint schedule board accordingly.

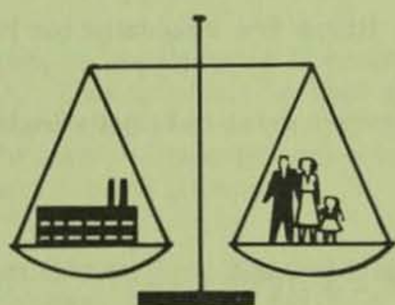
DISHWASHER AND DISPOSALL DEPARTMENT

LOUISVILLE, KENTUCKY



SCHEDULING IN BRIEF

MASTER SCHEDULE



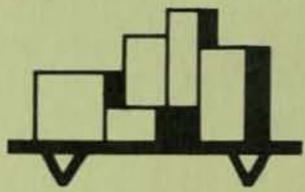
KEY FACTORS - - - -

- Product Mix: 3 Types of Dishwashers:
  - SE - Integral Unit with sink.
  - SU - Installed beneath counter surface in Kitchen.
  - SP - Portable, mounted on wheels.
- High Potential Market - only 3% of all electrified homes are equipped with electric dishwashers.
- Finished warehouse stocks carried at many points - at factory, at Company-owned and independently-owned district distributors, as well as in the retailers' stores.
- Demand is not noticeably seasonal, although new home construction rates correlate closely with the sales of type SU dishwashers.
- Volume - Close to 100, 000 per year.

HOW IT'S DETERMINED - - - -

- Market forecast is predicted on a projection of finished stock levels required to sustain estimated future sales requirements.
- The forecast covers a fiscal quarterly period, issued two calendar months in advance of the beginning of each quarter, and is broken down by months.
- The levels of finished stocks carried at the factory warehouse are set by joint decision of Managers of Finance, Manufacturing, Marketing, and the General Manager.
- Master Scheduling consists largely of establishing maximum assembly runs of each type of dishwasher; quantities scheduled in the runs are limited to monthly totals specified by the market forecast.

MATERIALS SCHEDULE



KEY FACTORS - - - -

- Approximately 200 raw and fabricated material items are vendor furnished.
- ABC principles of inventory control used.
- Annual InventoryTurnover = 13.
- No stock records kept of withdrawals or stock balances.

HOW THEY'RE DETERMINED - - - -

- One week's supply of "A" Fabricated vendor items are scheduled for receipt one week ahead of usage in final assembly.
- Two (2) weeks' supply of "B" Fabricated vendor items are scheduled for receipt two weeks ahead of final assembly.
- One month's supply of "C" Fabricated vendor items are scheduled for receipt one month ahead of final assembly.
- Raw material items are scheduled in one-month quantities to be delivered one month prior to the first manufacturing operation.

MANUFACTURING SCHEDULE

KEY FACTORS - - - -

- Single story factory building.
- Approximately 250 different component parts are manufactured.
- Product-flow layout; much of the materials handling is conveyorized.
- "Miscellaneous parts machining" (small and medium punch press, standard dishwasher parts) is a job shop unit.
- Final assembly line normally operated for one shift, while machining units run two (2) shifts.
- Only two (2) dispatchers for entire manufacturing operation: one in "miscellaneous machining", the other in "assembly".
- Miscellaneous machining is being scheduled on the UNIVAC, and this will be explained in detail.
- Both individual and group incentive wage payment systems are used.

HOW IT'S DETERMINED - - - - - - -

- The following manufacturing units each receive schedules: Miscellaneous Machining, Sheet Metal, Wire Rack, and Wire Harness Shops.

- Each unit's schedule sheet specifies: part number, part description, quantity on hand, quantity to manufacture, and week in which to start manufacturing the part. Schedule sheets cover a fiscal quarter, as exploded from the master schedule.

- Each dispatcher executes his own schedule, expediting the flow of materials through his respective area.

OUTSTANDING FEATURES

* The procedure for scheduling the Miscellaneous Machining Unit has been completely mechanized on the UNIVAC - - the first manufacturing schedule to be set on the UNIVAC. There has been no basic change in the actual data used; the UNIVAC has been programmed solely to mechanize a "manual" procedure. Hence, there has been little difficulty in adapting to the new routine, and no sacrifice of the flexibility of the procedure. The resulting savings in time and effort, and the achievement of far greater accuracy and speed are substantial.

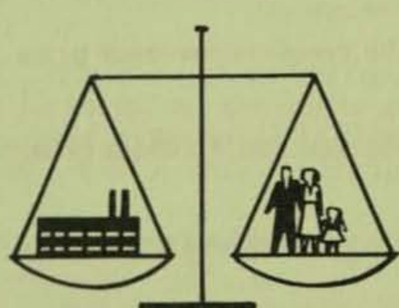
* The make or buy decision is constantly reviewed for all component parts of the dishwasher. Thus an effective cost reduction program is in progress -- which complicates the Production Control problems. Yet, the materials and products continue to flow through the factory with a minimum of delay, and with no excessive in-process inventory accumulation.

* The fact that only two dispatchers are required for the entire dishwasher manufacturing operation, indicates the inherent advantage of product-flow type layout, which greatly simplifies the Production Control problem.

* As part of the UNIVAC operation, a detailed Machine Load Report is prepared which serves as a guide in planning the manufacturing operations.

FULL DRESS VERSION

MASTER SCHEDULE



GET Market Forecast Well in Advance - -

The market forecast for the next fiscal quarter is received sixty days in advance of the start of the quarter. It is based upon the control by the marketing organization of the finished stocks at the factory and upon the status of stocks in district warehouses located all over the country. The forecast specifies the monthly quantities of each type of dishwasher to be delivered to the factory warehouse.

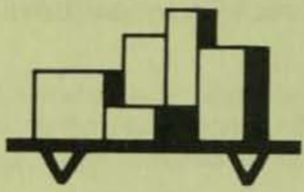
SCHEDULE the Product Mix - - - -

Each of the three types of dishwashers requires different amounts of assembly work, yet each type is made on the same conveyorized final assembly line. Consequently, in determining the Master Schedule, the production scheduler establishes assembly runs on each of the three types, so that the assembly line works on one type of dishwasher for as long as possible during a scheduled month. The quantity scheduled in any run is limited to the monthly totals as specified in the market forecast.

The labor load is stabilized insofar as practical, within the limits of the stability of the market forecast data, from one quarter to the next. The mix of the work is controlled by knowing the relative equivalent direct labor assembly hours per unit. For example, the deluxe model dishwasher requires 1.35 times the assembly manpower required by the medium priced model, while the inexpensive, portable model requires 0.87 times the assembly manpower required by the medium priced model. By using these data, the over-all labor requirements are determined, and leveling performed.

Since the quantities of the three types of dishwashers scheduled each month are explicitly set forth in the market forecast, the problem of establishing the Master Schedule is not an overly complex one.

MATERIALS SCHEDULE



USE the ABC Principles of Inventory Control - - - -

There are two hundred vendor-furnished material items in the dishwasher. Of course this number is constantly changing as make or buy decisions are reviewed. Each of these items is classified as "A", "B", or "C", as follows:

"A" Items - $ .50 or more
"B" Items - $ .10 -- .49
"C" Items - less than $.10

In terms of cost per finished dishwasher.

ESTABLISH Rules For Ordering Materials - - - -

According to the ABC materials classifications, procurement schedules are set according to the following rules:

"A" Items - Order one week's supply, to be received one week prior to use in final assembly.

"B" Items - Order two weeks' supply, to be received two weeks prior to use in final assembly.

"C" Items - Order one month's supply to be received one month prior to use in final assembly.

These rules apply chiefly to purchased-fabricated material items.

Generally, all vendors are notified once each year of the intention to consume a "Budgeted" quantity of materials. These notices do not constitute commitments, but rather, they serve to assist vendors in their planning. Monthly, or quarterly commitments are then made commensurate with requirements of the Master Schedule. These commitments take the form of brief memoranda, referring to the notice, in which all the detailed specifications of the purchasing contract are spelled out. As a result, a lot of paperwork in purchasing is eliminated.

Since Marketing does not issue the forecast until sixty days in advance of the execution of the schedule, and since some material items require more than sixty-days procurement time, separate information must be obtained from Marketing in order to schedule and purchase these items.

MANUFACTURING SCHEDULE

SCHEDULE Each Manufacturing Unit - -

The Master Schedule is exploded into manufacturing schedules for each of the following units:

Wire Harness - (Electrical circuit manufacturing)
Sheet Metal - (Cabinet, housings, tubs, etc.)
Wire Rack - (The dish and utensil holder)
Miscellaneous Machining - (Small parts, gears, etc.)

Final assembly is done in accordance with the Master Schedule.

Normally, the manufacturing units operate on two shifts, while the final assembly line operates one shift. All of the assembly areas, and most of the parts fabrication areas are arranged on a product-flow basis, except the miscellaneous machining unit, which is laid out as a job shop (by process, not product). Except for miscellaneous machining, many machines are set up to permanently perform one operation only, even though some are general purpose machines.

The schedule sheets cover the next fiscal quarter, broken down by weeks. These schedules specify the following information:

Part number and description (approximately 250 different parts involved).
Current inventory on hand.
Quantity to be manufactured and the week in which the parts are to be started, as determined by exploding the Master Schedule.

The dispatchers and foremen then originate the withdrawals for raw materials. As the operations are performed on each part, they post the count of actual quantities completed on the schedule sheet. A glance at the schedule sheet indicates the progress being made in carrying out the manufacturing schedule.

MANUFACTURING SCHEDULING on UNIVAC - - - -

In the past, a period of two weeks was required to establish all the factory schedules; the most complex was for the Miscellaneous Machining area. With this in mind, it was decided that factory scheduling would make a suitable project for programming on the UNIVAC, a large-scale electronic computer, located at Appliance Park. In order to simplify the installation, the Miscellaneous Machining area was tackled first.

UNIVAC Described - - - -

UNIVAC is a high-speed digital computer which uses magnetic tapes for both input and output. It is similar to many of the computers on the market in that it can be described in terms of its input, control, memory, and output.

The direct input to the computer uses magnetic tapes similar to those on tape recorders. These tapes are mounted on Uniservos which are connected to the control and memory unit. They may be prepared either by previous action of the computer, by direct typing on a Unityper, or from punched cards by a card-to-tape converter.

The control unit consists of a Supervisory Control Panel which enables the operator to oversee and modify, if necessary, the operation of the machine while it's in progress.

The memory can retain 12,000 characters in mercury delay tubes. Any one of these characters can be obtained for processing in an average of two thousandths of a second (.002 sec.). Connected to the memory units are special sections able to perform standard arithmetic operations and thereby perform any clerical routine such as sorting, summaries, extending, comparing, revising, interfiling, etc.

The direct output from the computer is always on magnetic tape. These tapes can then be used either to print reports on a Uniprinter (10 characters per second), or a High Speed Printer (600 lines per minute). The tapes can also be made into punched cards by tape-to-card converter.

HOW Miscellaneous Machining is Scheduled by UNIVAC - - - -

UNIVAC has virtually completely mechanized the previous method of establishing the Miscellaneous Machining Schedule. It was not necessary to make any changes in the procedure for collecting the data by which the schedule was established.

Each time it becomes necessary to prepare a new Miscellaneous Machining Schedule, the materials sub-section of the Dishwasher and Disposall Department transmits the following information to a representative of the Electronic Data Processing Center:

A. The new Master Schedule for the next 30 weeks by model by weeks.

B. The current inventory status of each fabricated part produced in the Miscellaneous Machining area.

C. A record of additions to and deletions from the Fabricated Parts Record File, Operation Planning File, and Machine Capacity File.

D. A list of changes and corrections to be made to the master files.

The Electronic Data Processing Center, after completing the necessary computer operations, delivers to the Dishwasher and Disposall Department the Manufacturing Schedule for the Miscellaneous Machining area as well as three copies of a Machine Load Report for each of the fourteen key machines in the area.

Since only primary operations were scheduled previously, this was continued in planning the UNIVAC routine. The time required for preparing these reports on UNIVAC depends to some extent upon the number of changes and revisions in the Parts Record and Operations Planning data files. On the average, however, six hours printing on two Uniprinters and one hour computer time are needed compared with approximately six days calculating and about 4 days typing when the job was done manually.

It was decided that a schedule alone would not be sufficient, but should be supported by a machine load report in order to permit balancing of the factory load; these two reports would be the final output from the UNIVAC routine. First, a schedule sheet would be printed for each machine tool indicating week by week for the next twenty weeks the quantity of those jobs that were to be started on each machine. Secondly, the machine load report would be prepared which would indicate for every machine tool the total load week by week, for the next twenty weeks; this load would be compared to the capacity and load deviations indicated when either above or sharply below the capacity.

Now specifically, what does the UNIVAC do:
(FS stands for Factory Scheduling)

Run FS 001 -- It takes actual scheduled shipments week by week for each of the models for the next thirty weeks and explodes these down to parts requirements. At the same time it calculates the due start date for each part.

The week-by-week requirements are then subtracted from the current inventory until the inventory reaches a negative state, at which point it schedules the manufacture of a quantity sufficient to cover the requirements during the next "N" weeks, where "N" is the order quantity in weeks. With the parts schedule determined, the necessary adjustments are made for vacations and spoilage and the scheduled parts are exploded to determine raw material requirements.

Run FS 002 -- The machine time requirements are then determined for each scheduled part for all operations.

Run FS 003 -- The machine load data is accumulated by station by week and compared to the machine capacity. This data is then rearranged for printing the machine load report.

Run FS 004 -- The schedule data is sorted by start station by week and is then arranged for preparation of the schedule sheets.

However, making the reports alone is not sufficient. The pattern described above would be adequate if there were never any changes in the material lists or planning cards and if the inventory conditions were completely predictable. Obviously, this is never so. Therefore, an entirely separate routine was necessary in order to maintain the records needed for the scheduling and load calculations.

The master files referred to are three in number:

The Fabricated Parts Record File (FPRF)

This contains the lead time data, raw material data, and where-used information for each part.

· The Operation Planning File (OPF)

This contains the operation planning data such as task per hour, machine station and operation number for each part.

· The Machine Capacity File (MCF)

This contains the capacity data such as number of machine shifts for each machine station.

The file maintenance routine performs the following actions:

Run FS 014 -- All of the changes to the master files are inserted in the proper position and new master tapes generated. In addition a "corrections made" tape is prepared to insure that all changes have been taken care of properly.

Run FS 013 -- Any additions and deletions to the master files are sorted into sequence by drawing number and part number.

Run FS 010 -- Additions are inserted into the master files and deletions eliminated from the appropriate master files producing as the end result new master file tapes.

Run FS 011 -- A tape containing the current inventory position of every item is then used to bring the master file inventory data up-to-date.

Run FS 012 -- The master tapes are rearranged and edited in order that printed master file records may be obtained.

What are the benefits that will be obtained from the installation of this factory scheduling routine? They seem to be in four areas:

1. The speed of response to changes.

2. The ability to have a detailed load analysis properly marked to indicate deviations.

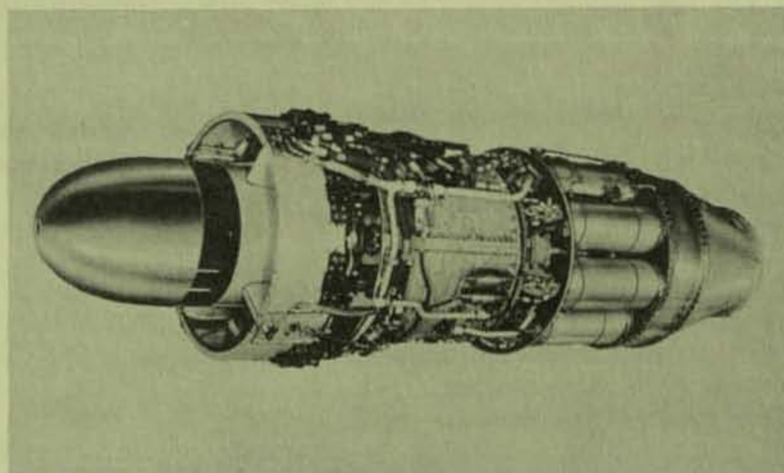
3. The releasing of the scheduler from the routine non-imaginative tasks.

4. A high improvement in the degree of accuracy obtained.

EVENDALE OPERATING DEPARTMENT

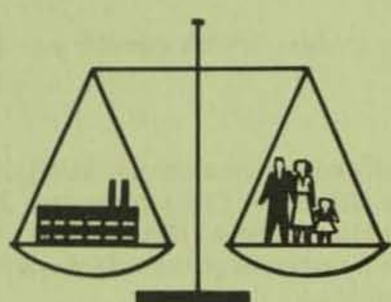
COMPONENTS MANUFACTURING

EVENDALE, OHIO



SCHEDULING IN BRIEF

MASTER SCHEDULE



KEY FACTORS - - - -

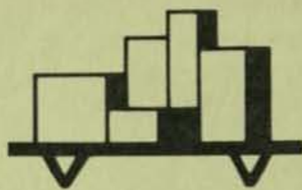
- Product - aircraft jet engines - including associated spares and test equipment.
- Long manufacturing cycle--six months to over one year.
- High rate of obsolescence -- frequent design changes.
- Quotations made prior to availability of detailed drawings.
- Allowance required for engineering, planning, tool design and procurement time in preparing quotations.

HOW IT'S DETERMINED - - - -

- Supervisors - Production Programming in each component manufacturing sub-section submit estimated scheduling data for each new quotation based on historical experience modified with new designs in mind.
- Production Programming Analyst, located centrally, consolidates individual sub-section reports, to prepare a Cost and Shipping Estimate.
- Cost and Shipping Estimate, when approved, is forwarded to Marketing where it becomes the basis for customer quotation.
- Shipping estimate data is used as the foundation for the Master Schedule if the contract is awarded.

PRELUDE
PROBLEMS
PROVOCATIVE

MATERIALS SCHEDULE



KEY FACTORS - - - -

- Many new materials required--difficult to procure.
- Special tools and fixtures have long procurement cycles since extremely close tolerances are necessary.

- Material purchases account for 65% of Shop Cost.
- 3000 different production material items purchased each year.
- Order quantities may not exceed total contract requirements.

HOW IT'S DETERMINED - - - -

- Each Sub-Section performs own explosion of parts needed--places orders on its decentralized Purchasing Sub-Unit.
- Bills of Material prepared by Planning from engineering blueprints--Make or Buy information is added before forwarding to production ordering.
- Requirements may only be consolidated within a Shop Order, which covers one contract release.

MANUFACTURING SCHEDULE

- Decentralized component manufacturing sub-units (Blades - Compressors - Machine Parts - Sheet Metal) have full control of component manufacture and sub assembly.
- Many component areas are arranged on a flow shop basis. The final engine assembly is a continuous production line.

- More than 600 items manufactured in the production shops.
- Processing lots average one month supply.

HOW IT'S DETERMINED - - - -

- Manual explosion of Master Schedule as Bills of Material are received.
- Each sub assembly area checks own labor load by comparing total number of components with previous operating levels.
- 3 by 5 paperwork used to direct material flow.

OUTSTANDING FEATURES

* Introduction of new models and processing of major changes handled by Production Programming.

* A Supervisor-Production Programming reports to each Superintendent. He is on a parallel with the Supervisor-Production and Purchasing.

* A Production Programming Analyst has central coordinating responsibility. He reports to the Manager-Component Material Control and has functional responsibility for guiding all the manufacturing sub-section programming activities.

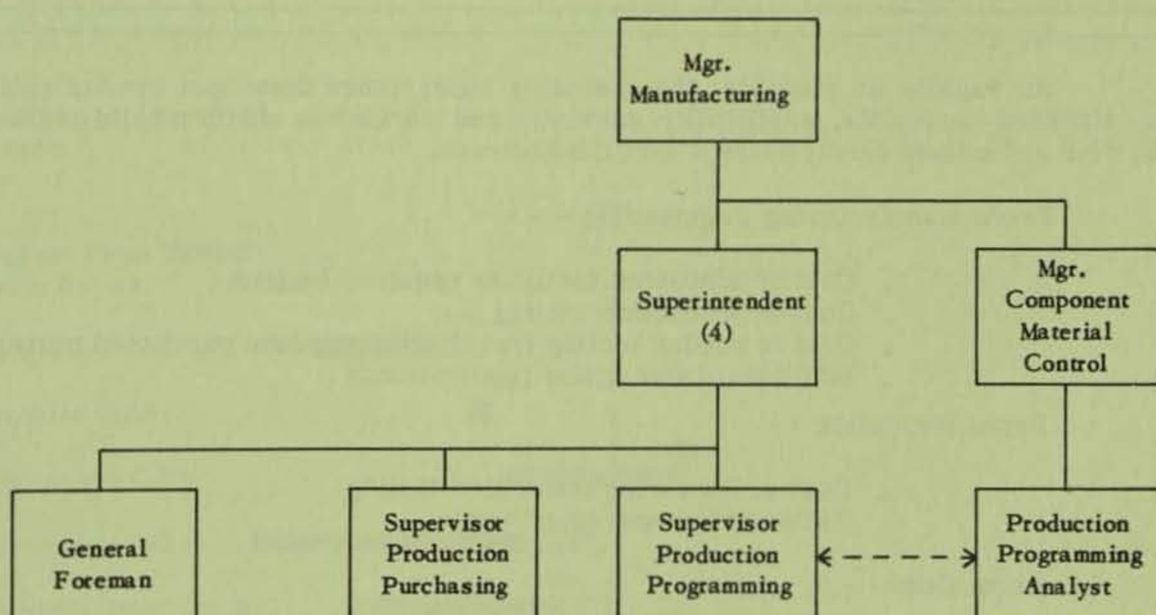
FULL DRESS VERSION

MASTER SCHEDULE

QUOTATION Requests Received - - - -

Marketing forwards requests for quotation to Manufacturing where the production programming team coordinates the preparation of the required Cost and Shipping Estimate information. This team consists of Supervisors-Production Programming in each of the Sub-Sections who answer directly to the Superintendents, and is coordinated by a Production Programming Analyst who is directly responsible to the Manager-Component Material Control.

PRODUCTION PROGRAMMING ORGANIZATION



PRODUCTION Programming Functions - - - -

Production Programming has the specific charter to:

- Coordinate the introduction of new models and all major design changes.

- Evaluate progress on these programs--

  . Issue reports of progress to management pointing out areas where difficulties have been experienced or are expected.

Take such steps as are permissible within the structure to overcome program impediments.

- Provide Cost and Shipping Estimate data for quotations.

PREPARE Cost & Shipping Estimate - - - -

The Evendale Operating Department makes a practice of having its line supervisors--the men responsible for performance--formulate proposition data. The Supervisor-Production Programming coordinates the formal preparation of these Cost and Shipping Estimates.

COST & SHIPPING ESTIMATE
FOR ____________ ENGINE
ASSY. NAME ____________ ASSY. # ____________

FACILITIES REQUIRED			PROC. CYCLE (WKS.)			MFG. CYCLE IN WKS.			ACCELERATION RATE - UNITS								
TYPE	QTY.	EST. COST $	FACIL.	PROD. TOOL.	MATL.	INSP. & LAB. REL.	MACH. & ASSEM. CYCLE	TIME TO SHIP 1st PC.	1	2	3	4	5	6		15	16

As rapidly as possible, the operating supervisors draw upon vendor quotations, standard time data, availability surveys, and so on - to obtain a valid estimate of the time and money required for a specific contract.

From Manufacturing Engineering - - - -

- Cost of additional facilities required by item
- Cost of production tooling
- Cost of vendor tooling (required to produce purchased parts)
- Additional floor space requirements

From Inspection - -

- Cost of Receiving Inspection tooling
- Estimated procurement cycle

From Cost - -

- Direct Material Cost
- Direct Labor Cost (Showing effects of "learning")
- Indirect Manufacturing Expense

From Production, Purchasing, and Shop Supervision - -

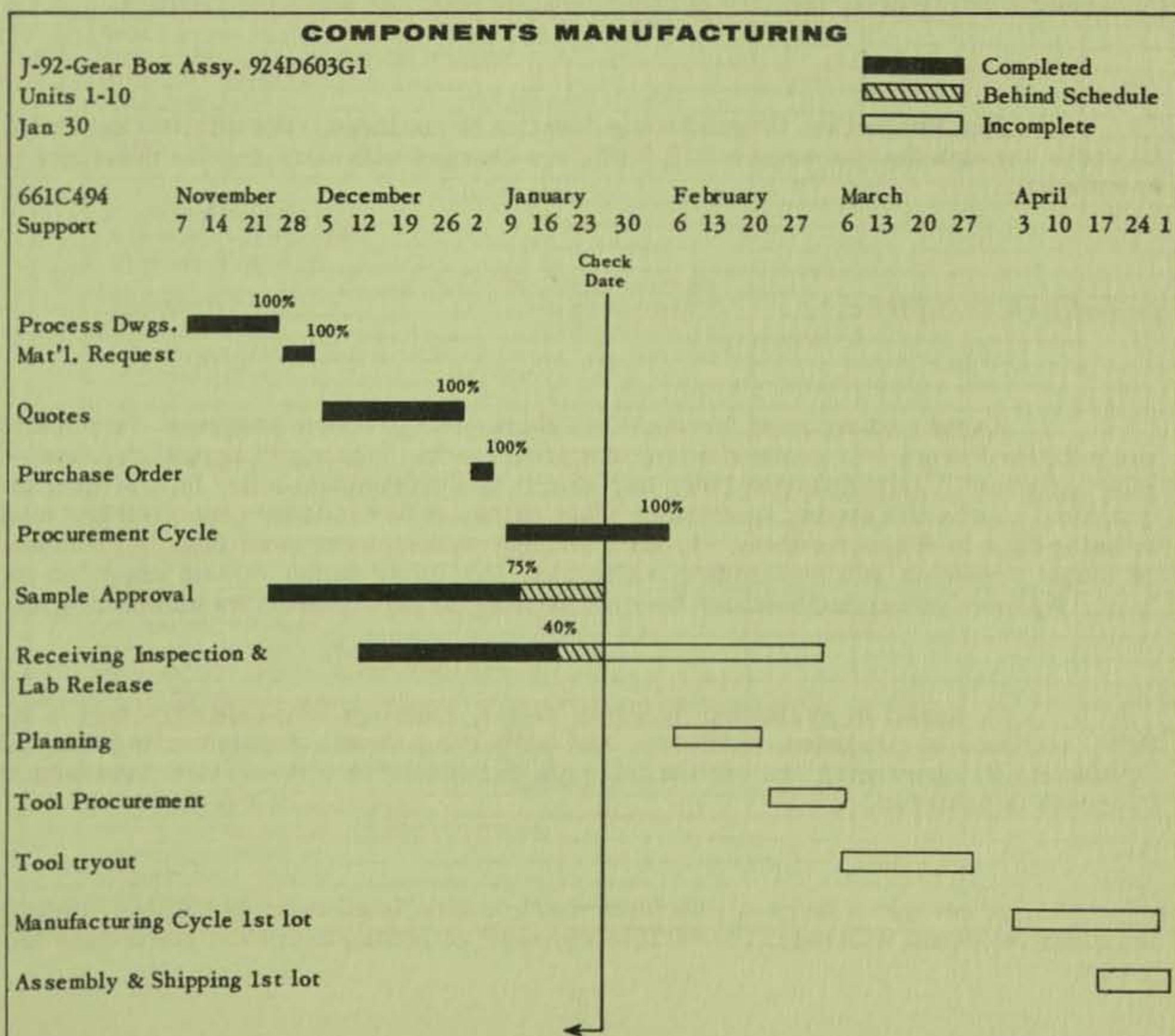
- Facilities procurement cycle
- Production tooling cycle
- Materials procurement cycle
- Inspection and Laboratory Analysis Cycle
- Total time to ship 1st piece
- Acceleration rate for items thereafter

All of this information is accumulated by individual sub assembly. It is then collated and condensed for the preparation of a final Cost and Shipping Estimate for the entire contract.

LAYOUT Initial Program - - - -

While the Supervisors-Production Programming have the prior chronological task of coordinating the preparation of quotation data, their most important job begins with the award of a contract for a new model. The Supervisor-Production Programming in each sub-section measures the various elements of the manufacturing operations. initiating action as required - - until the first run is made from production tooling. At that time the program is turned over completely to the regular Production Control organization.

The Supervisor-Production Programming commences by drawing up a bar chart for each sub assembly under his control. These charts show in time sequence all the functions which must be completed if the program is to run smoothly. In effect then, the bar chart is a pictorial representation of the time cycle which appeared on the Shipping Estimate submitted to the customer.



COORDINATES Program Completion ----

After having organized his objectives in a logical manner the Supervisor-Production Programming starts by making certain that all blueprints and process drawings have been released by Engineering. This is done to insure that operational planning and parts procurement will not be held up by any items missing engineering release.

Once Planning and Purchasing have all the information they need, the Supervisor-Production Programming constantly checks planning sheets, tooling requests and purchase orders to insure that no assembly or part drops behind the over-all program. He watches for trouble spots and utilizes his experience to make certain that the proper items are handled first. As problems occur, the Supervisor-Production Programming fulfills a continuing need for close coordination among Planning, Purchasing and Engineering. Often, major problems occur where it becomes his responsibility to advise management and to bring together the functions necessary to solve the problem.

The Production Programming function is not large. For efficient operation it works through the line organizations who are charged with carrying the contracts to completion.

EVALUATE Progress - - - -

As its next function, Production Programming reports progress. Bar charts are published every two weeks showing that progress has been made against the "budgeted" program. Accompanying these bar charts is a transmittal letter interpreting the graphical charts and stating specifically what obstacles have been encountered and what is being done to overcome them. In this manner, management is advised immediately of major problems and can inquire concerning any items which remain unsettled too long. This evaluation and feedback become an integral part of program administration.

To assist in evaluation program status, meetings are held regularly to inform everyone of progress, problems, and tasks lying ahead. Supplementing this, the Production Programming Analyst institutes his own checks to make certain that adequate progress is achieved.

A review of one analysis form which is circulated every two weeks, clearly indicates the detail with which the various elements of getting a product started are followed.

P-881

GENERAL ELECTRIC AGT COMPONENTS MANUFACTURING

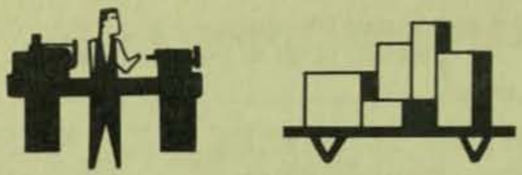
BI-WEEKLY REPORT TO PRODUCTION PLANNING

MASTER MANUFACTURING PROPOSAL______________________ SUBJECT______________________

Assy. Name   Assy. No.   Engine Model   Unit

No.		ITEM	START DATE SCHED. (e)	START DATE ACTUAL (f)	FINISH DATE SCHED. (g)	FINISH DATE ACTUAL (h)
1.	PLANNING	Tooling: (b) Number of items — Facilities	XXX	XXX	XXX	XXX
2.		(c) Longest procurement lead time — AAE	XXX	XXX	XXX	XXX
3.		(d) Estimated total cost — IME	XXX	XXX	XXX	XXX
4.		Tooling Requisitions: (b) Number involved: (c) Weeks required to prepare				
5.		Facilities Tooling: (b) No. of items (c) Weeks required to place firm orders				
6.		Rough Planning: (c) Weeks required to accomplish				
7.		Layout Planning: (c) Weeks required to accomplish				
8.		Planning and Operation Sheets: (c) Weeks required to prepare				
9.		Process Drawings, Drafting: (c) Weeks required to prepare				
10.		Compute Planned Time, Prepare labor stencils: (c) Weeks required to accomplish				
11.		Machining Report (Castings and Forgings): (c) Weeks required to prepare				
12.		Change Layout: (c) Weeks required to accomplish				
13.		Tool Tryout: (c) Weeks required to accomplish				
14.		Initial Manufacturing Cycle Time: (c) Weeks				
15.		Estimated Ultimate Capacity: (b) Units per month	XXX	XXX	XXX	XXX
16.		Planning Approval (a)	XXX	XXX	XXX	XXX
17.	INSP.	Rec. Insp. Tooling: (b) No. of items; (c) Longest procurement lead time; (d) Total Cost	XXX	XXX	XXX	XXX
18.		Tooling Requisitions: (b) Number involved; (c) Weeks required to prepare				
19.		Receive and Inspect Tools: (c) Longest cycle time (weeks)				
20.		Inspection Planning Approval (a)	XXX	XXX	XXX	XXX
21.	PURCHASING	Material, Classed by Type — OV: Class IV (3/4 to 1 year)				
22.		and Procurement Lead Time — III (1/2 to 3/4 year)				
23.		In Quarter-Years: — II (1/4 to 1/2 year)				
24.		I (0 to 1/4 year)				
25.		Indicate: — RS: Class IV				
26.		(b) Number of items per class; — III				
27.		(c) Weeks req'd to place firm orders; — II				
28.		(d) Total material cost per unit — I				
29.		C & F: Class IV (Include procurement				
30.		OV—Outside Vendor Items — III time for pattern and				
31.		RS—Raw Stock — II die equipment.)				
32.		C&F—Castings and Forgings — I				
33.		SF—Semi-Finished Items — SF: Class IV				
34.		III				
35.		II				
36.		I				
37.		Production Tooling: (b) Number of items — AAE				
38.		(c) Weeks req'd to place firm orders — IME				
39.		Receiving Inspection Tooling: (b) Number of items (c) Weeks req'd to place firm orders				
40.		Purchasing Approval (a)	XXX	XXX	XXX	XXX
41.	PROD.	Material Requisitions: — Class IV				
42.		Indicate: — III				
43.		(b) Number involved per class — II				
44.		(c) Weeks required to prepare — I				
45.		Receiving, Lab., Sample Mach., Insp.: (c) Longest cycle time (weeks)				
46.		Department and Area Schedules: (c) Weeks required to prepare				
47.		Production Approval (a)	XXX	XXX	XXX	XXX
48.	PROD. PLAN.	Engineering Releases: (e) Release dates — Drawings			XXX	XXX
49.		Tooling			XXX	XXX
50.		Material			XXX	XXX
51.		Manufacturing			XXX	XXX
52.		Bill of Material: (c) Weeks required to prepare				
53.		Preliminary Manufacturing Schedule: (c) Weeks req'd to publish				
54.		Production Planning Approval (a)	XXX	XXX	XXX	XXX
55.		Production-Purchasing Approval (a)	XXX	XXX	XXX	XXX
56.		General Foreman Approval (a)	XXX	XXX	XXX	XXX
57.		Superintendent Approval (a)	XXX	XXX	XXX	XXX

MATERIALS AND MANUFACTURING SCHEDULE



EXPLODE Requirements - - - -

Purchased parts, raw material and manufactured components are manually exploded from Bills of Material received from Planning. Parts scheduling is done on the basis of the original Cost and Shipping Estimate or Master Schedule using the planned time cycle charts. Because of the high cost and great risk of obsolescence, order quantities may not exceed total requirements and lot sizes are held to a minimum to prevent high inventory investment. This means that accurate feedback as to rejected parts is needed to permit revision of open order quantities.

Emphasizing the decentralization of manufacturing responsibility, each sub-section has its own production and purchasing unit. This permits a high degree of specialization on the particular items which each sub-section purchases and manufactures.

BUYING the Tools and Parts - - - -

The procurement problem takes its shape from the need to utilize new materials and processes in jet engine production. As might be expected, relatively few firms have developed the necessary technology and experience to supply the required items.

Another large factor in detail schedule preparation is the time allowance for tooling. Because of the extremely close tolerances required, much of the internal production tooling is purchased from precision tool manufacturers. Naturally, this is costly and time consuming. Large expenditures must also be made for vendor tooling which highlights the importance of selecting capable vendors. A vendor's failure to perform to schedule may jeopardize a large investment in tooling as well as hold up the entire program. Because of this, as well as for reasons of national security, alternate sources of supply are established wherever it is economically feasible to do so.

FACTORY Control and Feedback - - - -

Because of this further specialization within only one type of product, capacity may be checked on the basis of planned hours for each type of assembly. Load comparisons are then made for past, present, and expected levels of manufacturing activity.

As 3 by 5 paperwork is used for factory control, dispatchers issue job tickets directly to workers in accordance with the scheduled dates and the advice of production expediters. Most major manufactured items are followed individually and status reports for each of these are issued weekly showing the progress of the entire program and the details for each key item.

