File: Ideas

IDEA FILE

The Planning Of A Total Business

If you were designing a brand new product line to be manufactured in a brand new factory a number of aspects would have to be considered during the design stage. Some of these area are listed below:

1. Product Design Conception

   - conception -- development
   - engineering design -- standardization, quality, producibility
   - documentation

2. Manufacturing Planning

   - facilities -- automatic equipment, all other equipment
   - layout
   - methods - fixtures, tools
   - MTS
   - quality control
   - documentation

3. Manufacturing Control System

   - cycle
   - inventory -- finished, procured, manufactured, in-process
   - promise cycle
   - ordering rules
   - measurements

4. Data Processing System - Main Line

- order transmittal
- order edit
- unit design
- unit planning
- unit documentation
- unit measurement -- cost

The next two stages after planning would be implement and then operate.

The measurement of such systems should include consideration of direct labor, direct material, unassigned labor, indirect labor, cycle reductions which relate to sales increase, inventory.

B. Grad/pd
5/21/59

File: Ideas

IDEA FILE

Stock Quantity Determination

Reasons for Stocking An Item

1. cycle reduction
2. lot size - set up costs, paper work costs, discounts
3. unfortunately in demand variance, supply lead time, supply quality variance
4. leveling

Reasons For Not Stocking An Item

1. obsolescence
2. deterioration

B. Grad/pd
5/21/59

IDEA FILE

File Ideas

Protective Stock Quantity Determination

Would it be possible to use the practices and formulas like those used by actuaries in life insurance and accident insurance to determine proper protective stock quantities. It would seem that these are analogous problems in that in both cases we are dealing with the risk of an event taking place with definite penalties associated with the event having occurred.

B. Grad/pd
5/21/59

File - Ideas

IDEA FILE

Distribution Of Costs

Could the basic cost accumulation be done in such a way as to provide for cost distribution to a variety of accounts? If this flexibility could be built in, then the particular cost distribution required per day, week, month or year could be left entirely a matter of management discretion, where, by specifying the classification criteria, the computer could automatically make the necessary distribution.

B. Grad/pd
5/21/59

File: Ideas

IDEA FILE

The Storage of Blueprints

Could blueprints be stored on magnetic tape like that used for television transmission. If so, how would it be referenced and how would it be displayed?

B. Grad/pd
5/21/59

Ideas

Mfg Engrg –

decision rules

man-machine operation plng

man-machine methods plng

" " time standards plng

Routing, sequencing (intra + inter station)

physical "structures"

layouts

machine selection

tools, fixtures

Techniques:

Simulators

math programming

"dynamic" programming

dynamic flow charting (step beyond 3D) LH-RH

Planning

producibility

Capability analysis

Supporting -

provide operation plng transforms to Prod Cont

Capacity studies

tool, fixture, machine maintenance

~~Thant~~

Ideas

Decision Rules Program

~~SYSTEM~~ Production CONTROL ~~PROJECT~~

An analysis of production control decision rules -

Customer promises

Scheduling

dispatching

Inventory Control - Fin, IP, Raw

Personnel hiring, layoff - ~~a~~

Machine + man Assignment

A study of means for systems description

A Review of Systems Analysis Tools

development of techniques for Systems Synthesis

Supporting areas -

forecasting

~~Reporting~~ Techniques - Report preparation

~~A Review of hardware application~~

Development of G.P. research simulators or analytical tools

file
Idea

October 13, 1959

Mr. H. F. Dickie
OFFICE

I had a discussion recently with members of the Industrial Dynamics Group at MIT (including Jack Pugh and others), concerning the ability to measure management performance in terms of long range objectives. During the discussion the question was asked as to why couldn't we use some method similar to that which is used for rewarding salesmen of products where the interest is not just in the initial sale but rather in its continuing use? Illustrations of this include insurance, rental of data processing equipment and certain kinds of supply businesses. In other words, the idea would be to give the manager a future participation in the profit of his business.

One approach might be to set a practice of dividing up some percent of a department's profits above a minimum figure like the 5% investment charge among those entitled to incentive compensation. Among the participants would be any previous general manager still with the General Electric Company. He would participate at a decreasing rate for a period of five to ten years after he left the business. This would have the effect of reducing the current manager's incentive compensation somewhat but it would provide him with an incentive for establishing a basis for future profitability. It would seem to be intuitively sound since we all recognize the fact that it takes a new manager in a shop two or three years to really show results for which he is responsible and not the previous manager.

Another approach would be to give each general manager "stock options" on the department which he is managing. These options would not be claimable until five years after the man assumed management of that department. They would then be redeemable over the succeeding five-year period. The value of the options could be determined by some formula which was a function of profit level, sales and assets.

Obviously, this idea is not in our normal line of work, but I wonder if a discussion with Bill Bryant might indicate who would be interested in such an idea or whether it has already been explored in the past and rejected for some reason.

Burton Grad
OFFICE

BG/pd

Ideas

THE CONCEPT OF A PROGRESS PLANT

Prepared for the 1959 Business Review

As we look toward our future work we begin to see the possibility of General Electric building a "Progress Plant" -- a plant to be a show-place to the world for General Electric products, General Electric industrial systems, General Electric business systems. This Progress Plant would be a "living laboratory" to enable us to demonstrate and try out new concepts, new ideas, new theories and new philosophies of operating a business system.

It would be our hope that the product produced in such a Progress Plant would be directly sellable on the market, since this would give us a measure of the competitive aspects of the various ideas and concepts that were tried out. This plant would have built for it a comprehensive set of simulators which would enable us, even in this case, to pretest ideas prior to their being introduced in the factory.

The Progress Plant would be highly automated; it would be maintained as somewhat of an immediate ultimate in automation for the kind of businesses that General Electric participates in. It would have on-line control, complete feedback, and thorough management reporting and analysis. It could use the various principles which the different Services components have developed and expounded.

How soon this will come is, of course, hard to say. But the experience that we might learn in building such a Progress Plant to guide us in the building of future operating factories might be a worthwhile investment by itself. It would seem that this might be instituted prior to the next major expansion program, since in this way, we would get maximum benefit from the techniques and concepts developed in building the Progress Plant.

B. Grad/pd
6/26/59

IDEAS

Converter; Tape to Tape

→ ~~Pat please see~~ B.G.

OCT 17 1958

IDEA

Should we send copy of letter to Phoenix? — Burt

Letter from H. Dickie to Palmer

C. W. Bryant
→ B. Grad
K. R. Geiser
J. L. Miller

WAYNESBORO, OCTOBER 14, 1958

Mr. H. Ford Dickie
Manager-Production Control
Materials Service
Manufacturing Services
570 Lexington Avenue
New York 22, New York

Since Mr. H. L. Palmer is absent from his regular job, I have referred your August 19 letter concerning a magnetic tape to punched tape converter to our Product Planning people for review. We feel that this type of component, although desirable in some over-all systems applications, would not fall within our product scope since it is essentially one of data conversion. Perhaps you have already discussed this with some of the people in the Computer Department; but, if you have not, I would suggest that you do so.

We are always interested in any suggestions from you as to how we can assist in expanding the use of program control products within the General Electric Company.

J. R. DEVOY
Acting Manager-Engineering
Ext. 453--Room 201

JRD/jlg

Burt- why not! NCR 304 has the facility to produce 5,6,7,8 channel tape -- but it's another sales point to push via showing the application - suspect they have little interest in producing machine

FILE

bcc: TFKavanagh
~~HBMiller (?)~~

August 19, 1958

cc: C. W. Bryant
B. Grad

Mr. H. B. Palmer
Manager-Product Engineering
Specialty Control Department
Waynesboro, Virginia

The Integrated Systems Project has been working toward a fully integrated main line operating system which would permit direct transformation of customer orders into factory operator instructions or into punched paper tape for running automatic numerically controlled machine tools. As you know our progress has been quite satisfactory to date. However, there is one particular problem which we have solved in a temporary way but which might be suitable for consideration from a Company product standpoint. This is the apparent differences between factory and office automation equipment specifically, office data processing machines generally use punched cards and magnetic tape while the apparent standard for automatic machine tool controls is eight-channel punched paper tape. The problem is heightened by the variation in codes on the magnetic tapes from different manufacturer's computers.

What we are doing for our Fall demonstration is to convert the IBM 702 magnetic tape into punched cards, then, through the use of a Systematics Inter-coupler the punched cards are converted to eight-channel punched paper tape. This is certainly not a very impressive approach and is both time consuming and costly in the use of expensive tape to card conversion equipment.

It would seem to us that it should be possible to produce a reasonably inexpensive (though possibly relatively low speed) magnetic tape to punched paper tape converter which would perform this job quickly and easily.

To put the problem in the proper context let me describe the technical requirements for the system:

> Normal IBM 702 output consists of a seven-level, even parity check code, which is recorded on 1/2-inch acetate-based ferro-magnetic tape at a speed of 75 inches per second at 200 characters per inch packing density. Punched cards using a Hollerith code and punched at a rate of 100 cards or (8000 characters per minute)

can also be provided as auxiliary output. The eight-channel punched paper tape required as input to the Mark II is standard eight-channel Flexowriter code. This code is fundamentally a seven-level code with an odd parity check and is typically punched at about 10-20 characters per second and ten characters per inch. The extra level is used only for EL or "end-of-line" characters. Faster tape punches (Soroban and Teletype) can be obtained. This factor is significant because the relatively slow tape punching speed necessitates buffering to compensate for substantially higher magnetic tape reading speeds.

It is interesting to note that the parity check for the two codes are diametrically opposite (i.e. even versus odd) and the parity check channel in the IBM 702 code appears in the first level (C-B-A-8-4-2-1) while the Flexowriter code uses the fourth level for parity check (EL-X-O-"CH"-8-4-2-1). Thus, a code conversion is required in addition to the change in recording media.

We have talked with various manufacturers of equipment to perform this job. The only thing that seems to be on the market is produced by EPSCO Company in Boston, Massachusetts which has quoted $80,000 for magnetic tape to punched paper tape conversion. Nuclear Development Corporation of America has also produced a magnetic tape to punched paper tape (and vice versa) converter in the $85,000 range. IBM does not have any equipment on the market but would be pleased to build it on a special order basis with an indicated price of approximately $120,000.

Our purpose in writing to you is to solicit your comments and thoughts as to whether this would not be a logical tie-in with your own directors for numerical machine tool controls. Certainly one of the problems which is going to be faced by all companies as they begin to more extensively use numerically controlled machine tools will be efficient preparation of the necessary punched paper tapes. It is possible that many General Electric departments and outside companies could afford to pay the $80,000 to $100 000 required or would be willing to use magnetic tape to card and then card to punched paper tape. However, it seems that there might well be a market here which we should investigate for General Electric.

As we mentioned earlier our own particular needs for this demonstration will be handled by using available equipment, however, if we can be of any further help in discussing the need for such a magnetic tape to punched tape converter we should be very pleased to follow up with you.

H. F. Dickie, Manager
PRODUCTION CONTROL SERVICE
Room 2401 - ext. 3531

HFD/pf

~~Detroit~~ Ideas
~~Contamination~~

9/16/58

Items not covered in Demonstration

Feature Date order

Replenish for model Stock Orders

When stock control, ordering

Auto Table Conversion from natural to coded

Promising stock models

Component Pt Stock control

Product Structure except Arm Coil + mech base

Open structure except Arm Coil + mech base

Capacity for LCA

Bill of materials
delayed order release
Component Stk Replen Orders

Spare pts orders

File maintenance - Table Changes

No ordered Open order File
{ Punch order prep
{ Regn Typing
{ Shpg + Billing papers
{ Cost Structure
feedback control
Measurement reports

Test File of popular models (based on KP)

ISP DEVELOPMENT
~~TABSOL~~

JAN 19 1959

January 14, 1959 cc: B. Grad

Messrs. P. M. Currier, Bldg. 5, Rm. 531, Schenectady
R. L. Getis, 3198 Chestnut St., Rm. 5650, Philadelphia
R. V. Sickles, Bldg. 5, Rm. 531, Schenectady

In addition to the State Police, a favorite topic on last year's auto trips to Schenectady was, "How can TABSOL be improved?" One of the chief concerns was that we would allow many of the ideas, comments, and criticisms pass unrecorded -- and that this oversight would someday be regretted. It was with this problem in mind that the enclosed draft was prepared. I recognize that each of you is now busily engaged in other activities, nevertheless your interest and the importance of TABSOL justifies requesting your thoughtful comments. (Have you ever been asked to do "free" work so nicely?) Seriously, you will undoubtedly recognize some suggestions of your own; any additions or elaborations you care to make will be gratefully received.

To highlight the timeliness of a TABSOL review, there presently appears some hope that we may be able to re-program TABSOL incorporating many of these features.

Best regards,

T. F. Kavanagh, Specialist
Production Control Service
Room 2409 - ext. 3547

TFK/pf

enc.

DRAFT

CONTINUED COMPUTER APPLICATIONS PROJECTS

Introduction:

Integrated Systems Project efforts to profitably utilize electronic computer in business systems uncovered numerous opportunities to broaden the application, and significance of the central TABSOL concept. However, the external framework of the Project demanded that full efforts be directed toward completing an operating "breadboard" model, thus precluding any extension exploration of these ideas. The successful completion of the "breadboard" model in November 1959 proved the validity of the original concepts and underscores the importance of continuing TABSOL's development. This discussion is designed to outline a program to accomplish this objective.

Presently, foreseen work falls principally into two rather well-defined areas: -- TABSOL, the generalized table solution program and TABCOM, a series of generalized programs for automatically converting systems designer's structure tables into computer language for use in actual operating programs. Other related projects will be grouped under General Computer Application Projects:

TABSOL DEVELOPMENT PROJECTS

1. Develop TABSOL for the GE 304 in conjunction with the Computer Department. Also consider advisability of developing TABSOL for the IBM 704 to support Production Control Service's education programs in 1959 as well as direct department application to existing computer programming problems. (The Company can make money from TABSOL today!)

Obviously, this program would encompass the projects outlined below.

2. Generalize, by a careful revaluation, the various data areas used in conjunction with TABSOL and the manner in which they are specified. To be more precise the SPEC area (which was originally named because the area was initially reserved for customer SPECifications) shalx should be thought out in terms of a general problem DATA area whose size is under parameter control. The INT area should develop into a general problem oriented WORK area. Similarly, the present concept of HOLD area, TIME accumulator, and PAC pseudo-accumulators, can be profitably expanded.

3. Expand TABSOL test functions to include other types of tests. Past project experience has already indicated several desirable additions such as a "not equal" and an "unconditional column skip" test. The extension of the TABSOL test to other logical operations (e.g. logical or) also seems desirable. Provision should also be made to permit the use of formulas in testing. (At present pseudo-arithmetic calculations are restricted to TABSOL results.)

4. Expand TABSOL result operations to permit modification of tables. An "add memory" or "subtract memory" type of instruction which would permit the direct addition or subtraction of literal or non-literal values to any addressable data area would have obvious advantage in recordkeeping activities. The PRINT function should be able to address all of memory overlapping addressable data areas.

5. Incorporate the "error message" completely within TABSOL and without return to the executive program. This places systems error responsibility completely with the system's ~~dd~~ designer and should also improve certain data processing efficiencies. This also implies a TABSOL addressable ID (table identification area, not the subconscious mind).

6. Re-examine present print programs to determine what modifications might be necessary to convert it into a generalized fixed and variable output program.

7. Develop a flexible input program utilizing the TABSOL concept which will make the requisition edit sheet format (or any input) independent of the program. The concepts to support this development are available.

