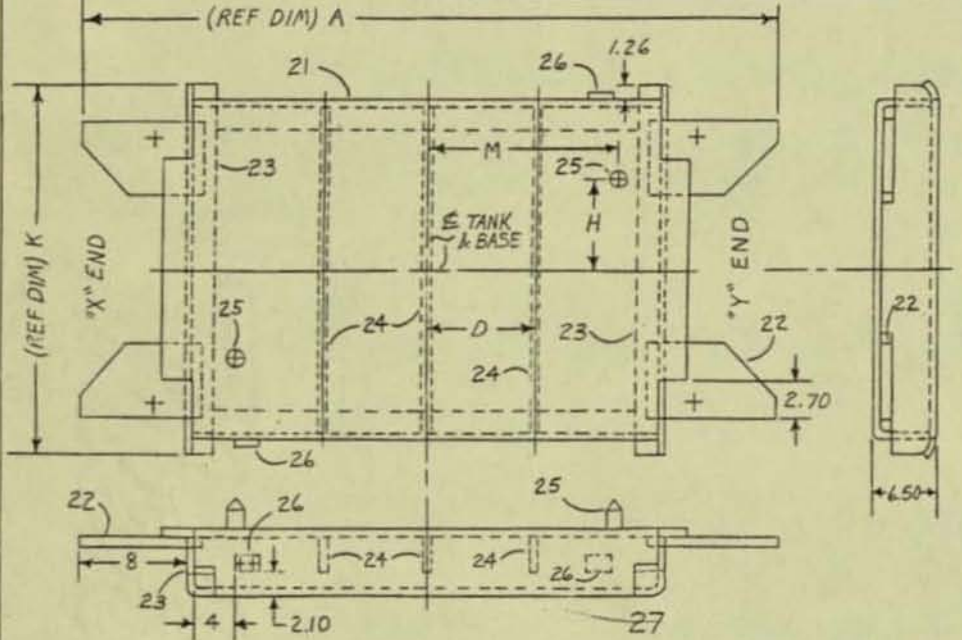
GENERAL ELECTRIC 555B102

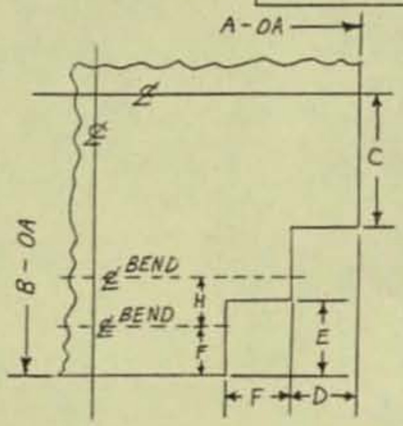
UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING:—

APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS	DECIMALS	ANGLES
	✓	±	±	±

TITLE **BASE**

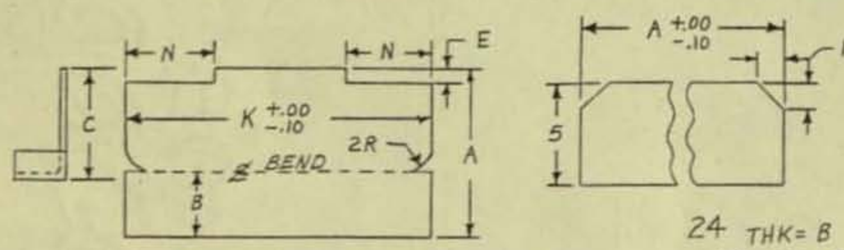
FIRST MADE FOR TRANS 1 ϕ





	THK	D	E	F	H
21A	.312	1.80	3.70	2.20	5.88
21B	.375	1.90	4.10	2.60	5.76

STL B4A8B



24 THK= B
STL B4A8B

	THK	A	B	C	E
23 A	.312	8	2.20	6.12	SEE PL
23 B	.375	8.30	2.60	6.06	1.06

STL B4A8B

4. FOR TAB DIM SEE PL WHERE CALLED FOR
3. WELD TO 744A210 FIG # 8C
2. IF QTY OF RIBS CALLED FOR IS (1), RIB IS ON ℄
IF QTY IS (2) CENTER RIB IS OMITTED
1. SEE 744A111AC FIG # 3