Shaft-632C462 1-29-

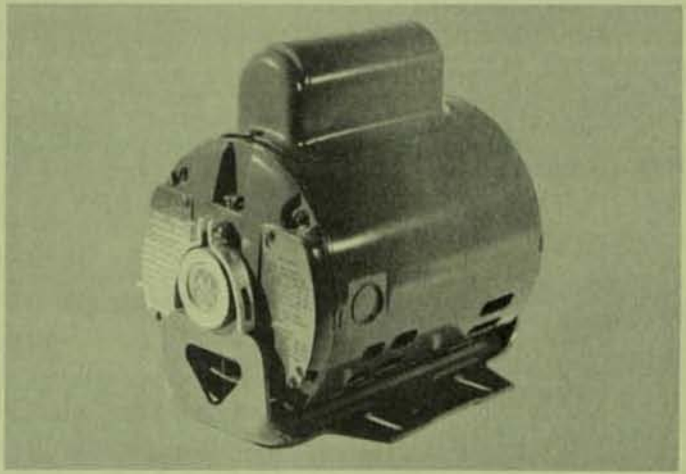
Material		Cycle	12		11	10		3			2		1		Sch. Fin.	
		Oper.	5	10	15	20		70	80	90	100	105	110	115	Req.	150
Reqd.	650	Reqd.	600		570	540		220			180		150		Act.	138
Avail.	700	Act.		610	580					250	138			138	Sht.	12
Short	–	Sht.		–	–		–			–	42			12		
Still in process																
Scrap											30			7		

Production Status Report

The requirements shown are as of 1/29 indicating the cumulative number of units which should be complete through each operation. Actual performance is recorded for each station and data entered for shortages and scrap. These reports are, of course, summarized for management, with each level receiving the appropriate detail.

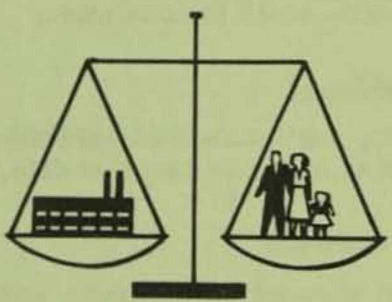
GENERAL PURPOSE COMPONENT MOTOR DEPARTMENT

FORT WAYNE, INDIANA



SCHEDULING IN BRIEF

MASTER SCHEDULE



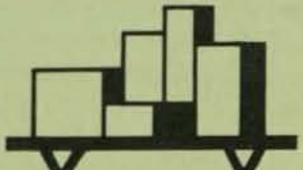
KEY FACTORS - - - -

- 1200 motors produced per day.
- 13 major types - 2500 variations produced during a year.
- Produced to customers' orders.
- 82% of orders for quantities of 1 to 10.
- Products are of large variety composed of standard components.

HOW IT'S DETERMINED - - - -

- Compiled from incoming requisitions.

MATERIALS SCHEDULE



KEY FACTORS - - - -

- ABC principles of Inventory Control used.
- 4500 purchased items.
- Each contributing unit (Stator Cores, Rotor, Windings, End Shields and Miscellaneous Control Points) maintains own stock buffers.

HOW IT'S DETERMINED - - - -

- Each contributing unit determines the parts and sub-assemblies required to produce its components.
- Special items ordered when finished product requirements Tel-Autographed to contributing units.

- "A" and "B" stock items checked weekly - last four (4) weeks' usage used as guide in determining order quantities.
- Material delivered to point of usage. Therefore, minimum stocks carried - aggregate average inventory turnover = 11.

MANUFACTURING SCHEDULE

KEY FACTORS - - - -

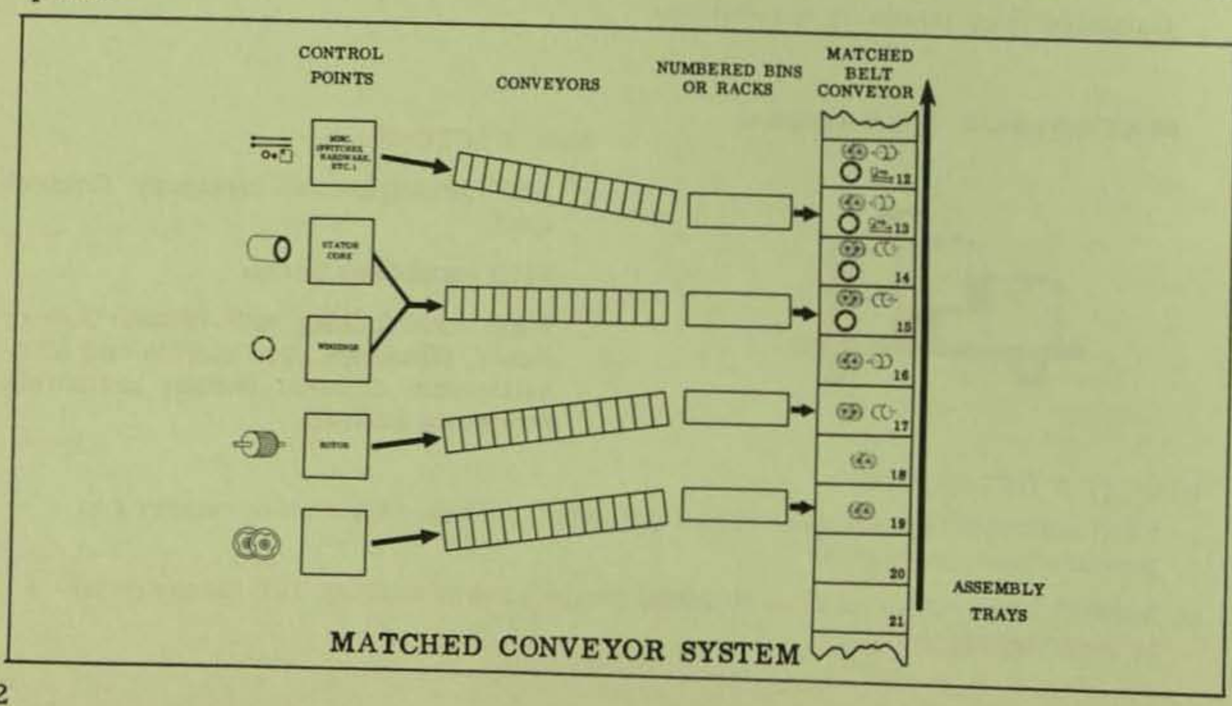
- Single story manufacturing facilities.
- Final assembly performed on a paced conveyor - virtually a Product-Flow line.
- Contributing units manufacture components mainly on flow basis - each turns out its product at a rate geared directly to movement of trays on matching order assembly line.
- No finished product or finished sub-assembly stock accumulation.

HOW IT'S DETERMINED - - - -

- Assembly units are scheduled in sequence by Production.
- Component parts are scheduled by each contributing section to meet assembly date - foremen schedule sequence of parts to be produced in order to meet that date.

OUTSTANDING FEATURES

* A system developed with a positive daily schedule of units in sequence - each component part synchronized so as to be brought together as matched sets by a number corresponding to its assembly location on the matched conveyor assembly line. This eliminates the necessity for a stockroom prior to assembly and the accumulation of parts.



MATCHED CONVEYOR SYSTEM

* All materials are delivered to point of usage to eliminate subsequent handling and to minimize records. This enables a visual means of inventory control and avoids dual responsibility.
* Synchronized flow results in rendering the best possible service to customers by establishing short manufacturing cycles. Yet there is great flexibility within the manufacturing layout which is effectively designed to minimize work in process inventories and effect a successful total manufacturing plan.
* Each contributing unit (Control Point) is an independent unit responsible for scheduling, ordering of materials, maintenance of stocks, etc. However, its output is so controlled that it meshes with the output of each of the other units.
* Tel-Autograph communication from the Production office to contributing units upon receipt of order. This permits a quick, yet detailed check on available materials and facilities to meet requirements.
* Manufacturing is always contacted and an acceptance received before any loading is put on the factory.
* Each contributing unit, except the Windings, carry an in-process stock of parts machined and/or assembled to a point standard to the majority of models produced. These are called "Liquid" stocks and balance the labor in each unit. No more than two (2) or three (3) days' supply is the general rule.
* To substantiate the success of the system employed, 95 to 98% of promises are kept.

FULL DRESS VERSION

MASTER SCHEDULE

CONSOLIDATE Customers' Orders - - - -

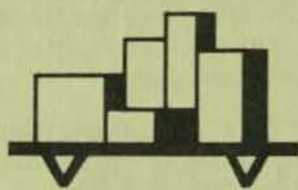
The Master Schedule is strictly a backlog of orders on hand. The orders are grouped according to model numbers of similar types and slotted into the schedule at available open spots. Each motor is scheduled to be completed at a definite assembly date.

CHECK Material and Facilities - - - -

Upon receipt of requisitions from Order Service, each of five (5) contributing units (Stator Cores, Rotors, Windings, End Shields, and Motor Assembly) is contacted via Tel-Autograph to determine if they have the materials and facilities available to fulfill the requirements. No orders are placed on the Master Schedule until accepted by these contributing units. A second check is made upon the receipt of a "Preliminary Matching Order". This is issued daily and shows the daily work load to be released on a "Final Matching Order" five (5) days hence. The word "Matching Order" describes the system employed. These Orders are received by each contributing unit containing information as to quantity and type of motors to be assembled. Each component must be manufactured to become part of a "matched set" on the assembly date. A number is allotted to each motor and each component part will carry that number to the corresponding location on the final assembly conveyor.

Periodically a sheet is issued to Manufacturing showing them the production pattern (the quantities of various types and models to be produced) in day's requirements for a future period until the load changes the pattern. This gives the factory still another opportunity to check its material, manpower and machines. At this time a change in the mix may be necessary, i.e. increasing one model and decreasing another. This may be especially true in the Stator Winding area which is the limiting component and all scheduling must be done considering that area's capacity.

MATERIALS SCHEDULE



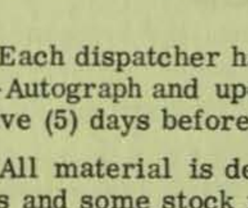
DETERMINE Parts Requirements - - - -

Each contributing unit has complete responsibility for ordering its required vendor items. At the time of the receipt of the Tel-Autograph any special materials not ordinarily stocked must be ordered. Orders are placed and that particular requisition cannot be scheduled until all material is on hand. Stock items such as the "A" and "B" items, are checked once a week at each contributing unit by the respective dispatchers. The last four (4) weeks usage is determined and the average weekly usage is used to determine an order quantity and order point - taking into consideration material on hand. The highest value items are the castings and the wire. A two (2) weeks' supply of castings and a one (1) week's supply of wire is maintained. Each contributing unit has a breakdown of parts required for its particular component and therefore has full control of its raw material stocks. Hardware and other "C" items are stored in one area maintained by a stockkeeper. By visual means and records of all procurement times these stocks are replenished when required.

Each dispatcher has an opportunity to check required material upon receipt of the Tel-Autograph and upon receipt of the "Preliminary Matching Order" which is received five (5) days before he will receive actual authority to manufacture.

All material is delivered to point of usage, therefore eliminating the use of stockrooms and some stock records.

MANUFACTURING SCHEDULE



The manufacturing in this Section is composed of the final assembly of the required mix of motors on a 387 foot matched conveyor and the manufacture of the component parts in independent manufacturing units. The output of each of these units is so controlled that it meshes with the output of each of the other units. Each piece is scheduled to arrive at the assembly area at a predetermined time; this eliminates the need for accumulating parts in an assembly stockroom.

TRANSMIT Mix to Manufacturing Units - - - -

A final "Matching Order" is issued daily to each contributing unit. This is six (6) days before assembly of the complete motors is scheduled to begin. This "Matching Order" date is a firm deadline as the precise hour of final assembly of each motor has virtually been set. Each contributing unit breaks down the models required into the component parts it must produce. Each component part is manufactured in any sequence determined by the foreman as long as the parts are delivered to the assembly area by the fifth day, including the "Matching Order" date. In all units, except the Windings, parts may have had some labor applied before an order is received in performing operations that would be common to the majority of applicable drawing numbers. It is then possible to draw on these so called "Liquid" stocks for a variety of jobs with very short notice. The windings, however, are not started until the actual orders for specific models are received. The balancing of labor within each contributing unit is accomplished by manufacturing for this "Liquid" stock. Preference is given to the special units and the special operations necessary to convert "Liquid" stock, allowing the variable to come in the basic or standard operations that must be performed.

Movement of all the component parts within their areas is accomplished by belt and roller conveyors as much as possible. This makes some units' performance strictly on a Product-Flow basis while others approach this to a large degree.

A "Space and Sequence Record" is issued with each "Matching Order." This Sequence Record is merely a grouping of the conveyor space numbers for the motors to be produced. Each individual motor has a specific number on that day's schedule. This number, together with the "Matching Order" date is stamped or written on each component part. A set of conveyors move the various component parts from their respective units to the matched conveyor assembly area.

TRANSMIT Load To Assembly - - - -

When the assembly foreman receives the "Matching Order" (six days prior to assembly date) and the "Space & Sequence Record" he is able to evaluate the labor required from the mix specified. As many as 13 major types consisting of forty (40) to seventy (70) different variations may be scheduled daily. The assembly times on each unit can vary as much as 350% and have been spaced accordingly along the conveyor. With the information of what he is to produce (this had been checked and approved by him upon receipt of the "Preliminary") and reference to a chart he has available, the number of operators required can be determined. The operators on the repair line directly in back of the assembly conveyor are used to balance this labor load.

MATCH Component Parts - - - -

As the parts are received in the assembly area they are put in racks or bins by their respective space and sequence number and date. On the specified date each part is placed on its respective assembly conveyor tray and matched with the other components.

FEEDBACK Of Performance - - - -

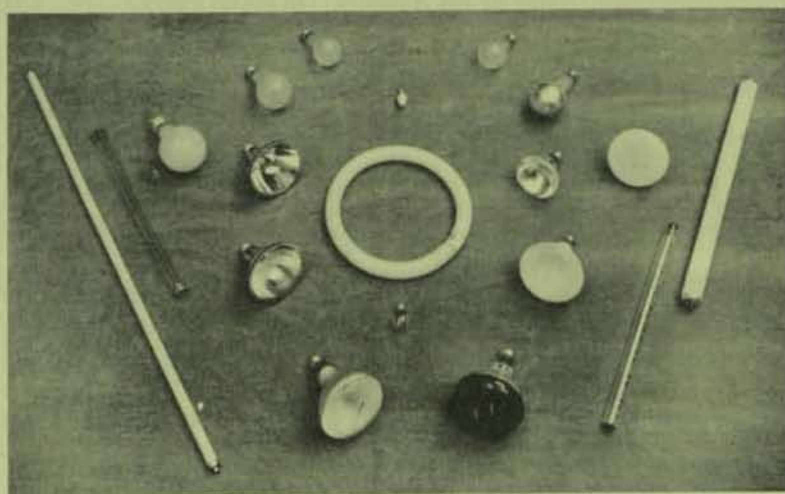
Each day a check is made at ten (10) predetermined points in the contributing units as well as in assembly. This check will tell how many units scheduled for that day are behind schedule and how many of the backlog of "misses" have been made up. This gives an immediate picture of any major bottleneck so that action can be taken at once. Because of the close day-to-day scheduling any holdup along the line can throw the whole schedule in arrears.

The identification tags on the finished motors are relayed to the Production Office as evidence that motors are available for shipment. Production makes a summary by types as required for a condensed production report. This total indicates whether the factory is on schedule when compared to the scheduled quantities.

A punched card setup is used to consolidate daily shipments. At 10:00 A. M. each morning a complete report of the preceding day's shipments is delivered to the Production Office.

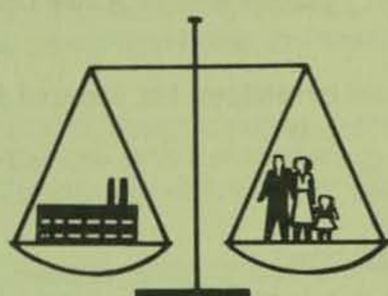
LAMP MANUFACTURING DEPARTMENT

CLEVELAND, OHIO



SCHEDULING IN BRIEF

MASTER SCHEDULE



KEY FACTORS - - - -

- One billion lamps of over 10,000 types and models produced per year - when different voltages are considered this figure pyramids to 30, 000 items.
- 85% of sales volume produced for warehouse stock - stocks must be available for immediate delivery to customers due to highly competitive nature of products.
- Products maintained on consignment basis to agents and retailers.
- Finished goods inventory (Factory and Service District warehouses) turnover = 4.
- Activity of all manufacturing plants coordinated by Home Office Production.

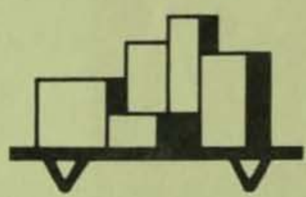
HOW IT'S DETERMINED - - - -

- Five (5) year forecast issued yearly by Marketing - used in planning capacity requirements.
- Yearly market forecast issued as result of meeting of Production and Marketing - broken down by months and by forecasted shipments to various sales channels.
- Monthly review of forecast so that future production rates will reflect changes in actual demand as evidenced by monthly reports of Factory and Service District Warehouses.

PRELUDE
PROBLEMS
PROVOCATIVE READING

. By use of statistical analysis and the employment of plotted curves of accumulated balances by items manufactured and shipped, a yearly schedule is determined and issued to each manufacturing plant. This is ordinarily issued in October for the next year's production and revised only if changes in demand occur.

MATERIALS SCHEDULE



KEY FACTORS - - - -

. 80% of material dollars spent within the Lamp Division - bulbs and other glass items from the Glass Manufacturing Department, other component parts from the Parts Manufacturing Department.

. Raw material turnover = 11.

HOW IT'S DETERMINED - - - -

. Explosion or parts requirements for the next month accomplished manually by each manufacturing plant.

. Requirements are placed on a "Stock and Demand Report" and issued to the supplying department, i. e. Glass Manufacturing or Parts Manufacturing, as a firm order by the 10th of the month for the succeeding month. Copies sent to Home Office for analyzing consumption and stock inventories.

. Parts ordered outside the Division determined from breakdown but ordered for delivery two (2) to three (3) months in the future.

MANUFACTURING SCHEDULE

KEY FACTORS - - - -

. 20 manufacturing plants.

. Automatic specialized machinery - flow type processing for 98% of output.

. All machinery designed and manufactured within Lamp Division - Equipment Works.

. Operations consist of assembly of parts mainly produced by Glass and Parts Manufacturing Departments.

. Sales divided into six (6) areas:

(1) Christmas Tree Lamps
(2) Large Lamps (standard incandescents, various specials)
(3) Fluorescent Lamps
(4) Photo Flash Lamps
(5) Miniature Lamps (automobile, flashlight)
(6) Sealed Beam (headlights)

HOW IT'S DETERMINED - - - -

Taking the Newark Lamp Works (Large Lamps - 15, 25, 40, 60, 75, 100, and 150 watt incandescent lamps) as an example --

. Long-range forecast received from Home Office - broken down into daily production (leveled throughout year) and daily mix (models, types and voltages).

. Daily production rates issued to foremen when yearly Master Schedule received from Home Office - not issued again unless rates must be revised. Short-range forecasting done at each plant.

. Semi-monthly schedule issued to foremen - daily rates broken down into number of units for each voltage. Types produced in 110, 115, 120, 125, and 130 volts -- 120 volt lamps account for 80% of volume, 115 volts - 12% of volume, 8% of volume is production of 110, 125, and 130 volts.

OUTSTANDING FEATURES

* The production activity in the Home Office has the responsibility for determining the quantities and types of units to be produced by each of the twenty (20) manufacturing plants. Constant coordination is maintained by this central office as to production rates, stock quantities and marketing activity.

* Records of manufacturing rates and shipments of all items are maintained so that coordination with the Marketing Section will achieve the goal of supplying the customer immediately with what he requires.

* This central activity can see the over-all picture in order to correctly control the constant rate of production for seasonal demand items as well as exert control of the various stock inventories (finished goods and raw materials) at each manufacturing plant.

* Production rates of all items are maintained at as near a constant level as possible. This accounts for increased finished goods inventory during slack demand periods, but is far outweighed by the following factors:

  . Levels parts procurement so as to minimize burden on suppliers.

  . Eliminates the necessity for frequent training of new operators.

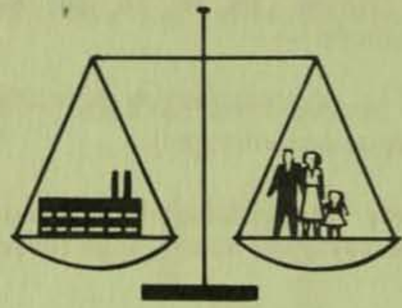
  . Minimizes the investment in plant and equipment.

  . Maintains a constant size organization which results in better employee relations.

  . Supports the quality of the product since it is not jeopardized by the necessity of hiring inexperienced help during peak demand periods.

FULL DRESS VERSION

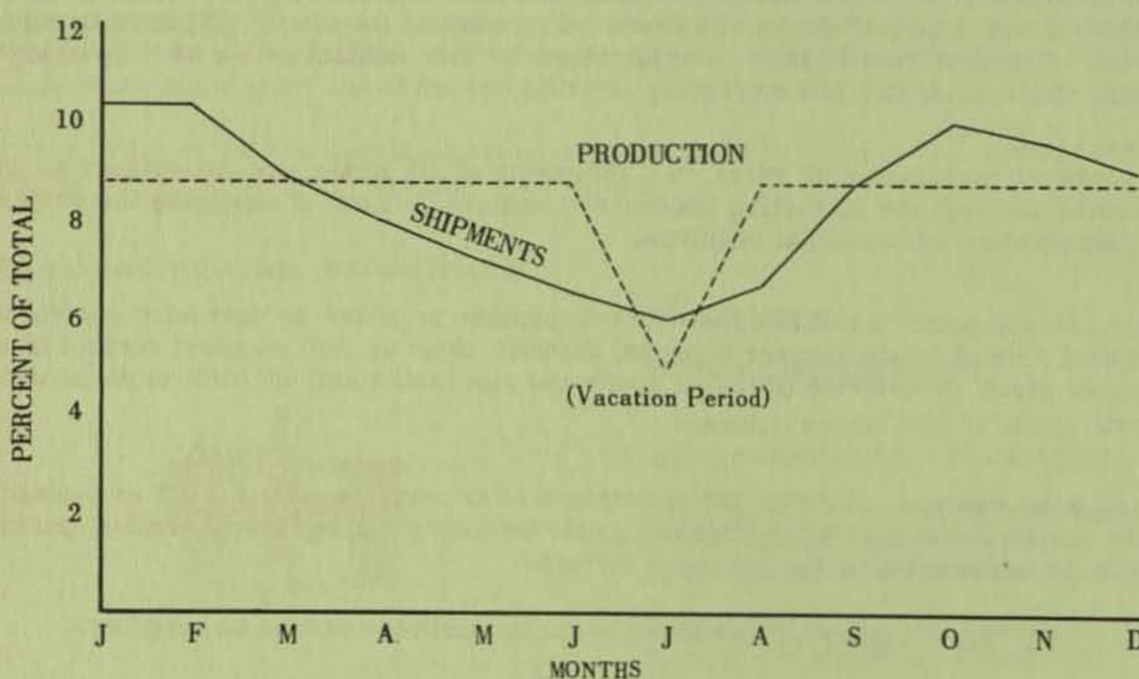
MASTER SCHEDULE



ANALYZE Market Forecast - - - -

Once each year a five (5) year forecast of customers' demands for all lamps is issued by the Marketing Section. This enables the Home Office production activity to plan capacity requirements of the various manufacturing plants as to labor and facilities required.

Each year there is a meeting of Production and Marketing to set a realistic forecast for the next year's activity for budget purposes. Estimates take into consideration the present business trends as well as reports from the various Service Districts and other distribution outlets. This forecast is broken down into monthly requirements and used for setting objective production rates for the manufacturing plants. During the year monthly meetings are held to review any changes in requirements so that corrective action may be taken immediately. It must be remembered that production is leveled throughout the year as much as possible so that the original forecast must be fairly accurate.



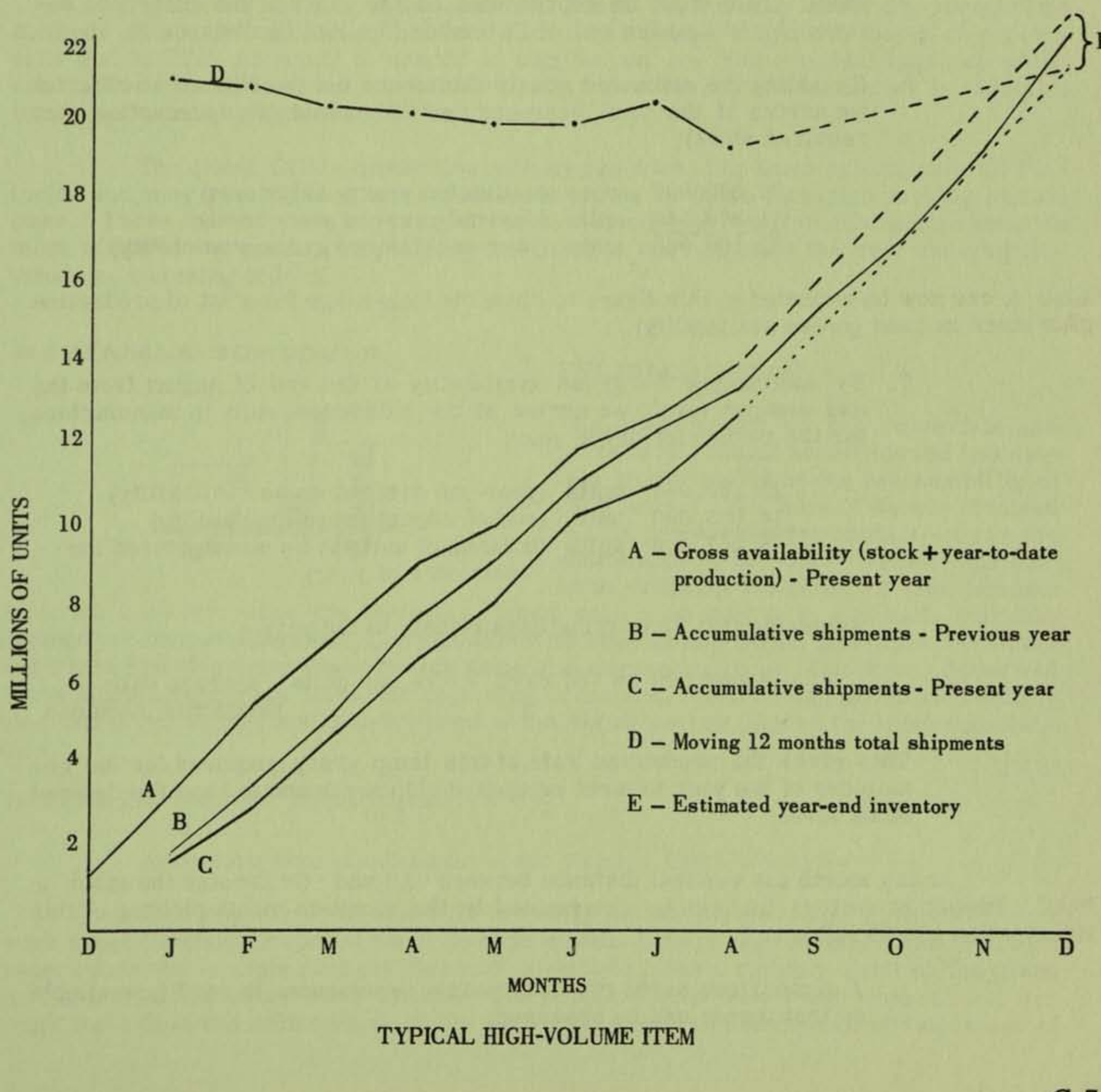
SEASONAL PRODUCT – MONTHLY PRODUCTION RATES COMPARED TO ACTUAL SHIPMENTS

If any sudden drastic change upward or downward in the demand for certain items occurs, it must be accounted for gradually so that the rates are maintained on a fairly constant plateau. The regular turnover of employees will often take care of decreases in the required output. Over-producing for a short period is the rule, rather than dismissal of personnel. Finished goods stocks are maintained at the factory as well as at the thirty (30) Service District Warehouses. These factory stocks, which average a one month's supply, take the cushion of unexpected demands. It is of prime importance in dealing with such highly competitive items that they be available at the time the customer wants them.

DEVELOP Long Term Forecast - - - -

Each month a "long term" forecast of production rates and shipments is developed for the major groups (Christmas Tree, Large Fluorescent, Photo Flash, Miniature, Sealed Beam Lamps) by Production in the Home Office. This gives the balance that must be manufactured for the remainder of the calendar year. If production rates must be changed, the appropriate plant is notified.

For clarity, let's set up a situation as of the end of August, which could well represent an average high-volume lamp.



TYPICAL HIGH-VOLUME ITEM

The steps necessary are:

1. Plot the accumulated shipments year-to-date (line C).

2. Plot the accumulated gross availability, year-to-date (line A).

3. Plot the accumulated shipments of the previous year (line B).

4. Determine the estimated yearly shipments - according to all market indications and examination of the trend of the moving 12-month total (line D).

5. Estimate the desired stock level at the end of the year. It has been determined from all demand indications and required stock "bogies" that the stock should be enough for January shipments or to cover past the next sales peak; in this case it is determined to be 1,800,000 units. This must be represented on the chart as the difference between A and C at the end of December (denoted by distance E).

6. By adding the estimated yearly shipments and the desired stock level we arrive at the total year-end desired availability (production plus required stock):

20, 300, 000	units	(estimated yearly shipments)
+ 1, 800, 000	units	(desired year-end stock level)
22, 100, 000	units	(year-end desired gross availability)

Line A can now be extended to this figure to show the long-range forecast of production plus stock on hand (gross availability).

7. By subtracting the gross availability at the end of August from the end desired level, we arrive at the balance of units to manufacture for the remainder of the year:

22, 100, 000	units	(year-end desired gross availability)
- 14, 033, 000	units	(end of August gross availability)
8, 067, 000	units	(balance of units to be manufactured for remainder of year)

8. Assuming that 81 working days remain in the year -

8, 067, 000 ÷ 81 days = 99, 500 units - average daily production required.

This gives the production rate, of this lamp group, required for the remainder of the year to meet estimated shipments and to keep the desired stock level.

At any month the vertical distance between "A" and "C" denotes the stock on hand. Important factors that can be determined by the month-to-month plotting of this information are as follows:

1. A comparison to the previous year's experiences is readily available so that trends can be observed.

2. The Home Office can more easily coordinate the efforts of all factories in establishing stock bogies, plans for future expansion or plans for decreases in facilities.

3. The increase or decrease of stocks on hand is readily determined so that immediate action can be taken to adjust production rates if necessary.

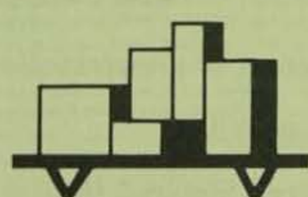
4. A constant check is available as to the accuracy of the year's sales prediction as the actual performance is plotted.

5. If the actual performance plotted shows a rapid decrease of stock on hand due to a sudden increase in shipments, it can readily be seen if immediate action should be taken or if the situation will balance out in future months.

Since forecasting of demands can never be perfectly accurate, forecasting methods cannot be completely automatic for best results. Judgment, based on experience and skillful analysis, is needed to supplement any mathematical approach which uses either past history or market forecasts. However, good forecasting is essential for proper production planning.

The Home Office production activity provides long-term schedules to all factories and may provide monthly detailed schedules to those factories making simple lines. Those factories making many items of a special or semi-special nature must do most of their own production planning and control work to meet the ever changing demands of incoming orders.

MATERIALS SCHEDULE



ESTABLISH Bogies - - - -

The procurement of raw materials and parts to fit planned schedules and to maintain proper stocks is the responsibility of each factory. The Home Office is involved in this procurement procedure only in the establishment of stock "bogies" and uniform ordering methods. It does become involved, however, when the factories cannot secure an adequate supply to maintain desired production schedules. Coordination with other Home Office activity in the Glass and Parts Manufacturing Departments assists in correcting these situations. Glass and Parts Manufacturing are informed regarding current and future lamp production schedules and plans as they are the suppliers of the major parts required for lamp manufacture.

DETERMINE Material Requirements - - - -

Again let's take the example of the Newark Lamp Works --

The long-range forecast as to yearly production required is exploded on a work sheet itemizing material required each month. This is used together with the stock record data and any rate changes that may develop to issue a monthly order on the Glass or Parts Manufacturing Departments. The parts ordered from these departments account for 80% of the dollar value of raw materials required and consist of 14 classes of

PRELUDE
PROBLEMS
PROVOCATIVE

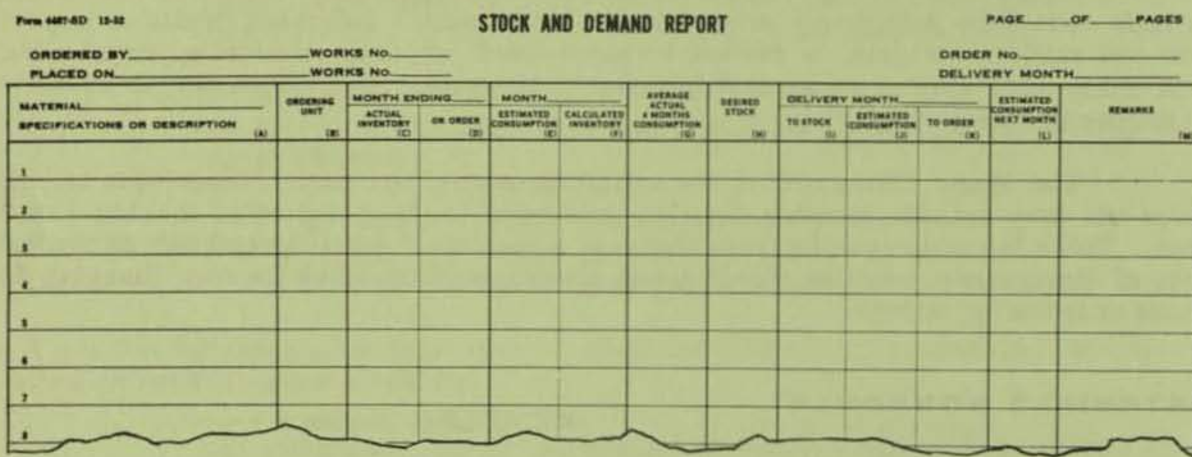
items (bulbs, filaments, wire, tubing, etc.). This order is a standard Lamp Division form called "Stock and Demand Report". This is issued on the tenth of the month for material required during the following calendar month.

This Report is designed to accomplish the following:

1. It provides a standard method for computing the quantity of material to order.

2. It gives the supplying section basic information regarding Lamp Works' stock and consumption as well as the order itself.

3. The final order is adjusted to minimize the effects of increasing or decreasing rate of consumption.



STOCK AND DEMAND REPORT

PAGE ____ OF ____ PAGES

ORDERED BY ____________ WORKS No. ______

PLACED ON ____________ WORKS No. ______

ORDER No. ____________

DELIVERY MONTH ____________

MATERIAL ____ SPECIFICATIONS OR DESCRIPTION (A)	ORDERING UNIT (B)	MONTH ENDING ____		MONTH ____		AVERAGE ACTUAL 4 MONTHS CONSUMPTION (G)	DESIRED STOCK (H)	DELIVERY MONTH ____			ESTIMATED CONSUMPTION NEXT MONTH (L)	REMARKS (M)
		ACTUAL INVENTORY (C)	ON ORDER (D)	ESTIMATED CONSUMPTION (E)	CALCULATED INVENTORY (F)			TO STOCK (I)	ESTIMATED CONSUMPTION (J)	TO ORDER (K)		
1												
2												
3												
4												
5												
6												
7												
8												

The key items in this Stock and Demand Report are explained as follows:

Column	Heading	Description
C	Actual Inventory	Quantity of raw material is shown as of the end of the calendar month just past, being careful to exclude all "in-process" material on which processing has been done.
D	On Order	Quantity due to be received to complete unfilled orders on file at end of month.
E	Estimated Consumption	Planned production plus average material shrinkage for the current calendar month.
F	Calculated Inventory	Columns C plus D minus E.
G	Average Actual Four Months Consumption	Actual average monthly consumption obtained by taking average actual consumption for the four months just past, adjusted to eliminate the distortion effect of vacation shutdown involved, if any.