8. Develop TABFOR - a generalized formula evaluation program - to supercede the present pseudo-arithmetic. TABFOR would be developed for direct incorporation into TABSOL as a subroutine. Preliminary work in this area has already been started. (see attachment)

9. Revaluate the present approach to programming TABSOL.

   a. Examine the possibility of calculating the answer column, rather than testing. In this regard a resurrection of the old "control word" idea may prove worthwhile. Simple file maintenance has proved a stumbling block to several previous achemes to accomplish this worthwhile objective.

b. Examine method of performing TABSOL tests. Tests (or conparisons) particularly on the serial computers (e.g. IBM 702) are quite time consuming and a more elaborate testing scheme which reduced the number of tests would ~~haxx~~ have a low breakeven point.

c. Extend TABSOL program to permit tables in both sections of memory. (upper and lower)

d. Examine for a variety of computers, the relative advantages and disadvantages of in erpretive versus generator approaches to TABSOL. Establish criteria for determining proper approach to other computers.

10. Evaluate the potential advantages ~~f~~ of a variable word length TABSOL versus the present fixed word length format.

11. Establish criteria for the design of new electronic computers specifically to operate in the TABSOL mode.

TABCOM Development Program

1. Develop TABCOM for the GE 304 computer in conjunction with the Computer Department. Also consider the advisability of developing the TABCOM programs for the IBM 704 to suppprt Production Control Service summer education programs as well as direct department ~~abdx~~ application to existing computer programming problems. The TABCOM program includes a series of separate programs for the automatic conversion of the systems designers structure tables into computer language:

TABVAL -- a generalized structure table edit and validation program designed to assure the data processing accuracy of the structure tables.

TABCON -- a generalized structure table conversion and compiling program designed to automatically convert the validated structure tables into an operating table tape.

TABPRINT --a generalized table print program designed to operate independently or as a subroutine to other TABCOM programs which will provide a print out of the structure tables.

TABFIX -- a generalized file maintenance subroutine designed to simplify maintenance of the operating table tapes.

2. <u>TABVAL Development Program</u>

Generalize, by careful revaluation and incorporation of revised TABSOL concepts, the present TABVAL program. New functions which the TABVAL will perform will include validity checking, data field assignment, parameter checking, etc. The output of the TABVAL program as presently envisioned will consist of a primary table tape and a correction tape (thus avoiding the necessity of rereading, reprocessing and rewriting the vast bulk of valid tables.) This output would be used in the TABCON program.

3. <u>TABCON Development Program</u>

Develop a conversion program to assemble a master program tape and one or more table correction tapes into a single ~~spxx~~ operating table tape.

The TABCON program may offer singular opportunities to improve the data processing efficiency of the TABSOL program by reducing the number of TABSOL tests actually performed and reduce memory requirements. This can be done by xhxx automatically recombing tables into better sequence for processing:

Analyze test conditions within a block of structure tables.

Combine tables with similar conditions into larger more comprehensive tables.

Split the resulting combined tables into a series of one condition, one director pseudo-tables to remove the test redundancy which is a necessary outgrowth of the preceding step.

In addition to the foregoing (which is intended incidentally to sketch a possible solution, rather than to specify the approach in detail) other simpler expedients could be adopted.

- Invert the order of test conditions. While it's easier for the hxx human to classify test conditions from the broadest to the more pr ecise, the electronic computer will solve tables more efficiently if it can dispose of the most discriminating test first.
- Rank the appearance of test condition values by frequency of xxxxxxxxx occurrence.

4. TABPRINT Development Program

Develop a generalized table print-out program which will function as a subroutine to any other TABCOM program or which can be used independently as may be required. The program will be required to produce converted and compiled tables for both the systems designer and the computer operators in both testing and operating the problem system.

5. TABFIX Development Program

Develop a simplified file maintenance program to ease the problem of changing tables.

This program has a difficult goal in that it must demonstrate superiority over merely "regenerating" the operating table tape. Past experience indicates that once the punched cards have been put on magnetic tape the TABVAL program goes quickly. Similarly, the more complicated the TABCON program becomes the more difficult it will be to write a file maintenance program to alter the table tape.

A parallel investigation should also be conducted into the best method for halding table data.

GENERAL COMPUTER APPLICATIONS PROJECTS

1. Examine the limits of application of the regenerative concept.

2. Examine the economic limits of TABSOL in systems design operation and maintenance.

T. F. Kavanagh
1/14/59

pf

Ideas

Production Leveling

classes of problem —

- deterministic
- non-cyclical – trend, etc
  random
- probabilistic cyclical
- product mix.

Split Inventory into 2 Classes

(1) a non-earning asset – what you need simply to do business –

(2) an earning situation where extra income accrues to you because of Inventory

(1) Lower operating costs (transportation) < lower mat'l prices; larger batches & fewer setups

(2) larger sales –

(3) charge higher prices.

Sched + Inv Cont

IDEAS

Harlan
Mills
Roger Pinkham

Assumptions

(1) No month to Month Sales stable correlation

expected value of 2 successive periods are fully independent except that they are drawn from a common distribution.
a high June does not imply a high July. or vice versa

→ truck convoy analogy to distribution chain
leverage factor.
speed, distance - ~~convoy~~ truck ahead

(2) No Long term trend.
steady state operation

(3) Non cyclical business.

Opm res

529 470-472

Sequence Selection

For a unit station or fixed flow line – (no buffer interlocked)

multi product -
variable changeover time

no symmetric

to →

from ↓ Prod	A	B	C	D	E
A	0	.2	.5	.1	.4
B	.1	0			
C	.4	.2	0		
D				0	
E					0

define each entry as

XY

X is initial product
Y is next

YX ≠ XY

Objective - Given a set of prod A, B etc
To be mfd during a given period
to find that set of transformation that minimize. $\sum XY$

Such that all X and Y are in the set once and only in both initiating and terminating position. except for the first initiating and last terminating product

The initial state of the system can be at ~~some~~ any selected product, but this must be stated and the system need not terminate in any particular state.

If any particular transformation is especially undesirable the transformation cost can be indicated ∞

Julia Robinson – special travel salesman
RAND non unifor

---

use mathematician or consulting basis to survey solutions to the problem

see Pinkham at Princeton

Ideas

B. Grad 3/6/58

How about the dynamic load idea of loading six times for 97% loading solution.

	-3	-2	-1	trial	+1	+2
CG #1	1	1	1	0	1	0
2	1	1	0	0	0	0
3	1	0	0	0	0	0
4	1	0	0	0	0	0
5	1	1	1	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	1	1	0	0	0	0
9	1	0	0	0	0	0
↓ m						

It uses control words !!

Tom K.

A FACILITIES PLANNING PROBLEM

One particular facilities planning problem which I have not previously seen described in text material can be stated as follows:

1. The processing line is treated as a fixed locked-in unit for each individual produce.

2. The limiting station varies with the product being manufactured.

3. The speed of the line is set by the limiting station for a specific product.

The problem: If we wish to increase production by 100% what specific additional facilities are required.

An example: We have a fixed assembly line consisting of stations A, B, and C. We manufacture products 1, 2, and 3 across these assembly lines. Station A is limiting for product 1, Station B for product 2, Station C for product 3. The limiting times are, Station A, 1/10 hour for product 1, Station B, 4/10 hour for product 2, Station C, 2/10 hour for product 3. It is now possible to prove that regardless of the quantity being manufactured of each of the individual products there is a one solution which will permit the increased level of production. For example, if you wish to produce one of each product every tenth of an hour we could obtain four elements of Station B and two elements of Station C. There are many other specific solutions however which would depend upon the specific product mix to be processed. This problem is similar to one expressed by the Distribution Transformer Department at Hickory and should have broad application to many of our assembly lines throughout the Company.

B. Grad
August 30, 1957

BG/ls

COMMUNICATIONS

In the area of external communications, we have three basic channels with which we are concerned. The first is a channel from the customer to the department; the second is from the department to the vendor; and the third is between components of the company. This could include branch plants to headquarters, within division or within group; from customer to vendor department; or from departments to central company operations. It would seem that because of the diverse needs, requirements and facilities available to each particular department, and because of the variety of information to be transmitted, that the successful external communications system would have the following characteristics:

1. It should accept any of the major forms of input such as punched cards, punched tape or magnetic tape.

2. It should consist of a set of modular components which were designed to translate these individual forms into a standard common language. This common language should be capable of being transmitted on either telegraph or telephone wires.

3. The input devices should be so designed as to insert self-checking bits in each character, word and/or message.

4. The output side should be just as flexible, permitting any one of the three major types of output, or it might permit direct on-line control of an operating phenomonon.

5. The message transmitting device should be capable of self correction, i.e., if an error is detected, a re-transmission of the information should be immediately called for and the information collected to that point destroyed.

The area of internal communication is far more complex and less well defined. One major area which seems to require work is that of sequence or station selection. This would permit a single central computer to operate in conjunction with a multitude of on-line devices, either in the factory or office. In effect, we must develop a more efficient telephone switching network, since it will probably not be economically feasible to operate a large factory from a series of independent computers, each on an on-line mode.

As part of the communications problem, it will also be necessary, on present general purpose computing equipment, to solve the problem of program interruption. If an immediate decision must be made to solve a particular instruction need in the factory, this should not disrupt nor wreck a "run" in process on the computer.

Another communications problem which deserves investigation is the economical balance between the computer detailing the instructions and fully transmitting this information directly to the operating station, versus the computer transmitting only the selected code data, and for the station itself to have this information translated into operating instructions.

It would also be desirable to investigate and explore the possibility of binary transmission, since it seems likely that much of our information may be of a simple binary nature. Another area for study is that of exception transmission whereby we might design a series of "burglar alarms" to monitor each operation characteristic, and that these only transmit information when new instructions are required.

Burton Grad,
April 12, 1957

Kavanagh
Canning
J Miller

Subject: Product Structure Analysis

There are three major approaches to the analysis of a product's structure. The first is by interview and discussion with the various engineers and operating personnel in order to gain a general understanding and feel for the product. The second is by explosion and then comparison of the various parts required to make different models. This material is often combined into a collation chart. The third approach is to analyze the parts characteristics in terms of the control elements which establish their specific values. This is best done by an examination of the various prints and parts lists associated with each class of part or assembly.

While each of these approaches have their advantages, it is our conclusion from the work done on the 39 frame shaded pole motor that the greatest gain can be realized through following the third approach after brief work in areas one and two. In support of this conclusion therefore I have presented below a description of the sequence of events to be followed in carrying out a thorough product structure analysis.

General Foundation

It is most useful to start by examining in actual physical form various representative products from the total product line to visually see similarities and differences. This review can be most useful if followed by a discussion with the various design engineers to learn from them what they consider to be the essentially stable elements of the product line. Their general insight and understanding will normally enable you to establish a framework upon which the balance of information can be erected. This discussion might consist of an indication of basic incremental spacing used in various parts of the product, a notation as to the major assemblies or components, some remarks as to the basic customer variables which affect the product design, an indication as to which components are most highly variable and which dimensions on these components seem to be the ones with the greatest variation. This might even have at this stage some indication as to inter-relationships between major components and assemblies. It is useful to try and make up a rough model at this stage listing all the various assemblies, parts that go into them, and some verbal notes as to the basic variations thereof, and what causes these variations. This is at best a cursory model and no matter how clearly it seems that you understand the problem, it is much too soon to have sharpened the knowledge which you need.

A Basic Parts Model

With the various parts generally classified, it is then often found desirable to select some representative number of models, possibly ten to twenty might be effective, and to obtain complete sets of model lists and parts lists detailing these particular models. The models should be selected either on the basis of greatest number of sales or by their being representative in covering the entire product line or some equally logical foundation. It is then desirable to keypunch the information contained on the various model lists and parts lists so that some analysis can be performed. If possible, the entire contents of a single parts list should be contained on one IBM card. This can often be done by finding common drawing characteristics or by elimination of obviously repetitive, descriptive and quantitative data. It is at this stage that the redundancy of quantity information becomes most obvious and frequently basic collations between assemblies and groups of assemblies also becomes obvious. A great deal of time should not be spent on this keypunching; however, it is often useful to insure that no parts are overlooked, no assemblies are missed and that the proper sequence in the chain is established. It is also desirable in that it makes sure that you have covered the full product line rather than just some most popular branch. When this is completed you should be able to improve your previous model by establishing a list of parts names which should be essentially correct and showing clearly which parts go into which assemblies on up to the major components and model level.

The Study of Parts Characteristics

To perform a thorough and complete parts characteristics study it is essential that a copy be obtained of every active blueprint and parts list. It is also essential to obtain copies of engineering and/or manufacturing instructions. It is also desirable to obtain a set of operation planning cards. With this material available, the first step is to segregate the information by assembly and then by part. The problem can be approached from either direction; that is, starting with the model characteristics and gradually working down to detailed parts or conversely starting with the parts and building up to the total model. It is our opinion that the most efficient approach is to start at the bottom, at the lowest common demoninator in the systems and gradually build up to the assemblies and finally to the model itself. To illustrate how this can be done we would take, for example, all the blueprints covering a particular type of part, for example, a shaft; a collation sheet would be set up on which we would list each variable shaft characteristic as it was discovered. For example, we would inspect the diameter of the first shaft blueprint. We might then look through the other shaft blueprints until we found one that was different. If a variation was found, it would be noted. The item would be noted as a variable characteristic. If no variation however were found, then this would be noted as a fixed characteristic and so indicated. Therefore the extent of the first pass is merely an identification of these variable and fixed characteristics. The second part of the program lies in establishing the minimum and maximum values of each of the variable characteristics as well as the incremental spacing between acceptable values. This also includes discrete states for non-dimensional characteristics. For example, if there were oiling grooves on the shaft, they might have two basic directions of rotation, either clockwise or counterclockwise. To insure that no variable characteristics have been overlooked, planning cards for making various of the active shafts should then be examined. It should be possible to identify for each characteristic, both variable and fixed, the specific operation in which this characteristic is inserted. Some of the characteristics of course, belong to the raw material itself and should be so noted. Certain characteristics have to do with positional relationship between items. These are generally just as valid and just as significant as those which deal with a particular dimension. Other characteristics may not even be noted on the blueprints but covered in engineering or manufacturing instructions or notes. These must also be picked up. One of the characteristics to be studied is always quantity, for example, how many shafts would be used per product? This may also be noted.

In studying the various parts characteristics it is often desirable not to treat the entire set of parts as an entity, but rather to break them down into two or three major classes and then develop the variable and fixed characteristics for each of these classes. This is a perfectly acceptable procedure, but should only be resorted to when it is not efficient to describe the entire set of parts with a common set of characteristics.

In doing the work then you may often want to build up the description and characteristics for all the parts that relate to a particular sub-assembly. Then to go on and study that sub-assembly and other related sub-assemblies continuing on to a major component. This often permits a number of individuals to work on the problem simultaneously, hence gaining multiple insight and greater speed. Nevertheless, it is usually desirable to have some one or two people reviewing the work done by all of those working on the program to insure that it coordinates well and that logical cross inferences are being drawn. As the next step in handling the parts characteristics, it should be the responsibility of the analyst to try and determine the ~~consideration~~ causation for the particular value of the characteristic. For example, if there are six different distances each varying by a quarter of an inch between the oil grooves on a shaft, it would be the responsibility of the analyst to inquire from the engineers or manufacturing people as to what caused these different dimensions. In this case his first conclusion might be that it was caused by the stack height of the rotor into which the shaft was assembled and this would be adequate for a first approximation. However, as the analyst then went on to study the rotor core and finally the rotor itself he might be able to be more specific, for example, he might say that it was related to the stack height and the number of poles. When the total information for the motor was brought together he might then see that it was actually related to the bearing positions in the motor assembly and this in turn related to the size of the shell which was controlled not just by stack height and number of poles, but also by special customer requirement, either for extra ventilation or for base standardization. In other words, a chain of logic is built up, step by step, as the information is procured. For an element to be controlled it implies that the knowledge of the control element alone will fully determine the particular value of the characteristic under discussion. By definition then, a control element to have reached a final stage must be one which is specified directly by the customer.