Column	Heading	Description
H	Desired Stock	Obtain by multiplying average consumption, Column G, by the Stock Bogey Ratio. The Stock Bogey Ratio has been determined for each major line and is set forth by the Home Office by month's requirements or fractions thereof.
I	To Stock	This stock adjustment depends upon the difference of Desired Stock (Column H) minus Calculated Inventory (Column F) and may be either a positive or a negative amount. The actual quantity is determinable from a special chart prepared for the purpose.

TABLE FOR USE IN PREPARING STOCK AND DEMAND REPORT - FORM 4487-SD-12-52. (COLUMN REFERENCES ARE TO SAME FORM).

ORDER TO STOCK (Column I)

Calculated Inventory (Column F)	Desired Stock (Column H)																									
	0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000	10500	11000	11500	12000	12500
0	0	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500
500	-100	0	110	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
1000	-200	-100	0	150	220	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1300	1600	1700	1800	1900	2000	2100	2200	2300
1500	-300	-200	-110	0	200	275	350	400	520	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200
2000	-400	-300	-200	-150	0	250	300	361	440	523	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100
2500	-500	-400	-300	-210	-200	0	300	355	420	490	550	640	740	820	910	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
3000	-600	-500	-400	-300	-120	-250	0	350	400	450	500	580	666	742	824	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900
3500	-700	-600	-500	-400	-300	-275	-300	0	400	450	500	565	630	700	775	850	940	1032	1123	1211	1300	1400	1500	1600	1700	1800
4000	-800	-700	-600	-500	-400	-300	-300	-350	0	450	500	550	600	650	723	798	880	963	1045	1122	1200	1300	1400	1500	1600	1700
4500	-900	-800	-700	-600	-500	-400	-350	-350	-400	0	500	525	600	650	710	775	840	916	992	1069	1150	1240	1333	1413	1510	1600
5000	-1000	-900	-800	-700	-600	-500	-400	-350	-400	-450	0	500	600	650	700	750	800	868	940	1017	1100	1183	1266	1346	1421	1500
5500	-1100	-1000	-900	-800	-700	-600	-500	-400	-475	-450	-500	0	500	625	700	750	800	860	920	980	1050	1135	1213	1292	1370	1450
6000	-1200	-1100	-1000	-900	-800	-700	-600	-500	-450	-450	-500	-500	0	500	700	750	800	850	900	950	1000	1085	1160	1238	1320	1400
6500	-1300	-1200	-1100	-1000	-900	-800	-700	-600	-525	-490	-500	-525	-500	0	500	625	800	850	900	950	1000	1068	1130	1200	1275	1350
7000	-1400	-1300	-1200	-1100	-1000	-900	-800	-700	-600	-523	-500	-550	-600	-500	0	500	800	850	900	950	1000	1050	1100	1161	1230	1300
7500	-1500	-1400	-1300	-1200	-1100	-1000	-900	-800	-700	-610	-550	-575	-600	-525	-500	0	500	675	900	950	1000	1050	1100	1155	1215	1275
8000	-1600	-1500	-1400	-1300	-1200	-1100	-1000	-900	-800	-700	-600	-600	-600	-650	-700	-500	0	500	900	950	1000	1050	1100	1150	1200	1250
8500	-1700	-1600	-1500	-1400	-1300	-1200	-1100	-1000	-900	-800	-700	-650	-630	-650	-700	-625	-500	0	500	725	1000	1050	1100	1150	1200	1250
9000	-1800	-1700	-1600	-1500	-1400	-1300	-1200	-1100	-1000	-900	-800	-700	-660	-650	-700	-750	-800	-500	0	500	1000	1050	1100	1150	1200	1250
9500	-1900	-1800	-1700	-1600	-1500	-1400	-1300	-1200	-1100	-1000	-900	-800	-730	-700	-725	-750	-800	-675	-500	0	500	775	1050	1150	1200	1250
10000	-2000	-1900	-1800	-1700	-1600	-1500	-1400	-1300	-1200	-1100	-1000	-900	-800	-750	-750	-750	-800	-850	-900	-500	0	500	1000	1150	1200	1250
10500	-2100	-2000	-1900	-1800	-1700	-1600	-1500	-1400	-1300	-1200	-1100	-1000	-900	-825	-800	-775	-800	-850	-960	-725	-500	0	500	825	1100	1250
11000	-2200	-2100	-2000	-1900	-1800	-1700	-1600	-1500	-1400	-1300	-1200	-1100	-1000	-900	-824	-800	-800	-850	-900	-950	-1000	-500	0	500	1000	1250
11500	-2300	-2200	-2100	-2000	[illegible]	[illegible]	[illegible]	[illegible]	-1500	-1400	-1300	-1200	-1100	-1000	-910	-850	[illegible]	-875	-900	-950	-1000	-775	[illegible]	0	500	875

Column	Heading	Description
J	Estimated Consumption	Estimated consumption for production including shrinkage.
K	To Order	Equals the combination or sum of the quantities in Columns I and J and is a firm order.
L	Estimated Consumption	This space is provided to notify the supplying works of a planned change in your rate of consumption for the month following the delivery month. It should be left blank only when no change is expected.

The Stock and Demand Report is personally signed by a responsible representative of the consuming works and sent out promptly on schedule - to be in the hands of the supplying works not later than the 10th working day of the current calendar month.

The chart shown for Column I has been prepared to provide a convenient method of easily determining the quantity that is to be added to or subtracted from "Calculated Inventory" (Column F) on the Stock and Demand Report, as the adjustment of actual inventory in the month. Assuming the "Desired Stock" quantity remains constant, the table automatically provides for accomplishing the total desired adjustment in a period of one to five months, depending on the size of the change.

The following examples illustrate the use of the chart:

1. If the desired stock adjustment is an <u>increase</u> --

   (a) Pick the quantity nearest to that of the "Calculated Inventory" (Column F) in the extreme right-hand column of the chart.

   (b) Read horizontally to the left to the figure under the column heading nearest to the Desired Stock quantity.

   (c) This selected figure is the one to be inserted in Column I on Form 4487-SD, taking due care to get the decimal point in the right place.

   EXAMPLE: For "Calculated Inventory" quantities, 4,751 to 5,250,

Calculated Inventory (Column F)	Desired Stock (Column H)	Order to Stock (Column I)
5,000	7,000	700

2. If the desired stock adjustment is a <u>decrease</u> --

   (a) Pick the quantity nearest to that of the "Calculated Inventory" (Column F) in the extreme left-hand column of the chart.

   (b) Read horizontally to the right to the figure in the column headed by the figure nearest to that of the Desired Stock quantity.

   (c) This selected negative figure is the one to be inserted in Column I on Form 4487-SD, taking due care to get the decimal point in the right place.

   EXAMPLE: For "Calculated Inventory" quantities 14,750 to 15,249,

Calculated Inventory (Column F)	Desired Stock (Column H)	Order to Stock (Column I)
15,000	7,000	- 1,600

The elimination of numerous calculations is the great advantage to be gained by the use of the chart.

MAINTAIN Consistent Orders - - - -

As long as the lamp factories' consumption rates are reasonably constant and the desired stock ratio is unchanged, the monthly orders are fairly uniform. Any change in consumption, however, has a magnified effect on the monthly order because of the desire to balance stocks. Wide fluctuations in orders are extremely difficult to handle efficiently in the supplying department.

Variations in factory orders from month to month are minimized based on the assumption that stocks are to be balanced in several months rather than in one month.

ORDER Items Outside Lamp Division - - - -

Items purchased outside the Lamp Division account for 20% of the material dollar and are composed of 12 miscellaneous classes of material - packaging being the largest. Requirements are determined much the same as was explained above, but orders are placed for delivery two (2) to three (3) months in the future.

MAINTAIN Stock Balances - - - -

Stock bogies for the various items of raw materials are established by the Home Office. The average stock on hand is approximately one (1) month's usage. This figure may vary slightly from one factory to the next depending on nature of product, procurement time, and the amount of storage space available.

MANUFACTURING SCHEDULE

ESTABLISH Detailed Requirements - - - -

The manufacturing activities cover primarily the assembly of purchased components to produce completed lamps.

Let's take the Newark Lamp Works again as a representative example of a producer of large-volume standard lamps - a plant that produces in the hundreds of thousands per day. Upon receipt of the long-range forecast from the Home Office, the daily rate by types (not divided into the various voltages) is issued to the foremen. This is used to determine required equipment set-ups; it is not issued again unless the long-range forecast is changed by the Home Office. Twice a month the daily rates are issued to the foremen as to type and voltage. Some voltages, such as 125 and 130, have a very limited demand, therefore, one day's production may take care of these items for the month's requirements. The fast moving quantity items, such as 115 volt lamps, would be run at a constant daily rate throughout the month. Before determining these daily rates and mixes, the stock situation is examined to see which ones need to be run during the first part of the schedule so that the various Service Districts will be supplied as required.

EMPLOY Short-Term Forecasting - - - -

Each factory, in order to do a better planning job, uses short-term forecasting with the procedure to be followed outlined by the Home Office. Two types are employed:

- Determination of a trend factor

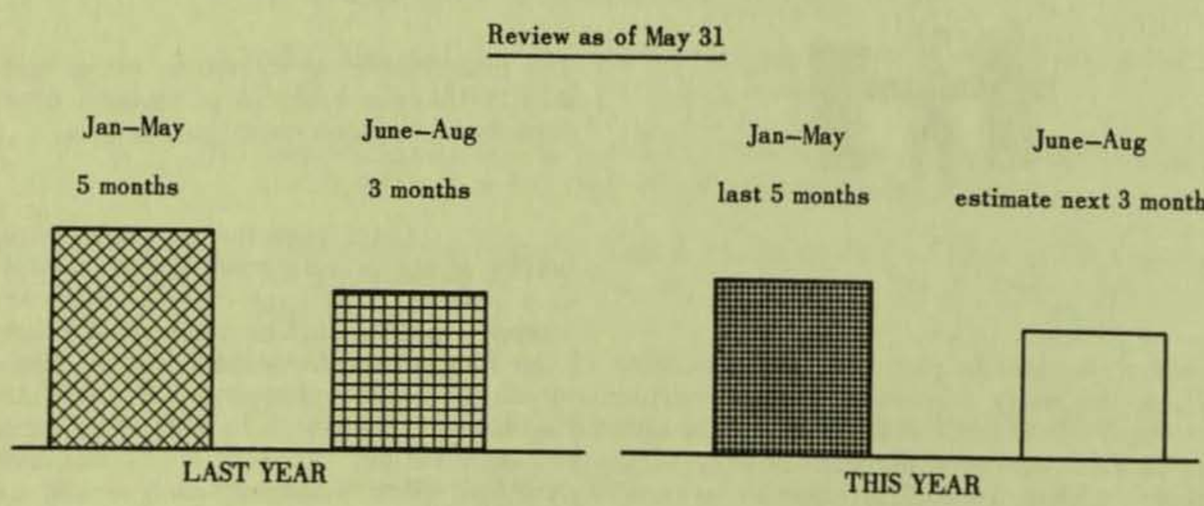
- Use of a projection curve

This forecasting is a systematic estimating of item demands (types broken down into the mix of voltages required) for a three (3) month period. To correctly set forth such a forecast, the items to be manufactured are divided into two (2) groups:

- Items subject to seasonal demand variations

- Items without seasonal variations

First, taking seasonal demand items -- information is available to the Home Office and at the factories as to monthly shipments and accumulative year-to-date shipments. It is also known from finished stock records how much stock is available at the factory at the end of the month. By taking last year's shipments during the previous five (5) months and comparing them to the shipments for the following three (3) months a "trend factor" is established. When this factor is multiplied by the shipments for the preceding five months of the current year, an estimate of the next three (3) months' needs is obtained.



Five months is selected as the best period for this purpose because a shorter period gives too much weight to random fluctuations and a longer period gives too much weight to old data and will flatten current trends.

SHORT TERM FORECASTING DATA (Figures in Thousands)

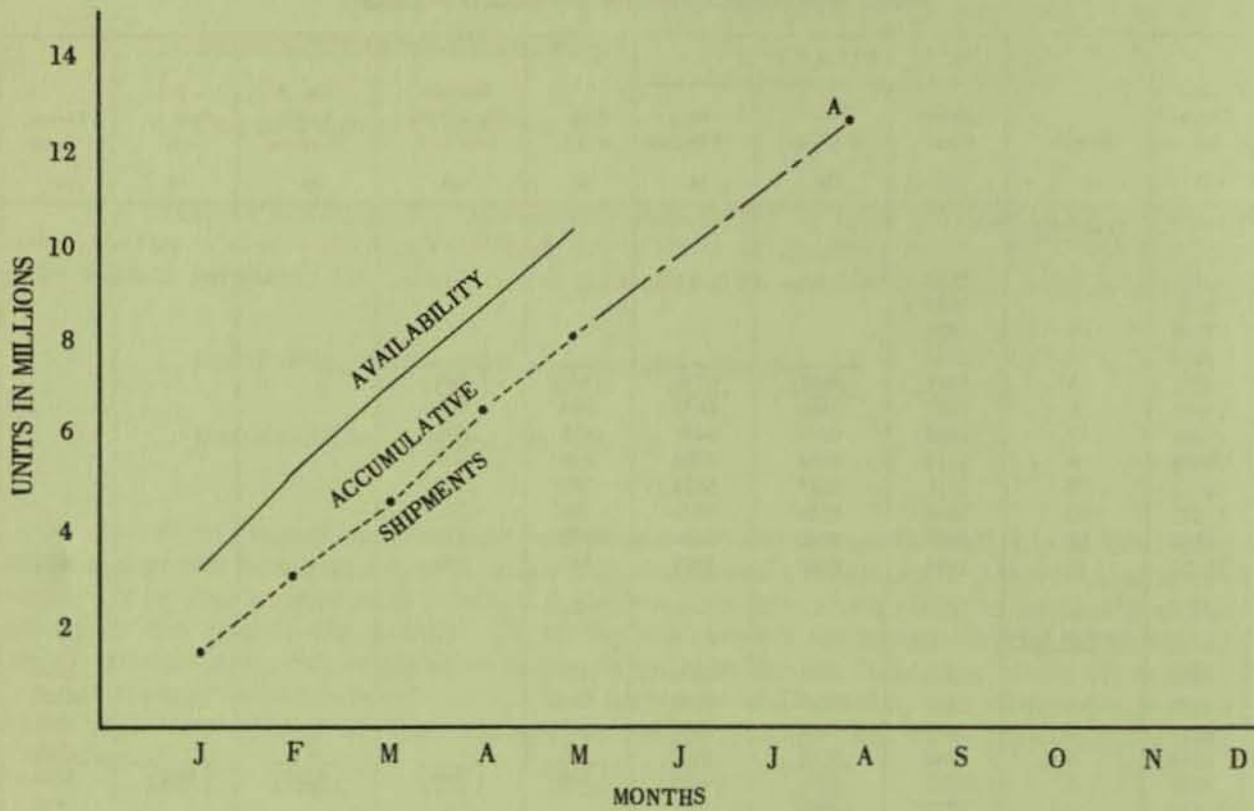
Acc. Factory Ship (A)	Month (1)	SHIPMENTS Current Month (2)	Past 5 Months (3)	Next 3 Months (4)	Ratio 4 to 3 (5)	Selected Ratio Previous Year (6)	Est. 3 Months Shipment (7)	% Est. Ship to Act. (8)	Factory Stock (9)
	Last Year								
1952	1	1952							
3591	2	2639							
5469	3	1878							
7676	4	2207							
9251	5	1575	9651	4751	.492	.606			
11038	6	1787	9486	4675	.494	.501			
12890	7	1852	9299	4487	.483	.495			
14002	8	1112	8533	5534	.648	.600			
15713	9	1711	8037	5814	.725	.731			
17377	10	1664	8126	5978	.736	.752			
19536	11	2159	8498	5186	.612	.617			
21527	12	1991	8637	4873	.565	.560			1394
	Current Year								
1828	1	1828	9393	4890	.523				1436
3195	2	1367	9009	5060	.562				2189
4873	3	1678	9021	5557	.617				2253
6718	4	1845	8707	4402	.505				2198
8255	5	1537	8255	4628	.560	.549	4520	94%	2215
10430	6	2175	8602						1466
11113	7	690	7825						1676
12876	8	1763	7910						1157
	9								
	10								
	11								
	12								

SEASONAL ITEM

Suppose, for example, we wish to forecast the next three (3) months' shipments after the fifth month of the current year. We find that for the first five (5) months of last year we shipped 9, 651, 000 lamps (column 3) with an associated ratio of .492 (column 5). Now from the year before this (not shown on example) we had a ratio of .606 (column 6). To make the forecast for the present year we now take the average of the two ratios (.492 and .606) and come up with a new selected ratio of .549. Applying this to the shipments during the first five (5) months of this year -- 8, 255, 000 (column 3) we get an estimate for the next three (3) months of 4, 520, 000 lamps (column 7).

At the end of this three (3) month period we can look and find that our actual shipments were 4, 628, 000 (column 4) which means that the estimate was 94% (column 8) accurate.

For items subject to random demand variations and with no apparent seasonal characteristics the use of a projection curve is more desirable and more accurate. In this case it is a more "practical" approach in that it allows more room for personal judgment.



SHORT TERM PLANNING CURVE

While the "available" line (solid line) on the chart is theoretically the sum of the initial factory stock and the accumulative year-to-date production, a more simple calculation is to add factory stock at the end of each month to the year-to-date accumulated shipments. For example, in determining January's availability, we add 1,828,000 (column A) to 1,436,000 (column 9) and have an availability of 3,264,000 units.

Next, we must estimate the points for the next three (3) months on the accumulative shipment curve (dotted line). This can be done by extending the accumulative shipments line by visual inspection (Point A).

FEEDBACK Of Data Within The Factory - - - -

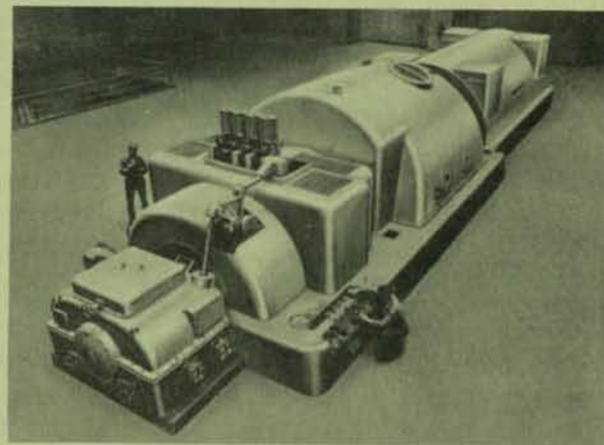
Tally sheets of finished goods put into the warehouse are delivered daily to production. These are checked together with contents labels and amounts recorded in stock records. Due to the high volume of output and the speed of the operations performed the rec⌐rds of rejects and classifications of rejects are reviewed at frequent intervals. In the Newark Lamp Works, this is done every hour so that immediate corrective action can be taken.

FEEDBACK Of Data To Home Office - - - -

In order that the Home Office can coordinate the operation of the various plants, constant and accurate reports must be issued by each plant. Weekly reports are issued showing the actual number of items put into stock ready for shipment. Each month reports are made out, by item, giving total production, stock on hand and shipments to Service District Warehouses and other marketing outlets. Also each month the Home Office receives a report of the planned production, shipping and stock data for the next period which are then available for Home Office's coordinating function.

LARGE STEAM TURBINE-GENERATOR DEPARTMENT

SCHENECTADY, NEW YORK



SCHEDULING IN BRIEF

MASTER SCHEDULE

KEY FACTORS - - - -

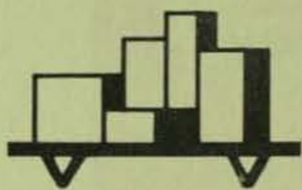
- 60 units produced per year.
- 70 units or 7 million KW per year capacity.
- 11 main prototype units subdivided into 28 types.
- All units made to customers' orders.
- 10 year market forecast issued - revised at least once a year.

HOW IT'S DETERMINED - - - -

- Consolidation of customers' orders.
- 18 - 20 limiting machine tools must be considered in master scheduling.
- Orders fit into Shipping Schedule.
- Shipping schedule dates backed off and a master schedule called "Internal Manufacturing Schedule" is issued - this lists customer, rating of unit, code number and month that assembly must be complete.

PRELUDE
PROBLEMS
PROVOCATIVE READING

MATERIALS SCHEDULE



KEY FACTORS - - - -

- 71% of items in each Turbine-Generator set carried as stock - 10% of direct material dollars per unit.
- 22 items in each Turbine are "A" items - 70% of material dollars.
- 1100 special items per turbine purchased from vendors and contributing departments.
- ABC principles of inventory control used. Order four (4) weeks' supply of "A" stock items, eight (8) weeks' supply of "B" items, and thirteen (13) weeks' supply of "C" (not bin reserve) items. Bin reserve items ordered for six (6) months to one (1) year's supply.

HOW IT'S DETERMINED - - - -

- Total of 7800 stock items - stock records maintained by punched card setup.
- Major vendors (such as foundries) issued ten (10) year forecast of requirements.
- Manual breakdown of parts requirements for each scheduled Turbine-Generator set.
- Engineering specifications for major items (longest procurement cycles) received first for ordering.

MANUFACTURING SCHEDULE

KEY FACTORS - - - -

- One story building.
- 1500 special items machined or sub-assembled for each Turbine-Generator.
- 20 "A" items account for 70% of labor dollars.
- Manufacturing cycle of turbines varies from eight (8) to ten (10) months.
- Job Shop operation (major components) -- some sub-section layouts are designed for direct flow.

HOW IT'S DETERMINED - - - -

- Internal Manufacturing Schedule received by each Manufacturing Sub-Section (Machine Shop, Control, Winding & Erection, and Buckets & Diaphragms). Each breaks down into the component parts they are to produce to meet the required shipping dates.
- Each Sub-Section schedules its output of component parts.

. "A" and components of "A" items are scheduled in detail (70% of dollar value of material and labor). Target dates (raw material due, finish machining, date of test, etc.) are established.

. Historical data plus past experience used in establishing schedule dates - time cycle charts have been established for the major items of the various prototype units so that the manufacturing times for the various codes and types are available.

OUTSTANDING FEATURES

* The various types and ratings of units have been coded and prototyped and time cycle charts have been established for the major items of each type of unit. By the use of these charts based on historical data and past experience a realistic schedule can be established and maintained.

* The "A" items (shells, hoods, frames, fields, rotors, etc.) have been classified as to the name of the item rather than by drawing number. This is pertinent because of the fact that each customer's order will require a special shape of these major items; thus each would use different drawing numbers.

* All bottleneck or restricting operations that must be performed on the major items receive prime consideration before establishing the capacity to produce a turbine to meet the requested shipping date.

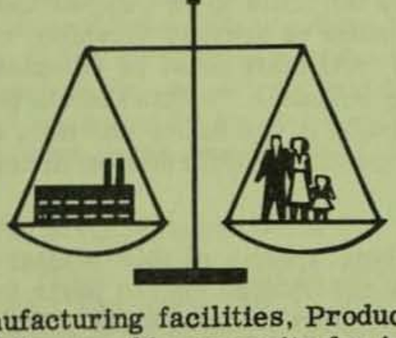
* Material requirements for one (1) year in the future are determined for each Manufacturing Sub-Section. This is established in dollar value - "A" items in detail by item, "B" and "C" items grouped in one,dollar figure. This is done on punched card equipment.

* Each Manufacturing Sub-Section is an entity in itself and schedules its own items, orders its own materials and operates in order to have its components available to meet the over-all Internal Manufacturing Schedule.

* The labor content of the Master Schedule by major areas is determined on punched card equipment. The labor dollar figures for the major components of typical units are available on punched cards. A comparison to the capacity available for the manufacture of various parts is thus readily determined.

FULL DRESS VERSION

MASTER SCHEDULE



ANALYZE Market Forecast - - - -

The Marketing Section issues a market forecast for the next ten (10) year period as to the number of units to be produced for customers' orders and the KW rating of each. This is revised at least once a year. By examining this forecast and analyzing the proposed changes of designs and manufacturing facilities, Production can get a long-range indication of future business and the possible necessity for increases or decreases in the work force.

Each of the major vendors receives a breakdown of this ten (10) year forecast as to the materials, in terms of prototypes, we anticipate we will require from them. This is done so that they can see the trend of requirements. They too must have a forecast of their business for purposes of estimating facilities and manpower -- and, so they will be in a better position to supply the Department with required items at specified times on long-range as well as a short-range basis.

SUBMIT Proposal To Customer - - - -

Upon receipt of a customer's request as to whether a certain type unit can be produced and shipped at a specified time, Marketing, Engineering, Manufacturing and the Finance functions must concur as to its feasibility. Present designs as well as new developments are reviewed - available plant capacity is considered, delivery date is determined, and the cost of the unit estimated. In committing to a promise date and scheduling the job in the factory, the capacity absorbed by KW rating and the number of units and types already promised must be taken into consideration. The proposal is then sent to the customer for his approval. If the customer approves the proposal a requisition for the manufacture of the required Steam Turbine-Generator is issued.

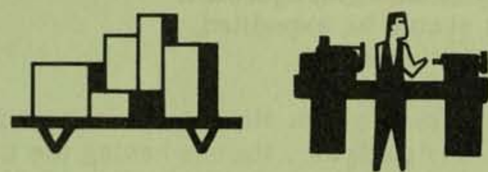
MARKETING'S Role- - - -

Marketing has available the present load on the factory as well as the factors to be considered in arriving at a maximum feasible load. Periodically, Production issues a Shipping Schedule listing by months the units to be shipped to specific customers and the composite KW ratings. The maximum capacity of the shop is directly related to the number of units, the mix of units and the total output (KW) rating. At present the yearly capacity is 70 units or 7 million KW, whichever is reached first. This capacity figure is divided into monthly output, so that Marketing has an indication if a unit can be scheduled per a customer's request. Marketing, in dealing directly with customers or potential customers, could indicate that a desired shipping date would be feasible if an open spot is available. However, Production always has the final say as to a promise of shipment. If the capacity for a particular month has been reached, all efforts would be made to schedule a Turbine as required or to furnish a satisfactory alternate date.

CONSOLIDATE Customers' Orders - - - -

The present factory load is a consolidation of customers' orders issued in the form of a Shipping Schedule which lists by months the units to be shipped and the customers. These shipping dates may be set back, in order to provide "cushion" or contingency, to a date manufacturing (including assembly and test) must be complete; this is issued in the form of an "Internal Manufacturing Schedule." This then is the Master Schedule of all units the factory has contracted to build in the future and lists codes and types, KW ratings, customers' names, and other pertinent information describing the Turbine and Generator.

Each Manufacturing Sub-Section receives a copy of this Master Schedule from which it can make its breakdowns for the sub-assemblies and/or parts to be manufactured and/or purchased in order to meet the scheduled shipping dates of the Turbine-Generator sets.



ESTABLISH Design Codes - - - -

The major components which make up the Steam Turbine-Generator units have sufficient design similarities to make it feasible from an Engineering and Production aspect to establish codes for the various models. Within the codes various characteristic patterns exist such as cost, time to manufacture and output ratings. At the present time the Turbine-Generator units have been grouped into ten (10) codes A, B, C,etc. For example, Code A is a "Single Cylinder Condensing - 3600 RPM, " while Code H is "Non-condensing - 3600 RPM." Each code is sub-divided into types A1, A2, etc. There are from one (1) to five (5) types in each code for a present total of twenty-eight (28). These types have variations in design features such as "Valves at top only" or "Valves at top and bottom".

This classification of units is a guide which enables Production to schedule with more assurance of meeting delivery dates and with realism based on patterns and trends indicated by past manufacturing activity.

DETERMINE Parts Requirements - - - -

Each manufacturing Sub-Section receives a copy of the Master Schedule showing the completion dates of all units on order. There are four (4) Sub-Sections: (1) Machine Shop (shells, hoods, fields, stator frames, rotors); (2) Control (miscellaneous control devices); (3) Winding and Erection; and (4) Buckets and Diaphragms. After examination of the units to be produced and the manufacturing cycle times required for the various items, engineering must be scheduled so that instructions and drawings are available for the ordering or manufacture of special items. The items requiring the longest procurement or manufacturing time must receive priority and be engineered first in order to meet the required end dates. Each Sub-Section must gear its schedule in order that its components are available to meet the completion dates and so that the proper integration of parts is achieved. When the parts lists are received from Engineering each Sub-Section manually explodes the parts requirements segregating the items that are carried in stock.

A cycle time chart is available for all the major components (shells, hoods, rotors, frames, fields, etc.). Applicable charts for each code and type of unit are needed since the major items vary in size and complexity of machining. These items are scheduled in detail. The time charts (designating "weeks before shipment") have been developed over the years from past experience and historical data. The "weeks before shipment" information refers to such events in the cycle as: material due, rough machining, finish machining, required for final assembly, final assembly, and final test and disassembly for shipment. Material procurement cycles for the various materials are issued periodically by Purchasing so that orders may be placed in time to meet scheduled dates in the remainder of the manufacturing cycle.

MAINTAIN Stock Records - - - -

There are a total of 7800 stock items (these include outside vendor parts, raw material and contributing department items, as well as internally manufactured parts). The stock records are maintained by means of a punched card setup. This setup accomplishes five (5) objectives.

(1) to notify whenever an order should be placed.
(2) to determine how much to order.
(3) to determine when delivery should be requested.
(4) to notify when open orders should be expedited.
(5) to notify when excess inventories exist.

Each Manufacturing Sub-Section maintains its own stock items except in the case where more than one Sub-Section uses the same part; then the one having the greatest usage will be responsible for maintaining the stock and other Sub-Sections will draw on it.

TRANSMIT Schedule To Manufacturing - - - -

In scheduling the various manufacturing operations there is no detailed machine loading. Material is released to the factory for manufacturing on a predetermined date. The accompanying paperwork will note the required completion date so that the particular part will be available for sub-assembly or assembly in order to meet the shipping date of the Turbine-Generator. The dispatchers within the Sub-Sections in cooperation with the area foremen have the authority to juggle the parts any way they see fit to best utilize labor and facilities as long as the required shipping dates are met. Manufacturing has the information on the units being produced and their manufacturing completion dates, so they know which components should receive priority.

Labor dollar figures for the major components of typical units are available on punched cards. By using these, the labor content of the Master Schedule can be determined by major areas and a comparison to the capacity available for the manufacture of various parts readily obtainable. This shows whether the schedule can be met with the present manpower, if overtime or multiple shifts must be used, or if the over-all schedule must be revised because of a bottleneck situation.

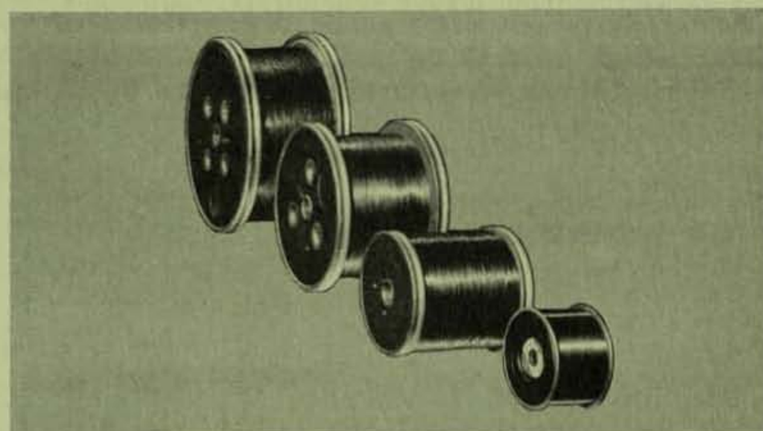
FEEDBACK of Progress - - - -

Each Production unit of a Manufacturing Sub-Section has production expeditors who keep up-to-date with the progress of all component parts. The foremen in turn keep their General Foremen advised. A weekly meeting of the General Foremen with the Superintendent is held so that any bottleneck situations can be immediately resolved within a Sub-Section. In order that further coordination can be achieved concerning the complete units scheduled, a weekly meeting is conducted which is attended by the Superintendents, the Manager - Materials, and the Manager - Manufacturing. This meeting coordinates the efforts of all Sub-Sections and further assists in the realization of the desired shipping dates.

MEDIUM INDUCTION MOTOR DEPARTMENT

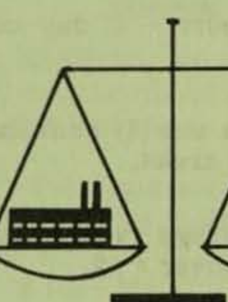
WIRE SUB-SECTION

SCHENECTADY, NEW YORK



SCHEDULING IN BRIEF

MASTER SCHEDULE



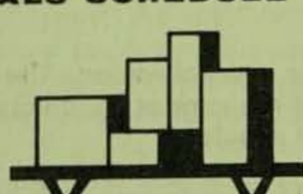
KEY FACTORS - - - -

- 1.5 million pounds of wire produced per month.
- 95% produced to customers' orders.
- 49 sizes of round wire produced in diameters from .001 to .775 - many variations of insulation and enameling.
- Any size rectangular wire, up to 250,000 sq. mils produced to customers' specification.

HOW IT'S DETERMINED - - - -

- Consolidation of customers' orders.
- 5% of output set aside to replenish warehouse stocks.

MATERIALS SCHEDULE



KEY FACTORS - - - -

- 300 purchased items.
- Materials purchased for stock.

HOW IT'S DETERMINED - - - -

. 3 months anticipated requirements received monthly from G. E. operating departments or sections as well as from larger commercial customers.

. Monthly review of stocked items - reordered on the basis of past usage plus anticipated orders.

MANUFACTURING SCHEDULE

KEY FACTORS - - - -

. Single story building.

. Three (3) separate manufacturing areas:
   1. Drawing
   2. Insulating
   3. Enameling

. Flow type processing in each area.

. Enameling room - 5 day continuous operation.

. No more than one (1) week in-process stock between areas.

. Aggregate average raw and in-process inventory turnover = 12.

HOW IT'S DETERMINED - - - -

. Weekly schedule of finished product requirements issued to all areas six (6) working days before start of scheduled week.

. Sequence of jobs determined by foremen.

. Drawing room issued monthly requirements.

OUTSTANDING FEATURES

* Each area (Drawing, Insulating and Enameling) has its own scheduler. The schedulers have a detailed knowledge of the machine layout and the processes involved. Their efforts are coordinated so that a smooth flow of work results.

* Not only is each machine loaded but a detailed labor loading is accomplished by Pro-

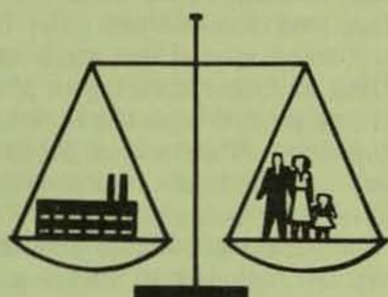
duction in a manufacturing setup where one operator runs a variable number of machines.

* A dispatcher is situated in each area. Constant coordination and communication among these dispatchers result in a smooth flow of work. The Enameling room must have the right size wire at the right time in order to start its continuous operations. The Insulating room must also have the correct wire available to load its machines as scheduled.

* The wire Sub-Section has a record of 94% promises kept.

FULL DRESS VERSION

MASTER SCHEDULE

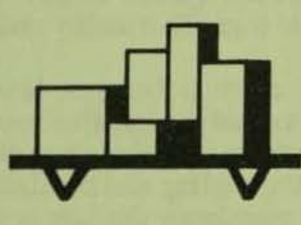


CONSOLIDATE Incoming Orders - - - -

Requirements from other G. E. Manufacturing Departments, (called "Manufacturing Schedules") and commercial and intra-department requisitions are received by Production. The requirements are loaded into the over-all schedule and shipments promised, depending on the present load. The Manufacturing Schedules are for one (1) month's requirements of that particular department or section and usually received one (1) month in advance.

The requirements of different customers are combined as to size and type, considering shipping promises, and entered into a weekly loading summary. A certain percentage of capacity is left open to fit in any rush jobs, increases of orders and to take care of possible breakdowns.

MATERIALS SCHEDULE



DETERMINE Material Requirements - -

Upon receipt of requisitions, no breakdown is made of materials required unless a special item is ordered. Monthly reviews of all 300 stock items are made. The past usage is considered as well as an estimate of future requirements. From this review, ordering quantities are set. A month's supply on hand of all items other than copper is usually the rule.

Copper, the high value item, is stocked for one (1) week's to ten (10) days' supply. Copper requirements are handled somewhat differently from the other components. The operating departments or sections submit monthly an estimate of their next three months' requirements. The larger commercial customers also submit their requirements. With this data and a look at the future trend of customers' demands, an estimate of the total quarterly requirements can be sent to the Purchasing Services Section. This Section handles the negotiations and informs the Wire Sub-Section's buyer where this copper can be purchased. The bare wire scheduler will submit to the buyer his monthly requirements as to sizes of copper rod to order and as to when delivery is required.

FEEDBACK Records of Material Usage - - - -

Material withdrawals, after being posted to the stock record cards, are forwarded to Purchasing. This enables Purchasing to have a constant check on material usage and enables them to purchase in economic quantities. Constant coordination between Production Control and Purchasing keeps inventories at the desired level.

MANUFACTURING SCHEDULE

Manufacturing within the Wire Sub-Section is divided into three (3) areas: Drawing, Insulating, and Enameling. The Drawing room performs operations such as drawing, rolling and heat treating in preparing bare wire to proper specifications. In the Insulating room either cotton, paper, glass, asbestos, or various combinations are wrapped around the bare wire. Alternatively a coating of a formex compound or enamel is applied to the bare wire in the Enameling room. Individual schedules are drawn up for each of these areas. However, all schedules must tie together to insure a smooth flow of work in-process.

DETERMINE Bare Wire Requirements - - - -

The Drawing area scheduler receives from each of the other schedulers their requirements for the following months. This information plus orders for bare wire as a finished product and his forecast of future orders enables proper capacity to be reserved.

The progressive drawing or rolling required must be processed on various machines through different size dies. The scheduler determines the quantities that are to be processed on the various machines. Data are available as to rod size, finished wire size and machine cycle times for a certain poundage of wire to be processed; the times required for the processing of various sizes can thus be readily determined.

About the middle of the month the Drawing room scheduler issues to the factory the average weekly requirements to be drawn or rolled on specific machines for the following month. The dispatcher in that area will cooperate with the other dispatchers so that the correct wire is supplied in order to meet the Enameling and Insulating areas' weekly schedules. The dispatcher in the Enameling room regulates the flow of wire from the Drawing room by informing that dispatcher twenty-four (24) hours prior to need. This close cooperation prevents undue storage of bare wire prior to further processing. No more than one (1) week's supply of bare wire is carried waiting for further processing.

TRANSMIT Requirements of Enameled or Insulated Wire - - - -

A weekly schedule is issued six (6) days prior to the start of the scheduled week by the Enameling scheduler and by the Insulating scheduler which shows specifications and quantities in pounds as well as the requisition numbers applicable. The Enameling room must have continuous runs of five (5) days, twenty-four (24) hours per day. Therefore, sufficient wires of a particular specification must be scheduled. All machines are automatic once the initial set up is made, but the set up time may be as much as four (4) hours per machine.

The scheduler in the Enameling area is limited to the number of machines he can load per week, which has been established through methods and time studies. Each machine is capable of processing so many pounds of a particular type of wire per week and each machine has a specific rating for purposes of loading and applying labor. For example, some machines may be rated as "2 units" while others may be "4 units". One machine operator can handle "12 units" which indicates that one (1) man can operate either three (3) "4 unit" machines or six (6) "2 unit" machines. By actually scheduling every machine in this manner Production establishes a definite labor load and the capacity that will be required. In scheduling of these machines the scheduler must make sure that the combination is equivalent to 12 units or multiples thereof, so that labor will be utilized most efficiently.

The Scheduler of the Insulating room has data available on all sizes of wire and the various combinations of insulations required. Such information includes: size of finished wire, pounds insulated per hour, type of machine, speed and tolerances. The most important information to the scheduler is the number of pounds of a particular size that can be insulated per hour. From the quantities on order he is able to determine the number of hours that a particular machine will be occupied. The scheduler prepares a machine capacity schedule which is submitted weekly to Manufacturing as a guide indicating the trend of business in the coming weeks. Each type of machine is listed with its total capacity in hours and the capacity absorbed by scheduled orders. The picture of the machine loading changes from week to week with additions of new orders. Although the machine schedule changes weekly it does serve as a guide. In addition it is used by the scheduler in determining the present loads on various machines and to what extent he can schedule additional orders. It is also useful to the factory for estimating what their labor requirements on a particular type of machine may be in the coming weeks and as a guide in determining the number of shifts required.

FEEDBACK of Factory Progress - - - -

The Factory works in close cooperation with Production by notifying them of absenteeism and machine breakdowns so that schedule adjustments can be made promptly.

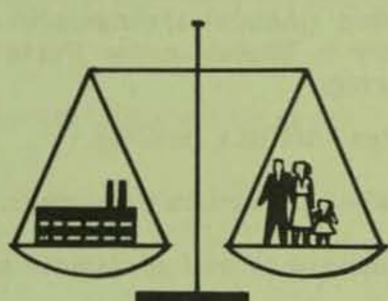
Records of completed items are received by the Production office so that shipments can be made rapidly against the appropriate requisitions.

METER DEPARTMENT

I-50 METER ASSEMBLY
SOMERSWORTH, NEW HAMPSHIRE

SCHEDULING IN BRIEF

MASTER SCHEDULE



KEY FACTORS - - - -

. 8 Models of Type I-50 Meter.

. Conveyorized lines delivering 1 meter every 10 seconds -- 21,000 meters per week.

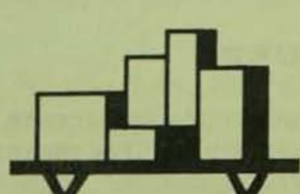
. Meters are shipped to stock at 37 district warehouses.

HOW IT'S DETERMINED - - - -

. A master schedule for an 8-week period is prepared by Production considering:

1. The market forecast issued every three months, projecting next twelve months' sales.
2. The analysis of status of inventories in the district warehouses, and finished products at the factory. The master schedule is issued to the general foreman in charge of assembly 3 weeks before final assembly is to begin.

MATERIALS SCHEDULE



KEY FACTORS - - - -

. 400 - 500 different vendor items purchased.

. "ABC" principles of inventory control used.

PRELUDE
PROBLEMS

HOW IT'S DETERMINED - - - -

- Materials requirements are computed quarterly considering:
  1. Master Schedule requirements.
  2. Inventory on hand.
- Miscellaneous Parts Manufacturing Sub-Section orders raw materials to cover its own needs.
- Materials clerk orders purchased finished parts to fill assembly needs.

MANUFACTURING SCHEDULE

KEY FACTORS - - - -

- Six story factory building.
- Conveyorized Product Flow assembly lines -- Sub-assemblies and Final assemblies.
- Job Shop (mainly) arrangement of machinery in Miscellaneous Parts Manufacturing.
- Light machining work, punch press, screw machines, drilling, milling.
- All jobs issued to parts manufacturing require detailed production paperwork.
- Over 5,000 different parts manufactured for I-50 meters as well as demand meters, time switches, etc.
- All parts manufacturing is done to replenish stocks of finished parts used in assembly.

HOW IT'S DETERMINED - - - -

- Net parts requirements (after explosion of parts lists and stock analysis) are issued to the Contributing Sub Section in terms of weekly demands for the next 8-week period. Economic production lots are run.
- The daily assembly schedules are prepared by the General Foreman from the Master Schedule, which lists the total weekly production rates of final assemblies for each product line and its mix.

OUTSTANDING FEATURES

* Scheduling procedures are decentralized. Decisions are made by persons who are on the scene, who know best the effects of various load conditions. This means that feedback information is used promptly and effectively. For example:

The general foreman of assembly work has a hand in translating the weekly mix of the master schedule into the daily mix. He knows best the effects of mix changes on his assembly lines.

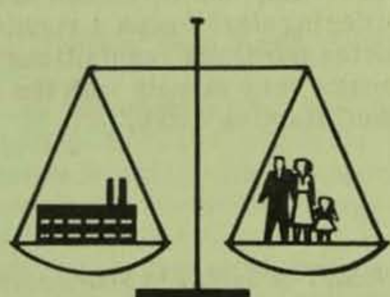
The contributing units schedule their work load - - that is the load control clerk works closely with the shop foremen in releasing the production orders, and in follow-up of progress.

* The method of determining the different manufacturing schedules is tailored to fit the particular shop. In the assembly area, the foreman considers daily capacities of his moving assembly lines and shifts his operators accordingly. In the contributing units, the machine hours of availability are analyzed. Yet these are all tied in with the master schedule.

* Factory inventories of finished parts are controlled simply and effectively using the ABC principles. No stock record system is necessary.

* There is close co-ordination between the Production and Marketing Components. The Marketing Component considers the effects of the mix upon the factory. The factory ships the meters to the district warehouses without factory requisitions so that Marketing can keep finished stocks at their desired levels.

MASTER SCHEDULE



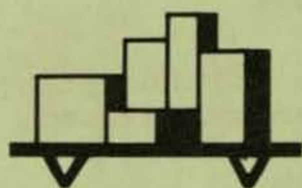
MEASURE Market Demand - - - -

The Marketing Section prepares market forecasts covering the second month of the current quarter plus the four succeeding quarters. This is done by referring to what is known as the "Balance Stock Control Plan" for some 37 warehouses located in 12 major districts throughout the country. Each warehouse has a "bogey" (a finished stock quantity) which is maintained as a buffer against unexpected increases in demand. Manufacturing and Marketing work very closely in balancing input to warehouse inventories with output of sales to customers. Weekly sales figures are submitted to the factory, so that the production section can schedule to replenish finished stocks at any warehouse without being prompted by requisitions. Since the forecasts are received regularly on the first Monday of the second month of each new quarter, four forecasts are made for each quarter prior to its arrival. With each forecast the possibility of a more realistic master production schedule becomes greater, and factory planning and scheduling can proceed in an orderly manner.

COMPARE Market Demand With Factory Capacity - - - -

From the market forecast, the production clerk prepares the master production schedule, which lists the total weekly production rates of final assembly for the various types of the I-50 meters comprising the "mix". Generally this mix will remain valid for an 8-week period, after which a new schedule is issued to the general foreman of the final assembly section. Of course, the "mix" may change from one period to the next. Such variations are likely to inflict drastic changes on the workload demanded of the final assembly section. The final assembly line is on a powered conveyor, moving at a fixed speed and delivering one meter (any model) every ten seconds. The workload must be reasonably balanced among all the various assembly stations as the "mix" is crucial to the determination of the master schedule. For example, a certain type of the I-50 meter may require 50% more assembly time than for the former model. Hence the assembly line capacity for the former model is limited. The production clerk, therefore, must use great discretion in determining the scheduled mix. Definite time cycles are available for the assembly of each model and type produced. This means that a balanced mix must be maintained for a desired output. Meetings are also held with Manufacturing to determine their capacity to produce the required component parts to support a certain mix.

MATERIALS SCHEDULE



DETERMINE Requirements from Vendors

Annual estimates of requirements of raw stock and semi-finished parts are reviewed quarterly by an analysis of the market forecasts. These estimates are made by using material required per hundred meters assembled (pounds, standard bar stock lengths, etc.). The procurement time required by the vendor is also known. Then by using the ABC principles of inventory control, a material procurement schedule is virtually set. Economic purchasing quantities and buffer stock points determine control levels, and materials are ordered when stocks fall to the buffer points. A materials ordering clerk keeps a running record of current balances of each stock item, and he initiates purchase requisitions when replenishment becomes necessary. In doing so, he works very closely with the load control clerk so that materials are available at scheduled starting dates.

MANUFACTURING SCHEDULE

TRANSMIT Schedule to Manufacturing - - -

The Master Schedule is issued to the general foreman in charge of all assembly work three weeks prior to the scheduled starting date.

REFINE Assembly Requirements - - - -

The daily assembly schedules are prepared by the general foreman from the master production schedule. He must elaborate on the master schedule so his foremen in charge of the various assembly lines can plan their daily work. Again the "mix" is important because of the necessity to maintain the desired balance of the work flow. The general foreman may make a man-hour load analysis using operation time elements established by the manufacturing engineering group. This will help him decide precisely how his daily workload is balanced for his assembly lines. Sub-assemblies as well as final assemblies are performed on overhead monorail and belt conveyor lines.

In this way the details of the master schedule of the weekly "mix" are expanded into a manufacturing schedule of daily assembly work. This daily schedule remains effective throughout the next eight-week period.

DETERMINE The Parts Requirements - - - -

To determine the manufacturing schedule for the Miscellaneous Contributing Sub-Section, the Master Schedule is broken down into the parts requirements, using the material lists. This amounts to an "explosion" of the material lists, and is done manually by referring to "parts explosion cards". Each card contains the part name, type and model of meter in which the part is used, and the number of parts used. Gross requirements of the parts equal the number of parts used on the meter, times the number of meters scheduled.

Next, a physical inventory of the stock of finished parts is taken. This inventory includes parts kept near the assembly areas and parts in process in the contributing units.

The inventory quantities are subtracted from the gross requirements to determine the net requirements of each part for the next eight-week period. Thus, for our I-50 meter, a "rate sheet" is issued to the screw machine contributing unit. The rate sheet contains the following information: drawing number, part name, part-item inventory classification (the ABC system of inventory control), the current inventory on hand, and the weekly rate of usage of the part. The rate sheet is the Manufacturing Schedule for the next eight-week period for each of the contributing units - - punch press and screw machines - - each unit receiving its respective sheet for each major product.

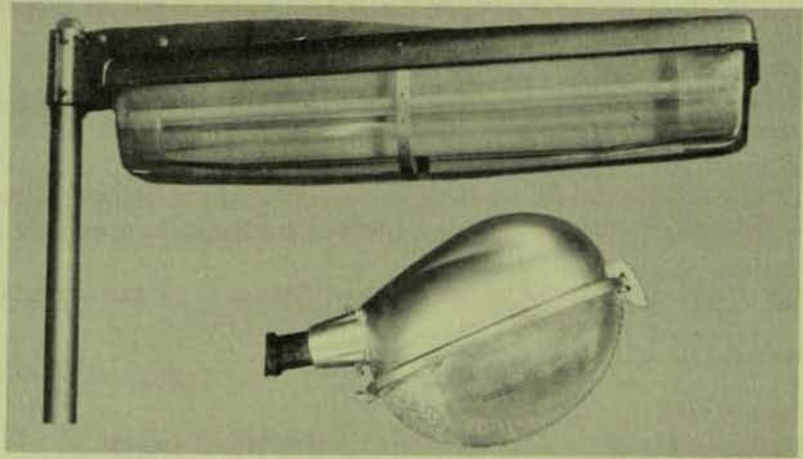
ANALYZE Current Shop Load Conditions - - - -

In the contributing unit is a load control clerk who assumes the scheduling and dispatching functions within the unit. He works in conjunction with the foreman on the floor and is familiar with the capacities of all machines. He maintains a "Visirecord" file of all machines on which is kept the status of the current loading of each machine. He also initiates all the paperwork incidental to the shop order authorizing manufacturing to withdraw the raw stock and to start work. The shop order is released approximately one week prior to the scheduled starting date. Thus, the foreman on the floor has sufficient time to plan his work so as to minimize the work of set-up change-over on the machines. Economic order quantities are used to keep set-up and inventory costs at a practical minimum from one rate sheet period to the next.

FEEDBACK of Progress - - - -

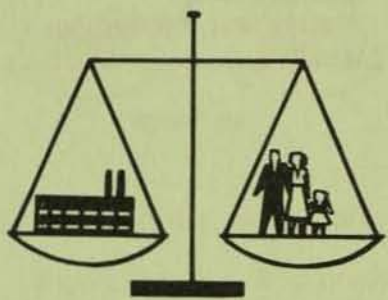
The load control clerk receives from the floor all the labor tickets which indicate the quantity of parts completed through a particular operation. In this way he is able to maintain a record of the actual progress of a job as it moves through the shop.

OUTDOOR LIGHTING DEPARTMENT
WEST LYNN, MASSACHUSETTS



SCHEDULING IN BRIEF

MASTER SCHEDULE



KEY FACTORS - - - -

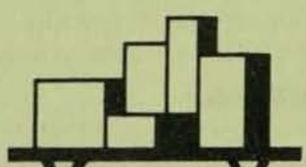
- 20 different product lines - thousands of variations.
- 5000 major units produced each week.

- 25% of dollar volume - authorized cataloged items.
- 75% of dollar volume - items requiring special features (basically produced from standard components).

HOW IT'S DETERMINED - - - -

- Consolidation of customers' orders plus requirements to replenish warehouse stocks issued in the form of a "program" of requirements (weekly production rates).
- Master Schedule issued every eight (8) weeks for a period of twenty-three (23) weeks.

MATERIALS SCHEDULE



KEY FACTORS - - - -

- ABC principles of Inventory Control used.
- Physical inventory of raw stock taken once a month.
- Raw and in-process inventory turnover averages slightly over six (6).

PRELUDE
PROBLEMS
PROVOCATIVE READING

HOW IT'S DETERMINED - - - -

. Peg Board Explosion of units developed into parts requirements to fulfill a "program" of future production rates.

. Stock records maintained and requirements mortgaged for scheduled units with exception of "bin-reserve".

. Special items for off-standard models ordered to customers' requirements through use of the "off-basic" system - addition or omission sheets to standard catalog listings.

. All completely special products ordered to customers' requirements.

MANUFACTURING SCHEDULE

KEY FACTORS - - - -

. 3 story building

. 4 contributing units
  Sheet Metal
  Machine Shop
  Plating and Enameling
  Winding

. 4 assembly areas (by line of apparatus)
  Transformers
  Traffic Lights and Controllers
  Flood Lighting
  Street Lighting

. Job Shop Layout - some bench work assembly.

. Units have low direct labor content - 10% of manufacturing cost.

HOW IT'S DETERMINED - - - -

. Long-range schedule, revised every 4 weeks, issued on "A" items to vendors - they can then meet requirements and help control plant inventory.

. List of parts required issued to contributing units weekly, two (2) weeks prior to required completion date - parts completion date is two (2) weeks before required assembly completion date.

. Sub-assembly requirements issued weekly, one (1) week prior to required completion date which is one (1) week before assembly completion date.

. Weekly schedule of assembly requirements issued one (1) week prior to required completion date.

OUTSTANDING FEATURES

* "Peg Board" explosion is used in determining sub-assemblies, parts, and raw material requirements in order to meet the programmed weekly production rates. This represents a logical and systematic approach to a manual system of determining parts requirements.

* Weekly production schedules are followed by dispatchers and foremen but final sequence of jobs determined by them in order to most efficiently employ machines and direct labor. This puts the responsibility at the point where the actual operations are being performed.

* A physical inventory of all raw stock and "A" items is taken once a month in order to determine an accurate status. This enables a more accurate base to use in ordering materials for future requirements--cuts down on excessive inventory as well as being assured of having a sufficient supply on hand.

FULL DRESS VERSION

MASTER SCHEDULE

The Outdoor Lighting Department manufactures four (4) major lines of lighting apparatus: Transformers, Traffic lights and controllers, Flood lighting, and Street lighting. Each of these lines is handled individually as far as setting up a "program" of production rates based on market forecast, orders on hand, and warehouse stock status.

EXAMINE Forecast and Open Orders - - - -

Marketing and Production get together periodically to examine the market forecast, the incoming orders, the factory's finished stock inventory, and the stock positions of the district warehouses in order to establish a "program" which will outline production requirements by weeks for a future period. When they concur, a list of requirements based on these criteria is issued. These "programs" are issued periodically by major lines so that each line is "programmed" once every thirteen (13) weeks, at least ten (10) weeks before the first scheduled week, and covers a thirteen (13) week period. The amount of lead time beyond the ten (10) weeks is based on procurement times of various purchased items within each line.

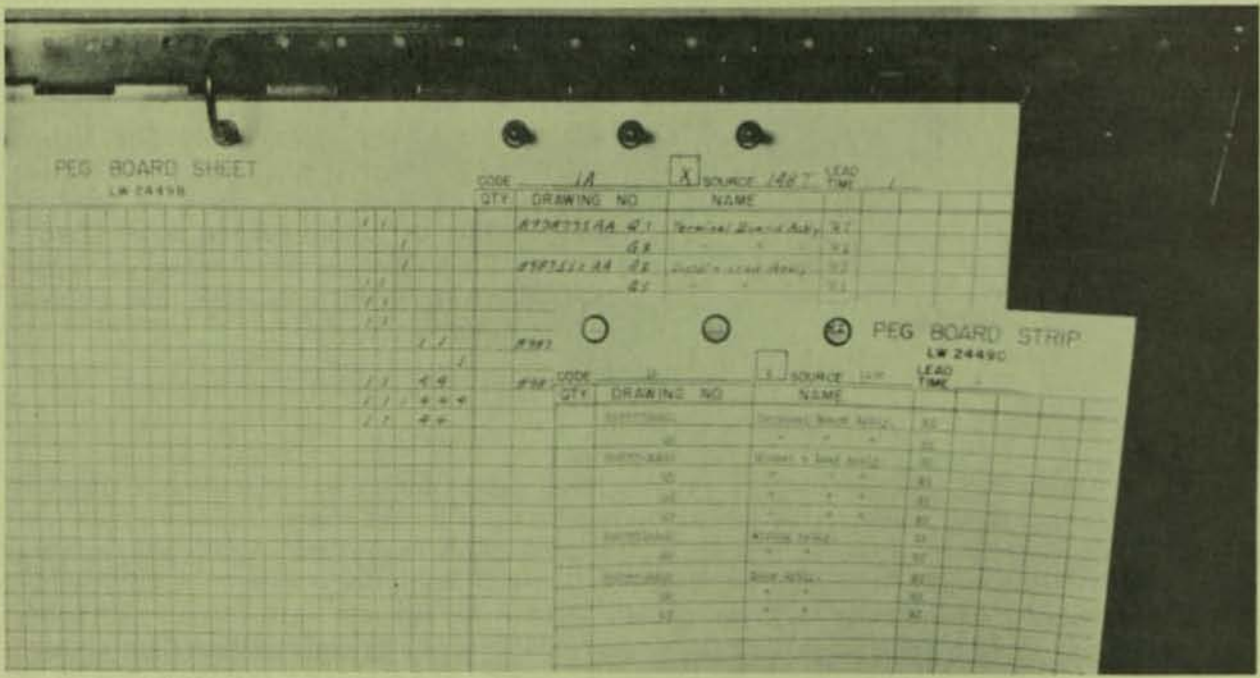
DEVELOP Master Schedule - - - -

From the "programs" that are developed for each line, a Master Schedule is compiled and issued every eight (8) weeks covering all lines. This includes the "programs" that have been issued during the last eight (8) weeks plus all other weekly production rates that have been established for up to twenty-three (23) weeks in the future. The Master Schedule thus includes all items required to replenish warehouse stocks plus items to cover specific customers' orders on hand as well as requirements for standard sub-assemblies to be used for special customer requirements.

This Master Schedule is issued to Manufacturing so that the proper labor adjustment can be made to effectively meet the desired schedule. These schedules are issued so that the first notice of requirements for any one line is received at least ten (10) weeks prior to the first week's production.

DETERMINE Parts Requirements- - - -

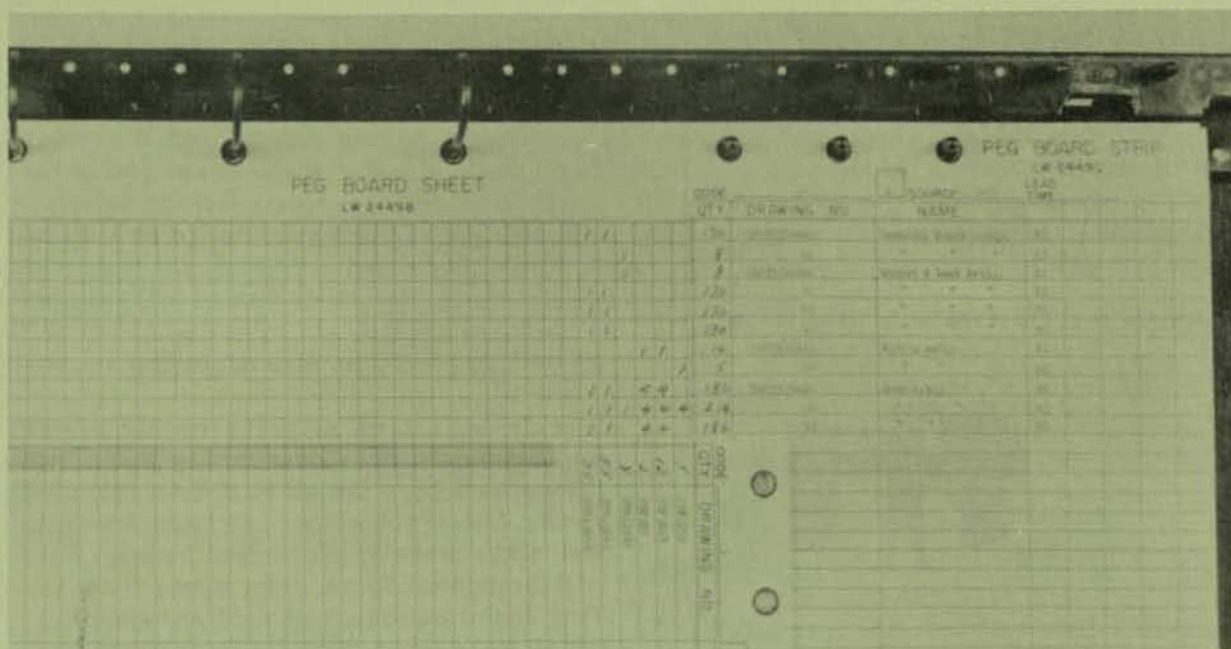
From each program of weekly production rates an explosion is made by the use of "Peg Board Strips". Sets of these strips are made up for all units and sets of standard sub-assemblies appearing on the program. They will be arranged for various levels of breakdown from the finished apparatus to sub-assemblies on down to the actual raw material requirements for each individual part. Each level is coded to correspond with the appropriate peg board sheet.



The completed apparatus strip is denoted by the code number "1", the next level of breakdown by 1A, 1B, 1C, etc. If the letter "X" appears in the box at the top of the strip, then a further explosion is necessary. The next level would be denoted by 1AA, 1AB, etc., 1BA, 1BB, etc., or 1CA, 1CB, etc. A further level of breakdown (again only if an "X" appears) would be denoted by 1AAA, 1AAB, etc., or 1ABA, 1ABB, etc. Still further breakdowns may be evident and would be denoted by further use of letter suffixes. This breakdown is carried down to the point of a purchased part, purchased sub-assembly or to actual raw material requirements.

A set of peg board sheets is maintained for each line of apparatus corresponding to the code number on the strip. The right hand portion of these sheets is a parts list of sub-assemblies or individual parts depending upon the level of explosion. The left side contains quantity information for the determination of total quantities of component parts or sub-assemblies that will be required. To begin the explosion, first take the strip that bears the same code number as the top peg board sheet (in this case 1A). This strip is placed over the corresponding portion of the sheet.

Now the first strip (the requirements of completed apparatus coded by number "1" - no letter suffix) is placed over the quantity portion of the corresponding sheet as shown below with its left side towards the top of the board.



The quantity in each block is multiplied by the quantity immediately below it on the strip. These products are added together and the sums entered in the quantity column to the left of the drawing number on the strip. This is continued until all drawing numbers on the strip have been covered.

Using each single letter coded strip (A, B, C, etc.) in turn in place of the complete apparatus strip, the same procedure is followed as outlined above. In every case, the strip will be processed against all the sheets on the board which carries its code plus one letter and will then be replaced by the next single letter strip. This explosion process is continued stage by stage until all strips marked with an "X" have been exploded to the next level of breakdown.

Each Peg Board Strip has a place for "Source". This tells the manufacturing area where the parts or sub-assemblies are to be manufactured as well as designating those which are purchased items.

When each strip has total quantity requirements determined, this explosion of each line is turned over to an order clerk for further processing. Reference is made to the corresponding stock record cards and the program requirements are entered for each part or sub-assembly.

A physical inventory of raw stock and "A" items is made once each month. The quantities mortgaged against each "program" are checked as well as past usage - orders are then placed in accordance with ABC principles:

"A" items - one (1) week's usage on hand
"B" items - two (2) weeks' usage on hand
"C" items - carried as bin reserve, three (3) months' usage on hand.

This buffer stock as outlined above is maintained for all purchased items including completed parts and sub-assemblies. The purchased parts and sub-assemblies are checked as each "program" of requirements is received and ordered when the ordering point is reached.

Certain items required for customers' special requests are ordered only to take care of the existing customer order and no stocks are maintained.

One of the largest volume purchased items is the casing for a certain type of transformer. These casings are ordered from another department within the company. A weekly schedule is issued to this department four (4) weeks before delivery is required. Adjustments are made each week to compensate for past usage as well as future "program" demands.

MANUFACTURING SCHEDULE

TRANSMIT Mix to Manufacturing - - - -

Weekly schedules of parts requirements are issued to the contributing units two (2) weeks before the start of the scheduled week. These schedules are issued weekly and state weekly production rates. This will include all items determined from the Peg Board explosion as well as "specials" which were taken directly from parts lists made to meet customers' special needs.

The weekly schedules of sub-assembly requirements are issued to the units concerned one (1) week prior to the scheduled week.

A weekly schedule of the final assembly of apparatus by lines is issued one (1) week before the scheduled week.

Within each of the contributing and assembly units is a dispatcher who works in cooperation with the foremen. The work will be dispatched according to the schedules but the sequence of jobs will be determined by the dispatcher and foremen to best utilize the labor and machines.

When the shop is not operating near capacity, the prime consideration in preparing to meet a schedule is the total number of units to be produced as compared to the number of direct laborers required.

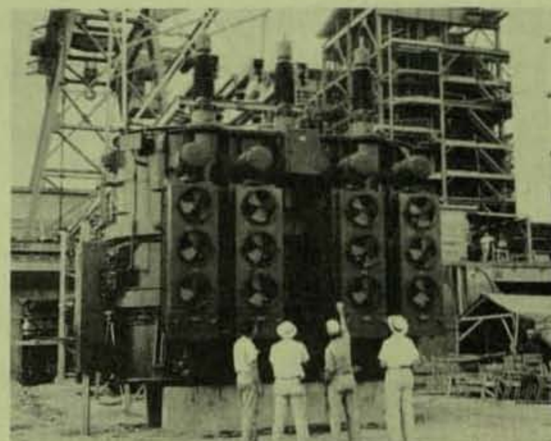
FEEDBACK Of Progress - - - -

A Data Report is issued weekly by the Marketing organization. This report compares the scheduled weekly rate and year-to-date rate with the actual year-to-date production. When year-to-date production figures are lagging, then proper action is taken to determine reasons and adjust schedules or bring production back up to desired output. This report also shows the orders that have been received, the total unfilled orders on the books, and the present finished stock status.

A weekly meeting is held bringing together Marketing, Production, Manufacturing and others that may be concerned. In this meeting the Data Report is reviewed to go over past performance and discuss any possible troubles that may be anticipated in order to meet customers' demands.

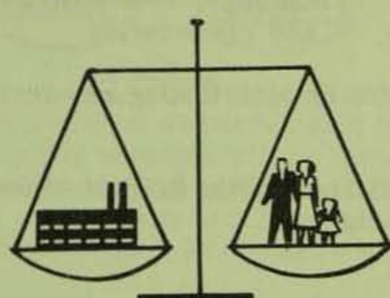
POWER TRANSFORMER DEPARTMENT

PITTSFIELD, MASSACHUSETTS



SCHEDULING IN BRIEF

MASTER SCHEDULE



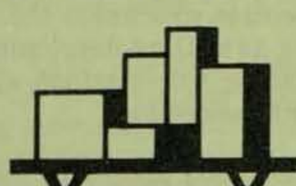
KEY FACTORS - - - -

- Power Transformer production divided into three (3) lines by size of units - Small, Medium and Large.
- Average of 42 units produced each week-
  - 30 Small -- 501-5000 KVA
  - 7 Medium -- 5001-15,000 KVA
  - 5 Large -- 15, 001 KVA and above
- Transformers divided in twenty-four (24) categories by design and output similarities; many special customer requested features possible.
- Produced to customers' orders - average two (2) units per requisition.
  - 15% Repetitive or Duplicate units
  - 85% Specially designed units

HOW IT'S DETERMINED - - - -

- Consolidation of orders
- Units slotted in shipping schedule by weeks - consideration given to mix and total weekly manufacturing cost in determining capacity.

MATERIALS SCHEDULE



KEY FACTORS - - - -

- ABC principles of Inventory Control used.
- Each contributing sub-section maintains own stock inventories.
- Raw and In-process inventory turnover averages close to 4.

HOW IT'S DETERMINED - - - -

- Manual breakdown of raw material and vendor item requirements made by each sub-section for production of its components.
- Long procurement items and "specials" ordered by Assembly and Test Sub-Section.
- Materials for Winding Unit ordered only for specific orders - balance of materials ordered to requirements plus consideration of past usage.

MANUFACTURING SCHEDULE

KEY FACTORS - - - -

- Multi-building manufacturing facilities.
- Four (4) Manufacturing Sub-Sections
  - Assembly & Test
  - Internal Components (Winding, Cores, and Insulation)
  - External Components (Tanks, Clamps, and Coolers)
  - Bushings, Load Ratio Control, and Accessories

- Assembly and Test Sub-Section issues requirements on contributing sub-sections and coordinates so that shipping dates can be met.
- Job Shop layout in most areas - Punch Press Unit approaches Product-Flow in producing core punchings and assembly of cores and clamps.

HOW IT'S DETERMINED - - - - - - -

- Weekly "Release Sheets" issued by Assembly and Test after referring to cycle charts of type and size of transformers ordered.
- "Release Sheets" tell contributing sub-sections start and finish dates for major components.
- Component parts manufacturing integrated to meet required shipping dates.
- Weekly schedules issued by sub-sections for daily requirements - sequence of jobs predetermined by Production and dispatched in cooperation with foremen.

OUTSTANDING FEATURES

* The Assembly and Test Sub-Section is the centralized coordinator in the scheduling of component parts into final assembly. This Sub-Section processes the requisitions, issues promises and performance data to customers as well as developing the over-all Master Schedule. Orders are placed on the contributing sub-sections who in essence are vendors supplying the major components for final assembly.

* Each Manufacturing Sub-Section is a business in itself and maintains the components in its inventory until completed component parts can be delivered to Assembly and

Test. In addition, completed parts may not be delivered to Assembly and Test until the requested delivery date.

* Each of the categories or "bands" of transformers has a time cycle chart that has been developed from past history. These break the "bands" down into the major component parts and show the manufacturing cycle times for each - the time by number of calendar working days to make and deliver the various components to the main assembly area.

FULL DRESS VERSION

MATERIALS SCHEDULE

EXAMINE Incoming Orders - - - -

The Master Schedule is strictly a backlog of orders on hand. Requisitions are received by the Assembly and Test Sub-Section of the Production organization. They in turn order on, and coordinate the efforts of, the contributing sub-section so that the final shipping schedule will be met. The requisitions are checked with an "Advance Data Sheet" that is received from Engineering. This Data Sheet gives all the specifications of the unit or units ordered, including the main features and the total manufacturing cost dollars required to produce each unit.

DEVELOP Master Schedule - - - -

The orders are slotted into a shipping schedule by weeks considering total manufacturing cost during that week, the mix, and the requested or committed delivery dates. This is in essence the Master Schedule. The schedule clerk segregates each unit ordered into the appropriate category or "band". Each of these "bands" has time cycle charts developed from past history so that lead times and manufacturing cycle times are available for assembly and testing as well as for the manufacture of each major component, such as cores, windings, tanks, etc. By having all this information available, a starting date can readily be determined, based upon the ability to fit effectively into the load on the factory. Each "band" is designated to cover a range of equivalent KVA and Test KV ratings. This equivalent rating is noted by Engineering so that Production can immediately refer to the proper time cycle charts. By this method each new unit falls automatically into a definite "band" and helps speed up the scheduling procedure.