The end result of this work then should be a complete listing of every single part and every part characteristic for the entire product line. These should be in some sort of assembly or disassembly sequence. The other dimension in the collation sheet is the full set of control elements, each taken back to a customer specified item if possible, or else as far back in the engineering chain as can be logically developed. For each part characteristic then we would indicate which control elements specified the value of that characteristic. If the characteristic were fixed, this would also be noted. Therefore in essence what we have when we are finished is the ability to determine thru formula the exact value of any characteristic of the entire product line uniquely from using the control elements together with certain fixed or constant factors.

Now what is the implication from this product structure summary? First, it should be expected that the amount of information needed to fully define an entire product would be significantly reduced from the present levels. Secondly, since every part characteristic is specified, we are in a position to uniquely determine the exact operations to be performed in the factory. This would be done by collating individual factory operations against parts characteristics to determine time relationships, operation characteristics, etc. At the other end of the chain we have determined what the customer should specify and therefore have established a set of values which are needed by the applications' engineer in order to uniquely determine a particular product from the product line. This could have direct value in specifying to Marketing what information they should obtain prior to the acceptance of an order.

Essentially in establishing a new product line the engineers create a basic structure; the product analysis plan is merely a means by which the rest of the business may benefit from the knowledge of this structure and may use it to maximum advantage. It is a powerful tool designed to aid standardization, aid mechanization and encourage automation.

~~Burton Grad~~

~~April 15, 1957~~

~~Dickinson~~

(1)

Mr Vinson make the following statement in a letter to Mr Strong

If Sales drop a certain percentage the percent of profits should not drop any more than this.

For example if profit/$ sales has been 6% and Sales drop 10%, Profits should drop no lower than 5.4% of new Sales.

S = Sales in dollars

U = Sales in Units

S_u = Average Sales Price per unit

$$S = U S_u$$

C = Cost in dollars

V_u = Variable Cost per Unit

F = total fixed costs

$$C = U V_u + F$$

$S - C$ = Profit

$$S - C = U S_u - (U V_u + F)$$

and $$\frac{S-C}{S} = \frac{U S_u - U V_u - F}{S}$$

when a prime is put on a symbol it indicates its value after the drop in sales

U' = reduced sales in units

etc

$$\frac{S-S'}{S} = R = \text{Ratio of Sales Lost}$$

Now if unit sale price stays constant

$$S_u' = S_u$$

Then $$\frac{S-S'}{S} = \frac{U-U'}{U} = R$$

To meet Mr Vinson's statement would require

$$\frac{S'-C'}{S'} \geq (1-R)\left(\frac{S-C}{S}\right)$$

Let's explore what this implies in terms of fixed costs. We assume that variable cost per unit is not changed

$$\frac{U'S_u - U'V_u - F}{U'S_u} \geq (1-R)\,\frac{US_u - UV_u - F}{US_u}$$

and $$\frac{U-U'}{U} = R$$ or $$U-U' = RU$$

$$U - RU = U'$$

$$U' = (1-R)U$$

$$U(U'S_u - U'V_u - F) \geq (1-R)(U')(US_u - UV_u - F)$$

if we make $R' = 1-R$; $\therefore R = 1-R'$

then $(UU'S_u - UU'V_u - UF) \geq (R'UU'S_u - R'UU'V_u - R'U'F)$

and grouping terms

$$(1-R')(UU')(S_u - V_u) \geq F(U - R'U')$$

or $$F \leq \frac{RUU'(S_u - V_u)}{U - R'U'}$$

given $$\frac{U-U'}{U} = R$$

then $U' = (1-R)U = R'U$

substituting

$$F \leq \frac{RU(R'U)(S_u - V_u)}{U - R'(R'U)}$$

$$F \leq \frac{RR'U(S_u - V_u)}{1-(R')^2}$$

$$F \leq \left[\frac{RR'}{1-(R')^2}\right] u(S_u - V_u)$$

let $$K = \frac{RR'}{1-(R')^2}$$

R	R'	RR'	$(R')^2$	$1-(R')^2$	K
.1	.9	.09	.81	.19	.473
.2	.8	.16	.64	.36	.444
.3	.7	.21	.49	.51	.412
.4	.6	.24	.36	.64	.375
.05	.95	.0475	.902	.098	.485
.01	.99	.0099	.98	.02	.495

$F \leq K u (S_u - V_u)$ to meet criteria now

$$S - C = U S_u - U V_u - F$$

$$(S-C) + F = U(S_u - V_u)$$

since $F \leq K U (S_u - V_u)$

hence $F \leq K(S-C) + F$

or $$1 \leq K \frac{(S-C)+F}{F}$$

$$\frac{1}{K} \leq \frac{S-C}{F} + 1$$

$$\frac{1}{K} - 1 \leq \frac{S-C}{F}$$

or $$F \leq \frac{S-C}{\frac{1-K}{K}}$$

$$F \leq (S-C)\frac{K}{1-K}$$

if $L = \frac{K}{1-K}$

$$F \leq L(S-C)$$

It can be proven that $L = R'$

R	K	1+K	
.1	.473	.527	.900
.2	.444	.556	.800
.3	.412	.588	.700
.4	.375	.625	.600
.05	.485	.515	.950
.01	.495	.505	.990

$$F \leq R'(S-C)$$

To interpret this further

$$\frac{F}{S} \leq R'\left(\frac{S-C}{S}\right)$$

$\frac{S-C}{S}$ = current profit to sales Ratio $\equiv T$

$$F \leq R'S\left(\frac{S-C}{S}\right) \quad ; \quad F \leq R'ST$$

$$\frac{S-C}{S} = T$$

$$S-C = TS$$

$$C = S - TS$$

$$\frac{C}{S} = 1 - T$$

$$S = \frac{C}{1-T}$$

therefore $F \leq R'T \frac{C}{1-T}$

or if $\frac{R'T}{1-T} = M$

$$F \leq MC$$

R	K	L=R'	T	R'T	LT	M
.1	.473	.9	.01	.009	.99	.0091
			.05	.045	.95	.0474
			.10	.090	.90	.1000
.2	.444	.8	.01	.008	.99	.0081
			.05	.040	.95	.0421
			.10	.080	.90	.0890
.3	.412	.7				
.4	.375	.6				
.05	.475	.95				
.01	.495	.99				

~~Product Sheet~~

Generalized Table Approach.

Condition statements

			Cond	Truth Trf	False Trf
A	Kind of Service	= DC	A	C	B
B	Kind of Service	= AC	B	F	(ERR)
C	Cal. Units	= volts	C	I	D
D	" "	= mv	D	L	E
E	" "	= amps	E	N	(ERR)
F	" "	= volts	F	S	G
G	" "	= amps	G	(1)	H
H	" "	= watts	H		
I	Cal value	≥ 1			
J	" "	< 300			
K	" "	≥ 300			
L	" "	≤ 150			
M	" "	> 150			
N	" "	< .0135			
O	" "	≤ .018 ~~.0135~~			
P	" "	< .023			
Q	" "	≤ .033			
R	" "	≤ 60			
S	Scale Dist	= Reg.			
T	" "	= Exp.			
U					
V					

(1) 0
(2) 13
(3) 15
(4) 26
(5) 60
(6) 120
(7) 230
(8) .300/cal. value

NOV 4 1957

B. Grad

INTEGRATED SYSTEMS PROJECT

Memorandum: Automatic Machine Control

Components can be permanently identified as they are processed by spotting a drill opposite the appropriate variety number: For example, Variety #4:

Variety No. 1 | 2 | 3 | 4 | 5 ----- n.

Obviously, binary notation could also be used. For demonstration purposes the identification numbers could be imprinted with a rubber stamp and fixture; later the mold could be changed.

TK.

T. F. Kavanagh

jw

NOV 4 1957

B. Grad

INTEGRATED SYSTEMS PROJECT

Memorandum: Automatic Machine Control

A display board--separate from the machine tool console--should be erected utilizing annunciator panels and Burrough's alpha-numeric neon tubes to continuously display the activities of the machine.

TK

T. F. Kavanagh

jw

File Memo

Subject: Use Of Condensed Card

Assuming that a basic punched card can be designed requiring something in the order of 500 bits of information to fully describe a particular motor in a product line. How can this be used to reduce the work required in an operating business? In the following paragraphs we will explore some of the various ways that this concept may be implemented.

First, a basic reduction in information content was made through the separation of fixed and variable characteristics. This was carried out by logically understanding that the individual part or assembly was essentially fixed in nature and that the variables would cover only 15 to 20% of the characteristics. Therefore, while previous General Electric drawing systems went toward the direction of identifying a part as a whole, ignoring the individual characteristics, this concept aims toward identifying the characteristics rather than the part itself. The reason this becomes less expensive in our present business is that the number of characteristics that are variable are usually quite limited and even many of those that are variable can be changed only in a binary sense and do not have a series of decimal, dimensional values. This possibility is available because of the basic standardization and growth of independent product lines - any one of which can justify its own drawings.

Therefore, the extrapolation of this concept is that the fixed data should be recorded once and once only, and recorded in such a manner as to be identified with the part itself, reducing to a minimum the information redundancy and resulting in certain direct savings. File maintenance would be substantially reduced through not having to change all the blueprints, parts lists, operation planning cards, quality control standards, records, and all the other documents which contain part of the fixed information. For instance, a single part may be called for on 20, 30, or even 100 parts lists. If that part were changed, each of parts list would have to be corrected. With this new concept, if the change involves some fixed characteristic, then the only change required would be to the one record which contained all the fixed information concerning the part; if the change were to a variable characteristic, then the generating equations would be adjusted.

Let's carry this idea a step further. The fixed information concerning a part is quite involved. First it has to do with the material from which the part is made; with the basic dimensions, hardness tests or certain quality characteristics; with the relative position of different characteristics, the depth of grooves, chamferring, direction of winding, and, angles; with the way in which a part is made, and with the kind of dies or machines used. The part number then has a special meaning since it is composed of a set of variable characteristics which may be motor oriented or oriented toward that particular part. Therefore, you must note the set of values which, taken as a whole, define the particular part under consideration. This part number, of course, is as directly usuable as any other part number. One problem arises however, in that some of the punched card columns may be used in a binary sense; this makes it very difficult for the average decimal type machine to handle it. Therefore, it becomes ideal for the binary or engineering style computer. A machine such as the IBM 701 or 704 which has 36 bits per word would work quite nicely in one of these applications. You could then have three columns represented by a single word since there is a maximum possibility of 12 bits per column.

As an illustration of the power of this type of application, we could store 500 bits, the entire variable model detail on a 39 frame motor in about 12 words in a 701 or 704. In order to handle 200 models then, we would require about 2400 words of memory. This is well within the memory size of present machines.

The principle on which we are operating is that of logical implication. Given a defined set of facts, a strong "cascade" effect occurs in that many operational characteristics can then be directly inferred. This rule may also apply in our office systems where the presence of one factor may imply the existence of other conditions.

In order to pick up the specific information necessary to operate under a semi-manual plan various interpretive decks would be required. Here the differences between a manual plant operation and automatic plant operation show up very clearly. If you have operators who must read the instructions, then you must print out for their use much of the fixed data as well as the variable information. For example, we would have an interpretive deck which would cover the machining of shafts. This would have on it the actual description of the operation such as cutoff, mill, grind, etc. It would also have in it the formula data needed to calculate the per unit time for a particular operation. It would also have space for entering the particular variable information such as the length to be cutoff or the length of the flat to be milled or the position of the pulley end groove, as well as the various control codes which would be used for selecting the proper product characteristics to be used in comparisons or selections. There would also need to be interpretive decks for material ordering, scheduling, loading, cost accounting, etc.

One way of accumulating quantitative data would be to run through the basic model deck and group out total quantities by various characteristic associations; for example, keep track of how many 4-pole, 1 1/2 inch stacks there were as well as 4-pole, 2 inch stacks, etc. These quantity accumulations could then be worked in with the interpretive decks to put the proper scheduled amount into the plant.

Incidently, there is nothing sacred about defining the part as a whole; it might be more desirable to have your coding arranged to define three types of shaft: one, straight through; two, with various shoulders; and the third, with some type of fitting at one end. There would certainly be nothing wrong with this approach which might even use the same columns for defining the variable characteristics of each type. In other words, there is no reason for defining all shafts under a single code or under a single column. It may be more useful to group them together.

In conclusion then, it is my expectation that if we examine all the information contained in the different records applying to the definition of a product and how it is made, we would find that close to 80% of that information was completely fixed across the entire product line, and that it was only the other 20% with which we need to deal; in addition, we would find that much of this 20% was repeated one place after the other, so that the total information redundancy was in the 95% range. This means that about 5% of the original information ought to fully define the product and we should therefore find means whereby shorter computational techniques are made available to us.

B. Grad

bjh

March 29, 1957

File Memo

Subject: Product Stability and Its Influence on Automation Potentiality

To design an automatic plant for a product which does not have guaranteed future stability is a very dangerous and possibly a very costly undertaking, since the risk factor becomes so high. This is one of the things that has probably held back automation in companies such as General Electric. While the oil industry and various chemical plants can foresee long, stable growth for many of their products, we in the discrete body manufacturing area have not had this kind of assurance. Even the automotive firms have had to take sizeable risks. Suppose for example that the Oldsmobile "Rocket" engine had not been a success or that the new Ford V8 engine had not clicked, then there would have been an extremely heavy investment in quite specialized tools which would have been almost a dead loss to the company. The loss could have come in one of two respects. First in having to sell tools at distress prices or second in making them stay in the field longer than needed; in other words, giving hardening of business arteries which prevents the flexibility to meet a changing or dynamic business situation.

Therefore, it seems to me that long-range product stability is critical to economical automation in General Electric. We cannot afford to automate a marginal product. This would be an especially dangerous thing to do under a reasonably strong competitive situation, because once you've sunk your money into the present design by building an automatic factory your competitors could afford to spend substantial sums in designing a new product advanced over your own and then automating their new design. You would then be in quite a bind in deciding whether to try and meet his new product or whether to try and live out the process life with your old product. This implies then that your product should be very much in advance of the field (product leadership) before you spend money to automate it, unless the competitive situation is such as to permit none of your competitors to indulge in as heavy automation as you can (market dominance).

The whole pattern of earnings in a business will also change with this type of automation planning. Instead of being on a relatively smooth consistent pattern as in the past, it now becomes similar to that of a military project. There is a heavy, steep, initial investment and then a high return over a relatively brief life, possibly some eight to ten years. At the end of the project life there is low salvageability of the equipment and we must start all over again with a new project.

There seems to be only one major hope which may stop this cyclical treadmill. This is the concept of flexibility: the use of standardized, interchangeable, automation components and controls. However to reach this goal, will require real deep work to build up the basic modules or building blocks and to design and evaluate the approach. This might involve having physically separate entities for machine base, stops, action heads, tools, fixtures, control circuits, memory devices, transfer machines, sorters, storage, etc. This may mean that we should carefully separate the product oriented portions of the equipment from the non-product oriented portions, so that these non-product oriented items could be used in multiple on various product lines. This would apply to conveyors, holding devices, motors, etc. To do this will require careful identification of the machine characteristics with which we are dealing. This would involve what we have called an Operations Structure Study.

This approach might well be the salvation for extensive automation in General Electric. I therefore would recommend most strongly that intensive work be initiated now by the Manufacturing Laboratory to try and define these basic machine characteristics and to explore the potentiality of standardization, interchangeability, and flexibility of automation components.

B. Grad

bjh

March 28, 1957

File Memo

Subject: Specifications For Manufacture

The concept of product structure analysis leads to an interesting semi-manual possibility; can we eliminate model lists, parts lists, blueprints and operation planning records and substitute 1 Specification Sheet for each part? In reality, what is the operator looking for? He wants to know what his operation is, the dimensions and tolerances to which he is to operate, the machine, tools, dies, and fixtures he is to use, the quantity he must produce and the price he will be paid per unit. Why not have 1 (or at most a very few) basic prints right at the station, showing only those portions of the part in which the operator is interested. A Specification Sheet then would convey a description of the operation, show the variable dimensions or characteristics, and include the quantity and price, as well as all the fixed data.

B. Grad

bjh

March 28, 1957

File Memo

Subject: Concept of Project Limitations

Any business with which we associate ourselves has a product or group of products whose characteristics has been designed to satisfy a particular set of customer needs. Each of these characteristics is generated or produced through the application of some process; but the basic development of a process itself is quite independent of the product use. For example, the development of the process of drilling may have come about through the fact that many parts needed holes; it was not through the product application that the process was developed but rather through a particular characteristic of the parts selected to be produced for which no available process was suitable or sufficiently inexpensive. This is somewhat of a cyclical experience since parts are designed around known processes.

Therefore, our logical approach is that we should stick with the basic product characteristics except where the processes which are now available for producing those characteristics are so difficult as to make automation expensive. It follows then that we should not try to develop new processes just for the sake of doing so, but only where the product characteristics cannot be readily changed and are such as to make current processes too difficult. This does not say anything against the long-range objective of basic investigation on new products or new processes, but merely that on a project of this type the emphasis must be on control and integration rather than on development of brand new techniques of manufacturing and brand new products for selling.

B. Grad

bjh

March 27, 1957

File Memo

Subject: Liquidation of Overhead

Our present practice which liquidates overhead based upon direct labor dollars leaves much to be desired. Other possible bases include direct material, machine hours, or pounds of output to accomplish this same distribution of overhead costs.

It seems to me that this practice can best be evaluated from two different aspects. First, all items which can, should be directly assigned to a particular machine, station, product and/or customer. This would considerably reduce the overhead problem, and give us more direct control and understanding of the exact cost of producing a particular product for a particular customer. In an automatic shop this concept has much to offer over the usual "standard cost" procedures, which are not standard at all, but only a convenient way by the accounting to save clerical effort.

The second aspect that should be considered is the selection of a proper base for those items which are not directly assignable. These would include management costs, certain accounting and clerical costs which are devoted to the entire business and not to a particular product line or customer, etc. One measure which has not been investigated too thoroughly in the past, but which has much to recommend it, is net sales billed. The billing price of an item is a measure of what customers are willing to pay for it. It is not dependent upon internal mistakes or errors but is a reasonably a true measure of the outside world's evaluation of our product. It is relatively stable and does not vary rapidly month to month as our business goes up or down. It would accurately measure the overhead in terms of the effect it has on profit since every percentage point of net sales billed devoted to overhead is that much less to be retained for future growth and stockholder dividends.

In testing out this approach, it might be possible to re-analyze many of our items of overhead in terms of their percent to net sales billed. This might give us a clearer picture of the benefits to be gained from such an approach.

B. Grad

bjh

March 27, 1957

File Memo

Subject: Scheduling Maintenance of Machine Tools

Mr. H. F. Dickie noted at an AMA Conference in March, 1957, that both Monsanto Chemical and Quaker Oats mentioned that they had separate schedulers whose job it was to schedule maintenance work. These men are of a similar skill and on a similar basis as those who schedule the physical operations. This sounds like a worthwhile concept since in an automatic factory the scheduling of maintenance becomes a more highly variable item then the scheduling of the automatic shop itself. There are two different types of scheduling involved here: one is the short-range rapid fire dispatching concept, the other the longer range planning basis. Both are valid problems and should be incorporated in any future plans.

B. Grad

bjh

March 28, 1957

Memo to File

RECEIVING

Probably the whole concept of receiving should evolve around the idea of multi-door delivery. This would imply that each item would be marked so that it could be delivered directly to the area where it is to be used. This would automatically separate tools from direct materials, steel from copper, hardware from bar stock, cafeteria from oil products.

Mr. E. C. Throndsen suggests having the basic paperwork attached by the vendor to the material to permit automated internal processing. Mr. Federspiel, Purchasing Agent at Appliance Motor Department, is apparently working with certain vendors toward this objective. Why should there be any receiving reference material at all? Isn't the packing slip good enough if we code in the proper amount of identification information. We could check this ~~tool~~ door number ~~of~~ to purchase order number or attach it to the item identification group.

Why should we bother to verify either the count or quality at receiving? Couldn't an effective vendor audit program be setup which would guarantee, to an adequate degree, the proper performance to these standards.

9/10/56
B. Grad

Concept for Information Transference

It should be possible to go directly from customer specifications to the direction of plant operations. For example, the customer's specifications of a certain horsepower and a certain length would clearly designate the number of turns of what size wire were needed. Therefore, rather than go through the multistep process of parts explosion and operations planning, should we not be able to take the specification and directly translate it into a winding order.

This concept might even be further evolved so that purchased parts and materials would be called for as subsidiary to the support of a particular manufacturing or assembly operation. In effect, we would then decentralize wholly the ordering and inventory control function.

B. Grad
10/16/56

Subject: Automation of Operation Planning

Memo to File

In order to be able to complete the entire cycle from customer's specification to direct control of machine operations, it will be necessary to translate part attributes and product attributes into actual directions for machine operations. One of the best ways I can think of to improve the validity of this concept is to show the logic of its being performed on the present machines with the present operations.

There are a limited number of such operations which have been listed in the planning studies being made for their punched card work. These one to two hundred operations can each be coded or defined. It is then only necessary to indicate which particular parts or product attributes are imparted by the machine operations. It should also be necessary to note what special operation instructions are required, such as, what special setup is needed, what fixtures, dies or tools are required. Where there are other special characteristics, such as, setting up a number of terms, things like this should be noted. In effect, we are to show the correspondence between a machine operation and the parts attributes which it produces.

B. Grad
11/16/56

Subject: <u>Forms Analysis</u>

Memo to File

Each field on a form by its very name specifies normally one of three things: either directions for obtaining the data, the actual information contained in the field, or directions for using the data. In our plans for naming the fields, it is implicit that we must aim toward the second of these characteristics. In other words, even though the field may say "mail to" or "send to", this is not adequate. The information that appears in the field is, for example, name of employee or name of customer, or customer address. Similarly, if the information in the field is credit or debit, the thing we are interested in is that it is an outgoing transportation account number not how it is to be used.

We are, therefore, agreed on a certain number of standard names or classifications of the kinds of information that appear in each field, and it has been necessary to assign adjectives and prepositional phrases to describe the information which appears in the field, as in the example given before; outgoing transportation account number clearly designates what the information contained in that space is. The degree of generalization that this name will have to have varies considerably. You may, for example, have name of employee. Even more general than that may be name of person. More specific would be name of foreman or name of tool room foreman.

We must come to a general rule such that when two fields of information have exactly the same name, then if they are both recording events related to the same customer's order or to the same transactions, then the number which appears in that field would be identical. Referring to Li^berman's article in Institute of Management Science Magazine, then we would have a true redundancy only if the names of the fields are so clearly designated that we will have no obvious misinterpretation of what is going to appear in that field. This implies, however, that date, for example, is not adequate. Date that such and such a document was written more clearly specifies exactly what is in the field and avoids the problem of redundancy.

B. Grad
R. Sisson
10/5/56

Subject: Decision-Making

Memo to File

Operations which are currently considered to be decision-making conform to any one of three classes: the first of these classes is where judgment or intuition is truly used, in other words, there is no specific set of operations which will transform the input factors into the output decisions. In certain of these cases the input factors are either not well known, are not clearly established, or so complex that no mathematical transformation has ever been devised. In these cases it would be necessary for us merely to list what the input factors are, if possible, in order of importance; to list also what the different outcomes are and, if possible, in words to indicate what some of the conditions or boundaries might be for taking certain of these output paths.

The second level of decision-making is where, by astute questioning, we can determine what all the input factors are, as well as all the outcome decisions. We would then construct a "truth" table. We would list the factors across say the horizontal and the various outcomes on the vertical. Then, for a given value or a group of values or within certain boundaries of each of the various factors, we could say that if the length, for example, were three and the grove-to-grove distance were four and the direction of rotation were two, then output number one should be followed. Then, for any given other set of values of those same items, a certain different outcome might be followed. This type of approach is perfectly adaptable to computer processing.

Third level decision-making is where a thing that is spoken of as judgment today is really no more than a formula, possibly not well defined, but still a formula which can be used. We would then be able to translate the decision making box into one which had possibly computing and compare and branching involved. In effect, we are saying that a compare and branch operation is the simplest type of decision making and one which is readily adaptable to machine use.

B. Grad
11/29/56

Subject: Functions Outside of Operating Department

Contact: E. F. Waldschmidt

Memo to File

Mr. Waldschmidt suggested in our discussion that there were certain areas which were really part of an over-all business system but which we were at the moment not planning to pick up. For example, he noted that Apparatus Sales was the hired agent for selling the products from Specialty Component Motor. This includes the actual getting of the orders plus all the credit and collection. He suggested that these areas certainly should not be ignored and that arrangements should be made to coordinate Apparatus Sales studies with our own.

Another area was the International General Electric Company which sells some few 39-Frame Motors overseas. It was decided that this area would be checked to see the magnitude of the work and, if it was great enough, some coordination of plans should be made with IGE.

A third area is Treasury Services. This includes the commercial banking activities, certain work on employee benefits, bonds, etc. Here again, it was felt that, since certain paperwork was required from the department by Treasury Services and in turn they supply certain paperwork to the department, that a coordinated study with them should prove desirable and beneficial. It would seem possible that such a study could be arranged if approached in the proper way.

B. Grad
11/28/56

Subject: Operations Structure

Memo to File

It seems, on re-analysis of our operations planning study, that an entire area has been overlooked; this is that which we have chosen to call Operation Structure. It relates to what the basic parameters are of the various operations in the shop and the manner in which these parameters are varied so as to produce the specific characteristics in the part being manufactured. For instance, speeds, feeds, various setups and control settings, tooling, dies, etc. For each of the particular operations used in the present factory, it should be possible to specify what these elements are, how they are interrelated, and what is the cost and time of changing these characteristics. Mr. Staley is to make an original pass at this study to see whether there is anything to be gained from an intensive evaluation of this area. This Operation Structure study should become an integral part of our total plan for automating the entire design to operation control calculation.

B. Grad
12/17/56

Subject: Customer Specification

Memo to File

It seems to me that the customer specification might better be written in terms of the application in which it is used; in other words, what the customer wants rather than in terms of the motor required. This, in effect, lets him specify the motor needs in terms of the device that he wants driven. It should be possible here to design some sort of standard form where, by filling in information, such as the speed, torque characteristics, resistance, and things like this, it might be possible to completely specify the basic motor requirements. This would also pick up quite readily the information concerning mounting and ventilation.

B. Grad
12/17/56

Subject: Departmental Cash Control

Memo to File

One of the weaknesses of a centralized company treasury organization is that each department loses a feel for its actual cash position. Each department always seems to feel that there is an inexhaustable wealth from which funds can be drawn. There ought to be some way whereby the individual department manager can feel quite strongly and clearly that he is running out of money.

There are a number of possibilities here: the first is that we should probably keep a complete cash balance record for each department and that whenever they went beyond this there was a necessity of:

1. Paying interest on the money borrowed.
2. Negotiating whenever they went beyond a certain stipulated credit line.

This would prevent, I believe, the build up of inventories without justification and the improper use of funds so that the Company was forced into short cash positions at inopportune times.

B. Grad
12/17/56

Subject: Factory Control and Feedback

Memo to File

Scope:

1. The objectives are usually externally applied as are the boundary conditions under which we operate.

2. The first step within the process is the analysis of these objectives in terms of the process capability. This implies a check for the feasibility of the objectives. Can they be met by the process which is to be controlled? This often also includes an outline of alternative courses of action which might accomplish the objectives proposed.

3. The next step is to choose a single (optimal) course of action which has the greatest opportunity of achieving the objectives. There is an implication here that the objectives have previously been checked out and are feasible; otherwise, the objectives have been changed to become more amenable to the process capabilities. This third step often involves a translation process where the externally applied measures are now translated into internal operating rules or procedures. It also implies that the external measures of performance are translated into internal measures which clearly reflect the inherent variability of the process and the response to deviation inherent in the process.

4. The controller then causes the process to act, in effect, pushing the start button. This also activates the response mechanism which will measure the performance of the process.

5. There is then the feedback loop where the information is returned on the performance measures of the process. These measures may be of two different basic types, either an absolute measure which gives the accurate value of some measured parameter or it may be deviation from a standard which tells you how far it has been deviated. Occasionally, these information measures can be short circuited so as to present a "go-no go" answer rather than the details of what are the deviations.

This whole phase of factory control and feedback is characterized by its relatively short-range nature. However, it operates within quite long-range objectives.

One way of looking at the dispatching function under an automated program may be to consider it solely as a control function; one which defines the specific kind of work to be done. This is actually closer to what dispatching has become or seems to have become in the present operation. Dispatching as we know it, is not really performed here in the sense of specific selection of jobs. Production schedules seem to do this pretty well or preplanned programs seem to do this. This does not imply that there will not be a dispatcher or dispatching computer in the new process, but rather that this dispatcher or dispatching computer will make certain control decisions, and as a result of these decisions, will not impart them to a human being, or to a person who will retranslate these into actual operating terms, but rather that the dispatching computer will itself translate these instructions into operating terms so that the machines will be caused to act in line with these instructions. This also implies that the dispatching computer will be directly connected to the feedback mechanisms from the machines themselves so that the dispatcher will be able to finally erase the old bugaboo of not knowing what is actually going on and what the actual progress has been compared to the plan which the dispatcher has made as to the instructions which the dispatcher has issued.

To control a process, which we might call a transformation, there is required for us to have knowledge of both the input and output sets. On the input side there are two basic types of input sets: those inputs which are consumed in the act of completing the job, and those which are not consumed.

Let's discuss first the consumed input set:

1. The actual materials, both direct and nondirect, which are used up. The nondirect, then would be considered the nondurable tools and nondurable items. This might also include paints, varnishes and various types of allocated materials.

2. The parts, themselves, are consumed in making of an assembly; this includes both purchased and manufactured items. In effect, the sub-assemblies are also consumed in the making of the final product.

3. The actual manpower is consumed in the sense that their time on the job has been used up. Manpower can be consumed in one of two manners: either through direct productivity or through nonproductive work, which would include absenteeism, spoilage rework, etc.

4. Tools, dies and fixtures are consumed to an extent; they don't last forever; a die is used up after so many runs.

5. All of the information which is date oriented is used up in the process, in other words, after the process is complete or after the process has been going on for some period of time, all that information which had been related to the starting date or finish date or status as of a certain date, is no longer valid; it does not accurately reflect the picture anymore.