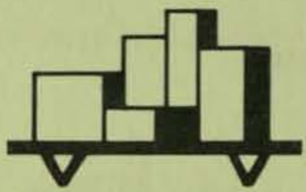
REQUEST Engineering Data - - - -

After each unit has been entered into a shipping schedule by weeks, cycle times for ordering, planning and material procurement are determined so that Engineering and Drafting information can be scheduled. If Engineering information (parts lists and new or revised designs) can be completed as scheduled, the scheduled finish date will stand, otherwise required adjustments may be necessary in order to allow for longer design time.

TRANSMIT Mix To All Concerned - - - -

Each week a "Release Sheet" is issued to the contributing sub-sections for each of the three (3) lines (Small, Medium and Large). These sheets list all the units on order and the required major component parts to be started several weeks in the future. Each sheet issued is numbered as to the fiscal week that manufacturing is to begin.

MATERIALS SCHEDULE



DETERMINE Special and Long Procurement Items - - - -

Advance information from Engineering is required on all special and long procurement items before the actual "Release Sheet" including the requisition is issued. The Assembly and Test Sub-Section will place orders for these items and route them for delivery to the sub-section that will require them in order to manufacture their components.

DETERMINE Parts Requirements - - - -

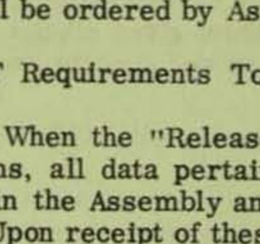
After the parts lists are received from Engineering, the units are manually exploded by Assembly and Test into parts requirements - both vendor items and parts or sub-assemblies to be produced by the Internal and External Component Sub-Sections. Other than long procurement items, only parts or sub-assemblies for use in final assembly will be ordered by Assembly and Test from outside vendors.

TRANSMIT Requirements To Contributing Units - - - -

When the "Release Sheet" is issued to the Internal and External Component Sub-Sections, all data pertaining to each requisition are turned over to a requisition clerk within the Assembly and Test Sub-Section who will follow the units through final shipping. Upon receipt of these weekly requirements (by fiscal week that manufacturing must begin) the contributing sub-sections will manually break down into the parts they are to produce and order the necessary vendor items accordingly. Each sub-section maintains its own stock inventories governed by the ABC principles of inventory control and guided by a central Inventory Control unit. "A" and "B" stock items are maintained and mortgaged against each scheduled transformer.

The Winding Unit within the Internal Components Sub-Section orders its major materials only after specific orders are received and, therefore, maintains no stock that can be applied as new orders are processed. Their weekly requirements are determined per the orders on hand and orders are scheduled so that planned requirements are received two (2) days before the coil winding start date.

MANUFACTURING SCHEDULE



COORDINATE Requirements Of Contributing Units - - - -

The weekly "Release Sheet" issued by Assembly and Test lists all the major component parts of each scheduled unit with their starting and completion dates. This also tells the test and shipping dates so that the whole schedule is readily available to the contributing sub-sections and others concerned. The total manufacturing cost for each transformer is listed as well as the direct labor dollars to be incurred by each of the manufacturing sub-sections. This weekly cost figure is used as a guide so that the factory will not be overloaded. Each line of transformers has a definite limit of total manufacturing cost that can be applied in any one week.

Before the issuance of the "Release Sheets", an explosion of requirements is made by Assembly and Test. Orders are then placed with each of the contributing sub-sections for the manufacture of the component parts. This means that in addition to the "Release Sheet" information (as to starting and completion dates for the major components), individual orders are issued as actual authority to manufacture.

DEVELOP Internal Schedule - - - -

Upon receipt of the "Release Sheets" and the orders for individual components, each of the contributing sub-sections begins scheduling its load for production to begin several weeks in the future.

Within each sub-section schedules are issued weekly to Manufacturing stating weekly requirements by days for up to six (6) or eight (8) weeks ahead. Production dispatchers in the area, in cooperation with the foremen, determine the actual sequence of jobs to be performed. However, this sequence has been partially predetermined by Production's daily requirements.

The total required manufacturing costs and direct labor dollars are used by the sub-sections in determining their labor load restrictions. A somewhat different approach is used within the External Component Sub-Section where the Punch Press Unit operates a partially continuous operation for the production of core punchings. This unit is loaded by direct labor dollars and by tons of material.

FEEDBACK Of Factory Progress - - - -

Each week a report is issued ("Release Sheet Status Report") by Assembly and Test which is a consolidation of weekly reports from the other sub-sections. This gives the activity concerning the major components as well as assembly and shipping. It tells the status of ordering, starting and completion for these functions as well as average number of units (major components plus assembly and shipping of complete units) completed during the last four (4) weeks.

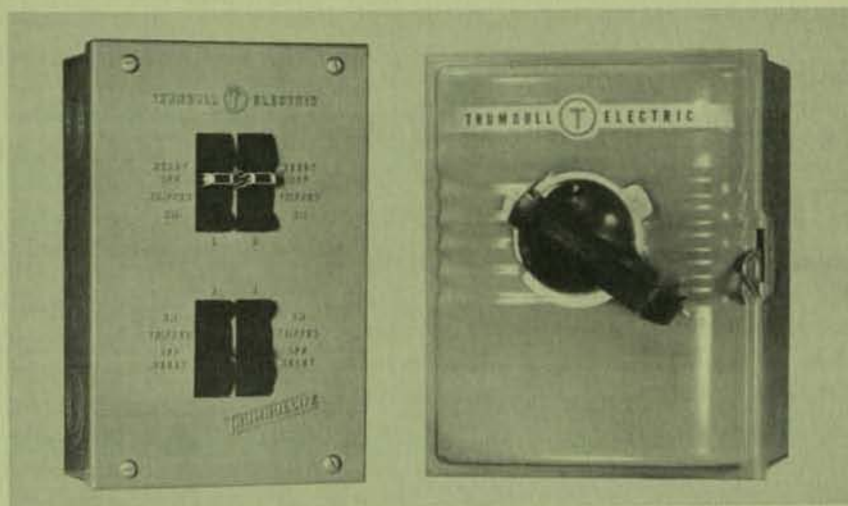
Every four (4) weeks a report is issued by Assembly and Test stating the backlog by manufacturing cost by transformer line, again in reference to the issued "Release Sheets".

Weekly meetings are held with Production and Manufacturing within the sub-sections to review all jobs for existing troubles plus a discussion of any future anticipated restrictions.

The Assembly and Test Sub-Section will conduct periodic meetings with the contributing sub-sections in order to tie in parallel completion dates. This enables this sub-section to more effectively examine the load ahead and be more assured that shipping dates can be met.

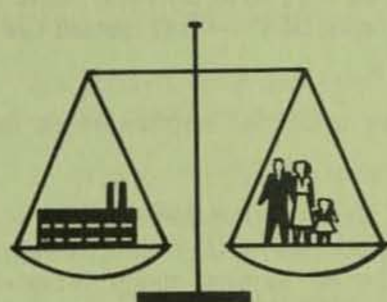
TRUMBULL COMPONENTS DEPARTMENT

PLAINVILLE, CONNECTICUT



SCHEDULING IN BRIEF

MASTER SCHEDULE



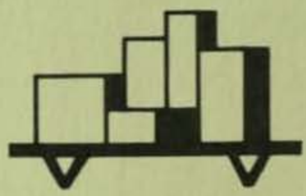
KEY FACTORS - - - -

- Hundreds of thousands of units produced each month.
- 3500 different devices (circuit breakers, knife switches, enclosed switches, etc.) produced during each calendar year.
- 1500 devices stocked in eight (8) warehouses.
- 380 "fast movers" - 70% of business (all for warehouse stock).
- 500 "slow movers" - 20% of business (some for stock, some to order).
- "Specials" - 10% of business.

HOW IT'S DETERMINED - - - -

- "Fast movers" - forecast of monthly requirements issued three (3) months before required month.
- "Slow movers" - past experience used by Marketing and Production to forecast monthly parts requirements three (3) months before required month.
- "Specials" - Marketing transmits orders direct to Production as received.
- Three (3) weeks before scheduled month actual consolidation of orders on hand plus anticipated business developed into Master Schedule.
- Total Shop Cost dollars plus the mix balance used as guide to loading of factory.

MATERIALS SCHEDULE



KEY FACTORS - - - -

- ABC principles of inventory control used.
- Over 900 different raw stock sizes carried.
- 7000 different purchased parts.
- Each of "fast" and "slow movers" fall into one (1) of 100 "families" - each "family" contains devices that use 85% common component parts.
- Raw and in-process inventory turnover = 4.

HOW IT'S DETERMINED - - - -

- One (1) month forecast exploded on punched cards by a central unit for "fast movers" and standard parts decks of "slow movers" and "specials" - list issued for parts to be purchased as well as parts to be manufactured.
- Parts to be manufactured further exploded into raw material requirements in central unit by punched card operation.
- Each of three (3) decentralized Production units order component parts - quantity for "fast movers" firmly determined by forecast plus past usage data; standard parts for "slow movers" taken from forecast and balanced to past usage--non-common component parts requirements doubled to meet possible fluctuations.

MANUFACTURING SCHEDULE

KEY FACTORS - - - -

- Two (2) groups of assembly areas - bench-work operations.
- Two (2) groups of parts manufacturing areas - mainly job shop with some common parts manufacturing performed as product flow.
- Three (3) decentralized Production units each responsible for own Production Control functions.

HOW IT'S DETERMINED - - - -

- Original forecast of monthly requirements divided into weekly rates by Production units and factory foremen.

. Requirements of component parts to be manufactured issued by central unit at time of forecast - parts are ordered by the Production Units to be complete by the assembly date.

. Schedule of devices to be produced issued three (3) weeks before start of scheduled month - weekly rates again set and any increases or decreases from forecast accounted for. This schedule shows assembly foremen actually what is to be completed.

OUTSTANDING FEATURES

* Three (3) decentralized Production units, each responsible for a specific group of devices, perform the following functions: ordering and scheduling of component parts and sub-assemblies; expediting purchased items as well as parts manufactured within factory; maintaining stock inventory records; and the fulfillment of the schedule of finished devices. The Production Planning and Control functions are performed nearest the "firing line".

* A Central Production Planning unit orders all raw materials to produce the parts required for the forecasted quantities. Economies can be realized by taking advantage of quantity purchases when like material is used by more than one (1) Production unit.

* Sets of punched cards are maintained by the Central Production Planning unit and are used for the following purposes:

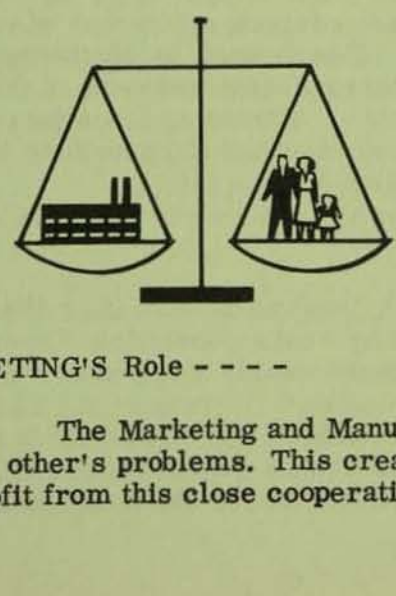
  1. Determining the total shop cost dollars of a forecast or a schedule by month or week.

  2. Exploding the devices into the component parts and sub-assemblies required and dividing these into parts to be purchased from outside vendors and parts to be manufactured.

  3. Performing a further explosion of parts to be manufactured into the quantities and specifications of raw materials required.

FULL DRESS VERSION

MASTER SCHEDULE



The finished products produced by the Trumbull Components Department are divided into three (3) groups according to their sales volume: (1) "fast movers" which account for 70% of the business (2) "slow movers" which account for 20% of the business, and (3) "special" devices which account for the remaining 10%. The scheduling activities in each one of these groups is handled differently.

MARKETING'S Role - - - -

The Marketing and Manufacturing organizations have a mutual understanding of each other's problems. This creates a team-like attitude so that the over-all business can profit from this close cooperation. Marketing has the responsibility of forecasting, processing requisitions and warehousing (75% of the dollar value of finished products are produced for warehouse stock). Manufacturing uses the Market Forecast, after conferring with the factory concerning capacity, as a guide to order materials, component parts and sub-assemblies.

Marketing receives orders for devices from individual customers as well as for replenishing the district warehouse stocks. These orders are then placed on the factory.

EXAMINE Market Forecast - - - -

For the "fast movers" a monthly Market Forecast is sent to Production three (3) months prior to the forecasted month. The following criteria are used when establishing this forecast of building rates for each of the 380 fast moving items:

(1) Usage figures for the corresponding previous quarters. Detailed records of all fast moving devices are kept by Marketing showing week by week usage.

(2) Average usage of the device over the previous year.

(3) Stock position at the present time - Marketing maintains records of all devices in the various warehouses and receives a stock status report weekly from each.

(4) Objectives set by the Sales organization.

(5) The level of production that the factory has been maintaining and what can be expected in the months ahead.

This forecast gives Production the opportunity to notify Manufacturing of the proposed load, so that the necessary facilities will be available and weekly rates can be set.

A forecast of the requirements for "slow movers" is issued by cooperation of Marketing and Production for the same period and at the same time as the forecast for "slow movers".

The orders for "special" devices are sent to Production and fitted into the schedule depending on the availability of special materials.

Each month the District Sales organization issues a forecast of expected gross sales in dollars for the next three (3) months. This is used by Marketing in determining and comparing forecasted rates. All the "fast movers" and some of the "slow movers" are stocked in each of the eight (8) warehouses. Marketing keeps detailed activity records of all finished devices stocked in these warehouses and sets their authorizations of quantities to be stocked.

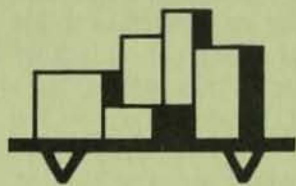
ESTABLISH Master Schedule - - - -

The monthly forecast is reissued to each Production unit after the weekly rates are determined and a shop cost figure tabulated by weeks (punched card operation). The shop cost per week must be in balance as well as the weekly mix breakdown.

Three (3) weeks before the start of the scheduled month all orders on hand are consolidated. This consolidation plus anticipated orders within the next month are developed into the Master Schedules which are each Production unit's requirements.

These are the actual authority to manufacture and at this time any increase or decrease in requirements from the forecast must be determined and proper action taken.

MATERIALS SCHEDULE



EXPLODE Parts Requirements - - - -

When the monthly forecast has been examined by Production and Manufacturing and weekly rates set, the finished products required for the month are exploded by a punched card setup into parts requirements. This is done each month for parts required in the forecasted assembly requirements for three (3) months in the future. This explosion makes two (2) lists for each of the three (3) Production Planning units - one lists parts to be purchased, the other lists parts to be manufactured. This explosion is done for all the "fast movers" and the standard parts deck for "slow movers" and "specials". When the requirements of component parts have been determined, the stock record cards and/or order cards are checked by an order clerk to determine what orders should be placed and for what quantity. Orders are placed in economical lot sizes based on their usage, procurement time, price versus quantity variations, and their ABC inventory value. Stocks are maintained as follows: "A" items, 0-8 weeks' usage; "B" items, 8-12 weeks' usage; "C" items, 17 weeks' usage and over. In the case of cutbacks in the forecasted quantities, the quantities of the next forecasted month's explosion are adjusted accordingly, so that a build-up of inventory does not take place. A constant check is made of the usage so that proper adjustments can be made in order points and order quantities.

Ninety percent of the total sales volume has been standardized into 100 "families". In each family approximately 85% of the component parts are common within that family group. All of the "fast" and "slow movers" belong to one of these families. By this form of standardization many forms of economy have resulted in the purchasing and manufacturing of component parts.

The materials required for "slow movers" are ordered in accordance with the original forecast but with double the quantity for the non-common parts. This is necessary because it is the demand for the "slow movers" that has the greatest fluctuation. By so doing, the fluctuations can be handled with the least amount of delay to customers even when requirements are considerably increased. If the common standard parts are not mortgaged due to the receipt of less "slow movers" than scheduled, Production may do one of the following: (1) Ask Marketing to take additional "fast movers", (2) Manufacture additional "specials" next month, or (3) Balance out parts in next month's parts procurement.

The special parts required for "special" devices are either carried on a bin reserve basis, or are ordered as required.

DETERMINE Raw Material Requirements - - - -

Material such as copper and sheet metal is handled somewhat differently from other raw materials. Punched cards are used to determine the monthly copper requirements. Each month a card is keypunched for each required copper part. The quantity, size and all other pertinent information is contained on the card. The cards are then put through a sorter which picks out all like size material. The weight required is determined by a calculator, and then a tabulator summarizes the total requirements. At the present time sheet metal requirements are figured manually, but a system similar to that used for copper determination is being developed. A one (1) month's buffer stock of copper and sheet metal is maintained.

All raw material is ordered by the Central Production Planning component. Following the issuance of the parts requirements a further explosion is made by punched cards which will list the raw material requirements to produce the manufactured parts. Raw materials, because of procurement times plus parts manufacturing cycles, are generally ordered for assemblies to be produced one (1) month beyond the forecasted month. This being the case, past usage plus available forecasts and previous forecasts versus the actual usage must be considered so that inventories are kept at the desired level. Economical ordering quantities and points are used and continually changed as conditions vary. Material for "special" items must be factored in as well as the forecasted requirements for "fast" and "slow movers".

MANUFACTURING SCHEDULE

SCHEDULE Parts Requirements - - - -

Before the actual receipt of the Master Schedule each Production unit will order most component parts from the fabrication areas. This is done by referring to the Marketing Forecast, checking past usage and balancing with economical lot sizes. In general, component parts are scheduled for completion one (1) month before the assembly date. A few days previous to the scheduled month, all orders for component parts are checked by the central unit as to the availability of raw materials. All items that have material available are given to the Production unit concerned where the specific priority is noted for each job. They are then issued to the manufacturing floor. Considering the priority of each job, the foremen will load the jobs to best use the facilities and labor within their sections. The actual loading of component parts and subassembly manufacturing is related to the shop cost dollars which have been determined for the finished products.

TRANSMIT Assembly Requirements to Manufacturing - - - -

Three (3) weeks before the scheduled month, the Master Schedules are issued to Manufacturing as well as each of the three (3) Production units. Any items required in addition to the forecast are accounted for by ordering additional component parts (a check of stock records may show that additional material is or will be available).

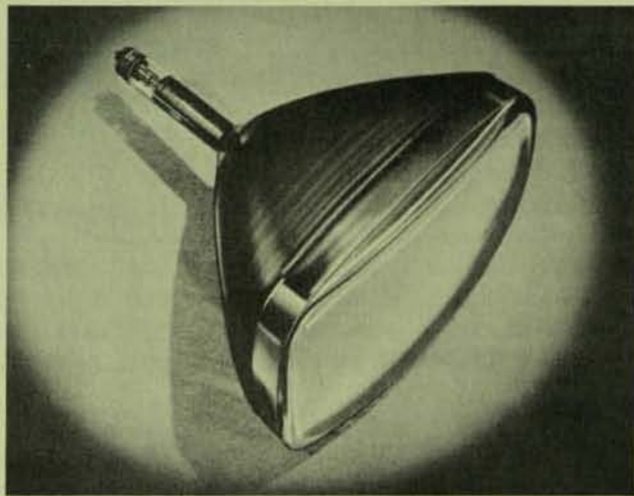
These Master Schedules are the actual orders to complete the designated finished devices. The Production units will also use these when accumulating parts to be issued to the assembly benches. Production must deliver these accumulations to the assembly areas in order to meet the scheduled completion dates. Production sets the weekly rates in conjunction with Manufacturing, but does not set the actual sequence of devices or parts to be manufactured. The foremen schedule sequence to best utilize facilities and labor and to eliminate set-up charges as long as the scheduled dates are met and designated priorities maintained.

FEEDBACK Manufacturing Progress - - - -

On the Master Schedule form there is a space for actual production figures which are filled in by Production as well as by the assembly foremen. This gives an immediate week by week comparison with the scheduled weekly rates. These performance figures are converted into shop cost dollars. A monthly report is issued by the central Production organization showing weekly shop cost figures taking into consideration carryovers from last month's schedule as well as the current month's figures. A certain fixed percentage is added to take care of "specials" that never appeared on a schedule and the total, excluding items manufactured but appearing on a future schedule, is compared to budgeted shop cost dollars. As a further comparison actual labor dollars expended during the period is determined from payroll records.

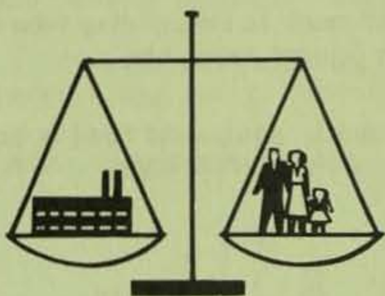
These figures of actual shop cost dollars expended not only give the attainment versus scheduled output, but act as a guide in determining future capacity.

TUBE DEPARTMENT
CATHODE RAY TUBE SUB-DEPARTMENT
BUFFALO, NEW YORK



SCHEDULING IN BRIEF

MASTER SCHEDULE



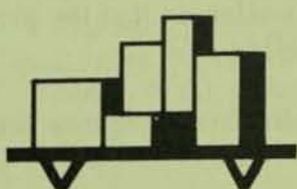
KEY FACTORS - - - -

- **3200 television tubes produced per day.**
- **28 types of tubes manufactured - up to 13 produced during any one month.**

HOW IT'S DETERMINED - - - -

- A Market Forecast is issued monthly by Marketing estimating types and quantities required by month for the next six (6) months' period.
- The Market Forecast is a consolidation of customers' orders, anticipated customers' orders and requirements for warehouse stocks.

MATERIALS SCHEDULE



KEY FACTORS - - - -

- **500 purchased items.**
- **ABC principles of inventory control used.**
- **60% of all parts used in assembly are purchased.**
- **Raw material inventory turnover = 12.**

HOW IT'S DETERMINED - - - -

. Six (6) month forecast issued by Marketing is exploded for material requirements.

. Glass bulbs ordered for daily delivery.

. A stock of one month's supply maintained for most items.

. Purchasing function is performed by a Central Purchasing unit in Syracuse.

MANUFACTURING SCHEDULE

KEY FACTORS - - - -

. 3 story building.

. Conveyorized through all stories for bulb treatment and assembly.

. Bench work in assembling tube mechanism (mount assembly).

. Automatic equipment used in manufacture of sub-assemblies.

HOW IT'S DETERMINED - - - -

. Monthly schedule on a daily basis issued to foremen listing final assemblies to be completed. This also used for parts and sub-assembly manufacture.

. Schedule detailed as to quantity of each type to be started through each major operation of bulb processing.

OUTSTANDING FEATURES

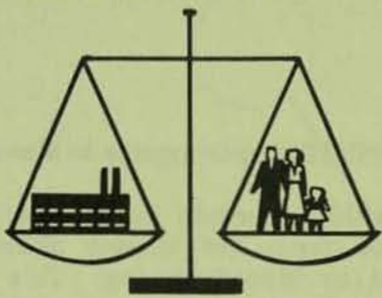
* The "shrinkage factor" during bulb processing is given prime consideration by detailing the quantities to be started through each major operation so that the proper number are available to start through the succeeding operation.

* Sundstrand machine used in keeping stock records up-to-date. Figures are immediately available for all stock items as to balance on hand.

* Main "A" item, glass bulbs, is scheduled for daily delivery. No more than one day's usage is ever stocked ahead of production.

FULL DRESS VERSION

MASTER SCHEDULE



EXAMINE Market Forecast - - - -

A six (6) month Market Forecast is developed by the Sub-Department's headquarters in Syracuse and sent to the Buffalo Tube Plant. This is a consolidation of customers' orders plus anticipated sales on a monthly basis. Priority to fill customers' orders or replenish warehouse stocks is noted by Marketing so that the immediate needs are taken care of first. This forecast is examined very closely by the Plant Manager and his Production organization to be sure that the required mix can efficiently be produced.

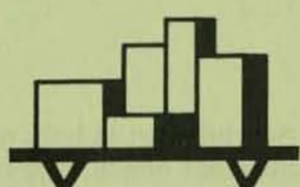
The operation of exhausting the air from the tubes is the limiting operation and must be considered as well as the product mix.

The quantities are increased to take care of the "shrinkage factor" (each operation in bulb processing has a definite percentage "mortality rate" and this must be compensated for, so that the desired number of finished tubes are produced).

DEVELOP Master Schedule - - - -

This Market Forecast, after adjustments of mix and consideration of bottleneck situations are made, becomes the Master Schedule placed on the Tube Works.

MATERIALS SCHEDULE



DETERMINE Parts Requirements - - - -

Each month upon the receipt of the six (6) month Market Forecast, Production takes an inventory of the 500 purchased items. Orders are placed for the next six (6) months' requirements but scheduled for periodic delivery to meet schedules. A card is maintained for each of these items and kept up-to-date by a Sundstrand machine. All entries as to receipts and withdrawals are noted and a figure of balance on hand is readily available. By examining these stock records together with the information of future demands, economical orders are placed.

SCHEDULE Material Delivery - - - -

A requisition for the parts required together with their required delivery in Buffalo is sent to the Purchasing organization in Syracuse from where the actual orders are placed. Copies of the orders are sent back to Buffalo where the actual expediting of orders is done. The monthly check of inventory also is a check on open orders so that proper expediting can be accomplished.

The main "A" item is the glass bulb. This item is scheduled for daily delivery so that no more than one day's supply is ever in a stock area. Blanket orders are placed with vendors for a six (6) months' period. Each month, detailed daily delivery schedules are issued to these vendors. The daily rates are subject to change due to the fluctuation in demand. When determining material quantities to order, the "shrinkage factor" must be considered so that the right quantities of finished tubes will be produced.

MANUFACTURING SCHEDULE

TRANSMIT Requirements to Manufacturing

A monthly schedule by daily rates is developed from the Master Schedule and issued to Manufacturing. This monthly schedule is broken down by major operations performed (exclusive of parts manufacture) and tells the foremen how many bulbs must be started of each type in order to produce the required number of good tubes. This takes into consideration the "shrinkage factor" which has been determined by past performance.

The shop capacity is established by time studies of machines and labor. The superintendent knows what present labor and machines are available and what can be produced. This allows him to know by past performance approximately what scheduled quantities can be produced.

Parts and sub-assemblies are manufactured in accordance with the schedule of finished tubes. The foremen concerned break down the scheduled finished items into the parts required. They withdraw the required material and manufacture them in order to meet the scheduled finish dates. The miscellaneous parts and sub-assemblies are produced on automatic equipment. The parts are produced for the "mount assembly". They are stocked at point of usage in a bench assembly area where all "mounts" are hand assembled by the use of intricate fixtures.

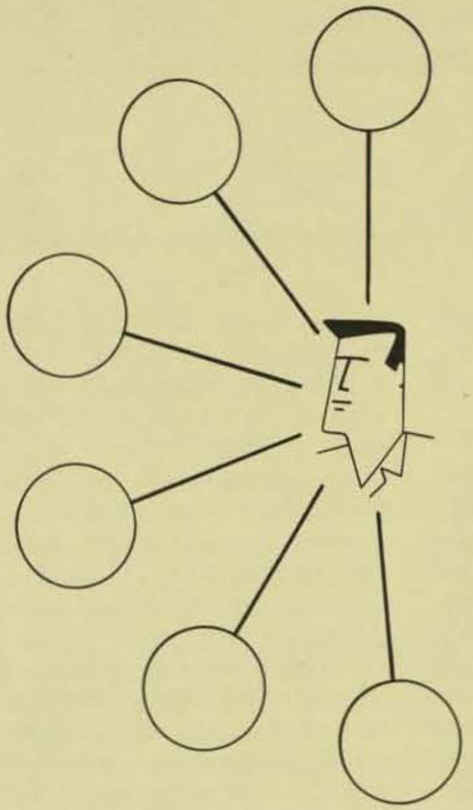
The processing of the bulbs and assembly of "mounts" into the bulbs is accomplished on conveyors throughout the three manufacturing floors and automatic equipment is extensively used.

FEEDBACK Of Production Progress - - - -

As has been emphasized, the problem of "shrinkage" in bulb processing is very real and stems from many different sources. A constant check of production progress must be maintained so that immediate action can be taken in order to meet the schedule. Every two (2) hours reports are received by the Supervisor of Production Control from each operation in the processing of bulbs. Each hour, reports of "mount assembly" production is received so that it is known that enough will be available for final assembly.

A daily report is issued by Production listing the output by types. This also gives the month to date total and its comparison to scheduled quantities. A detailed weekly Production Report is issued showing the production rates by major operations of bulb processing. The actual "shrinkage" percentage is shown and compared against the schedule. These actual percentages are used for future scheduling. The quantities delivered to test, number rejected, quantities to stock, and number of items shipped are also listed.

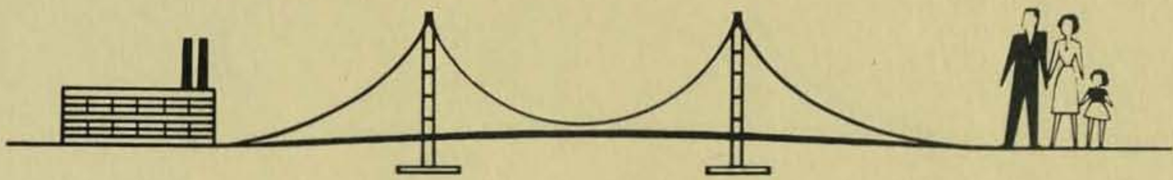
These reports are sent to all concerned in Buffalo as well as headquarters in Syracuse. The actual performance is compared to schedules and used for purposes of future forecasting and Master Scheduling.



PART FOUR

Some new techniques which appear to be a Prelude to the Future

CHAPTER VIII AUTOMATION AND SCHEDULING



Bill Brown pushed his chair away, put his feet up on the desk and took another look at the follow-up panel of NAPSAC - Numerical Automatic Production Scheduler And Computer. No red lights! This meant everything was working smoothly just as he had planned it. Last week, after six months of hard work, he had finished programming a brand new set of instructions and had them put on magnetic tape. For the past three days, the magnetic storage tapes and memory drums of NAPSAC had been whirring away, transmitting new signals to the automated transfer and machine tool equipment out in the plant. Bill's company was turning out the first completely assembled unit of a new solar operated home dust precipitator. And to think, this was manufactured on the same equipment used to make the ultrasonic home washing machine! Two different products manufactured in the same fully automated factory.

The manufacturing engineers had designed the process for the solar dust precipitator so that component parts could be produced on existing equipment, but with an entirely new alignment of transfer (automatic handling), machining, and assembly machines. They had used a lot of ingenuity in adapting the existing facilities to this radically new product.

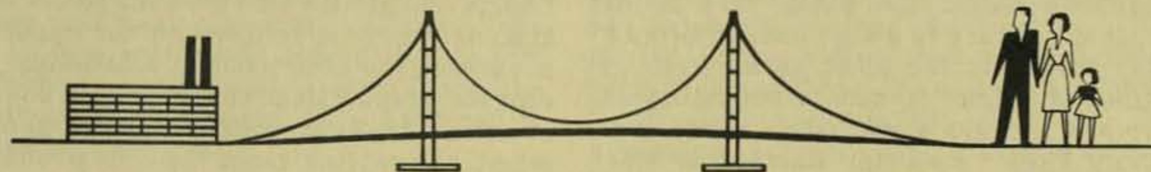
Bill thought of the long hours he had spent in programming NAPSAC, making certain there would be no lost time in starting the manufacture of the precipitator. As the last washing machine for this month's schedule cleared the various sections within the plant, NAPSAC had signaled the automated equipment into a new alignment to begin processing the parts for the solar dust precipitator. In three short days, all components were being transferred to the automated assembler (the same one used for the washing machine) and they had arrived at the precise time they were needed!

Maintenance specialists had been on duty around the clock, standing ready to adjust or to align manually any transfer machine or tool, which might fail to follow NAPSAC's instructions. But the changeover had worked like a charm, and the specialists were not needed. Only once did any of the follow-up lights on NAPSAC's control console flash red to indicate that bad quality shafts were being turned out on a lathe. But NAPSAC had also acted immediately to correct this situation; it signaled instructions to a stand-by lathe, and within two minutes, good shafts were again being turned out. The maintenance specialists could take their time about repairing the first lathe.

A fully automated factory capable of producing multiple products! A factory having the flexibility of a process machine layout yet producing many different products with the efficiency of today's oil refinery which turns out gasoline, diesel oil and fuel oil in controlled quantities! Automatic machine tools and transfer machines, together with a large scale computer acting together as a system -- this is automation of the future -- a single automatic production process used for several different products, controlled by an automatic production scheduler!

Does all this sound like something out of "Astounding Science Fiction"? It shouldn't. For already in General Electric, engineers are designing an automatic factory capable of assembling many different types of electronic components on a single automated assembler, to be controlled automatically by punched card computing machinery. THIS IS TODAY!!

CHAPTER IX SCHEDULING SYSTEMS FOR THE FUTURE



THE GOALS FOR IMPROVEMENT

There are real and cogent reasons for production control personnel to be concerned with automation. The fact that automobile manufacturers have received the most publicity for their progress toward automation, is no reason for us to assume that they are the only companies who will benefit from its advantages. The implications are no less significant to General Electric production personnel, even those in job shop plants. As has been pointed out, it is necessary to boost the efficiency of production control routines by transferring clerical skills to office machines. In a previous chapter we have discussed the need for designing better communications media which are capable of providing accurate, instantaneous follow-up information to remote dispatching points.

But automation in production control goes beyond the mechanization of *existing* paperwork routines, because such mechanization would only enable us to obtain *feasible* solutions to our scheduling problems faster and more accurately. The day has arrived when we can afford to search for the *optimum* (best possible) solutions to our problems. We can now afford this search, because electronic computers can consider alternate answers at great speeds. Moreover, if we do not take advantage of the available tools for obtaining optimum solutions, we will surely be sacrificing opportunities for large profits and continued growth. The true automation of production control will exist when the *best* of all possible scheduling and dispatching decisions are made, *as a matter of routine*!

HOW CAN WE IMPROVE OUR METHODS OF PRODUCTION CONTROL

The ultimate answer to this question has already been suggested in our goals for improvement:

- to mechanize more paperwork routines and communication procedures.
- to adopt ways and means of making the best possible scheduling decisions.

The two parts to this answer are not meant to be considered as separate and distinct. For, as the paperwork and communication procedures of production control are executed faster and more accurately, more time may be devoted to processing the additional data and information needed to improve the quality of decisions being made by the production scheduler. To consider ways and means of mechanizing existing routines one has to reappraise the system objectives; inevitably, the two parts to our answer are closely interrelated. However, it is perhaps clearer to discuss these improvements in two chapters.

We shall begin by describing some examples of mechanization in production control procedures for handling paperwork and for communicating information.

A. MANUAL TECHNIQUES

1. Pencil and Paper

It is entirely possible that good (if not the best) scheduling decisions can be made by simple pencil computations. For example, a spread sheet, summarizing the capacities of certain "key" bottleneck operations within the plant, may be all that is necessary to determine the proper rate of input to the plant as a whole. In another situation, it may be necessary to keep only a dozen stock ledger records of certain "key" material items (the "A" items) in order to decide what the materials schedule should be.

Still another situation occurs when a scheduling decision must be made at a time when even the design of the product has not yet been made firm. For example, in some departments extremely scarce materials may have to be scheduled for purchase even though specifications as to the quantities needed are not yet fully determined. In such a case the materials scheduling decision may be based only upon a pencil memorandum from the engineer.

In general, pencil and paper techniques for scheduling and production control are entirely adequate in situations where the number of factors that must be considered -- or are available for consideration -- are few.

2. Charts and Graphs

Probably the most common device used for scheduling and control, is the Gantt Chart, which contains certain desired classes of facilities (materials, machines, products, etc.) listed down the side, and time periods (hours, days, weeks, months, etc.) listed across the top of the chart. Gantt Charts can be used for showing the load ahead of machines, determining future inventory needs, and indicating the time when replacement parts must be started. The obvious advantage of the Gantt type chart is that it shows at a glance the results of scheduling decisions. Hence, it is a very useful tool for dealing with a larger number of factors than can be handled using only a simple spread sheet.