In contrast to the consumed input set, we have those which are not consumed; these are:

1. Plant facilities, including buildings, utility carriers, storage space; in other words, the general environment of the operation.

2. The actual making equipment itself.

3. The various physical handling devices.

4. The communications links.

5. That information of relatively fixed nature, such as long-range schedules, forecasts, etc.

6. All structural files, including routing sheets, time standards, tooling, employee classifications, machine locations, operations sequence, and descriptions of the processes applied to these specific machines. This would also include items such as: basic parts lists, specification sheets, blueprints, drawings, and all those other items which, in total, make up the pattern into which the variable data is fitted.

Next, let's take a look at the output set:

1. This includes manufactured parts in the sense that they are output from a previous process.

2. Finished products are another output.

3. There are also certain unwanted items as outputs; for example, scrap, rework, salvage, plus waste material.

The connection between this input and output set is a process which is defined in the economic sense as adding time, place, or form utility to an object. There are a number of these particular processes:

1. There is the null process in which no useful work is performed.

2. There is a physical transformation process which makes some physical change in the input set.

3. There is a data transformation process which makes some change in the informational content or their relationships from the input set.

4. There is an inspection, test, check or verify transformation which is somewhat difficult to define. In reality, all that is added is an assurance of reliability. It establishes the probability of meeting a set of criteria or it establishes the existence of certain characteristics which increase the value of the part or product. Whenever an inspection, check or verify operation is performed, there is an implication of noncertainty in that characteristic which is being checked for. To the extent that a process can guarantee certainty, we should be able to eliminate substantially the need for any of these inspection type operations.

5. There may be a fourth type of transformation called an orientation, which is a movement within a process of any item in the input set. This may be linked with our data process in which we speak of changing relationships.

Every process is also characterized by a control mechanism. This has a certain number of parameters which can be measured, including:

1. Response rate.

2. Damping characteristics.

3. Parameters being controlled.

4. Where in the process these control operations appear.

5. The communication links between the control mechanism and the process itself.

6. The information content that is transmitted by the controls or implied by the controls.

7. The points of information input as contrasted to the points of physical control.

8. Some measure as to the available alternative courses of action.

9. A detailing of the rules for analysis.

Feedback is another characteristic of every process, if it is not to be of an open loop nature. The parameters of feedback are:

1. The frequency.

2. The form of the information flow.

3. The communications links between the machine and the feedback digestion mechanism.

4. Where in the process these feedback loops occur.

5. What are the standards or measures of deviation which are used.

6. The response speed of the loop.

B. Grad
A. J. Rowe
12/3/56

IDEAS ON COST

Materials	direct indirect	
Machine life	E	Product
Manpower	direct - O nondirect - E	Present direct 2/5 < 1/2 cost

Input - meter materials

Output - control, feedback loop

time { men, machines }

quantity, quality

Cost is not a basic measure but rather a reflection of some other measure evaluated on a dollar scale.

Communications

The communications activity involves all those verbal or written transfers of information external to a specific activity of the business. Since each communications channel implies two terminals (a sending and a receiving point), trying to classify communications leads to a breakdown somewhat as follows:

1. One terminal external to the business, such as a vendor, carrier, customer, etc.
2. The two terminals are each in a different function of the business. For example, one in Engineering and one in Manufacturing.
3. Where both terminals are in a different activity but within the same general function, such as scheduling and dispatching.

In describing a communications system independent of the particular method and media for communicating, it is necessary primarily to define the records or fields of information which are being transferred. To compare ~~a~~ one particular communications system with another, it is also necessary to obtain a measure of the response speed and cost of the communications process.

To gain a full picture of the "band-width" of a particular communications channel, it is necessary to define the volume of records flowing in each direction.

To gain the appreciation of the accuracy of the information transferred and the effort required to use ~~or designate~~ the information received, it is necessary to define what communications processes are used in various instances such as mail, telephone, teletype etc.

B. Grad
10/16/56

File Memo

Meeting December 20, 1956, With Mr. P. M. Deal and R. R. Hofmann

Subject: Auditing

After a review of the Audit manual, it was agreed that there was no need to have a specific study devoted to the auditing procedures; but rather, the whole team should review this manual in some detail about May or June prior to the planning of the new system. In addition, it was agreed that traveling auditors might be able to identify the areas where the system would permit clerical errors, systems errors, or most significant, errors of intent or fraud.

Also during the meeting, there was a discussion concerning the participation of Accounting Operations and Treasury Services in the Project and whether it might not be useful to have them do a review of their related functions similar to the approach taken by Apparatus Sales. This would have the advantage that if any new ideas came out of the combined study, they would be able, as a Services function, to have a wedge to swing other departments over to these new ideas. One of the finest ways, it seems to me, to promote General Electric automation is by improving our Services and Company-wide operations since these affect all the departments. A fine example of this, of course, is our Warehouse Program; where, by improving the way in which Apparatus Sales handles Warehouse requisitions, eight or nine or ten departments who might not otherwise have been interested in punched card equipment are now using it for their internal warehouse and stock control procedures.

In addition, a discussion was held concerning the charting techniques, in effort to demonstrate their logic and to identify the magnitude. Another point of discussion was the size of the data processing package. It was agreed that we could not at this time tell whether the 39 Frame business alone would be large enough to justify a really automatic office system; but that, the only way we felt that this could be told for sure was by an actual design plan for the system. Thereby, we can identify if we are in the right ball park or not.

B. Grad

February 5, 1957

File Memo

Subject: Factory Automation

To design a fully flexible, fully automatic factory, implies to me the addition of one significant concept to our present bag of tricks. This is the idea of fixed or zero setup. For example, the only thing in our economical order quantity formulas which requires the use of a lot size larger than one is the setup time; this includes both machine setup and paper work setup. Therefore, if these setups could be eliminated, or if the setup took the same time regardless of which part followed which in either the office or factory, then economic lot size would be whatever you wish to make if for external reasons and not for internal systems reasons. This seems like a very important point to me: in the past we have of necessity forced a batch size because of internal systems requirements. With this new concept, the batch size would be decided by the customer or by external needs such as transportation rather than by our internal systems requirements.

Now there is obviously one major thing to be concerned with in this approach, and that is cost. It is quite conceivable that to obtain such flexibility with such a low fixed setup that the equipment cost might become prohibitive. Nevertheless, using programmed equipment it might be possible to develop the concept of moving the piece or machine to a certain tape-designated position each time rather than controlling by a fixed, preset cam or stop. This idea seems to have substantial merit. However, it does introduce many difficulties such as in the winding machines where it would require that the machine would be able to self-thread and pick whichever reel of wire it wanted each time rather than keeping the one reel engaged until a new size was required. It's quite possible there may be a compromize to this concept, where on certain machines we would retain the setup time but reduce it to a fairly low minimum while others would be fully programmed. You might design this on the basis of the needs of the systems. For example, in the preparation of punchings there is certainly less need at the present time for flexibility in setup; whereas, on the shaft and winding this need for setup change is quite high and there might be a substantial payoff in being to eliminate or reduce the setup time.

This same concept holds true for the office. It seems quite conceivable to me that we must make programs available to the machine such that can be changed one program to another very rapidly; if an explosion routine is to follow a stock control routine and then to be succeeded by a purchasing routine the transition time should be very small or even non-existant.

B. Grad

February 5, 1957

File Memo

Subject: Description of Files

1. A reference file is defined as one which provides data which is to be used in a process.

2. An historical file is a collection of event records.

B. Grad

February 20, 1957

bjh

File Memo

~~Subject: Applications Engineering For 39 Frame Motors~~

An idea came up in a discussion the other day with Messrs. Canning, Bouton, and Oldenkamp. One of the prime difficulties today in a more efficient calculation of the motor design is the lack of effective data concerning how his motor will actually work in the customer's operation. These difficulties are primarily not dimensional, but rather torque, heat, vibration, and noise. To try and compensate for this difficulty, we have an extensive sample building program whereby, when a customer requests a new motor from us, we normally build one or more samples and actually take them out to the customer's plant and run it in his application to observe these operating results. This seems to be a wasteful process and one that must cost the department a substantial amount of money since building samples is a special and individually handled process.

In an effort to obviate the need for this special sample building, and in order to speed up the process which may on occassion cost us orders, it was suggested that a standard motor be built, possibly with a variable base distance and with certain external variable controls which will permit the motor to act in a number of different ways. For example, there could be an external reactor which would permit a variance in the amount of ampere-turns being applied to the turning of the motor. There should certainly be the potential of using different voltages externally through a simple switching device. The heat problem could be analyzed by taking temperature readings off the motor and/or by measuring the flow of air caused by the fan over the motor in the application itself. It's possible that some fairly simple flow device (such as a pitot tube) might be directly attached to the motor to record the air flow as well as the temperature of the air. The noise frequency might be measured through varying the second and third harmonic of the field by varying the speed and/or the frequency of the motor. To simulate the performance of a smaller motor, it might be possible to have heating elements built right in the shell of the motor itself, to simulate different heating conditions. Another possibility is the testing of the motor as closed or open which would merely require that we have some inserts or blocks that could fit into the holes in a normally open motor. This insert might be in the nature of a second shell and/or end shield which was an exact match for the first - sort of a negative image.

It seems to me that this concept, properly thought through, might well provide a design tool which would enable the applications engineer right at the the first contact visit or very shortly thereafter, to make running tests to show the customer specifically what the needs were, to see clearly what our performance requirements would be, and to enable us to design an optimal motor - not one that was heavily over-designed for the particular application.

B. Grad

bjh

File Memo

Subject: Customers' Specifications

Completely independent from the Product Structure work, it seems quite possible to use that, through the analysis made by Mr. Bouton and Mr. Canning, there may be additional customer variables which have not been included in the past or included only intuitively which could be related on a computational basis to the eventual parts characteristics, and might enable us to produce a motor either more efficient or less expensive than by the present engineering calculations. There is also great likelihood that the computational processes might be varied to provide for a closer approximation to an ideal motor for a particular application. This potential might result in substantial savings if motors are significantly over-designed today. However, this would take substantial work, so Mr. Bouton's report should give us some indication as the amount of time that will be required and some concept as to the savings which might be realized.

B. Grad

bjh

March 5, 1957

Memo to File

~~THE~~ MY BEST CONCEPT ~~FOR~~ OF THE TOTAL IMPACT OF PLANT AUTOMATION

It would be my estimate that in the next 20 years automation will have the following results:

1. Barring inflation, the direct labor content of our current products would decrease to approximately 15 per cent of ~~their~~ its present value, an 85 per cent drop.

2. The office functions would be reduced so that 95 per cent of the present non-exempt employees would be eliminated.

These estimates are ~~particularly~~ predicated on certain existing trends of our present progress in the factory, which has dealt in the past almost exclusively with automatic materials handling ~~manufacture~~ rather than the actual performance of the physical operations. Strictly end-tool process today. Increase in electronics business. Increase in consumers' products. Increase in components. Decrease in defense and apparatus percent-wise. Quadrupling of copper. Larger volume of individual products.

9/10/56
B. Grad

Inventory Plng

D.C. Miller

New York - November 12, 1956

Mr. J. A. Zegers
Bldg. M-2, Room 7
SCHENECTADY

In accordance with our telephone conversation, I have listed below some of the ideas which we feel will be fruitful in developing a more effective surplus and obsolete inventory control plan.

There are two basic decision points in the inventory control problem where cost information is needed relative to keeping inventories. The first of these is prior to the investment, prior to the actual purchase of the item. The second is after the item is already bought and the planned application has failed to materialize or the item has been used in a non-destructive test. In the first case, the largest two items to be considered are: the potential return investment from alternate application of the funds and the potentiality of obsolescence. In addition you should consider the possession cost and any general business trends which might effect the future cost of the item. Attached is a writeup called "Keep Your Inventory Carrying Cost Down", which describes in detail how to calculate these various costs.

We have often found that the total cost of carrying inventory is around the 40 per cent mark or higher in a volatile business such as your own. This is the price you would pay for buying more than you need of an item.

However, let's look at the other side; suppose there is an item already in inventory that is left over and not used. What do you do about it? First, you have to remember not to use the regular inventory carrying cost, since you cannot realize the original value of the item but only the resale or scrap value (possibly 5 to 10 per cent of original price). Furthermore, obsolescence as a concept no longer applies when an item has already become obsolete. Therefore, what do we have left? Possession costs are still with us and return on investment of resale value has to be considered. Also deterioration may be a continuing feature in that protection for storage may be required or accuracy adjustments may be needed.

On the other side of the scale from these items is the chance that you will put this part to use. Not having any better name for it, I have called it "disobsolescence". This implies that an item which was once considered obsolete or unusable has found an application. To measure the value of the disobsolescence, it is necessary first to gauge what it would cost for a new item of the same category bought at the time needed. In the sense that the money would not be spent until some time in the future, we must discount the cost at possibly 6 per cent per year and, in effect, say that the item, instead of costing $100 2 years from now, would be worth only $88 today. It is also a fairly well known fact that as time progresses the odds in favor of finding an application for a part decreases at an accelerating rate. Hence, it should be possible to study, for each class of goods, your historical experience in terms of the frequency of reapplication of obsolete material and, by using this percentage multiplied by the discounted value year by year into the future, set an anticipated gain figure. Comparing this with the cost of carrying inventory which would probably be in the order of 10 per cent per year, you should come to a point at which it is more economic to throw the part away then to retain it in anticipation of future use. This might be 3-5 years from today.

Certain other techniques seem applicable in your type of business. The use of formal reports specifying how long various segments of inventory have been on hand, as well as the age of material being applied or scrapped, should prove quite forceful. Applying the ABC principle to obsolete inventory review is also beneficial. For example, you might decide that any item under $25 should be discarded without review. Any item between $25 and $100 should require only an engineer's signature or your own. For a part in excess of $100, it might be necessary to obtain the signature of the section manager. Clear records should be kept on the causes for obsolescence. In addition, it might be advisable to have a clearly defined policy which states that a "clear-out" date will be established for each item and that once that "clear-out" date is set, the material will be disposed of at that time without further review.

If we can be of any further assistance to you in this program, please feel free to call on us.

Very truly yours,

Burton Grad, Specialist
Mfg. Control Systems Development
Materials Service Department

BG:km
Enclosure

1635 Broadway
Fort Wayne, Indiana
April 11, 1957

Mr. H. Wolte
Purchasing Services
Room 2501
570 Lexington Avenue
New York Office

In our recent conversation I indicated my continuing interest in the establishment of company-wide standards for information transmission. While the Financial function has done quite well in setting up instructions governing the preparation and format of accounting reports, we in Manufacturing have not yet been able to do the same.

A case in point is the internal or CP requisition. Before decentralization there was one CP form used throughout all of the Apparatus departments. With the change in job assignments which resulted from reorganization, Purchasing and Production Control were, of course, combined under the Materials banner, and it was an obvious next step to have Purchasing prepare all orders for material, both external and internal. Therefore each purchasing agent used his own purchase order form to cover these CP orders.

From a decentralized viewpoint, it is easy enough to justify each department's independent choice of forms; nevertheless, it is also evident that our volume of internal orders deserves special consideration and probably some high degree of standardization. Furthermore, in the interests of advancing our data processing integration there is much to be said for a single company-wide standard purchasing form to be used for all purchase orders.