Line charts, showing the machine utilization "scores" during previous periods, are also useful. It is desirable to remember that the accomplishment of the schedule depends upon practically all the personnel concerned with manufacturing. Charts and graphs are excellent tools for keeping everyone reminded of the important objectives of production scheduling. A chart or graph placed on the bulletin board at some strategic point within the plant, might accomplish more than six production expediters, because all employees can quickly see the progress being made toward the production goals.

B. MECHANIZED TECHNIQUES - MANUALLY OPERATED

1. Adding Machines
(Remington Rand, Burroughs, etc.)

As the production data increases in quantity, it becomes necessary to adopt mechanized handling procedures. So we must consider using machines to accelerate data processing. A first step might be to use an adding machine to obtain sums of parts ordered by all customers, sums of machine hours on certain machine tools as demanded by the parts ordered, sums of total numbers of each part used during past periods (in order to determine the latest average rate of consumption of these parts), etc.

2. Desk Calculators
(Friden, Marchant, Monroe,
Felt & Tarrant, etc.)

Since adding machines will help us only to add and subtract, the next step necessary is to consider desk calculators which multiply, divide, extract square roots, and automatically sum the squares of numbers. Multiplication is involved in exploding the master schedule into the detailed parts requirements for the manufacturing and materials schedules. In calculating economical ordering quantities, the estimated order paperwork preparation and machine set-up costs are divided by the inventory carrying charges; the square root of this quotient must then be found.

In calculating the amount of variation from the average in workload mix from one period to the next, we take the square root of the sum of the squares of the deviations; this yields the "standard deviation" which is a good yardstick of variability. All these computations can be done on a desk calculator; indeed the use of a calculator would be imperative if any one of these computations were required in large numbers.

3. Bookkeeping Machines
(Sundstrand, Burroughs,
National Cash Register, etc.)

The use of adding machines and calculators is, of course, somewhat limited in that the actual posting and writing must still be done manually. Here is where the bookkeeping machine comes in since it can post the answers on properly designed forms as well as do the required adding and subtracting. There are numerous cases where it is being used for inventory and stock control purposes.

4. Edge-Punched Cards
(McBee Keysort, etc.)

The use of edge-punched cards permits flexibility and ease in the selection and arrangement of information. The punches along the edges of the cards indicate classes or categories of data. For example, it is possible to punch source department, ABC classification, price per unit, predicted usage or the fact that a certain material is obsolete. However, the big drawback is that data must be written or typed on the card. It cannot be automatically reproduced or used in any direct way for calculating or analysis purposes.

C. MECHANIZED TECHNIQUES - SELF CONTROLLED

1. Punched Card Equipment
(IBM, Remington Rand, Samas, etc.)

The subject of edge-punched cards leads of course to the next level of mechanization -- the use of standard punched card equipment. To explore fully the possibilities of these machines would require a chapter all to itself; but primarily, they permit the punching of holes into the body of a card in such a way as to activate or operate other machines which will calculate, reproduce, compare, merge, select and print the desired information. The speeds of these machines are generally quite high and therefore permit the use of relatively large numbers of cards. The equipment has been used for parts explosion, machine and labor loading, stock control, "ABC" studies, and on into the night. This is frequently the first level at which true mechanized systems are originated. In all the steps up to this one, one phase or one segment of the work would be placed on mechanical equipment or expedited through the use of such equipment. But now, the point has been reached where the design of the entire system can be based upon the availability of machines which not only do the physical job of sorting and printing but also the mental job of choosing the proper course of action. We have also reached the step where the machines, once programmed, can be operated many, many times on the basis of the original instructions. The only manual operations are those of converting input data to punched cards and handling these cards between machine operations.

2. Card Programmed Calculators (IBM)

One of the basic limitations of standard punched card equipment is the extensive card handling involved. In order to avoid this, an interconnected combination of punched card machines has been made to provide for a variety of operations during a single pass through the machine. The limited storage availability in the standard machines provide a second reason why this advanced equipment is needed. This lack of storage space restricts the amount of data which can be used during the course of calculation. The Card Programmed Calculator (C. P. C.) permits the performance of a variety of tasks through the use of cards which bear the actual instructions. It is the first stage at which the instructions are in the same form (punched cards) as the data to be processed, not just wired into boards. The C. P. C. is being used for inventory control, parts explosion, labor loads and other standard production control jobs.

3. Magnetic Drum Computers (Remington Rand, IBM, ElectroData, Teleregister, etc.)

In spite of all the advantages of the C. P. C. it still has a very limited memory (about 200 digits) and basically is a slow speed machine since it is electromechanical. The next step up is the use of a magnetic drum memory connected with an electronic computer. Here we have a larger amount of memory storage available to us, frequently in the order of magnitude of 50,000 – 100,000 or even more digits. Today, there is a large variety of this type of machine available, ranging in price from $50,000 to as high as $500,000. Naturally, these differences in price reflect the speed and ability with which various operations can be performed. Some of these machines are fed by cards, some by punched tape and others by magnetic tape or by manual entry.

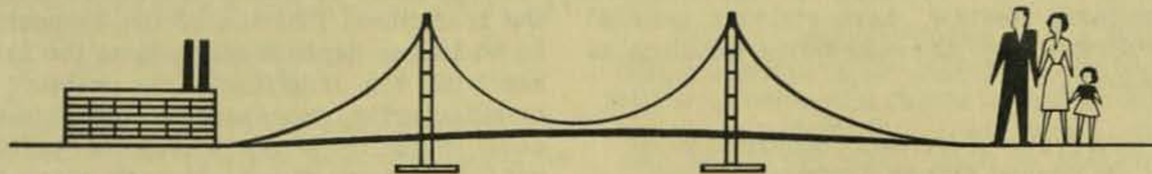
The IBM 650 is an example of a general purpose magnetic drum computer, capable of processing both alphabetic and numeric data. It can be programmed to do a variety of problems, such as parts explosion, stock record keeping, requirements consolidation, and so forth. In the IBM line of equipment it is the next step above the C. P. C. Although present machine installations utilize punched card input, the 650 can be modified to accept magnetic tapes similar to those being used on the larger digital computers.

4. Large-Scale Computers (Remington Rand, IBM, General Electric, RCA, etc.)

The final stage at present in the mechanization of clerical techniques is the use of large-scale digital and analog computers. These sell for a million dollars and up, but with adequate programming they can be used for virtually any business problem. Their calculating speeds are extremely high so that input and output data are normally recorded on magnetic tapes. The digital computers are the machines that have received the greatest amount of attention in the recent surge toward office automation. The analog machines have as yet seen little use in the manufacturing area; however, from the standpoint of model simulation these may well provide the most effective tool for cut and try solutions. Any list of machines will naturally be very incomplete since new ones are being announced almost every day. Some of the better known digital computers include Remington Rand's UNIVAC and E. R. A. 1103, IBM's 701, 702, 704, and 705, and Burrough's C. R. C. 102.

Work now being performed on these large computers include payroll, load analysis, manufacturing schedules, material control reports, etc. There appears to be no limit to the variety of applications which can economically be programmed for these computers. The restrictions in their use lies in the size of business necessary to support them and the ability of that business to express its procedures in a logical, analytical fashion.

CHAPTER X ADVANCEMENT OF PRODUCTION SCHEDULING CONCEPTS

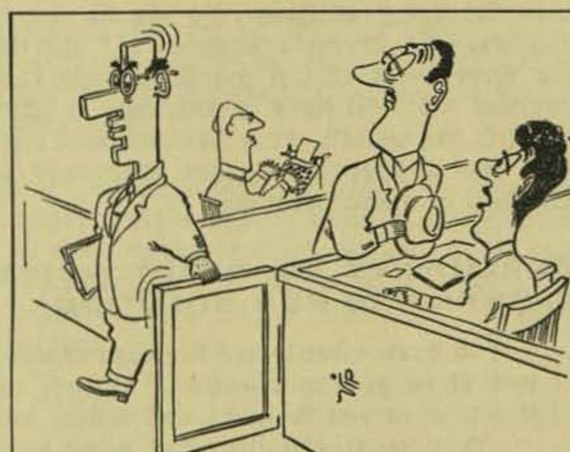


Discovering ways and means of making not just feasible but the best possible scheduling decisions is the second requirement of our program for advancement. The discussion in Chapter IX concerned itself with improving and transferring existing manual skills to various business machines and computers. But if progress is to be made toward the goal of true automation, new concepts as well as new skills in production scheduling and control must be developed.

PROBLEM OF SCHEDULING WITH PRESENT TECHNIQUES

Anyone who has been faced with the problem of trying to schedule the parts for even 20 or 30 individual products through a machine shop when each part requires numerous operations, can testify that Gantt Charts are of little or no help in deciding upon the schedule which will get out the products at the lowest cost. Nor do Gantt Charts in individual areas aid in trying to devise a schedule which will assure the most profitable utilization of the facilities as a whole. The production scheduler who uses these charts usually gives up as soon as he finds one arrangement which will get the products out by the due date. He doesn't have time to be concerned with determining the best of the many feasible schedules. Gantt Charts, in other words, are nothing more than one picture of the anticipated results of a scheduling decision after it has been made.

Production scheduling problems are among the most complex which management must solve. It has been shown that some supervisors and managers are able to come close to the best possible solution, simply because of some kind of "know-how", but this is nearly always the result of a process of trial and error, which requires considerable time and lots of painful experience.



"That's Mr. Steger. He's the key man around here"

Men having the ability to arrive at good solutions after only a few trials or estimates are scarce; hence the job of determining the schedule is often delegated to clerical personnel, who are generally not equipped with the kind of empirical knowledge required to devise best solutions to scheduling problems. After all, how can a clerk be expected to solve a problem of such magnitude with little more than pencil and paper, a schedule board and limited knowledge of the actual day-to-day variations in the shop. The tools are too crude. What is needed, of course, is a new set of tools which will simplify the procedure for obtaining the most profitable, feasible schedule so that a clerk can follow a specific routine and then make a Gantt Chart, knowing that the chart shows the best of all possible schedules.

Messrs. A. Henderson and R. Schlaifer, authors of "Mathematical Programming" which appeared in the Harvard Business Review, have stated a general description of the scheduling problem as follows:

> "A group of limited resources must be shared among a number of competing demands, and all decisions are 'interlocking' because they all have to be made under the common set of fixed limits".

In other words, the production scheduler who receives the market forecast must fit this demand into the limitations of the manufacturing facilities. To use the screw machines to produce product "A" during the first week of the month, means that product "B" will have to wait until a later week in the month. This fit must be a logical one so that the highest efficiency is attained in manufacturing.

QUALITATIVE VS. QUANTITATIVE TECHNIQUES FOR SOLUTION

You have often heard the expression, "I can show you in black and white", or "I can't show you in black and white, but . . .". This usually implies that some kind of mathematical (numerical) proof is or is not available. Such a statement also implies a common acceptance that mathematical logic will stand up under test better than any hunch, intuition, or rule of thumb.

The power of mathematics as a tool for industrial management has already been clearly demonstrated in the function of quality control. Since the '30s, many companies have adopted various forms of sampling inspection plans, and thereby greatly reduced the high costs previously incurred from checking every piece. Not only has it been possible to minimize the number of inspectors and eliminate entire inspection operations, but at the same time quality standards have actually improved. The tool which has made all this possible is mathematical statistics which encompasses --- theory of small samples, measures of probability, tests of statistical significance, and estimates of population parameters. The application of mathematical statistics has even changed the traditional function of the inspector: he no longer depends solely upon the artisan with his indefinable "know-how" of manufacturing processes to maintain the desired quality level. Instead of "putting out fires", inspection routines in many industries have radically changed to scientific quality planning and control.

WHY IS MATHEMATICS SO IMPORTANT

Mathematics is a concise language. The immense number of factors which bear on the problems of production scheduling and control indicates clearly the need for a brief, shorthand method for considering all of them simultaneously. To demonstrate the conciseness of mathematical symbols: suppose we had a part A5 which was used on sub-assemblies A1, A7, and A8; all of which are used on a major assembly, A2. If we wanted to determine the total number of A5's required for each unit of A2, we would write:

Total Number of A5's required for each A2 equals
(Number of A5's going directly into each A1)
times (Total number of A1's required for each A2)
plus (Number of A5's going directly into each A7)
times (Total number of A7's required for each A2)
plus (Number of A5's going directly into each A8)
times (Total number of A8's required for each A2)

But if we adopted mathematical symbols, for example:

Total number of A 5 , required for each A 2 or $T_{5,2}$

and

Number of A 5, going directly into each A 1 or $N_{5,1}$

We could abbreviate the long, verbal equation into:

$$T_{5,2} = (N_{5,1} \times T_{1,2}) + (N_{5,7} \times T_{7,2}) + (N_{5,8} \times T_{8,2})$$

This states exactly the same relationship as the word equation in much less time and space. This example which illustrates so well the simplicity and construction of mathematical symbols is taken from a paper published in "Management Sciences", October, 1954, by Mr. A. Vazsonyi of Ramo-Wooldridge Corporation.

When you stop to consider that there are dozens of situations where shorthand notations such as this can be used, the utility of such conciseness can be better appreciated. Not only is this notation helpful in determining parts requirements from a master schedule, but also in computing labor or machine loads. Since there are many instances where different products and assemblies require the same detail parts, and where different parts require the same machines, you can see that the use of mathematical symbols enables us to more efficiently explode the master schedule into its specific details.

The inherent logic of mathematics is the second reason why it is so important to deriving new concepts of production scheduling. To merely be aware of the many different factors entering into the establishment of a production schedule is not sufficient; we must also know the exact nature and interrelationship of all these factors.

For instance, you may recall from high school physics that "work" is comprised of two factors, force and distance. A mathematical equation is used to describe exactly how the factors of force and distance are combined to result in work, i. e. work is equal to force times the distance over which the force is exerted. The equation W = FxD becomes a <u>mathematical model</u>, which can be used to calculate the amount of work involved for different values of force and distance. You are now able to avoid performing the work, because you can calculate in advance the exact amount of work involved.

<u>It is possible to make such a mathematical model of the factory</u>. This model might consist of a group of mathematical equations with the individual terms representing factors which must be considered in scheduling decisions. One equation might represent the objective of the schedule, for example, to maximize profit. Thus if we are attempting to schedule products A, B, C and D, we might write:

Maximize: $3.35 A + $4.50 B + $2.00 C + $1.70 D

where the dollar figures represent the marginal income received by manufacturing and selling one unit of each of the four products.

Other equations would be written to represent the restrictions to the quantities of each of the products which can be manufactured. If products A, B, C and D are made on the same machine, we might write:

$$.35\,A + 1.2\,B + .69\,C + .80\,D \leq 40$$

This would mean that whatever quantities of products A, B, C or D we schedule, the total machine load for a particular machine must not exceed the 40 hours available during the week. The coefficients .35, 1.2, .69 and .80 are the required machine hours per unit of the respective products.

USING A MATHEMATICAL MODEL

For the moment, let's concede that a mathematical model of the factory system can be postulated. This model will be a practical duplication of the actual factory, and will contain the formulation, in quantitative terms, of the specific objectives of the over-all manufacturing and marketing system. It will also contain the restrictions within which the basic factors or components of the system will operate, i. e. men, materials, machine and money restrictions, as they reflect the policy of management. What is the value of such a conceptual model? Is such a model better than having none at all?

One answer to these questions is found by comparing the advantages of cut and try experimentation on the model, versus cut and try procedures in the factory itself. Certainly, the most straightforward method of proving whether one schedule or process is better than another, is to try out both of them. For example, production control may want to test the idea of building buffer stock inventories between the parts fabricating sections and the assembly section, since it may seem desirable to permit more flexibility in parts fabricating, so machine set up costs can be minimized. This proposal makes sense to the general manager, so a trial is permitted.

In experimenting with the real factory, you would proceed to build these buffer stocks very gradually, being careful not to disrupt the current manufacturing program. Naturally, buffer stocks cannot be built immediately, and still expect to fabricate all the parts required by assembly during the experimental period. After about six months, the Manager-Finance phones and says that according to his analysis, the average inventory turnover has been reduced from 5.2 to 3.1 and therefore, he is advising the general manager that carrying buffer stocks is not profitable. You may call attention to the fact that during the six months, the nonproductive machine time due to set up changes has been reduced by 20%, and that the productive machine time has been increased from 65% to 83%. He refutes this argument by saying that during the six-month period, the mix of the shop workload has stabilized to the point where it would not have been necessary to build the buffer stocks in the first place. And so the problem is taken to the general manager. But the issue is never clearly drawn because the experiment could not be carried on under controlled conditions.

On the other hand, with the mathematical model, you could simply plug into an equation the various quantities of parts put into the shop load, measure the amount of buffer stock created for several different mixes of shop and assembly workloads. Then you could compute the total cost involved by summing the cost of carrying the buffer stocks and the cost of nonproductive machine time. The results of such an evaluation would demonstrate not only whether the idea of creating buffer stocks was good or bad, but also how good or how bad, in dollars and cents.

In experimenting on the actual factory:

- The results of the experiment were inconclusive because the mix of the workload on the factory had changed during the period.
- The experiment required a lot of time and money.
- There were many headaches in conducting the experiment. For example, there was difficulty in obtaining floor space for the buffer stocks, because the shop layout did not provide room for such stocks. A different stock control procedure had to be established. A new system for selecting quantities of parts to order from the fabricating sections had to be determined.

On the other hand, in experimenting with the mathematical model:

- The results were far more conclusive. All the key factors of the over-all production program were considered. It was possible to experiment with different mixes of workload in both the machining and assembly sections. From the experiment with many different "simulated" runs on the program, we were able to "see", in quantitative terms, the effects of these changes upon the total program.

- The existing production control procedures were left undisturbed until the economic feasibility of the idea had been proved or disproved.

- The experiment could be conducted in a scientific manner; one factor could be varied without disturbing the other factors, and the effects could then be evaluated. In short, it was possible to control the experiment.

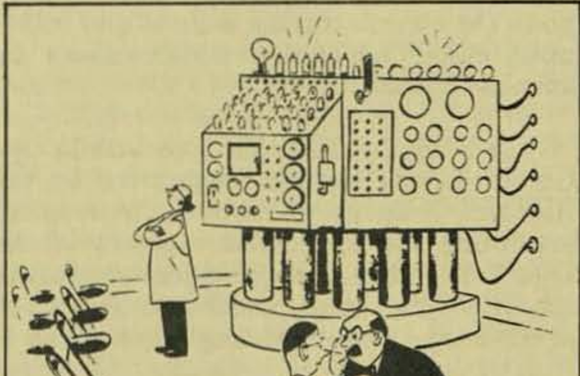
Thus it would seem that applied mathematics offers a significant new addition to the bag of tools needed for reaching the best possible scheduling decisions. Because of its conciseness, mathematical language enables us to deal practically with all the interrelated factors; these factors can be handled simultaneously with explicit results in quantitative or "black and white" terms.

All this discussion of the benefits of applied mathematics to scheduling doesn't mean that mathematicians would necessarily make good materials managers! Mathematicians may be well versed in theories and techniques which can be used, but at the same time, few, if any, are familiar enough with the conditions surrounding the scheduling problems. Therefore, in order to derive maximum benefit from these new tools, it would seem logical for materials management personnel to become more familiar with mathematical potentialities and applications.

THE IMPACT OF ELECTRONIC COMPUTERS IN PRODUCTION CONTROL

Many of the mathematical theories now being used have been around a long time. They have not been applied before because the sheer amount of arithmetic involved was simply too much for a person using a desk calculator. Their application has been made feasible by the recent development of large-scale digital computers. The synthesis of production scheduling and control problems into mathematical models containing quantitative values for all the restrictions and variables affecting a scheduling decision is now practical. Large-scale computers are constructed with memory units capable of "memorizing" facts and figures by the millions. Many computers can be programmed so that they can take any one of these items from a memory storage location in a few millionths of a second. Hence, it is now feasible to construct a mathematical model of the over-all factory system, have a computer experiment on this model in an orderly manner, and finally print the best answer. Thus, mathematical models and electronic computers are both necessary components of a system for making better scheduling decisions.

EXAMPLES OF COMPUTER APPLICATIONS TODAY:



COLLIER'S "Sonic Lab's electric brain is getting more publicity than ours. They have a bathing beauty demonstrating it" CHARLES PEARSON

- Labor Loading is a relatively simple task on a magnetic drum computer such as IBM 650. There is adequate memory available for the computer to store accumulated totals for each of the key areas instead of having to punch them on cards as they are calculated. This avoids sorting cards into the proper arrangement and summarizing the results since it is possible to total the quantities in a predetermined memory location for a particular station for a particular week.

• Material Control, including parts explosion, order quantity determination and purchase order preparation can be processed quickly and effectively on a machine such as Remington Rand's UNIVAC. The input consists of the production schedule, a list of where different parts are used and in what quantities, and the procurement data. As a result of a series of internally controlled operations, the purchase orders will be produced for these items requiring replenishment. This is truly operation by exception.

• Factory Scheduling is an easy chore for a machine such as the IBM 705. This includes as you would expect, detailed quantity scheduling and labor load analysis---but, even more significant, it is possible to eliminate unbalanced conditions, by comparing calculated loads with capacity. The computer automatically adjusts the manufacturing schedule to minimize either excessive requirements or unused capacity.

• A wholly different approach to Optimum Scheduling has been tried by the Aircraft Accessory Turbine Department exploiting the speed and memory of the IBM 701. This study's objective was to establish the best possible priority or preference list for guiding dispatchers in handing out work to operators. A series of different job arrangements was tested with the computer programmed as a model of the factory. Examining the results of these trials indicated which arrangement was most likely to result in the least idle time and the lowest inventory. One of the significant new ideas resulting from this project is that of using statistical "noise" factors to take care of employee absenteeism, machine break-down, material delays, spoilage, etc.

THE PROBLEM OF CONTROL

Production scheduling bears the same relationship to production control as military strategy to military tactics. The schedule (strategy) is always made in advance to guide the operation; the production control decisions (tactics) are made while the schedule is being carried out---in "real" time. Control involves a comparison of actual progress with the original schedule; then, a decision is reached as to whether or not to take corrective action--this may involve reissuing the schedule, changing the facilities, or both. For example, one step in control might be to obtain confirming information that materials have been shipped on time by a vendor so they will arrive in the factory on the scheduled starting date. If they have not been shipped on time via rail, the follow-up action might be to authorize shipment by air, changing the shipping arrangements. Alternately, the corrective action might be to revise the starting dates of all parts fabrication and assembly schedules for those products requiring the unavailable materials. This simple, everyday illustration demonstrates that the foundation of good control is the communication system which feeds back the information required for effective follow-up action.

From the previous pages one might conclude that a mathematical model could be postulated so that it included all the so-called "noise" factors which affect the fulfillment of the schedule--employee absenteeism, machine breakdown, tool failure, failure of the materials handling system, etc. If a computer were constructed with sufficient capacity to operate on such a model, we might conceive that a schedule could be established which was so valid and so truly predictive that there would never be any need for elaborate feedback communication and control procedures in the production scheduling system of the future.

However, the real factory system of men, processing machines, tools, and equipment is always undergoing some kind of change. It is dynamic and subject to unpredictable variations--or as the mathematicians say--"stochastic". Thus, any purely probabilistic concept of scheduling ignores the proven importance of the dispatching and follow-up functions. It under estimates the need for feedback communication between production dispatchers and the production supervisor. Feedback is the very foundation of control, and control is the only real means of insuring that a schedule is maintained and carried out. Based on feedback information, the schedule can be revised as the production office is informed of actual progress in executing the schedule. Even in the fully automated factory where the computer operator may be the only human directly concerned with routine production, there must be feedback of information from the automatic machines and transfer equipment. The computer would then act upon this information and recompute the next required scheduling or dispatching decision.

DEVELOPMENTS IN COMMUNICATION FOR CONTROL

In this connection, there have been some outstanding developments in the use of communication apparatus for production control purposes during the past few years.

- Speed Tally is put out by Remington Rand's ERA Division, and is being used by a mail-order house (which incidentally calls the machine Distributon) to maintain a running record of requirements during the peak season. This computer stores 39,000 digits on its magnetic drum and receives information from as many as 10 different keyboards. For each order received, one of the ten keyboard operators enters the catalog number and quantity. The machine automatically locates the accumulated quantity required for that particular catalog number and after adding the new requirements it returns the net balance to the drum. The machine is fast enough so that during the course of a day each operator can record one transaction every three seconds or a total of 150,000 entries per day for the ten operators. At the end of the day the desired reports are printed on a standard adding machine tape directed by and under the control of a pre-punched paper tape; this list, in catalog number sequence, reviews the items to be checked for reordering.

- American Airlines' Reservisor, built by the Teleregister Corporation, is a magnetic drum computer which permits reservation clerks, working either at La Guardia Field or at ticket offices scattered throughout New York City, to get immediate confirmation of flight space upon request. It has direct hook-up with 100 "agent" keyboards and remote connection with as many additional stations as desired through transmitter - receiver circuits. The reservation clerk enters the date and number of seats desired on the keyboard and inserts a plate, coded for that particular city or flight, into a special slot. Within a fraction of a second indicator lights on the keyboard will show whether or not the number of seats desired are available and on which flights during the day. If the person requesting space actually wishes to make the reservation, a release key is depressed; this causes the computer to deduct the number of seats required from the number of seats available for the flight chosen; the new balance is then stored on the magnetic drum.

- In a different vein an automatic explosion routine has been developed by Mr. J. E. Hines of the Distribution Transformer Department. Called Telecountrol, his system proposes automatically accumulating detailed parts requirements in each manufacturing area. These totals are registered on individual counters identified as to drawing number and physically located at dispatch stations on the factory floor. The counters would be activated by entering catalog number and quantity on a keyboard in a central production control office when an order was received. The machine would be wired to transmit pulses to the proper counters in the different areas exploding out all the different parts needed to make up the final model. To keep the counters up-to-date a subtracting pulse would be generated each time a part was completed. In order to provide the necessary feedback one proposal envisions using closed circuit television cameras focused on the counters in each area, connected to a centrally located receiver.

- United States Steel feels that intracompany communication may well be the most critical phase of office automation. Much of their effort has been spent in analyzing and working with five-channel punched paper tape which not only can be transmitted over telegraph wires but also used to activate typewriters and adding machines. Since certain computers are also designed to accept punched paper tape as input, all the possibilities of extensive automatic computation and decision making are available to its users.

• Mr. R. H. Huebenthal has put punched paper tape to a new use in production control at the Light Military Equipment Department. A typist prepares the fabricated parts schedule on a Flexowriter which at the same time automatically punches an eight-channel paper tape. This tape can be used to run another Flexowriter which will type this data into a new format without manual supervision. In addition the same tape can later be processed through a Tape-to-Card Converter to prepare punched cards. To facilitate feedback, small mechanical key punch machines have been located in the dispatch cages permitting each dispatcher to punch operator number, date and quantity on the pay vouchers.

• In the past, rapid communication between two facilities has been limited to the use of telegraph and telephone. This meant that if input data was in punched card form it was necessary to prepare a punched tape prior to automatic data transmission. However, with the new IBM Transceiver, punched cards put into the machine at a remote location will reproduce exact duplicates at a receiving center, thousands of miles away.

• Ticketfax offers still a different approach to the problem of data transmission. Designed and built by Western Union for the Pennsylvania Railroad it permits centralized control of Pullman space reservation, yet still allows decentralized customer contact. Each ticket agent in the Philadelphia area for example is equipped with a Ticketfax transmitter and receiver at his decentralized location. He records the customer's travel requirements on a 1-1/2" x 4" form which is inserted in the transmitter; 8 seconds later a buzzer sounds in the central office indicating that a copy of the space request to be processed is on the central receiver. A large record board is maintained showing all the space availability for the next few days on each train. After examining the board the central agent is able to determine if the accommodations desired are available. A preprinted ticket is then removed from file and inserted in the central Ticketfax transmitter. At the remote location the ticket is duplicated--a perfect facsimile copy of the original master. This total process including facsimile transmission takes place in less than two minutes.

REAL TIME CONTROL

"Real time" control means making production decisions just as actions are about to take place. In its extreme, the real time concept of manufacturing scheduling might involve an elaborate communication network between a central computer and all the machines and work stations within the plant. Thus, when an operation has been completed on a part, a signal would be transmitted to the computer. The computer would then scan the list of all the jobs waiting to be dispatched to this particular machine, select the best job, and transmit the job number and operation data to the dispatcher. Real time scheduling emphasizes the importance of making schedule decisions immediately preceding their execution.

A well designed production control system might first involve the determination of an over-all plan called here the master schedule, which could even be a simple priority list. This should be the best possible schedule, in the sense that the expected sum of inventory carrying charges and cost of failing to deliver the products on time is at a minimum. Next, the manufacturing schedule would be exploded from the master schedule and, after consolidation of parts requirements, operation vouchers would be prepared and forwarded to the dispatch cages. Each dispatcher would be given a set of rules to follow in deciding whether or not to deviate from the initial schedule. The rules might be very simple, but would insure that each dispatcher's decisions were in line with the over-all objectives of the plant.

For example, one simple set of rules might be:

- Always dispatch the job having the earliest due date (or the highest priority number, or the latest starting date).
- If, in dispatching a job to a work station, you estimate the job can be completed 5 or more days earlier than its assigned due date, do not dispatch the job unless permission is received from the production control supervisor.

These two rules would insure that the original schedule was being followed to the greatest extent possible considering available current capacities, and that the schedule was not being "beaten" to the extent that excessive floor stocks of parts were accumulated. If followed, these simple rules would prevent a dispatcher from changing the original priority list just to reduce machine setup time on a turret lathe or screw machine. They would also prevent the dispatcher from acting solely for the purpose of keeping the machines busy. At the same time the rules are flexible enough to permit the dispatcher to take advantage of "lap-phasing" (dispatching a single lot to two or more sequential work stations) whenever it becomes feasible. This permits several operations to be performed during one time period, and decreases the total time from start of the first to finish of the last operation. In short, these rules would prescribe the specific scope within which each dispatcher could use his own good judgment in arriving at effective decisions.

THE COMPUTER IN REAL TIME CONTROL

It is possible to describe a production scheduling and control system containing today's equipment, but which is fully integrated to provide optimum scheduling and control. This discussion is based on a paper by Dr. M. E. Salveson and Mr. R. G. Canning, prepared while the writers were under contract to the Logistics Branch, Office of Naval Research at the University of California at Los Angeles.

As customers' orders come into the plant, the information on these orders is initially typed to prepare a standard sales invoice. By using an electric typewriter capable of punching a paper tape simultaneously with the typing of the invoice (such as Flexowriter), the data are transscribed into a form suitable for feeding directly into an electronic data handling machine. Bills of material for the appropriate products are then fed directly into the machine as prepunched cards. The electronic data handling machine (EDHM) combines the variable information peculiar to each customer's order, and after computing the scheduled parts requirements, puts the results onto a magnetic tape. Then, the machine proceeds to scan this requirements tape and compares the requirements with the inventory data which is on another tape already in the machine. It prints a list of part numbers for which a manufacturing order may be necessary, which the production clerk then scans. He decides which parts to order, verifies in what quantities they should be ordered, and finally puts this information back into the machine.

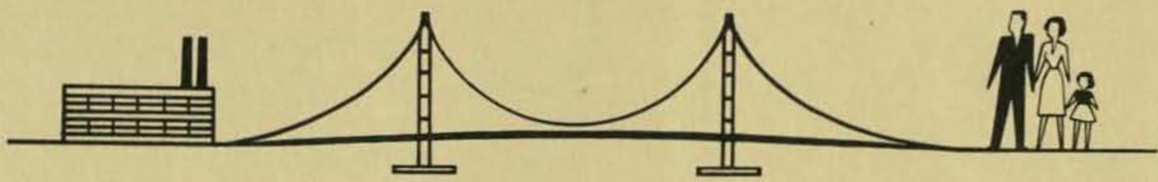
In the assembly ordering procedure, the EDHM combines the bill of material data with the quantities ordered and their promised due date and produces individual requisition cards. The stock clerk upon receiving these cards has them sorted into two categories -- one for those parts which are issued to fulfill the requisition, and the other for those stock parts which are in short supply. Parts disbursement and day-to-day changes in the shortage list are recorded in punched card form by the stock clerk, who has a key punch in the stockroom. Thus the materials disbursement cards can be fed into the data handling machine and the inventory status tape kept up-to-date.

As new shop orders are issued, the shop order status tape is posted automatically. Day-to-day postings of pre-punched move cards, filled raw material requisition cards, and rejection cards are recorded on the shop order status tape. This tape is fed into the computer whenever the production supervisor desires to get an idea of when the open orders might be completed, considering the over-all status of the shop. The computer has all the planning data stored within its memory unit. Thus from the shop order status tape and the planning data tape the computer can gradually work its way into the future. Whenever a machine tool becomes available, the computer scans the waiting shop orders, and selects the one with the highest priority slated for that particular work station. In this way the computer can project the entire schedule for the plant, using the backlog of customer orders. The time required for such a computer operation in a medium sized plant is estimated as one minute of time on the computer per three hours of actual time in the shop.

When the machine allocates a job to a work station, it causes a card to be punched with all the pertinent planning and move data required. These cards are then automatically sorted to compute future work loads for the various manufacturing units throughout the plant.

Thus, the role of the computer in this situation is one of both scheduling and control. It involves an integration of a communication system with an electronic computer capable of deriving the optimum schedule according to the mathematical model of the scheduling and control system. The computer might even be set up to operate directly on the various bits of data fed into it from the dispatching stations, stockrooms, and order service section. The computer's function would comprise mainly the handling of data, transferring it from one magnetic storage tape to another, revising the data files kept in its memory units, and reproducing or transcribing the data from one source to another. Then, during the night, the computer would take these records of the events and happenings of the day, and process the data into a new and revised optimum over-all program or schedule which would become the basis for its "scanning" during the next day's operations. In this system, the optimum production schedule is being determined and carried out on a realistic basis because both the scheduling and control procedures are kept dynamic!

CHAPTER XI YOUR BRIDGE TO THE FUTURE

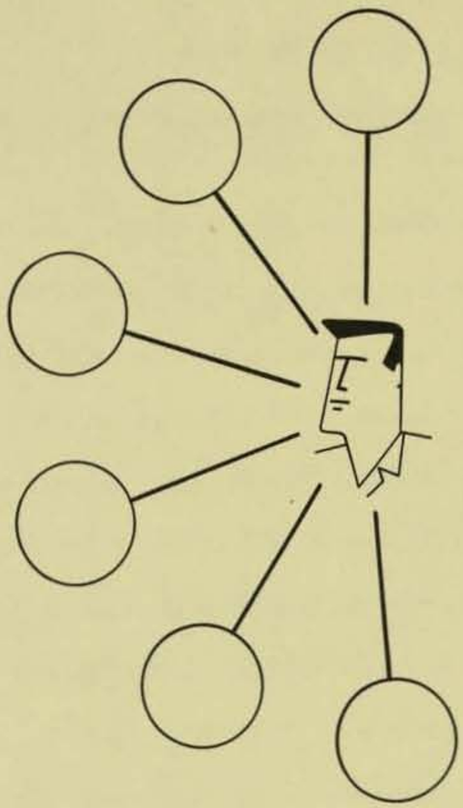


Our friend, Bill Brown, whom we met in the beginning of Part Four was not introduced as a figment of someone's imagination. Bill was meant to symbolize the fact that, today, Production Scheduling is a broader and deeper job than is apparent on the surface. The production scheduling system literally breathes life into the whole manufacturing process. If well designed, it creates customer confidence through better service, encourages proper inventory regulation, and permits effective development of solutions to the dynamic problems of factory operations. To go back to the original analogy we can think of the production schedule as being the "time bridge" between the customers' desires and the factory's ability to deliver products commensurate with those desires. It can surely be appreciated that the design of the production scheduling system is as critical as any other bridge-design problem. Indeed, the factors influencing the design of the "time bridge" are frequently more numerous -- and infinitely more dynamic.

Bill Brown realized that his inherent mental ability to memorize facts and figures and to combine these facts and figures into many feasible (practical) schedules was too severely limited. He "borrowed" some of the scientific techniques being used by people in the research laboratories and applied these techniques to his problems. He used mathematical concepts so that the routine of "cut and try" would be both orderly and less time consuming. He borrowed the scientist's large scale digital computers so that he could delegate work on his mathematical model to a machine. This left time for mental efforts toward making still further improvements in the over-all design of the scheduling procedure. Mathematical models and computers are not the panacea for production scheduling and control. As with all managerial functions, the only true solution is good sound thinking by human beings on ways and means of creating better designs, policies, procedures, and methods.