The impetus and justification for this approach could very well be obtained from the Apparatus Sales Division's attack on first, warehouse invoicing and now, on all district order requisition preparation. Though twenty-five or more departments are involved in the handling of these customer requisitions, it has nevertheless been found possible to standardize on a single form which all departments are then able to use. This has made possible by the use of punched card and even computer equipment in the digestion and handling of the information transmitted. It is my impression that the requisition form follows very closely the warehouse invoice form. With this in mind and since a requisition is merely a means of transmitting the information required by the customer to his vendor, which is one of our own departments, would it not be possible to design our purchase order form in a similar manner so that we might transmit our information to our vendors more effectively and efficiently. This could lead very directly and simply toward unified procedures in the preparation of purchase orders using punched paper tapes, and/or punched cards or directly from computing equipment where possible. This is obviously a question which only you will be able to answer after study of the situation, but certainly Mr. Baldwin's group in Schenectady would be most cooperative in jointly exploring any of these problems.

One point of further note is that as our Company plans for automation progress, it will become more and more necessary that internal transmissions, at least, are fully standardized and patterned. Without this, the work of translation and interpretation of different records and different reports and different forms will become so large as to invalidate much of the gain from electronic data processing machines. If our Automation Study Project can be of any use in the further investigation of a standardized purchase order either for internal or external use, we should be most pleased to participate or even serve as a guinea pig if required.

Burton Grad
Mfg. Control Systems Development

BG:y

Added Note: In order to get started and to eliminate one of the worst present problems, the Internal Purchase Order Number might be standardized. Ralph DeRubbo's survey certainly indicates the extent of variation which implies the difficulty of mechanization. The biggest single step would be to make the number generally non-significant, and to make it serve as an identifier only. The additional information that the department wishes to insert on the order to show delivery location, etc., might better be placed in the "Notes" or "Marks" area of the form. This approach would be a good wedge to get a full scale standardization program started.

B. Grad

Intra Department Orders

Fort Wayne, Indiana
April 2, 1957

Mr. H. J. Wolte
Material Services Dept.
Purchasing
New York Office

Dear Hank,

We didn't get an opportunity to discuss this problem when you were here last week, so I am forwarding the results of the sampling, which you will find attached. This confirms our discussion concerning this interdepartment problem and certainly points toward a logical services task, as we mutually anticipated. Mr. Grad has expressed some interest on this subject with relation to the automation project and will discuss it with you sometime this week.

Enclosures:

A. Results of survey
B. Analysis of survey
C. Orginal letter sent to selected individuals
D. Replies received

Best regards,

R. H. DeRubbo
Specialist, Manufacturing Control

RHD:b
Attach.

Subject - Intra Department Orders
Sent letters to this list

			Alpha	Numeric	Dash	Total
1.	F. L. Buckland	Peterborough, Canada	0	18	4	22
2.	W. H. Bobear	Johnson City, N. Y.	4	8	1	13
3.	David Blair	Erie, Penn.	0	10	2	12
4.	James Baird, Jr.	Schenectady, N. Y.	3	18	6	27
5.	K. W. Ashman	Baltimore, Maryland	1	9	2	12
6.	N. F. Barbeau	West Lynn, Mass.	2	9	2	13
7.	W. E. Brown	Evendale, Ohio	2	10	4	16
8.	W. T. Carr	Rome, Georgia	3	11	2	16
9.	R. J. English	Somersworth, N. H.	1	10	3	14
10.	J. C. Farmer, Jr.	Lynn, Mass.	1	12	2	15
11.	S. J. Garahan	Schenectady, N. Y.	3	18	6	27
12.	R. L. Getis	Bloomfield, N. J.	2	9	2	13
13.	C. F. Hauser	Lowell, Mass.	2	11	3	16
14.	C. F. Koenig	Louisville, Ky.	2	12	3	17
15.	R. T. Lens	Morrison, Ill.	1	8	1	10
16.	F. Weisman	Milwaukee, Wis.	2	6	1	9
17.	F. L. Gale	Fort Wayne, Ind.	2	8	1	11

Analysis of Survey

1. Total Alpha, Numeric and Dashes range from 9 to 27 as follows:

0 - 10	1
10 - 15	8
15 - 20	5
20 - over	3

2. Alpha ranges from 0 to 4 as follows:

0 - 0	2
0 - 1	4
2s	7
3s	3
4s	1

3. Numerical ranges from 6 to 18 as follows:

0 - 5	0
5 - 10	7
10 - 15	7
15 - 20	3

4. Dashes ranges from 1 to 6 as follows:

1s	4
2s	6
3s	3
4s	2
5s	1
6s	1

Supplement #13 August 9, 1957

THE SIGNIFICANCE OF BUFFER STOCKS

Burton Grad
Specialist--Manufacturing Control Systems Development
Production Control Service

Buffer stocks have long been relegated to a secondary position in the analysis and management of inventories. Economic Order Quantities, ABC Analyses, Mechanized Stock Control and other approaches have successfully stolen the limelight. Part of this has been the result of a poor "press" since few have found it a glamorous enough subject to write about; but, more important, there has been a lack of basic communication ability since "buffer stock" apparently means something different to each person. It's called cushion stock, process stock, safety, backup, in-line, excess, protective, balancing, leveling, reserve, and so on. The use of these different words is really the clue to buffer stock's lack of appeal.

There are four major, different objectives that buffer or reserve stocks can serve whether we deal with raw material, in-process components or finished goods:

1) to prevent stock shortages caused by usage variation or lead time change

2) to permit use of economical lot sizes

3) to provide a variable cushion between two processes so that they may operate at different or variable rates or may have independent lot sizes

4) to permit more rapid response to changing product demand.

With this topic organization, buffer stock can now be subdivided, analyzed and new control techniques devised. In the balance of this paper then, there will be an operating definition given for each of these classes and an effort made to describe the manner in which an analytical solution can be reached for your particular problems. This is intended to be a survey of present knowledge and as such will require further reading or reference for detailed applications.

Insurance Stocks

The first objective, that of preventing stock shortages, has been much discussed in other papers; nevertheless it seems worthwhile reviewing some of the pertinent conclusions.

The size of the stock needed generally varies with the square root of both the rate of usage and the lead time. This problem has not been well studied yet in terms of stability of these two factors, but it is evident that, regardless of the magnitude, the buffer stock should also vary with the degree of uncertainty in the prediction of these elements. These factors can be analyzed so that the various materials and parts might be classified into:

- highly variable usage or lead time
- moderately variable usage or lead time
- minimal variation in usage and lead time

The results of this objective show up in the reorder point or frequency of order review. The measure of efficiency is the probability of being out of stock on one reorder cycle multiplied by the number of orders placed per year. This yields a stock-out per year ratio. It is therefore possible to select any desired degree of confidence and adjust the "safety" stock to compensate. This measurement shows the strong dependence that these stock levels have on frequency of reorder. With large order quantities, the frequency of being subjected to the likelihood of a stock-out is correspondingly reduced. Therefore, as a general rule the reorder point stock for C items should be proportionately smaller than for A items.

One item frequently overlooked is that there is a reasonable likelihood of obsolescence in holding high reserve stocks. This is dependent on the accuracy of future forecasts and ability to be forewarned of design changes.

Another potential source of "stockouts" is quality failure. To guard against needing 100 of a certain assembly and only having 95 in satisfactory condition, it is sometimes customary to start more of the assembly than is actually desired. This extra quantity is normally determined by examining historical experience and calculating the average failure rate for that class of parts. A technically sounder procedure would be as follows: Record the actual probabilities of having 1, 2, 3, etc. failures; approximate the cost involved in rectifying the shortage using overtime expense, added setup, longer inventory cycle, short-lot premium (if purchased), or whatever figure gives the lowest cost; next, compare the product of the "make good" cost and the frequency of spoiling 1 part with the cost of "running" 1 additional part times the frequency that the 1 part will not be needed (the probability of 0 failures). By performing this same computation for each possible number of failures the optimal protection level can be uniquely determined. It can be concluded that this type of buffer could be called "Insurance Stock" and is designed to achieve an implicit balance between inventory carrying cost and the cost of being out of stock considering the probability of each eventuality occurring. It is an insurance policy protecting against an out-of-stock condition.

Utilization Stocks

The second objective, the use of buffer stocks to permit the use of economical lot sizes, is normally not recognized as a true buffer stock problem. Rather it is treated as an independent computation related only to Inventory Carrying Costs versus paperwork, setup, and quantity discounts. But this is not the whole story. As mentioned under Insurance Stocks there is a strong correlation between frequency of order and size of buffer stock. It is also true that inventory tied up in large lots can be justified in terms of increased process utilization. Naturally, there is a reverse connotation: if completely flexible plants existed in which the order preparation and setup costs approximated zero (or were fixed regardless of product sequence or lot size) the economic lot size as presently computed would also reduce to zero. This would imply that the lot size could then be determined by external factors--stock availability, customer needs, transportation requirements, etc.

Therefore, it can be concluded that we are carrying "Utilization Stocks" to make up for our own or our vendors' lack of flexibility. We should carefully measure the price we are paying for our batch operation concept and make reasonable efforts to bring our preparation costs to a minimum.

Cushion Stocks

The third objective is to provide a variable cushion or "fluid clutch" between two processes so that they may operate at different or variable rates or may have independent lot sizes. This serves to "disengage" two successive operations, be they both shop processes, raw material and initial machining, or assembly and shipment.

This shows up just as strongly in the job shop as in the flow shop though in the job shop it is usually charged to transportation, waiting, or delay time. It seems appropriate that we examine this "cushion" stock in some detail to see how it functions, why it is needed and in what way it can be optimally determined.

Essentially, there are two major types of cushion stock: selective and in-sequence. The first is seen in virtually all job shops where, in effect, the parts are sorted or segregated by shop order and drawing number so that the next operation or process has full flexibility in selecting any one of the available jobs. The in-sequence buffer is usually observed where the parts or shop orders are locked in sequence on a conveyor line. The succeeding process may have flexibility in determining when it starts on the next part, but it must take the next one in-line; it cannot select what job it is to work on. There are, of course, all gradations and variations between these two extremes: side tracks, fixed dispatch rules, "kitties", etc. But we think of a cushion stock as providing some amount of process independence or of permitting a new degree of freedom. Since there are only two possible degrees of freedom: when a job is started and what job is started, we can compare these stocks in terms of their effect on these factors.

The "what" problem is being subjected to intensive study in the job shop through work in Production Control Service under Alan J. Rowe and independent explorations at UCLA in the Management Sciences Research Project. These are both efforts to quantify the relationships between various jobs and to uniquely determine an optimum selection rule. By testing or simulation with various rules it should be possible to determine the amount of "slack" time to be introduced in a parts schedule in order to permit achievement of the process objectives.

The "when" problem is sometimes solved by a fixed series of operation start and stop times. This is clearly seen in most "automated" lines and in many chemical or continuous processes. In other words every 20 seconds the line moves and the operator must work on the next selected product. This can also be seen in certain office systems where the scheduling is built on a fixed operation interval such as at Sears, Montgomery Wards, etc. If we have an in-sequence cushion stock with fixed start-stop times then the only purpose the stock serves is to prevent process shut-down in case of prior process failure.

It is axiomatic that once a cushion stock is depleted the only two ways by which it can be reestablished is through delay in the subsequent process or through excess speed in the prior process. This raises the issue as to whether the individual stations on an automated line should not have a "high-speed" mode in which they could operate for short intervals to establish optimal buffers. An interesting side light is that though this increased potential speed would not directly reduce the size of the cushion stock needed to cover process failures it would permit more frequent operation at maximum protection levels and hence might indirectly affect the stock position required.

The whole concept of cushion stocks is complicated by the use of multistage processes. We start with raw material cushion stocks to take care of inherent time variances through daily delivery schedules, truckload lots for transportation efficiency, efficient mill runs, etc. We can then have stocks at every intermediate stage of manufacturing and assembly, culminating in warehouse or shipping room stocks to recognize seasonal demand variation, distribution channel convenience, and customer order size. Of all the buffer stocks this is probably the most difficult to compute or analyze. There is some hope that through simulation testing some indication may be obtained of the proper magnitude and location of these cushion stocks. It also seems likely that further work in analyzing product and operation relationships may lead to logical computational procedures. Certainly, better information regarding machine breakdown, employee absenteeism, spoilage frequency, and operator effort will permit some intelligent mathematical determination of the risks involved.

The problem is also being approached from the other direction. To the extent that scheduling techniques can be improved and economical sorting and selection devices designed it should become practical to increase effective machine output when needed so as to maintain a more balanced intermachine relationship. As we automate more of our manufacturing processes we find that the in-line or "product" layout permits significant reductions in the level of cushion stocks. Another program has to do with effective preventive maintenance programs allied with machine component standardization and unit replacement techniques. It's surely within the realm of possibility that we shall soon be able to set optimal lot sizes for each operation and use controlled cushion stocks to absorb the variable impact.

Cycle Reduction Stocks

The fourth and final objective for buffer stocks is to permit more rapid response to changing product demand. The extreme of this case is seen in objective (1) where a finished goods insurance stock may be maintained to lower the likelihood of running short. The purpose here though is more directly related to the reduction in response cycle by determining those stocks of raw materials, parts, and assemblies which will have the greatest impact on the delivery cycle.

This problem arises primarily in a business where the final output product is not fully standardized and where customers can select from alternative features. It is illustrated by automobiles, fractional motors and electronic assemblies. Generally, it is characteristic of that class of products lying between "custom design" and standard off-the-shelf models. The customer usually will give the business to the company with the shortest delivery promise, other things being equal, so there's a real incentive to reduce the cycle to a minimum.

Now in talking about the delivery cycle we should include the total time it takes from the time the customer writes the order until he receives the desired product. This will consist of transmitting the order to the factory as well as transporting the material to the customer; although these two items fall outside the range of this discussion, it's worth noting that they are frequently overlooked in attempts to reduce cycles, and buffer stocks are created where they could be avoided.

The objective of a "cycle reduction" stock is the shortening of some of the elements in the total procurement-manufacturing program so that the net delivery time may be reduced. To do any type of effective planning of "cycle reduction" stocks it is necessary to have a good clear picture of the product structure and model to model relationships. Stocks do the greatest good where there is a maximum of standardization. It is also logical that the greater the number of models which use a particular component, the smaller the total insurance stock needs to be. For example, if our output is 1000 motors a week and only one diameter of bar stock is used for shafts we can very effectively plan our shaft stock needs and require very little insurance stock because the usage rate will be quite stable. This indicates that standardization and its recognition is implicit in a planned delivery cycle reduction program.

One other major point is the need for sound, unbiased forecasting of demand. Since, by definition, this type of stock is bought or manufactured in anticipation of actual orders all we have to go on is historical trends or experienced Marketing judgment.

Now let's put aside for the moment questions concerning the amount of detail and the time extent of these schedules and look instead at the single most important element in this portion of stock planning: the Manufacturing Cycle chart. The Manufacturing Cycle chart is a pictorial representation of the procurement, machining and assembly times involved in the processing of a Customer Order. The base is time before completion against which each material, part, and assembly is shown in terms of "goes-into" relationships. This is a time oriented picture of a product structure graph. Each individual line must begin at the junction of two or more parts or at the initial procurement of a "make from" material; the only alternative is to begin at a stock-pile, but since this is actually the problem we're trying to solve we'll assume that there is no stock of any sort yet. To illustrate some of these ideas let's review a sample product chart .

To analyze this chart we start at the left hand side. If we're going to reduce the cycle by establishing proper stocks we've got to take some time off the longest cycle item. In this case aluminum ingot has to be ordered 12 time periods ahead of product completion. However, if we purchase aluminum ingot just 1 time period before the customer's order arrives we can reduce the cycle by 1 time period. This is really a "cycle reduction" stock since a commitment to a vendor is the equivalent of carrying extra inventory.