Make no mistake, a period of dynamic evolution in improved production scheduling is now with us. The results of our ability to transfer mental skills to electronic computers might very likely surpass the results of transferring physical skills to machines, which characterized the Industrial Revolution. The computers, the communication equipment, the scientific techniques and the engineering know-how are all now in existence. It's up to the Schedulers of today! We must bring all these resources into the organization for the automation of Production Scheduling of the Future.

PROBLEMS



PART FIVE

Some solutions to actual Scheduling Problems

P R O B L E M S

TYPICAL SCHEDULING PROBLEMS AND THEIR SOLUTIONS

Decisions by production schedulers can and should be backed by factual analyses as often as possible. There is nothing complex about these analyses, once the problem is clearly defined. The purpose of including these sample problems is to show that they are simple. High school algebra and arithmetic will solve practically all of them. The largest stumbling block lies in defining the real problem in analytical or mathematical terms, but even this is not too difficult, as these examples will show.

Every possibility and every factor are not necessarily included in each example, since each is designed to illustrate a specific point or points concerning a logical approach to different scheduling problems:

MANUFACTURING CAPACITY ANALYSIS

THE ALBRIGHT COMPANY

FACTS OF THE PROBLEM

The Albright Company manufactures three items, Product A, Product B, and Product C. All three are routed through the same manufacturing areas:

- Section 1 - Machining
- Section 2 - Assembly

Parts manufactured in Section 1 are delivered to a finished parts stockroom, and are withdrawn for use in Section 2 when needed. Finished stocks are kept in various district warehouses throughout the marketing area.

After receiving the market forecast and warehouse stock data from the marketing section, the production section has full responsibility for determining the master schedule.

On December 1, the production section was furnished with the following:

- From Marketing:

MARKET FORECAST

Anticipated Requirements	Product A	Product B	Product C
Jan-June (first six months of coming year)	120,000	70,000	14,000

- From Manufacturing Engineering:

TIME STANDARDS DATA

Manufacturing time required	Product A	Product B	Product C
Section 1 (machine-hours/unit)	0.75	3.00	2.25
Section 2 (man-hours/unit)	1.50	0.75	3.00

CAPACITY DATA

Three Shift Operating Capacity	
Section 1 Machine-hours/month	56,000
Section 2 Man-hours/month	44,000

There is <u>NO</u> subcontracting vendor available in the next six months.

• From Accounting:

SELECTED COST DATA

Cost Per Unit	Product A	Product B	Product C
Direct Material Cost.	$ 1.50	$ 3.00	$ 4.90
Direct Labor Cost	3.38	5.63	7.90
Variable Indirect Manufacturing Expense	3.60	6.80	8.60
Total Variable Expense	8.48	15.43	21.40
Sales Price	15.00	30.00	49.00
Marginal Income (difference)	$ 6.52	$14.57	$27.60

Variable indirect manufacturing expense includes the cost of factory supplies and materials handling labor. It does NOT include depreciation of machinery and equipment, factory buildings or any other fixed charges. This is important. Variable indirect manufacturing expenses consist solely of the incremental overhead costs per unit; hence, accounting data on total unit costs are not usable in this analysis.

Marginal income are the dollars remaining to pay the fixed expenses such as salaries of foremen, engineers and managers, fire insurance, depreciation of machinery, etc. Any dollars remaining after subtracting these fixed expenses are called profit before taxes. Marginal income is a measure of profitability, but it is not pure profit.

QUESTION #1 - Is the manufacturing capacity at Albright Company sufficient to meet the forecasted market demand?

ANALYSIS - Determine hours required for each product; summarize total hours required; and compare to hours of capacity available.

HOURS

Product	Section 1 - Machining		Section 2 - Assembly	
	Req'd.	Capacity	Req'd.	Capacity
Product A	90,000		180,000	
Product B	210,000		52,500	
Product C	31,500			
	331,500	336,000	274,500	264,000

- Since 331,500 hours is less than 336,000 hours, machining capacity in Section 1 is adequate.

- Since 274,500 hours is greater than 264,000 hours, the assembly capacity in Section 2 is insufficient by 10,500 hours.

RESULT - Albright has sufficient capacity to meet the market demand in Section 1 but not in Section 2, where capacity is exceeded by 10, 500 hours.

QUESTION #2 - Since Albright cannot meet the forecasted market demand, which of the three products should be "sacrificed"? In other words, which of the three products can we best afford not to produce because of insufficient capacity in Section 2.

ANALYSIS - Since the capacity of Section 2 is exceeded by 10, 500 hours, compare the change in marginal income which would result from this decreased production. While this could be accomplished in a great variety of ways, let's consider the results of decreasing, in turn, each product by this amount and observing which causes the least reduction in marginal income:

PROJECTED LOSS OF MARGINAL INCOME

	Product A	Product B	Product C
Section 2 - Assembly (hours/ unit)	1. 50	0. 75	3. 00
Hours forecasted in excess of capacity	10, 500 or	10, 500 or	10, 500
Number of units which must be eliminated to reduce forecast to capacity	7, 000	14, 000	3, 500
Marginal Income per unit	$ 6. 52	$14. 57	$27. 60
Loss of Marginal Income	$45, 640	$203, 980	$96, 000

RESULT - The analysis shows that by "sacrificing" Product A, the manufacturing capacity of Section 2 is utilized to produce the greatest marginal income.

CONCLUSIONS AND DISCUSSION

From the cost analysis, profits are reduced least by permitting finished goods stocks of Product A to drop, while Products B and C are manufactured in accordance with the market forecast.

Before deciding that A should take all the cutback however, there are other factors to be considered by the management:

- Would the inability to supply Product A have any adverse effects upon the sale of Product B or C? If so, a decision to cutback entirely on Product A, as indicated by the preceding analysis may not be advisable.

- How reliable are the market forecasts?

- Will the price and cost relationships used in the analysis remain proportional during the next six month period?

- Would the new operating level in Section 1, resulting from the change in product mix and volume, incur any additional manufacturing cost?

Nevertheless, the production manager is on firm ground in recommending a cutback on finished stocks of Product A. He has made a rational decision after analyzing the data available. There is no need "to experiment" with the mix as was the case with the Vitamin Pill Scheduler mentioned in Chapter II. The number of "unknown", intangible factors which must be weighed intuitively by management has been reduced.

This is an example of the kind of decision-making, production personnel can do today. It points out an area where frequently the entire decision is made without comprehensive factual analysis. With the approach used above, the decision will be both logical and rational. There is much to contribute to the search for greater profit through optimizing product mix.

PRODUCTION LEVELING

J. K. LUTHER COMPANY

The J. K. Luther Company manufactures a complete line of magnetos for small gasoline engines used on power lawnmowers, outboard motor boats, motor scooters, light airplanes, etc. These magnetos are sold directly to manufacturers of the gasoline engines. From a manufacturing standpoint, they can be divided basically into three types:

Type "S" - A rotating stator-type magneto for use chiefly on various lawnmower gasoline engines.

Type "V" - A rotating armature-type magneto for use on certain models of small aircraft engines.

Type "T" - Equipped with two circuits - engine ignition and lighting for use on motor scooters, motor bikes, etc.

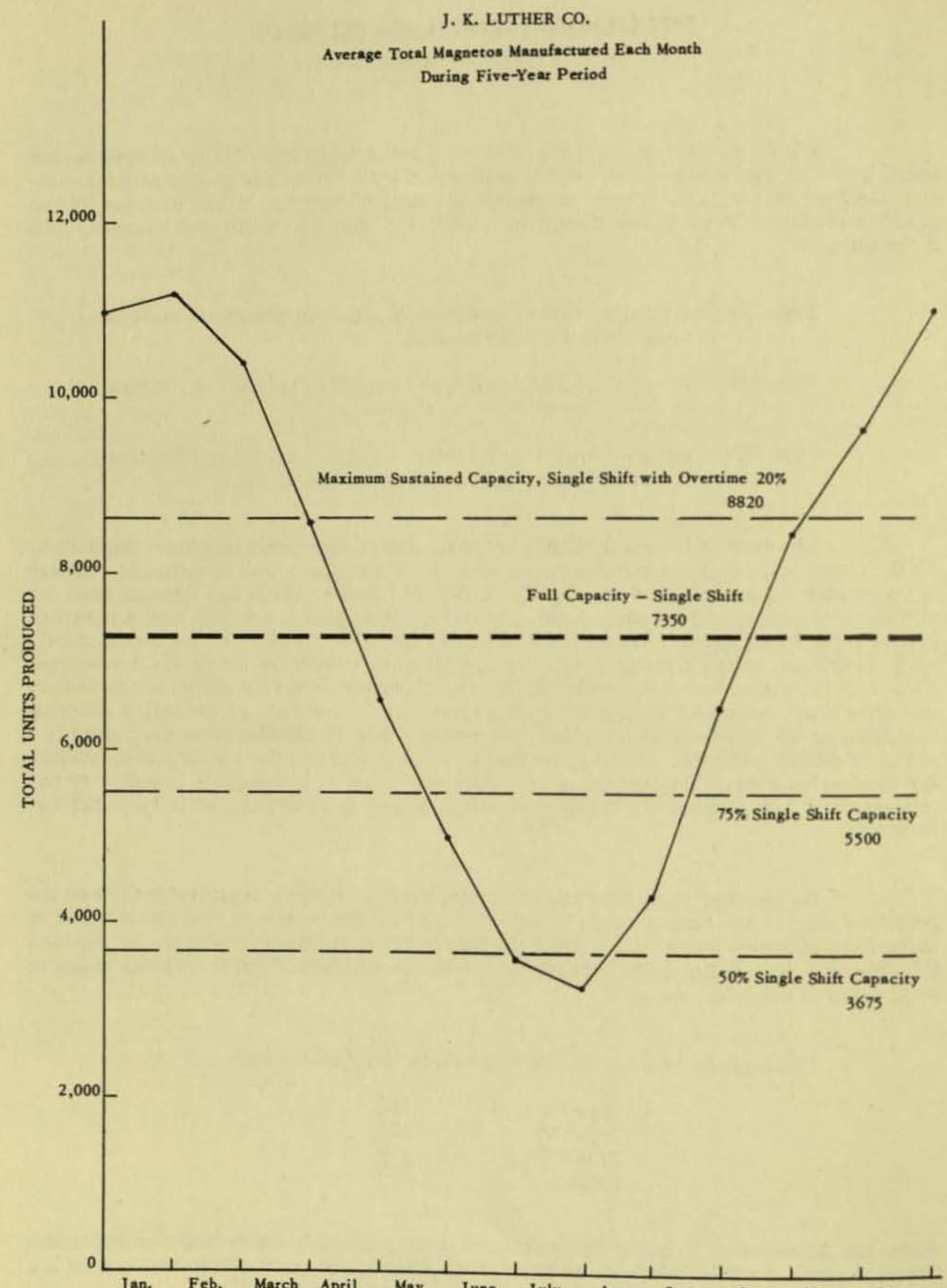
The market is not only highly seasonal, but is also expanding and competitive. J. K. Luther has adequate manufacturing capacity to meet peak season demands because of expansion which took place during World War II. Hence, there has been no need for any subcontracting work with outside suppliers. Management has followed a policy of producing at rates equal to the forecasted sales rate. This, of course, has meant multi-shift operation during peak seasons, and partial shift operation during slack seasons. This has been done because it was felt that the Company could not afford the inventory carrying charges caused by producing at a level rate. However, no extensive analysis has been made to prove or disprove this policy. The Production Manager, after two years of hectic seasonal activity, decided to make a study of the possibility of leveling the production rates. The purpose of his study was to show, by analysis, whether or not management had adopted the most economical policy in producing strictly to market forecast.

He decided to review the available figures on units manufactured over the past five years. He summarized the data by months, and computed average number of units manufactured per month. After plotting a graph of this information, he decided that the mix was quite stable, therefore; he dealt only with figures on total magneto production in his later analyses.

The product-mix breakdown was substantially as follows:

Type "S"	60%
Type "V"	30%
Type "T"	10%
Total	100%

Since the Production Manager has been furnishing a monthly labor load report for the past few years, he knew the labor requirements pattern, and was able to indicate on his graph the output which would be obtained at various levels of operation:


J. K. LUTHER CO.
Average Total Magnetos Manufactured Each Month
During Five-Year Period
TOTAL UNITS PRODUCED
12,000
10,000
8,000
6,000
4,000
2,000
0
Maximum Sustained Capacity, Single Shift with Overtime 20%
8820
Full Capacity – Single Shift
7350
75% Single Shift Capacity
5500
50% Single Shift Capacity
3675
Jan.
Feb.
March
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

After examining this graph for some time, the thought occurred that, if the plant operated at a full single shift capacity (approximately 7350 magnetos per month) during the year, there wouldn't be any need for changing production levels.

The Production Manager's next step involved a considerable amount of time and effort obtaining the cost data needed. He tried to measure the dollar costs of the leveling program with its increased expense of carrying finished goods inventory. He wanted to compare this with the cost inherent in maintaining the present seasonal program, with its frequent changes in the level of employment.

COSTS OF CHANGING PRODUCTION LEVELS

After talking with payroll and cost personnel, the Production Manager decided that he would make an estimate of the cost of changing the production level by 1000 man-hours per month. It was agreed that a change of 1000 hours would be equivalent to either hiring 6 additional employees or laying off 6 employees.

Overtime operation was primarily caused by machine breakdown, material shortages, and other emergencies. It was usually of short duration and since it could not be attributed to variations in production level, all overtime operation was ignored in the comparisons. Because of this the estimated expense of changing production levels may be, in the further analyses, somewhat on the low side. The following is a summary of the calculation of the estimated costs of the present program of producing strictly to forecast:

Basic Facts

Average output per month = 7350 units

Average hours per month = 9300 hours

Increasing manufacturing level by 1000 man-hours	Cost per 1000 man-hours
1. Employment and Training:	
. Interview and Selection: 6 men interviewed at 40 minutes per interview at $3.00 per hour for employment office clerical overhead and interviewer's salary.	$12.00
. Physical Examination: 6 employees at $5.00 per examination, including physician's retainer, clinic overhead expenses, supplies, etc.	30.00
. Security check: Identification badge, investigating character references -- $3.00 per employee x 6 employees	18.00
. Payroll entry preparation: 15 min. per new employee at $2.00/hr. for payroll clerk and overhead x 6 new employees.	3.00

- Training new employees:
  Assume 4 hours per man x 6 men at $3.00 per hour for foreman's and experienced worker's lost time as trainers' expense. — $72.00

- Additional spoilage, rework and makeup. — 20.00

2. Auxiliary Functions:

- Additional Production Effort:
  The costs of more work by order clerks (telephone calls to vendors, calculating new quantities, authorizing vendors to work overtime, traffic activities, etc.). A conservative estimate is -- — 20.00

- Additional Materials Handling:
  Receiving, Stockroom, and Materials Handling personnel vary from 10 to 3 as production drops from a peak of 14,000 hours of direct labor per month to the minimum of 4000 hours. This means that approximately one man must be added per thousand hours of increase in direct labor. Cost of Employment and Training estimated at -- — 18.00

3. Additional Maintenance and Supervisory Costs:

- Maintenance and Repair do not fluctuate in accordance with the varying direct labor. The addition of a second shift, however, causes the addition of two extra plant maintenance and repair personnel:
  Employment and Training expense is estimated at $18.00 per employee x 2 employees -- — 36.00

- Additional Supervision:
  The initiation of a second shift requires the appointment of an additional foreman, who would be promoted from within the organization. This will require the hiring of an additional direct laborer. Employment and Training expense would be -- — 26.00

Total initial costs of increasing direct labor 1000 man-hours. — $255.00

Decreasing manufacturing level by 1000 man-hours	Cost per 1000 man-hours

1. Unemployment Compensation Insurance:

- The cost of state unemployment compensation insurance premiums varies with the degree of stability of employment at the company. The maximum employer's contribution is 2.7% of the employee's annual pay, up to the first $3000. If, however, the cumulative amount of withdrawals from the compensation fund by employees laid off is small for the past 3 years, the employer's contribution may drop as low as 0.1%. J. K. Luther has been paying at an average rate of 2.5%. With leveled production, it was estimated that the contribution would drop to 1.0% because of the increased stability of employment. Since the total payroll is approximately $400,000 per year, the unemployment insurance could be reduced by 1 1/2% x $400,000 = $6000. The total direct labor varies from 14,000 hours per month to a low of 4000 hours per month; therefore, the change in unemployment insurance would be $6000/10,000 or $600 per 1000 hours. — $600.00

2. Employee Transfer:

- Union contract clauses regulate seniority, "bumping", etc. during layoffs. Laying off six men could involve transfers of ten or more men to different jobs; thus there is a "mushrooming" of training costs involved. To be conservative, say 3 men are "bumped" to new jobs. These men have to be trained, therefore:

  3 men x 2 hrs/man x $3.00/hr for foreman's and experienced worker's time. — 18.00

- Payroll Record change for 9 men - similar to increasing 1000 man-hours. — 5.00

- Plant - Community Relations:

  Employee layoffs due to production level changes may be costly in terms of bad will in the community. Union-management relations are strained. To assist overcoming this, J. K. Luther Company spent $1020 in public service advertising in the local community last year. $1020/10,000 hours total range in production levels give $102 of cost. — 102.00

Thus, each time the production level was decreased by 1000 man-hours, an estimated expense of $725.00 was incurred. — $725.00

ESTIMATING THE COSTS OF LEVELING PRODUCTION

The Production Manager was forced to use his best judgment in estimating the costs of carrying finished inventories -- since in the past, no such inventories were carried. He reasoned that whatever these carrying costs might be, they would comprise the costs of a leveled production program. After reading up on the subject, he learned that inventory carrying charges consisted of the following factors:

Investment Charges:

- The cost of tying up the working capital invested -- consisting of the dollars of "profits" forfeited for the period of time the money is "tied up" in inventory.

- The risk that the magnetos might suddenly become obsolete, or that they might deteriorate in some way.

Space Charges:

- The taxes, heat, light, and insurance on the building used as a warehouse (or the rental of the warehouse, if it is leased). Also the depreciation expense of racks, fixtures, etc. used to stack the stocked items.

- The administrative costs of operating the warehouse: Stock handlers, stock record clerks, security guards, etc.

In every case, these costs were expressed as a certain percentage of the total manufacturing cost of the unit being stored. For example, the Production Manager noted a report of a survey which stated that companies were estimating inventory carrying charges at 15% - 25% of the unit manufacturing cost per year. But in another case, he discovered a manufacturer of parts for military aircraft using a figure of 40% because of the higher obsolescence factor. He realized, to be on the safe side, his percentage factor should be high, since this would give a high cost to the proposed leveling program. Therefore, after some detailed analysis, he chose a figure of 24% of the manufacturing cost per year.

COST COMPARISON

FINISHED WAREHOUSE INVENTORY CARRYING CHARGES VERSUS
COST OF CHANGING PRODUCTION LEVELS

1. Estimated costs of average finished goods inventories carried throughout the year.

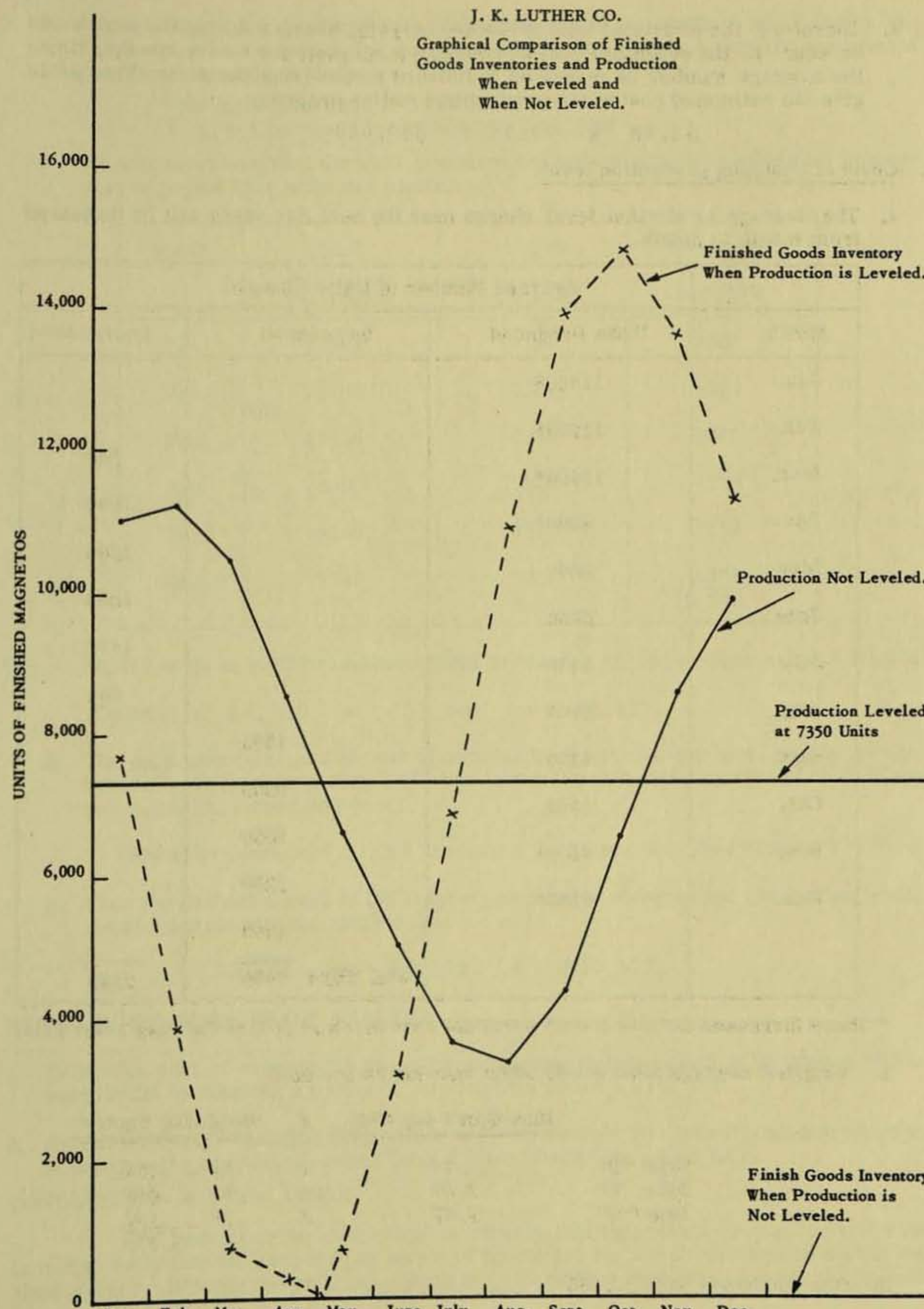
a. Weighted Average Manufacturing cost per unit:

	Total Manufacturing Cost/Unit		Weighing Factor (Total Mix)		
Type "S"	$4.38	x	.60	=	$2.628
Type "V"	9.40	x	.30	=	2.820
Type "T"	7.25	x	.10	=	.725
Total					$6.173

Average manufacturing cost per unit = $6.173. Thus the estimated cost of storing one magneto for one year would be $6.173 x .24 = $1.48.

b. The Production Manager plotted a graph of the proposed producting leveling program and the present program of producing strictly to orders.

From the graph and the data, the average number of magnetos which would be stored in finished stock was calculated at 7385 units, during a year.



PROVOCATIVE READING

c. Therefore, the estimated total inventory carrying charges during the year would be equal to the estimated cost of storing one magneto for twelve months, times the average number of magnetos in finished stock during the year. This would give the estimated cost of the production leveling program.

$$\$1.48 \times 7385 = \$10,929$$

2. Costs of changing production level:

a. The average production level change over the past five years will be measured from month to month.

	Average Number of Units Changed		
Month	Units Produced	Increase (+)	Decrease (-)
Jan.	11000*		
		200	
Feb.	11200*		
			800
Mar.	10400*		
			1900
Apr.	8500*		
			1900
May	6600		
			1600
June	5000		
			1400
July	3600		
			300
Aug.	3300		
		1000	
Sept.	4300		
		2200	
Oct.	6500		
		2000	
Nov.	8500*		
		1200	
Dec.	9700*		
		1300	
		Total Units 7900	7900

* These increases involve a shift premium cost which is 10% of the base labor rate.

b. Weighted average total direct labor man-hours per unit:

	Man-hours per Unit	x	Weighting Factor
Type "S"	.83	x	.60 = .498
Type "V"	2.00	x	.30 = .600
Type "T"	1.67	x	.10 = .167
			1.265

Average hours per unit = 1.265

c. The estimated total annual cost of increasing the production level equals the increased cost for increasing 1000 man-hours times the total number man-hours increased throughout the year:

7900 units increased x 1.265 hours per unit
x $.255 per hour increased = $2,548

To this must be added the shift premium charges during the period that production exceeded 7350 units per month.

Month	Units Produced	- 1 Shift Capacity	= Net Units 2nd Shift
Jan.	11000	7350	3650
Feb.	11200	7350	3850
Mar.	10400	7350	3050
Apr.	8500	7350	1150
Nov.	8500	7350	1150
Dec.	9700	7350	2350
			15,200

15,200 units on shift premiums x 1.265 hrs/unit x $1.50 per hour x 10% = $2,884

The total is: $2,548 + $2,884 = $5,432.

d. The estimated total annual cost of decreasing the production level equals the estimated cost for decreasing 1000 man-hours times the total number of man-hours decreased throughout the year:

7900 units decreased x 1.265 hrs/unit x $.725 per hour decreased = $7,245.

e. Thus the estimated cost of the present program of changing the production level, commensurate with the market demand is:

$5,432 + $7,245 = $12,677.

SUMMARY OF RESULTS OF ANALYSIS

1. Estimated cost of storing the average warehouse finished stock of magnetos which would exist by adopting a policy of leveling production = $10,929.

2. Estimated cost of changing the production level monthly so that scheduled production is equal to the number of orders booked from customers = $12,677.

CONCLUSIONS AND DISCUSSION

The results of the analysis show clearly that the present production program is more costly than the proposed program of producing for warehouse stocks during the slack season. Although the production manager was deliberately conservative in estimating the cost of production level changes, and liberal in estimating the warehouse carrying charges, the figures showed that the present program of scheduling to orders on the books, is more costly than the leveled production program.

The analysis has been made using data from the past five years. Although the results show clearly that a leveled production schedule is less costly and hence, more profitable, there are other factors to consider before deciding to adopt a policy of complete leveling of production:

1. Will customers continue to renew orders in the future and will the seasonal pattern continue to remain fixed? Can salesmen get more advanced notice of customers' plans so the Company does not risk losing 100% of the investment in finished warehouse stocks which are being built up during slack season?

2. If management is planning to manufacture an entirely new product whose peak season "counter balances" the magneto pattern, would the proposed leveling be advisable?

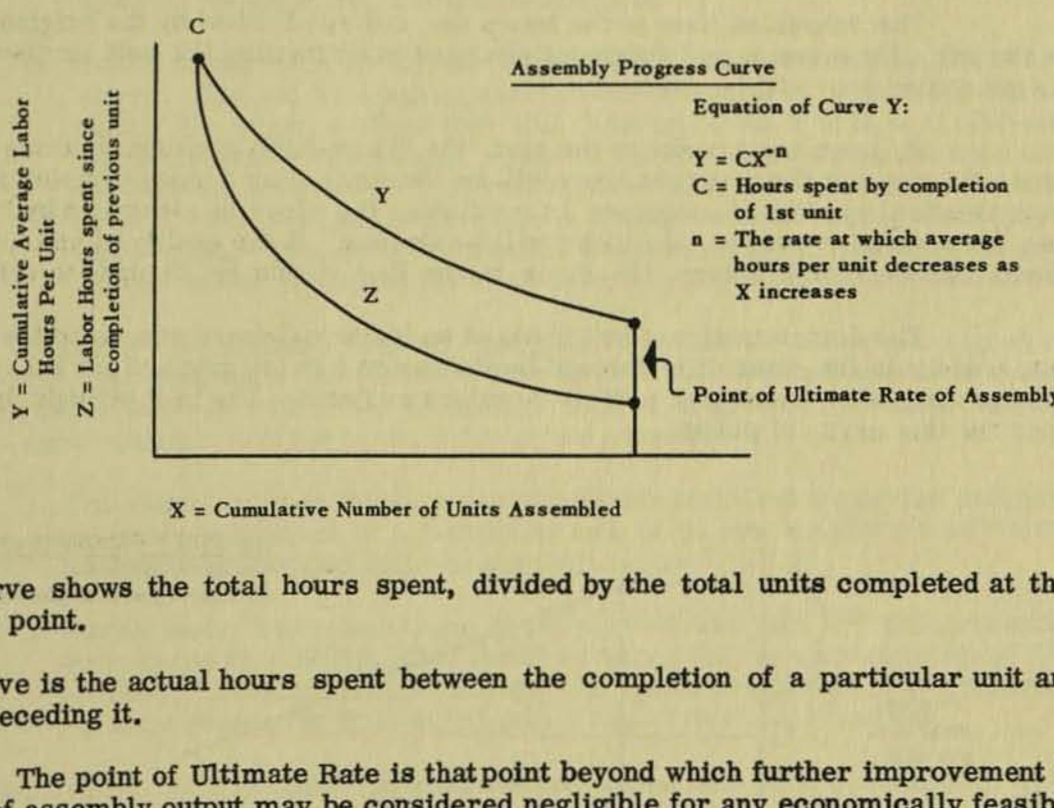
Generally speaking, there are many degrees of production leveling to be considered. This analysis was based on a 100% leveling program for the whole year, involving all products. Another approach might involve leveling to a lesser degree, in which production was increased and decreased with changing sales; in this situation, there would be both production level changes and inventory costs, but the sum of these would not be as great as the cost of the "violent" changes in production level. Still another approach is to select one product which involves the lowest cost of inventory carrying charges (i. e. the lowest unit storage cost per hour of production) and accomplish the leveling by producing only this type product for warehouse stock. The other products would continue to be produced in quantities directly proportional to the orders "on the books".

ASSEMBLY PROGRESS CURVE
THE BRONSON COMPANY

The Assembly Progress Curve used at the Bronson Company shows the overall, aggregate progress characteristics of the Assembly Unit. Actually the assembly progress curve is a graph of historical experience. It records labor input per unit as the total quantity assembled increases. It can be used as a key control yardstick since it provides:

- Cumulative results of manufacturing experience and know-how as increasing quantities of a product are assembled.
- A method for planning an orderly build-up as an assembly becomes "debugged" and operators gain more skill on the job.

The curve was developed from past experience with many totally different projects by the Production Supervisor, Assembly. He reasoned that assembly personnel developed their skills on each new project in a definitely patterned rate. This rate of developing increased productive efficiency is approximated by the following progress curve:



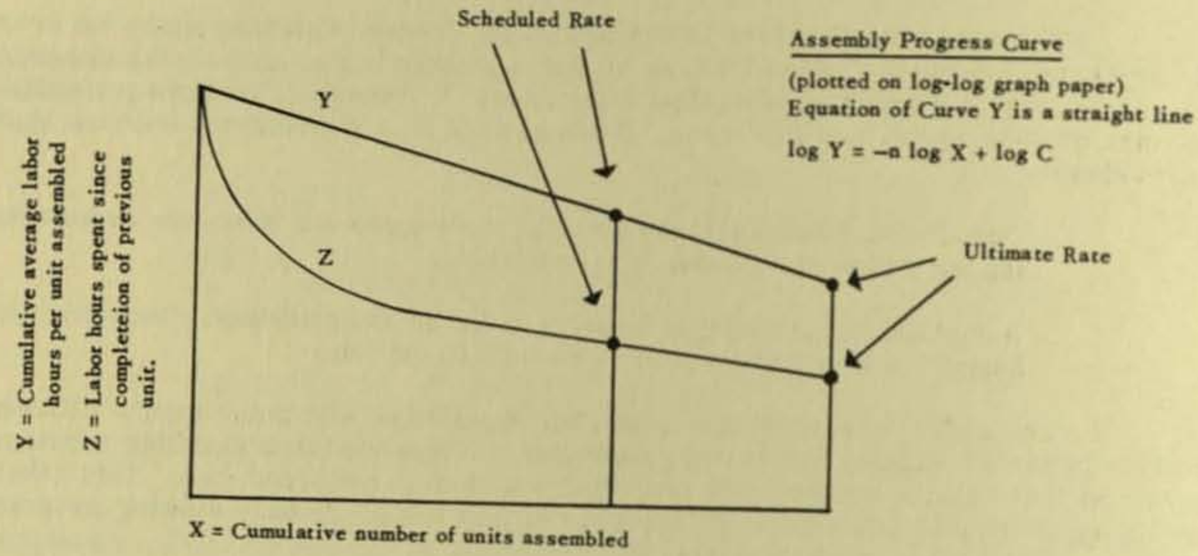
The Y curve shows the total hours spent, divided by the total units completed at that particular point.

The Z curve is the actual hours spent between the completion of a particular unit and the one preceding it.

The point of Ultimate Rate is that point beyond which further improvement in the rate of assembly output may be considered negligible for any economically feasible method involved in the assembly. It is established by careful inspection and analysis of the plotted curve.

The assembly progress curve permits making the quick estimates required for bidding on the many contracts available. After the basic design work has been done, and prints are available, quotations can be prepared in as little as two days or a week.

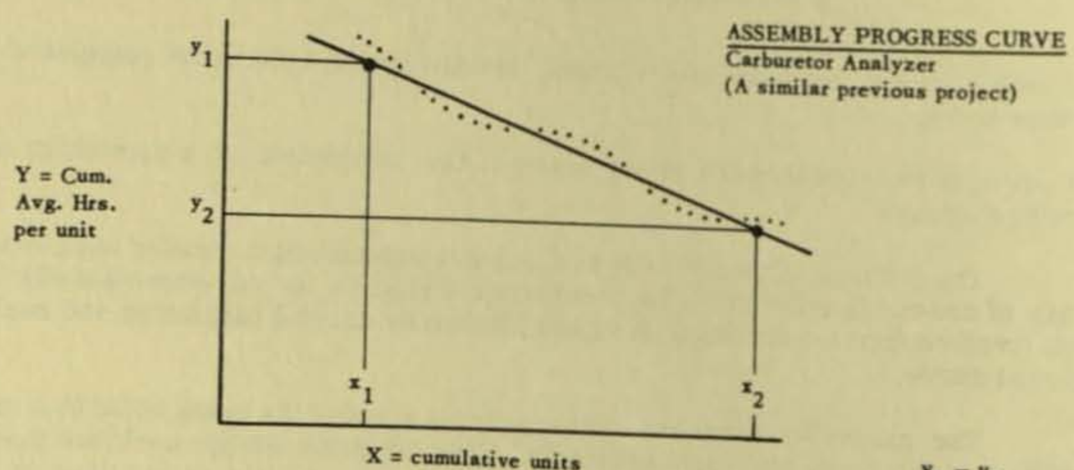
Plotted on log-log graph paper, the curve becomes a straight line which can serve more readily as an analytical tool.



The Scheduled Rate is the hours per unit established by the original planning for the job. Experience and judgment are used in estimating the unit number at which this scheduled rate will be attained.

If, from one project to the next, the "know-how" problem in assembly is the same, the slope of the progress lines will be identical. For a more complex assembly, if the identical quality of employee is available, the slope as measured by "n" will be less; for a simpler project, the slope will be steeper. If the quality of employee available is different than before, the slope of the line should be changed to reflect this.

The determination of "n" is based on historical experience as to the improvement pattern in the plant. It is derived by plotting on log-log graph paper the cumulative average assembly hours per unit on previous projects. The best straight line is then found for this array of points.



$$n = \frac{y_1 - y_2}{x_2 - x_1}$$

The scheduled rate is found by analysis of the drawings for the job. The more detailed and thorough the original planning, the closer this estimate will be to the Ultimate Rate. Generally, however, the Ultimate Rate will be lower than the Scheduled Rate and will indicate the hours which can be squeezed out by an effective cost improvement program.

With each new project, the proposed assembly schedule can be determined quickly and accurately by following these five steps:

1. Determine the rate at which the assembly organization develops its efficiency as the number of units increases, i.e., the slope of the progress line, as estimated by comparing the know-how factors of this product with previous experience.