But to buy in advance of actual orders implies forecasting the demand. Here's where standardization comes in. If there is only 1 size and grade of aluminum ingot used in making all end shields and if all end shields use exactly the same amount of metal, then the only forecast necessary is by total volume. It is not necessary to get a 12 time period forecast if 1 time period in advance is adequate. Similarly it is not necessary to specify the forecast to an accuracy of 1/10 time period or even 5/10 time period--to the nearest 1 time period will be good enough. This has a very significant implication to market forecasting. It is only necessary to predict sales for: (1) the degree of variation needed to support "cycle reduction" stocks; (2) the time period in advance of order receipt for which stocks are prepared; and (3) the incremental time periods for which individual requirements will be ordered.

How far should we go in reducing the Manufacturing Cycle? Only as far as the customer will reward you adequately for your additional inventory costs and risks. Unfortunately this is most difficult to determine. The customer can reimburse you in two different ways: by giving you more business or by paying you a higher price per unit. Therefore, it is essential to obtain an evaluation of these two possibilities before embarking on extensive stocks of this type. Sometimes a trial program or discreet sales inquiries can give you a feel for the situation. On the other hand it's often a matter of having to match a competitor's delivery cycle and this, of course, gives you a concrete objective to shoot for.

Let's go back to the manufacturing cycle chart for a moment. Suppose we want to cut the cycle from 12 to just 6 time periods. This means preordering:

Aluminum ingot	6 time periods
Steel bar	5 " "
Scroll steel	4 " "
Steel plate	4 " "
Copper wire	3 " "
Base	3 " "
High purity aluminum	2 " "
Misc. mounting parts	2 " "
Punchings	1 " "
It also means prestarting shafts	1 " "

Now on some of these parts the number of variations might be quite large such as on bases or mounting parts. This is often especially true of manufactured parts. We have one additional tool to bring into the picture here and with it we can make a substantial dent in the problem. An ABC curve of individual part drawings by name showing yearly dollar usage will indicate clearly where the money should be placed. Instead of offering across-the-board a 6 time period cycle, we might offer this only on those models using a preponderance of "A" items and then fully support these models through preordering their parts. On models with mostly "B" items we might offer 9 time periods and on the others a 12 time period promise. A slightly different approach would be a volume of sales classification by model and arrange for cutting the cycle only on the high volume models.

This all leads to a very interesting rule: Never carry a cycle reduction stock of any item unless all longer cycle items are similarly covered.

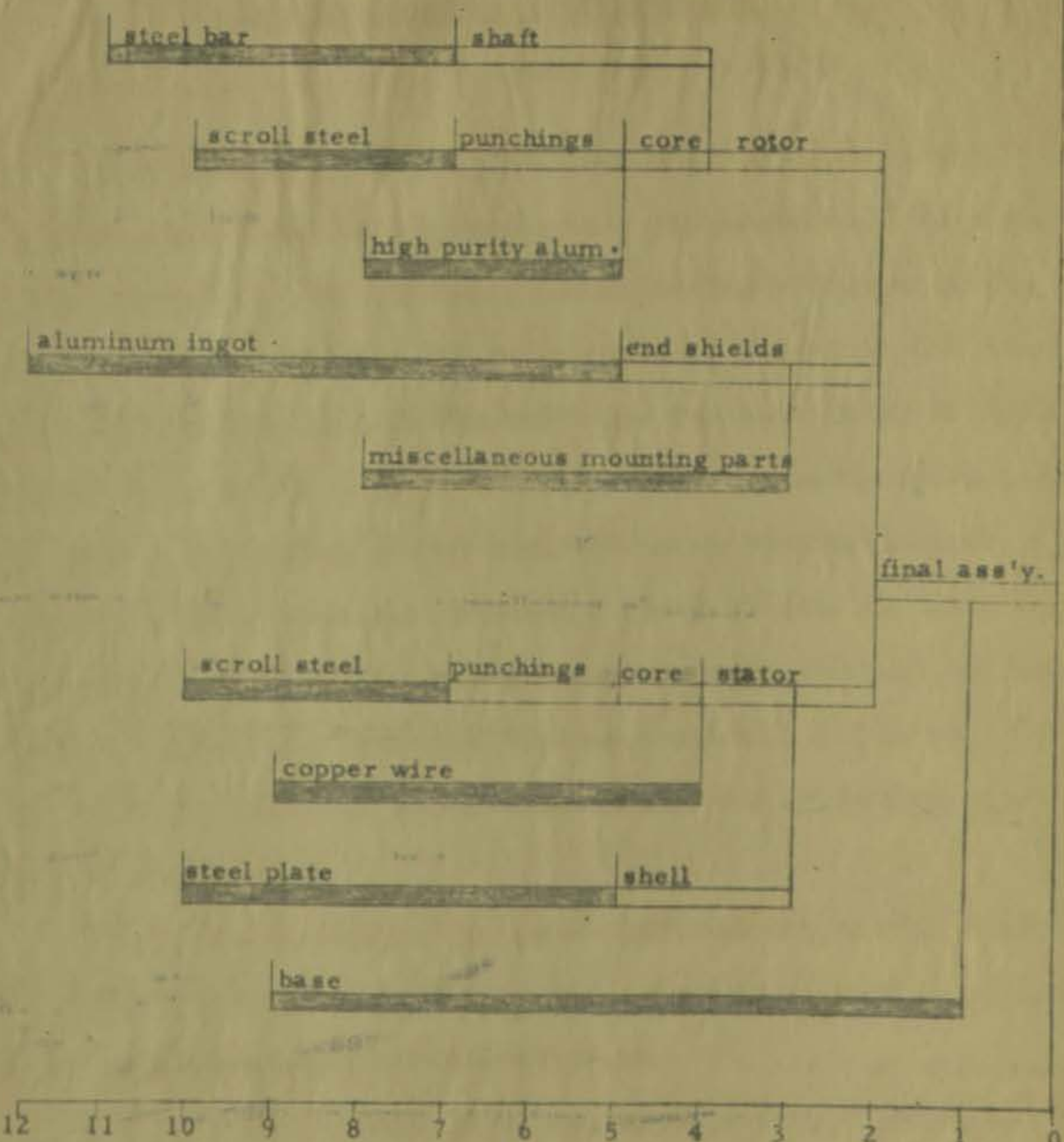
For example, if we cannot preorder a certain base by 3 weeks it's wasteful from a cycle reduction standpoint to preorder or prestart the corresponding shafts or punchings. This one rule alone, carefully followed, could make a substantial impact on our inventory obligations.

This area of cycle reduction stocking has not in the past been carefully and separately analyzed, yet it is a problem close to the heart of management considerations: how can we most effectively service our product demand? Numerical analysis using the tools suggested will offer many opportunities for improved profit through logical planning.

Conclusions

With this summary of the impact and attack on buffer stocks it should be evident that there are now a variety of ways to improve and advance the hard core of our inventory control problems. The key apparently is to separate the inventory into its various segments according to the function which it serves. Only in that way can you uniquely determine the optimal inventory level for your business. The payoff is ready for those who can think through and analyze their need for buffer stocks.

MANUFACTURING CYCLE CHART



TIME BEFORE COMPLETION
(This can be minutes, hours, days, weeks, or months)

Legend

Procurement
Internal Processing

<u>The Significance of Buffer Stocks</u>

Burton Grad - 4/15/57

Buffer stocks have long been relegated to a secondary position in the analysis and management of inventories. Economic Order Quantities, ABC Analyses, Mechanized Stock Control among others have successfully stolen the limelight. Part of this has been the result of a poor "press" since few have found it glamorous enough to write about; but, more important, there has been a lack of basic communication ability since the words "buffer stock" apparently mean something different to each person who uses it. It's called cushion stock, process stock, safety, backup, in line, excess, protective, balancing, leveling, reserve, and so on. The use of these different words is really the clue to buffer stock's lack of sex appeal.

There are in reality four major different objectives that buffer or reserve stocks can serve whether we are dealing with raw material, in-process components or finished goods:

1) to prevent stock shortages through usage variations or lead time change

2) to permit use of economical lot sizes

3) to provide a variable cushion between two processes so that they may operate at different or variable rates or may have independent lot sizes.

4) to permit more rapid response to product demand

With this clearer organization, buffer stock can now be broken into its components, analyzed and new control techniques devised. In the balance of this paper then, there will be an operating definition given for each of these classes and effort made to describe the manner in which an analytical solution can be reached for your particular problems. This is intended to be a survey of present knowledge and as such may require further reading or reference for detailed applications.

Insurance stocks

The first objective, that of preventing stock shortages, has been much discussed in other papers; nevertheless it seems worthwhile reviewing some of the pertinent conclusions.

The size of the stock needed generally varies with the square root of both the usage and the lead time. This problem has not been well studied yet in terms of stability of these two factors, but it is evident that, regardless of the magnitude, the buffer stock also varies directly with the standard error (sigma) of the probability distributions. I believe that these factors can be analyzed so that the various materials and parts might be classified into:

. highly variable usage or lead time

. moderately variable usage or lead time

. minimal variation in usage and lead time

The results of this objective show up in the reorder point or frequency of order review. The measure of efficency is the probability of being out of stock on one reorder cycle multiplied by the number of orders placed per year. This yields a stock-out/year ratio. It is therefore possible to select any desired degree of confidence and adjust the "safety" stock to compensate. This measurement shows the strong dependence that these stock levels have on frequency of reorder. It is almost obvious that with large order quantities, the frequency of being subjected to the likelihood of a stock-out is correspondingly reduced. Therefore, as a general rule the reorder point stock for "C" items should be proportionately smaller than for A items.

One item frequently overlooked is that there is a reasonable likelihood of obsolescense in holding high reserve stocks. This is dependent on the accuracy of future forecasts and ability to be forewarned of design changes.

Another potential source of "stockouts" is Quality Failure. To guard against needing 100 of a certain assembly and only having 95 in satisfactory condition, it is customary to start more of the assembly than is actually desired. This extra quantity is normally determined by examining historical experience and calculating the average failure rate for that class of parts. A technically sounder procedure would be as follows: Record the actual probabilities of having 1, 2, 3, etc. failures; approximate the cost involved in rectifying the shortage using overtime expense, added setup, longer inventory cycle, short-lot premium (if purchased), or whatever figure gives the lowest cost; next, compare the product of the "make good" cost and the frequency of spoiling 1 part with the cost of "running" 1 additional part times the frequency that the 1 part will not be needed (the probability of 0 failures). By performing this same computation for each possible number of failures you will be able to uniquely determine the optimal protection level.[4] Therefore, it can be concluded that this type of buffer could be called "Insurance Stock" and is designed to achieve an implicit balance between inventory carrying cost and the cost of being out of stock considering the probability of each eventuality occurring. It is an insurance policy protecting against an out-of-stock condition.

Utilization Stocks

The second objective, the use of buffer stocks to permit use of economical lot sizes, is normally not recognized as a true buffer stock problem. Rather it is treated as an independent computation related only to inventory carrying costs versus paperwork, set up, and quantity discounts. But this is not the whole story.

As mentioned under Insurance Stocks there is a strong correlation between frequency of order and size of buffer stock. It is also true that inventory tied up in large lots can be justified in terms of increased process utilization. Naturally, there is a reverse connotation: if completely flexible plants existed in which the order preparation and set up costs approximated zero (or were fixed regardless of product sequence or lot size) the economic lot size as presently computed would also reduce to zero. This would imply that the lot size could then be determined by external factors--stock availability, customer needs, transportation requirements, etc.

Therefore, it can be concluded that we are carrying "Utilization" Stocks to make up for our own or our vendors' lack of flexibility. We should carefully measure the price we are paying for our batch operation concept and make reasonable efforts to bring our preparation costs to a minimum.

Cushion Stocks

The third objective is to provide a variable cushion or "fluid clutch" between two processes so that they may operate at different or variable rates or may have independent lot sizes. This serves to "disengage" two successive operations, be they both shop processes, raw material and initial machining, or assembly and shipment.

This shows up just as strongly in the job shop as in the flow shop though it is usually charged to transportation, waiting, or delay time. It seems appropriate that we examine this pneumatic "cushion" stock in some detail to see how it functions, why it is needed and in what way it can be optimally determined.

Essentially, there are two major types of cushion stock: selective and insequence. The first is seen in virtually all job shops where, in effect, the parts are sorted or segregated by shop order and drawing number so that the next operation or process has full flexibility in selecting any one of the available jobs. The in-sequence buffer is usually observed where the parts or shop orders are locked in sequence on a conveyor line. The succeeding process may have flexibility in determining <u>when</u> it starts on the next part, but it must take the next one in-line; it cannot select <u>what</u> job it is to work on. There are, of course, all gradations and variations between these two extremes: side tracks, fixed dispatch rules, "kitties", etc. But we must think of a cushion stock as providing some amount of process independence or of permitting a new degree of freedom. Since there are only two possible degrees of freedom: <u>when</u> a job is started and <u>what</u> job is started, we can compare these stocks in terms of their effect on these factors.

The "what" problem is being subjected to intensive study in the job shop through work in Production Control Services led by Mr. A.J. Rowe and independent explorations at UCLA in the Management

Sciences Research Project. These are both efforts to quantize the relationships between various jobs and to uniquely determine an optimum selectivity rule. By simulation with various rules it should be possible to determine the amount of "slack" time to be introduced in a parts schedule in order to permit the optimal achievement of the process objectives.

The "when" problem is sometimes solved by a fixed series of operation start and stop times. This is clearly seen in most "automated" lines and in many chemical or continuous processes. In other words every 20 seconds the line moves and the operator must work on the next selected product. This can also been seen in certain office systems where the scheduling is built on a fixed operation interval such as at Sears, Wards, etc. If we have an in-sequence cushion stock with fixed start-stop times then the only purpose the stock serves is to prevent process shut-down in case of prior process failure.

It is axiomatic that once a cushion stock is depleted the only two ways by which it can be reestablished is through delay in the subsequent process or through excess speed in the prior process. This raises the issue as to whether the individual stations on an automated line should not have a "high-speed" mode in which they could operate for short intervals to establish optimal buffers.

An interesting side light is that though this increased potential speed would not directly reduce the size of the cushion stock needed to cover process failures it would permit more frequent operation at maximum protection levels and hence might indirectly affect the stock position required.

The whole concept of cushion stocks is complicated by the use of multistage processes. We start with raw material cushion stocks to take care of inherent time variances through daily delivery schedules, truckload lots for transportation efficiency, efficient mill runs, etc. We can then have stocks at every intermediate stage of manufacturing and assembly, culminating in warehouse or shipping room stocks to recognize seasonal demand variation, distribution channel convenience, and customer order size. Of all the buffer stocks this is probably the most difficult to compute or analyze. There is some hope that through simulation testing some indication may be obtained of the proper magnitude and location of these cushion stocks. It also seems likely that further work in analyzing product and operation relationships may lead to logical computational procedures. Certainly, better information regarding machine breakdown, employee absenteeism, spoilage frequency, and operator effort will permit some intelligent mathematical determination of the risks involved.

The problem is also being approached from the other direction. To the extent that scheduling techniques can be improved and economical sorting and selection devices designed it should become practical to increase effective machine output when needed so as to maintain a more balanced intermachine relationship. As we automatize more of our manufacturing processes we find that the in-line or "product" layout permits significant reductions in the level of the cushion stocks. Another program has to do with effective preventive maintenance programs allied with machine component standardization and unit replacement techniques. It's surely within the realm of possibility that we shall soon be able to set optimal lot sizes for each operation and use controlled cushion stocks to provide the variable impact absorption that we need.

Cycle Reduction Stocks

The fourth and final objective for buffer stocks is to permit more rapid response to product demand. The extreme of this case is seen in objective (1) where a finished goods insurance stock may be maintained to lower the likelihood of running short. The purpose in mind here is more directly related to the reduction in response cycle by determining those stocks of raw materials, parts, and assemblies which will have the greatest impact on the delivery cycle.

This problem arises primarily in a business where the final output product is not fully standardized and where customers can select from many alternative features. It is illustrated by automobiles, fractional motors, and electronic assemblies. Generally, it is characteristic of that class of products lying between "custom design" and standard off-the-shelf models. The customer usually will give the business to the company with the shortest delivery promise other things being equal so there's a real incentive to reduce the cycle to a minimum.

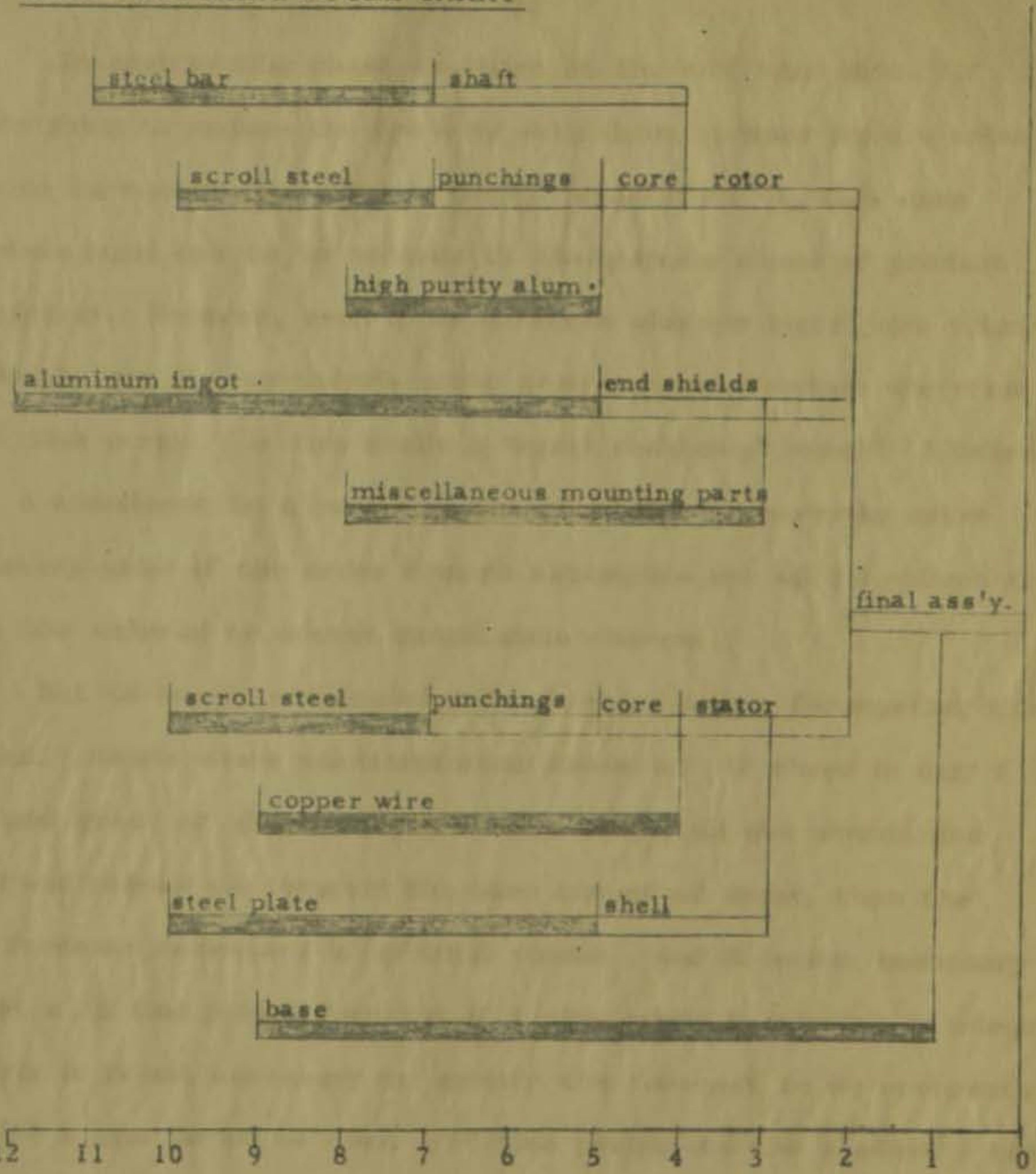
Now in talking about the delivery cycle we should include the total time it takes from the time the customer writes the order until he receives the desired product. This will consist of transmitting the order to the factory as well as transporting the material to the customer; although, these two items fall outside the range of this discussion it's worth noting that they are frequently overlooked, in attempts to reduce cycles, and buffer stocks are created when they could be avoided. The objective of a "cycle reduction" stock is the shortening of some of the elements in the total procurement-manufacturing program so that the net delivery time may be reduced.

To do any type of effective planning of "cycle reduction" stocks it is necessary to have a good clear picture of the product structure and model to model relationships. Stocks do the greatest good where there is a maximum of standardization. It is also logical that the greater the number of models which use a particular component, the smaller the total insurance stock needs to be. For example, if our output is 1000 motors a week and only one diameter of bar stock is used for shafts we can very effectively plan our shaft stock needs and require very little insurance stock because the usage rate will be quite stable. This indicates that standardization and its recognition is implicit in a planned delivery cycle reduction program.

One other major point is the need for sound, unbiased forecasting of demand. Since, by definition, this type of stock is bought or manufactured in anticipation of actual orders all we have to go on is historical trends or experienced Marketing judgment.

Now let's put aside for the moment questions concerning the amount of detail and the time extent of these schedules and look instead at the single most important element in this portion of stock planning: the Manufacturing Cycle Chart. ~~The Manufacturing Cycle chart~~. The Manufacturing Cycle chart is a pictorial representation of the procurement, machining and assembly times involved in the processing of a Customer Order. The base is time before completion against which each material, part, and assembly is shown in terms of their "Gozinto" (Goes into) relationships. This is a time oriented picture of a product structure graph. Each individual line must begin at the junction of two or more parts or at the initial procurement of a "make from" material; the only alternative is to begin at a stock-pile, but since this is actually the problem we're trying to solve we'll assume that there is no stock of any sort yet. To illustrate some of these ideas let's review a sample product chart (attached)

MANUFACTURING CYCLE CHART



TIME BEFORE COMPLETION
(This can be minutes, hours, days, weeks, or months)

Legend

Procurement
Internal Processing

To analyze this chart we start at the left hand side. If we're going to reduce the cycle by establishing proper stocks we've got to take some time off the longest cycle item. In this case aluminum ingot has to be ordered 12 time periods ahead of product completion. However, even if we purchase aluminum ingot just 1 time period before the customer's order arrives we can reduce the cycle by 1 time period. Is this really a "cycle reduction" stock? I believe so: a commitment to a vendor is the equivalent of carrying extra inventory since if the order doesn't materialize you will be obliged to take the material or accept cancellation charges.

But to buy in advance of actual orders implies forecasting the demand. Here's where standardization comes in. If there is only 1 size and grade of aluminum ingot used in making all end shields and if all end shields use exactly the same amount of metal, then the only forecast necessary is by total volume. And it is not necessary to get a 12 time period forecast if 1 time period in advance is adequate. Similarly it is not necessary to specify the forecast to an accurracy of 1/10 a time period or even 5/10 time period--to the nearest 1 time period will be good enough. This has a very significant implication to market forecasting. It is only necessary to predict sales for: (1) the degree of variation needed to support "cycle reduction" stocks; (2) the time period in advance of order receipt for which stocks are prepared; (3) the incremental time periods for which individual requirements will be ordered.

How far should we go in reducing the Manufacturing Cycle? The answer: only as far as the customer will reward you adequately for your additional Inventory Costs and risks. Unfortunately this is most difficult to determine. The customer can reimburse you in two different ways: by giving you more business or by paying you a higher price per unit. Therefore, it is essential to obtain an evaluation of these two possibilities before embarking on extensive establishment of this type of buffer stock. Sometimes a trial program or discreet sales inquiries can give you a feel for the situation. On the other hand it's often a matter of having to match a competitor's delivery cycle and this, of course, gives you a concrete objective to shoot for.

Let's go back to the manufacturing cycle chart for a moment. Suppose we want to cut the cycle from 12 to just 6 time periods. This means pondering:

	Aluminum ingot	6 time periods
	Steel bar	5 " "
	Scroll steel	4 " "
	Steel plate	4 " "
	Copper wire	3 " "
	Base	3 " "
	High purity aluminum	2 " "
	Misc. mounting parts	2 " "
It also means prestarting	shafts	1 " "
	punchings	1 " "

Now on some of these parts the variations might get pretty rough such as on bases or mounting parts. This is often especially true of manufactured parts. Does this mean we shouldn't try to stock them? The answer is an emphatic NO! We have one additional tool to bring into the picture and with it we can make a substantial dent in the problem. An ABC curve of individual part drawings ~~part~~ by name showing yearly dollar usage will show clearly where the money should be placed. Instead of offering across-the-board a 6 time period cycle, we might offer this only on those models using a preponderance of "A" items and then fully support these models through preordering their parts. On models with mostly "B" items we might offer 9 time periods and on the others a 12 time period promise. A slightly different approach would be a volume of sales classification by model and arrange for cutting the cycle only on the high volume models.

This all leads to a very interesting rule: NEVER CARRY A CYCLE REDUCTION STOCK OF ANY ITEM UNLESS ALL LONGER CYCLE ITEMS ARE SIMILARLY COVERED.

For example, if we cannot preorder a certain base by 3 weeks it's wasteful to preorder or prestart the corresponding shafts or punchings. This one rule alone, carefully followed, could make a substantial impact on our inventory obligations.

This area of cycle reduction stocking has not in the past been carefully and separately analyzed, yet it is a problem close to the heart of management considerations: how can we most effectively service our product demand? Numerical analysis using the tools suggested will offer many opportunities for improved profit through logical planning.

Conclusions

With this summary of the impact and attack on buffer stocks it should be evident that there are now a variety of ways to improve and advance the hard core of our inventory control problems. The key apparently is to separate the inventory into its various segments according to the function which it serves. Only in that way can you uniquely determine the optimal inventory level for your business. The payoff is ready for those who can think through and analyze their need for buffer stocks.

"PROJECT IDEAS"

Provide standard vellum pads for notes and charts. - not necessary

Process Charts - Add forms info/statistical study? - doubtful for space reasons

Breakdown by account numbers instead of activities for final costing ease? - No

Process Studies - Include forms and files analysis - all files & Forms - ok -

Information Flow - Do forms control study first? - Then process chart? - Or select department which has done some forms control analysis already. few have done much

"IDEAS"

Get all Vendors on standard terms and shipping FOB Fort Wayne! - loses transportation control.

Send advance payment with P.O. - why bother.

STANDARDIZE:

All factory equipment made of interchangeable components (motors, motor mountings, air cylinders, linkages, etc., so that spare parts may be stocked for breakdown repair. Good

All business recorded on 5 forms (Finance, Manufacturing, Engineering, Personnel, Etc.) (With multiple fields and many copies). Not basically logical since work is not structured that way

Microfilm all customer and vendor correspondence, punch into cards and use microfilm card for historical files, quotations, etc. - difficult access

Use wire-wrap for stator winding connections. - probably sound.

TRAFFIC:

Instruct vendors at same origin point to use the same carrier. The advantages of this are listed on page 19 of "Practical Handbook of Indust. Traffic Mgt", (DeRubbo). - Good Idea use — can on incoming

Design automatic computer machine to attach to MTS man who would go through motions of operation and receive an MTS based standard time for each element. Interesting concept - try to follow human's motion - sort of an "Omnia"

Two principles of manufacturing flow:

(1) Put all models through same machines and have choice on program - action or no action - schedule to bottleneck machine only - load FIFO or back up from delivery req'ts. – only logical if cycle times correspond – otherwise holding up line for tough operation – Cust sched could probably help – should reflect customers' wants

VS.

(2) Branch from main line for variations in model - schedule much more complex. – Why not By pass rather than branch.

* * * * * * * * * * * * * *

Actually make machine instructions travel with parts in manufacture.

- Keys on pallets – where do pallets come in
- IBM cards run parallel to mfg. line – analog basis : may be valid

* * * * * * * * * * * * * * *

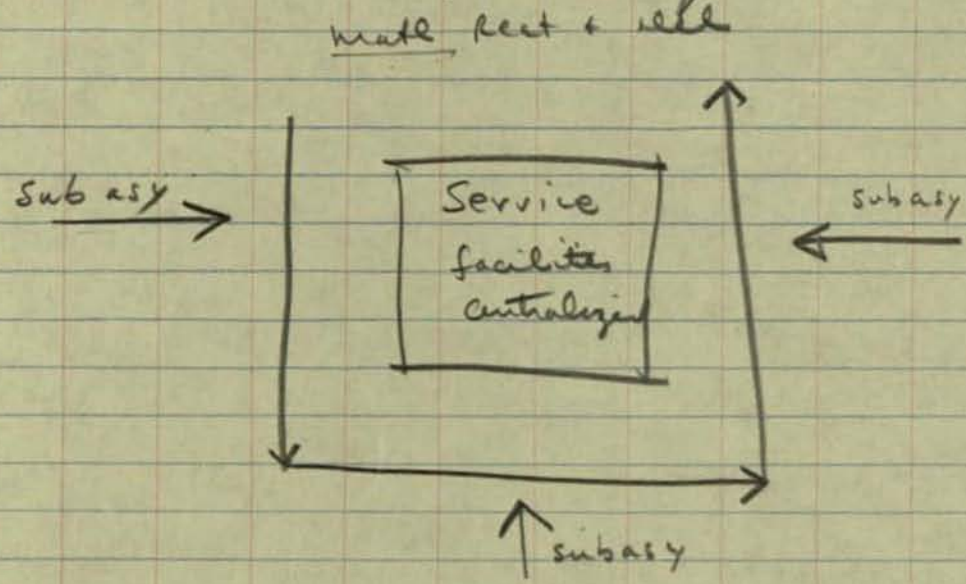
(Key Customer Variables)
KCV's to machine programs via math - relationships. – OK –

A. C. Close

bjh

March 26, 1957

Concept of a square plant



Cost of Carrying Inventory

Marginal return for this class of Risks

General notes

four phases to business structure

planning

control (integrating ?)

operations

measurement

check Sniddy's list of functions

- Define difference between data + physical processes.

- Matls Classification - separate non direct into:
  - durable
  - non durable

- a physical process is usually not reversible... there is a destruction of mat'l.

-

delineate clearly the difference between functions which are vital, main line and those which are essentially peripheral.

BG.
9/17/52

11/19

Walt's idea that we should spend an hour a day or so, trying to abstract from the detail — see relationships, gain understanding. This will help in doing further analyses — & can cut down on the amount of detail gathered.

Separate out those things which are logically necessary — not the things due to human or machine limitations

The Dept mgmt has long since learned (& forgotten) the detail — & are primarily interested in the relationships.

We seldom provide adequate time for this abstraction, during the course of the detail study.