2. Calculate the Scheduled Rate of assembly in hours per unit; this figure will be based on the normal skill expected from assembly personnel.

3. Estimate the point at which the Scheduled Rate will be reached, expressed in terms of the cumulative number of units assembled (at the 85th unit, 101st unit, etc.).

4. Solve for C, using these three factors, to determine the assembly hours spent by the time the first unit is shipped.

5. Plot a tentative progress curve on log-log paper using C and the known slope. This can be visually checked for comparison to previous experience. The point at which this line intercepts the Y axis is C, the estimated assembly man-hours required for the first unit plus necessary sub-assembly labor. If the resultant line appears to be unreasonable, the point at which the Scheduled Rate is attained may be moved, keeping the same slope. This is where careful judgment is critical to the success of the assembly progress curve as a scheduling and control yardstick.

Recently the Bronson Company received an order for a newly designed engine analyzer. In preparing a firm delivery promise for the customer it was necessary to determine the build-up rate. The following factors, determined by experience and judgment, were considered in the preparation of the schedule:

- The assembly floor foremen can effectively train and supervise additional assembly personnel at a maximum rate of 20 new employees per month during the production build-up period.

- During their first month these 20 employees average 70% efficient within their respective skills. After the first month they are assumed to be 100% efficient. The accounting procedure segregates 30% of each new employee's earnings during the first month into a non-direct labor account.

- There are 7 assembly specialists and technicians who are the core of the assembly work force; they start all new assembly programs.

- The maximum rate of delivery -- 120 units per month -- was specified in the customer's quotation request.

- The Scheduled Rate, which should be reached at the 90th unit, will be approximately 85 hours per unit.

- The working month is 160 operating hours (4 weeks). This, of course, means that every 3rd month there is a one week margin of safety.

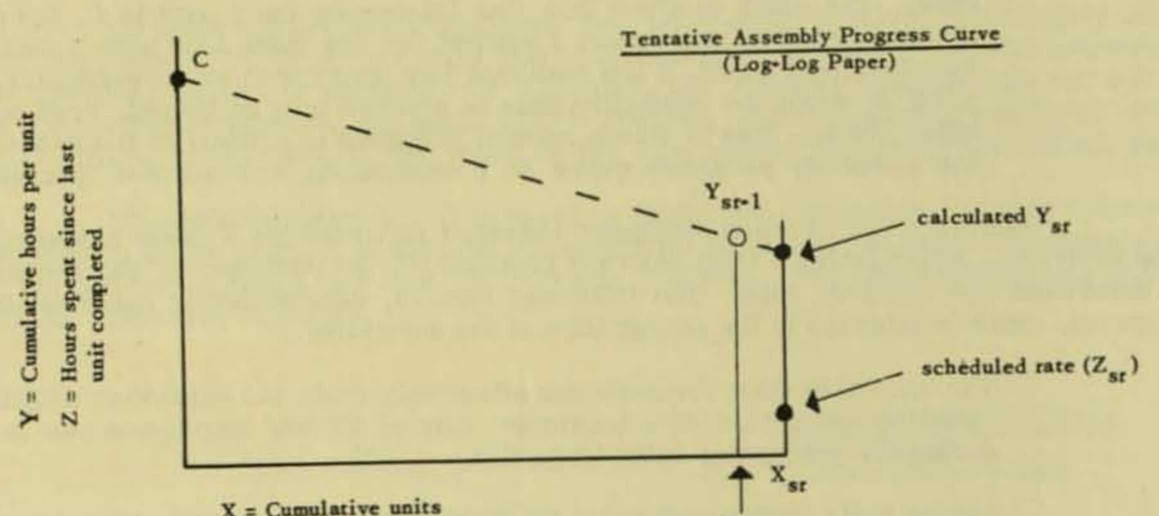
- The total cycle is 2 months of which 4 weeks is for assembly and 4 weeks for sub assembly.

- Buffer stocks are maintained between stations to insure assembly continuity.

- The initial assembly "tool lot" will be 2 units -- just enough to test the performance of the assembly tools and methods; it will be started during the first month of production.

- The "learning rate" (slope of the progress curve) on this project should be about the same as the carburetor analyzer which was built recently; its slope was .465. This is the same as a 72% progress function -- that is, every time the cumulative number of units doubles the average labor drops to 72% of the original value.

Using the factors listed above, Bronson's Production Supervisor performed the five steps necessary for establishing the assembly progress curve for the engine analyzer.



1. Determine slope of progress curve:
   $n = .465$

2. Calculate Scheduled Rate:
   $Z_{sr} = 85$ hours

3. Estimate point at which Scheduled Rate is reached:
   $X_{sr} =$ 90th unit

4. Solve for C:

$$Z_{sr} = (X_{sr})(Y_{sr}) - (X_{sr-1})(Y_{sr-1})$$

In other words the hours spent since the previous unit was shipped is defined as Z_{sr};

we also know that:

$$Y_{sr} = C(X_{sr})^{-n}$$

and

$$Y_{sr-1} = C(X_{sr-1})^{-n}$$

dividing we find that:

$$\frac{Y_{sr}}{Y_{sr-1}} = \frac{C(X_{sr})^{-n}}{C(X_{sr-1})^{-n}} = \left(\frac{X_{sr}}{X_{sr-1}}\right)^{-n}$$

or

$$Y_{sr-1} = Y_{sr}\left(\frac{X_{sr}}{X_{sr-1}}\right)^{n}$$

substituting in this equation:

$$Y_{sr-1} = Y_{sr}\left(\frac{90}{89}\right)^{.465} = 1.0052\ Y_{sr}$$

Then substituting this in the first equation:

$$Z_{sr} = (X_{sr})(Y_{sr}) - (X_{sr-1})(Y_{sr-1})$$

$$85 = 90\ Y_{sr} - 89\ (1.0052\ Y_{sr})$$

$$85 = Y_{sr}\ (90 - 89.463)$$

or

$$Y_{sr} = \frac{85}{.537} = 158.4$$

since

$$Y_{sr} = C(X_{sr})^{-n}$$

$$C = \frac{Y_{sr}}{(X_{sr})^{-n}} = \frac{158.4}{90^{-.465}}$$

or

$$C = \frac{158.4}{.1234} = 1284$$

5. Plot tentative progress curve and check for accuracy:

After examination it was decided that this curve appeared to be suitable and required no adjustments; the equation to be used was:

$$Y = 1284 \ (X)^{-.465}$$

Where:

Y = cumulative average labor hours per unit

1284 = hours expended when the first unit is finished. (C)

X = Cumulative number of units assembled

.465 = Rate at which assembly efficiency increases so as to reduce the labor hours per unit assembled. (n)

The production supervisor was then required to go through the actual calculations which are necessary to derive the assembly build-up schedule. He considered the following questions:

1. What is the total man-hours required for assembling the "tool lot"?

$X = 2$

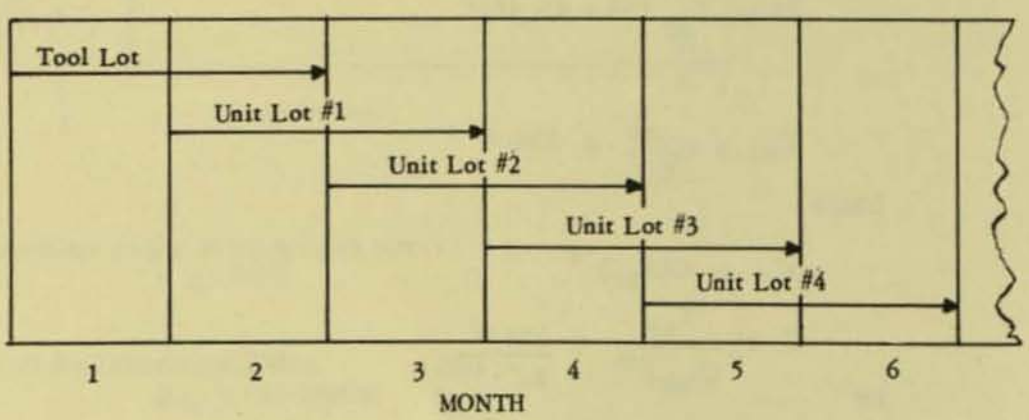
therefore

$$Y = 1284 \ (2)^{-.465} = 930 \ \frac{\text{man hrs.}}{\text{unit}}$$

and total hours

= 2 units x 930 = 1860 man hrs.

The tool lot will be assembled over a two-month period by the assembly specialists who will be assigned as needed to provide the required total man-hours.



Therefore 7 men will be assigned by the completion of two months and the total man-hours expended will be 1860.

2. How many units can be produced during the succeeding months?

- Assign 20 new assembly operators each month, initially these operators will be 70% efficient. The total monthly man-hours available [7 + 20 (.70)] 160 - 3360

In general terms, the calculation of the assembly build-up schedule is:

$(X_m)(Y_m) = K$, where K = cumulative total labor expended by the time that X_m units have been assembled. This is simply the cumulative average number of hours (Y_m) multiplied by the total number of units (X_m).

Now

$$Y_m = C(X_m)^{-n}$$

Substituting then

$$K = (X_m)\ C(X_m)^{-n}$$

or

$$= C(X_m)^{1-n}$$

if K and C are known, it is simple to solve for X_m

$$(X_m)^{1-n} = \frac{K}{C}$$

or

$$X_m = \left(\frac{K}{C}\right)^{\frac{1}{1-n}}$$

$$K = K_1 + K_2 + K_3 + \ldots\ldots K_m$$

Where the subscript indicates the month in the future: hence K_m equals hours expended during the m^{th} month.

therefore

$$X_m = \left(\frac{K_1 + K_2 + \ldots + K_m}{C}\right)^{\frac{1}{1-n}}$$

- for the 3rd month

$$C = 1284$$
$$n = .465$$
$$K = 1860 + 3360 = 5220$$

so

$$X_3 = \left(\frac{5220}{1284}\right)^{1.87}$$

$$= (4.07)^{1.87} = 13$$

Therefore during the 3rd month we will have assembled 13-2 = <u>11 units</u>.

. During the 3rd month we will have

$$K = [27 + .70\ (20)]\ 160 = 6560 \text{ man-hours available.}$$

- With three months actual experience available the Ultimate Rate of assembly can be accurately approximated.
- After careful analysis it was judged that the Ultimate Rate would be 65 hours - to be reached at the 160th unit.

Cumulative total man-hours required to assemble the units through the 4th month.

$$K = 1860 + 3360 + 6560 = 11780$$

By the end of the fourth month we will have assembled:

$$X_m = \left(\frac{K}{C}\right)^{\frac{1}{1-n}}$$

$$X_4 = \left(\frac{11780}{1284}\right)^{1.87}$$

$$= (9.17)^{1.87} = 62$$

During the 4th month the assembly output could be

62 - 13 = <u>49 units</u>

. Before calculating the 5th month we should check to see what number of men will be working when the program is up to the going rate of 120 units per month at 65 hours per unit which is the estimated Ultimate Rate reached at the 160th unit.

120 x 65 = 7800 hours per month with 160 hrs. per employee per month.

$$\frac{7800}{160} = 49 \text{ employees}$$

Therefore during the 5th month we should add enough employees to come up to the level of 49 employees.

hence

$$K_5 = [47 + .70\ (2)]\ 160 = 7744 \text{ hours}$$

$$K = 11780 + 7744 = 19524$$

$$X_5 = \left(\frac{19524}{1284}\right)^{1.87} = 162$$

During the 5th month the assembly output would be

162 - 62 = <u>100 units</u>

. Before calculating the 6th month we should check to see at what unit the Ultimate Rate will be reached. The Ultimate

Rate of 65 hours is reached at the 160th unit. Since by the end of the 5th month we will have just reached this point ($X_5 = 162$) the rest of the program will be at a flat rate.

49 employees x 160 hours/month = 7840 hours/month

$$\frac{7840 \text{ hours/month}}{65 \text{ hours/unit}} = 120 \text{ units/month which is the desired going rate.}$$

- By these calculations we are able to set forth the proposed assembly schedule which shows:
  - The scheduled build-up of assembly manpower required.
  - The scheduled build-up of assembly output.
  - The measured rate of expected improvement of productive output, as experience is gained on the new manufacturing project.
- These calculations illustrate the method by which the Production Supervisor set up his proposed output schedule, shown below. This schedule is then used as a basis for determining the output schedule quoted in the bid for the contract.

ASSEMBLY SCHEDULE

				Output Schedule	
Month	Assembly Operators Required	Assembly Operators Increase	Net Man Hours Available	Engines during period	Cumulative Build up
1 & 2	7	7	1860	2	2
3	27	20	3360	11.	13
4	47	20	6560	49	62
5	49	2	7744	100	162
6	49	–	7840	120	282
7	49	–	7840	120	402

After being awarded the contract the Bronson Company plotted actual cost experience against the budget derived from the learning curves. This provided Bronson with an effective yardstick for the control of cost and manpower utilization.

Note: Much of these data have been taken from an unpublished master's thesis, "Methods of Control and Integration of Planning for Release of a New Product for Manufacture", University of Wisconsin, 1953, by T. M. Phillips, who was at that time General Foreman of Non-Allied Products Assembly, X-Ray Dept.

MATHEMATICAL PROGRAMMING

Where the activities of a plant can be described accurately by a series of factual statements, it is possible to calculate the best or optimum solution to operational problems. The development of these descriptive statements and their translation into mathematical terminology is referred to as model synthesis. Examining this model for the best course of action is called model operation.

This process of mathematical programming involves:

1. Model synthesis

   . the formulation of an objective function for evaluating in quantitative terms the results of different courses of action. The usual objectives are to maximize profits or minimize costs.

   . the formulation of restrictions which, acting simultaneously and interdependently, tend to limit the attainment of the objective.

2. Model operation

   . the actual determination of a program for maximum potential gain.

Mathematical Programming, which is applicable in financial and marketing problems, is also an excellent tool for production scheduling. In the paragraphs below we will explore first an example which illustrates the model synthesis phase of mathematical programming. This example was originally developed by Dr. Melvin E. Salveson, Major Appliance Division, and published in the Journal of Industrial Engineering, March 1954.

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Assume that there is a firm which manufactures and sells two types of gears, type #1 and #2. The unit profit margin on type #1 is $0.30 and on type #2 is $0.40. Unit profit margin means the difference between the unit sales price and the direct material and labor costs. No fixed indirect manufacturing expense -- depreciation of machinery, taxes, managers' salaries, etc. -- is included in the data used, because these costs do not affect product mix decisions.

Assume that two machines are used for making the gears: an automatic screw machine for machining blanks and a hobber for cutting teeth. The machine operation time standards are:

	Gear Type #1	Gear Type #2
Automatic Screw Machine	2 Minutes/pc	3 Minutes/pc
Gear Hobber	5 Minutes/pc	2 Minutes/pc

Assume for simplification that --

- During one week there are 60 hours, or 3600 minutes of machine availability on each of the two machines.
- No set-up time is required for changing either machine from one type of gear to the other.
- Since the gears are produced to back orders, all that can be produced of either type during a week's production can be sold.
- Both gears are made from the same stock of raw material of which there is an ample supply regardless of the quantities of gears produced.

The objective is to select the most profitable combination of quantities of each gear to be dispatched to each of the machines during a one-week period.

With these facts in mind, a mathematical model can be built to express the program objectives in mathematical terms.

Using mathematical symbols for convenience, let T_1 indicate the number of units of gear type #1, and let T_2 indicate the number of units of gear type #2. Since the number of units has not yet been determined the objective is stated in algebraic terms as:

Maximize: $\$.30T_1 + \$.40T_2$

Where the \$ .30 and \$.40 are the unit profit margins of gear types #1 and #2 respectively.

There are, of course, restrictions as to the number of each type of gear that can be produced. Therefore, using the time standards, we can write that on the automatic screw machine:

$2T_1 + 3T_2 \leq 3600$ ($\leq$ means that the left side is less than or equal to the right side)

and on the hobber:

$5T_1 + 2T_2 \leq 3600$

These mathematical expressions state that the assigned work load in minutes must be less than or equal to the number of minutes of machine availability during the scheduled week. Thus, the sum of the assigned loads on any machine tool for gear types #1 and #2 must be equal to or less than the 3600 minutes of machine time available.

One final restriction states that a solution which indicates that a negative quantity of gears was to be produced would be meaningless.

$T_1 \geq 0, \ T_2 \geq 0$ ($\geq$ means that the left side is greater than or equal to the right side)

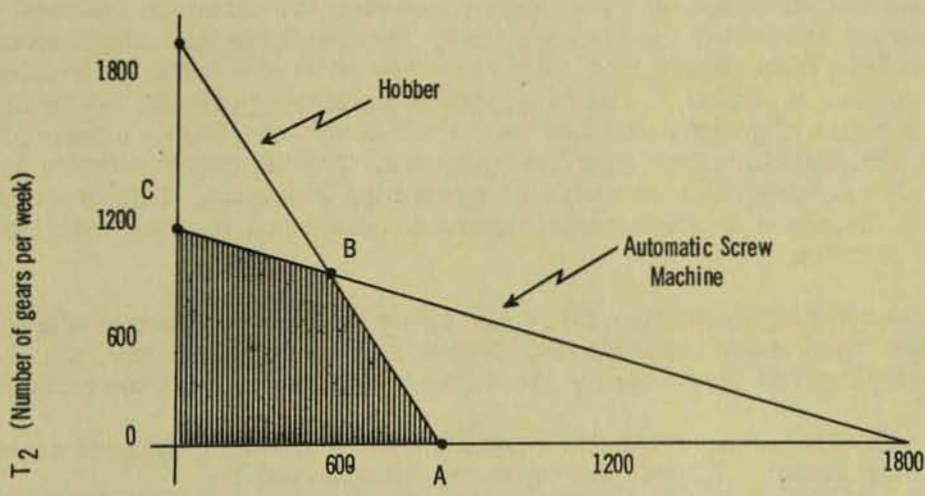
This of course would be obvious to any clerk, but if the problem were to be solved on an automatic computer, it would be necessary to tell the machine not to accept negative answers.

The statement of the problem is now complete; the mathematical model is fully constructed:

Maximize:	$.30T_1 + .40T_2$	(Objective function)
Subject to:	$2T_1 + 3T_2 \leqslant 3600$	(Availability of Screw Machine)
	$5T_1 + 2T_2 \leqslant 3600$	(Availability of Hobber)
	$T_1 \geqslant 0, \; T_2 \geqslant 0$	(Non-negative answers)

This model states the objective and tells explicitly all of the interdependent restrictions which operate simultaneously to hinder the attainment of this objective. The value of the model is in its explicit, concise formulation of the scheduling problem in quantitative terms. Experimentation with this set of equations and inequalities is now possible; no longer is it necessary to experiment with the actual manufacturing operations, and wait for the accountant to tell us the results.

The second phase of programming is concerned with the rules for conducting the experiment on the model. In this simple example, the problem can be expressed graphically:



T_1 (Number of gears per week)

The shaded area of the graph represents feasible quantities of the two types of gears to be scheduled. Any quantity which falls outside this shaded area would mean that the restrictions were not satisfied; that quantity and mix of gears could not be produced.

In this case we would not choose any point which falls below lines AB and BC since we could make more profit by choosing one close to or on the line. This is equivalent to saying that we would make as many gears as we can up to the limit of capacity. Hence the only feasible solutions which are of interest are those which lie on lines AB and BC.

The optimum solution will always lie at some intersection such as point A, B, or C. This concept can be checked by selecting several points along lines AB and BC and comparing their profits with that realized at the most profitable intersection.

Since it is necessary to begin somewhere it might be reasonable to make as many of gear type #2 as possible since it is the more profitable item. The maximum feasible number of type #2 occurs at point C where the computed total profit realized by producing 1200 units of gear type #2 and none of type #1 is found by substituting in the profit equation:

$.30 (0) + $.40 (1200) = $480.00

But this may not be the highest total profit. A glance at the time standards indicates that this schedule will result in a fairly large amount of idle time for the hobbing machine. Therefore, it's worth examining the profit at point B:

$.30 (327) + $.40 (982) = $490.90

This shows an improvement in the profit and therefore this is a better mix. Finally, trying point A, to determine what the profit should be:

$.30 (720) + $.40 (0) = $216.00

Thus, it's clear that the most profitable schedule (or the optimum program) is to plan to produce 327 units of type #1 and 982 units of type #2.

In operating with the model, a step by step or "iterative" process of solution was used. But the important fact about this cut and try procedure is that the model clearly showed the logical direction to go -- logical because the direction followed gave the optimum program solution in the shortest time. Admittedly in this simple example, the solution could have been determined in three steps even if it had been decided to start at point A, instead of point C. But in a more complicated problem, where there were three or more types of gears instead of two, it would not have been a simple problem to decide which direction to follow after the first step. The "Simplex" solution is the procedure used for solving more complex programming problems. This procedure is described by Dr. Salveson in the article mentioned above and in other references under "Provocative Reading".

In real scheduling decisions, there are likely to be many more products for consideration, and many more restrictions. Nevertheless, the procedure for constructing the mathematical model is precisely the same as demonstrated in the example above.

These additional, more realistic restrictions can also be expressed quantitatively in the scheduling model. Suppose the following situation exists:

Products →	T_1	T_2	T_3	T_4	T_5	Availability
Profit Margin $/Unit	2.30	3.40	1.50	5.20	3.20	
Machine Hrs./Unit						
Turret Lathe	.05	.12	.03	---	---	390 Machine Hrs per Mo.
Milling Mach.	.12	.20	.10	.13	.22	550 " " " "
Punch Press	---	---	---	.03	.02	150 " " " "
Raw Material Requirements lbs/Unit						
Material A	3.2	---	2.3	---	5.0	5000 lbs. per Mo.
Material B	---	1.2	---	4.5	---	3500 " " "

Products →	T_1	T_2	T_3	T_4	T_5	Availability
Product Mix products sold must not be greater than	1500	2000	1100	900	1400	

The mere fact of expressing these data summarized in quantitative terms is a long step toward synthesizing a model. For, if the production scheduler can specify his entire program in these terms, he can then delegate the job of operating on this program to a person who is competent in mathematics and in the operation of digital computers. This person might then write:

Maximize: $$2.3T_1 + 3.4T_2 + 1.5T_3 + 5.2T_4 + 3.2T_5$$

Subject to:
$$.05T_1 + .12T_2 + .03T_3 \le 390$$
$$.12T_1 + .20T_2 + .10T_3 + .13T_4 + .22T_5 \le 550$$
$$.03T_4 + .02T_5 \le 150$$
$$3.2T_1 + 2.3T_3 + 5.0T_5 \le 5000$$
$$1.2T_2 + 4.5T_4 \le 3500$$
$$0 \le T_1 \le 1500$$
$$0 \le T_2 \le 2000$$
$$0 \le T_3 \le 1100$$
$$0 \le T_4 \le 900$$
$$0 \le T_5 \le 1400$$

It is not necessary to discuss the techniques for operating on this model since the only reason for its inclusion is to show how a model can be constructed so as to faithfully reveal the problem of scheduling in explicit, quantitative terms. This concept of constructing a mathematical model will be applied to an increasing degree in the future, for the tools are now available by which such complex problems can be economically solved on digital computers.

There are limits today to the use of mathematical programming techniques for making the best scheduling decisions. The techniques developed to date do answer the problem of determining the best use of the various productive facilities. But they do not deal with the technological sequence of the operations to be performed on the product. In other words, a solution may indicate that the milling machines are operated most profitably by producing first product X, then product Y, then product Z. But if the turret lathe is used for the preceding operation for these three products, and if the most profitable program for the turret lathes is to produce first product Z, then product X, then product Y, it's clear that the sequence of operations is a restriction tending to prevent the adoption of the best solution to the problem of optimum scheduling both the turret lathe and the milling machine. If we were to adopt the results of the programmed solution, we would be forced to create inventories, piled on the floor, waiting processing through the machines as required by the methods or planning instructions.

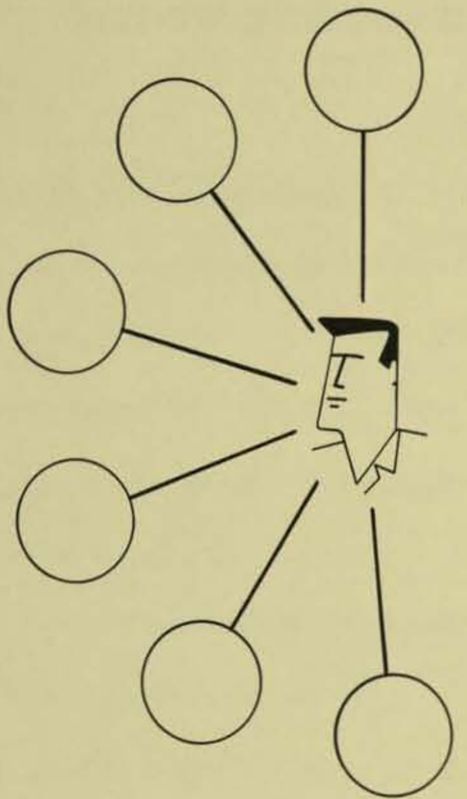
On the other hand, great progress is being made in dealing with the problems of restrictions in the sequence of operations. For instance, Dr. Melvin E. Salveson at the Major Appliance Division has solved the "Assembly Line Balancing Problem" which involves sequential restrictions using a method of combinatorial analysis. Such an analysis and technique could conceivably be incorporated into mathematical programming solutions of operational scheduling.

A second restriction in the use of mathematical programming techniques is concerned with the quantitative data used in the formulation of the model. It has already been emphasized that the profit objective discussed in the two examples is not the net profit data calculated by the accountant. The accountant cannot ignore fixed costs in determining his profit per product. Instead, he must allocate, often arbitrarily, a certain portion of the fixed operating costs to each unit of product being manufactured. In programming, however, fixed costs such as depreciation on machinery, taxes, executive salaries, insurance, etc. are not directly relevant to the problem of determining best production schedules, since these fixed costs are generally incurred regardless of what quantities of each product are manufactured. As a result, great discretion must be exercised in selecting the data to be used in the model.

Other mathematical techniques:

Many of the factors which affect the actual accomplishment of production schedules are probabilistic with respect to the frequency of their occurrence. For example, employee absenteeism, machine breakdowns, bad quality parts and actual manufacturing performance, are just a few such factors. Therefore, certain mathematical, statistical techniques are necessary to assign quantitative values to the probability of occurrence of such events.

Other mathematical theories such as the "Monte Carlo" technique, and "game theory" are used to determine the logical number of trials to be used in operating with the variables of the mathematical model. As a matter of fact, mathematical theories and techniques are being developed steadily, as more knowledge is gained of the production scheduling problem.



PART SIX

Some current books and periodicals on Production Scheduling

PROVOCATIVE READING

PROVOCATIVE READING

In an area as dynamic as production scheduling, it is vital to keep up with the latest thinking in the field. The selected books and articles do not by any means cover all the reference material on the subject of production scheduling and control. They are merely representative of the better literature in this field. Many of the items themselves contain extensive lists of references.

For your convenience in selecting additional reading, the listings are divided into eight categories:

Master Schedule

"Production Handbook"

An extremely comprehensive analysis of manufacturing problems. Contains many suggested procedures and is an excellent reference text.

. L. P. Alford and J. R. Bangs
. Ronald Press
. 1947

"Production Control"

A broad but practical view of the subject is given. The various operations in the planning and control of production are explained. Many forms are shown. Has an extensive bibliography.

. L. L. Bethel, W. L. Tann, F. S. Atwater, E. E. Rung
. McGraw-Hill
. 1948

"Plant Production Control"

Control of production, flow of material through a shop. Revised to incorporate current practices.

. C. A. Koepke
. Wiley
. 1949

"Production Planning & Control"

A good, usable text describing various procedures used throughout industry with emphasis on General Electric practices.

. T. M. Landy
. McGraw-Hill
. 1950

"Production Forecasting, Planning, and Control"

Integration of the factors of production. Economic and social implications of production engineering. The case study technique is used.

. E. H. MacNiece
. Wiley
. 1951

"Production and Inventory Control"

An approach to systematic analysis with an insight into the variety of techniques in existence. Many practical illustrations.

. W. E. Ritchie
. Ronald Press
. 1951

Materials Schedule

"Management of Industrial Inventory"
A study of the Inventory Control practices of many leading companies. Includes General Electric examples.
. B. Melnitsky
. Conover-Mast
. 1951

"Theory of Inventory Management"
A derivation of the mathematical interrelationship between the economic ordering quantity and the reorder point. With this, the level of inventories can be predicted. An extensive bibliography on the subject of inventory control is included.
. T. M. Whitin
. Princeton University Press
. 1953

"ABC Inventory Analysis Shoots for Dollars"
A description of the well-known "ABC" principles of inventory analysis.
. H. F. Dickie
. Factory Management & Maintenance
. July, 1951

"Economic Lot Size and Inventory Control"
A set of rules which incorporate the "ABC" principles of inventory control in a technique for determining economic ordering quantities.
. W. V. Clark, Jr. and W. E. Ritchie
. National Assn. of Cost Accountants Bulletin
. February, 1953

"On the Inventory Problem"
Describes a statistical method for setting rules whereby optimal inventory levels may be established.
. L. Weiss, W. L. Laderman, and J. S. Littauer
. Journal of American Statistical Association
. December, 1953

"Keep Your Inventory Costs Down"
Some new concepts for the calculation of inventory costs.
. R. C. Hartigan and B. Grad
. Mill & Factory
. April, 1954

Manufacturing Schedule

"The Gantt Chart"

Use of the Gantt Chart as a working tool for management. Shows many standard applications.

. W. Clark
. Pitman
. 1938

"Production Line Technique"

Advantages and limitations of line production. Establishing and operating the line with special consideration of diversification and flexibility.

. R. Muther
. McGraw-Hill
. 1944

"Work Routing, Scheduling, and Dispatching in Production"

Interrelation of work routing, standardization, and cost accounting. The Gantt Chart in work routing. Centralized versus decentralized planning.

. J. Younger and J. Geschelin
. Ronald Press
. 1947

"The Effect of Dead Time on Inventory in Process"

How idle material causes increased inventory.

. R. C. Davis
. Advanced Management (SAM)
. May, 1936

"Dynamics of Manufacturing Interval"

A technique for analyzing manufacturing time cycles and practical applications of the results.

. W. V. Clark, Jr. and W. E. Ritchie
. Advanced Management (SAM)
. April, 1953

"Six Steps to Better Inventory Management"

A concise description of some techniques used in determining yardsticks for effective inventory control.

. H. F. Dickie
. Factory Management & Maintenance
. August, 1953

Mathematical Programming

"An Introduction to Linear Programming"
A lucid discussion of linear programming so arranged that readers desiring general information on the subject are well served.
. A. Charnes, W. Cooper and A. Henderson
. Wiley
. 1953

"Linear Programming for Production Scheduling"
A good discussion of the interacting cost factors which enter into the master scheduling decision.
. J. F. Magee
. Arthur D. Little, Inc.
. 1953

"Notes on Linear Programming"
A continuing series of studies ranging from basic concepts to computer routines and two illustrative applications.
. G. B. Dantzig
. RAND Corporation

"Linear Programming and Profit Preference Scheduling for a Manufacturing Firm"
The techniques described in this article are similar to those applied at SKF Industries.
. A. Charnes, W. Cooper and D. Farr
. Journal of Operations Research Society of America
. May, 1953

"Application of Linear Programming to the Solution of Refinery Problems"
Shows how Linear Programming can be used for distribution and mix analysis.
. G. E. Symonds
. Esso Standard Oil Co. Manufacturing Technical Committee
. January, 1954

"Mathematical Programming - Better Information for Decision Making"
Description of mathematical programming for three groups -- top executives, administrators of sections interested in using mathematical programming and those interested in actual techniques.
. A. Henderson and R. Schlaifer
. Harvard Business Review
. May - June, 1954

Progress Curve

"Production Engineering in the Aircraft Industry"

An extensive description of applications of the manufacturing progress function by the aircraft industry.

. A. B. Berghell
. McGraw-Hill
. 1944

"A Mathematical Method of Calculating Labor Requirements and Optimum Production Output"

Mathematical derivation of the progress curve for the airframe industry. Shows formulae for estimating the size of standby contracts needed to insure speedy build up.

. H. Bergmann
. Econometrica
. 1951

"Factors Affecting the Cost of Airplanes"

This is the first known article published on the subject of the manufacturing progress function.

. T. P. Wright
. Journal of Aeronautical Sciences
. February, 1936

"Manufacturing Progress Functions"

An extensive analysis of the basic statistical mathematics underlying use of the progress curve.

. W. Z. Hirsch
. Review of Economics and Statistics
. May, 1952

"The Learning Curve as a Production Tool"

Briefly describes the manufacturing progress curve.

. F. J. Andress
. Harvard Business Review
. January - February, 1954

Operations Research

"Operations Research and its Role in Business Decisions"

A good general discussion of the key concepts of operations research. Some interesting examples are included.

. R. W. Crawford
. American Management Association
. Manufacturing Series No. 206

"Operations Research as Applied to Industrial Production and Development"

How mathematical models can be used for production and inventory scheduling, planning machine runs, determining inspection intervals, etc.

. J. B. Lathrop
. Society of Automotive Engineers Journal
. May, 1953

"Operations Research for Management"

Explores the boundaries between Operations Research and other business functions. Certain simple illustrations are included.

. C. C. Herrman and J. F. Magee
. Harvard Business Review
. July - August, 1953

"For Better Answers to Your Tougher Problems...Operations Research"

A good commentary in simple terms on what industrial operations research is, and the techniques used; the article also contains a glossary of terms.

. M. G. Melden
. Factory Management & Maintenance
. October, 1953

"New Machine Loading Methods Break Bottlenecks"

This is a brief summary of the consulting job done by the Methods Engineering Council for SKF Industries.

. Factory Management & Maintenance
. January, 1954

"First Course in Abstract Algebra"

Each concept is illustrated by a working model, prior to the development of that concept in abstract form.

. R. E. Johnson
. Prentice-Hall
. 1953

Computers and Data Processing

"Arithmetic Processes for Digital Computers"

Reviews electronic computer procedures for newcomers to the field; explains special codes, and arithmetic processes performed by digital computers.

. J. H. Felkner
. Electronics
. March, 1953

"Cost Reduction Through Electronic Production Control"

On the uses of electronic data handling equipment in production control functions.

. R. G. Canning
. American Society of Mechanical Engineers
. June, 1953

"I.R.E. Proceedings - Computer Issue"

Entire issue is devoted to articles on digital and analog computers.

. Institute of Radio Engineers
. October, 1953

"Tabulating Equipment for Better Inventory Control"

Describes the installation of a punched card system at Micro-Switch Division of Minneapolis-Honeywell.

. R. D. Dash
. Factory Management & Maintenance
. December, 1953

"Proceedings - Association for Computing Machinery"

A rather technical summary of developments in the design and operation of digital and analog computers.

. Richard Rimbach Associates, Pittsburgh, Pa.
. 1952

"An Introduction to Theory of Dynamic Programming"

Develops methods of optimal choice-making in certain broad classes of production problems.

. Richard Bellman
. RAND Corporation
. 1953

New Techniques

"On the Application of Servomechanism Theory in the Study of Production Control"

Illustrates how "feedback" control concepts can be useful for studying production control methods, inventory levels, and production scheduling when sales demand is changing or uncertain.

- H. A. Simon
- Econometrica
- April, 1952

"On a Quantitative Method in Production Planning and Scheduling"

Presents the mathematical concepts of production schedules.

- M. E. Salveson
- Econometrica
- October, 1952

"A Mathematical Theory of Production Planning and Scheduling"

Asserts that mathematical methods are useful in planning and scheduling; outlines areas and methods of application.

- M. E. Salveson
- Journal of Industrial Engineering
- February, 1953

"Dynamic Behavior of Linear Production Systems"

Describes the analogy of production control to servomechanism circuit theory.

- D. P. Campbell
- Mechanical Engineering
- April, 1953

"Mathematical Methods in Management Programming"

Describes the simplex method of solving linear programs and how it can be used for certain scheduling problems.

- M. E. Salveson
- Journal of Industrial Engineering
- March, 1954

"The Use of Mathematics in Production and Inventory Control"

A clear, effective explanation of the use of mathematical symbols in production analysis. Includes a simple explanation of matrix notation.

- A. Vazsonyi
- Management Science
- October, 1954