DO NOT CHG WITHOUT C.A.P. APPROVAL

REVISIONS

1 — OCT 30, 57 — N-3(CAP)-27 CHG "K" TO "A" ON P24

PRINTS TO: 1A, CAP, 3A4, 3B, (9)

MADE BY: OCT 2, 1957
ISSUED:

ROME

555B102

COMPUTER DWG.

P-177-15

FF-806-F PRINTED IN U.S.A.

Exhibit 6

GENERAL ELECTRIC 422C207

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING: APPLIED PRACTICES | SURFACES ✓ | TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS ± DECIMALS ± ANGLES ±

BASE DATA

FIRST MADE FOR TRANS

BASE PARTS LIST SHOULD BE MADE AS SHOWN BELOW

TITLE: BASE

PT NO	NAME OF PART	USED WITH	DESCRIPTION	QTY
21 A	PLATE		*P21A A= B= C=	1
21 B	PLATE		*P21B A= B= C=	1
22	JACK PAD		744A207 P__	4
23 A	ANG		*P23A E= K= N=	2
23 B	ANG		*P23B K= N=	2
24	RIB		*P24 A= B=	
25	BUMP PIN		744A211 P__	2
26	GROUND BLK		755A168 G1	2
27	ASM		*P27 A= K= D= H= M=	X_1

* = 555B102

PT NO	INFORMATION REQUIRED FOR ORDERING BASE
21A	USE IF TOTAL WEIGHT OF TRANSFORMER DOES NOT EXCEED 25000#, OTHERWISE OMIT A = INSIDE TANK LENGTH + 3 B = INSIDE TANK WIDTH + [2 X BASE EXT] + 15.50 C = (.50 X INSIDE TANK WIDTH) + 1.50
21 B	USE IF TOTAL WEIGHT OF TRANSFORMER RANGES FROM 25001# THRU 50000# A = INSIDE TANK LENGTH + 3 B = INSIDE TANK WIDTH + [2 X BASE EXT] + 16 C = (.50 X INSIDE TANK WIDTH) + 1.50
22	#1 = 744A207 P110 SEE LD. CHART #2 = 744A207 P108 AT RIGHT
23A	USE WHEN P21A IS REQUIRED, OTHERWISE OMIT E = .70 WHEN JACK PAD #1 IS USED FOR P22 E = 1.06 WHEN JACK PAD #2 IS USED FOR P22 K = "B" ON P21A - 13 N = BASE EXT + 2.50
23B	USE WHEN P21B IS REQUIRED K = "B" ON P21B - 13.50 N = BASE EXT + 2.50
24	RIB QTY CALC STRESS USING THE FORMULA: $f = \frac{[P+HC]W^2L^2}{4T^2[W^2+L^2]}$ IF f = 20 000 OR LESS NO RIB IS REQUIRED WHEN f = MORE THAN 20 000 RECALCULATE USING .50 THE VALUE OF L IF f = 20 000 OR LESS (1) RIB IS REQUIRED HOWEVER, IF f = MORE THAN 20 000 RECALC USING .333 THE VALUE OF L. IF f = 20 000 OR LESS (2) RIBS ARE REQUIRED WHEN f = MORE THAN 20 000 SEE MDG SECT

24 CONT'D

P18 LENGTH, A

A = "B" ON P21A - 16.25, WHEN P21A IS USED
A = "B" ON P21B - 16.88, WHEN P21B IS USED

RIB THK, B

CALC SECT MODULUS USING THE FORMULA:

$S = \frac{[P+HC]W^2L_1}{[L_1+W][160,000]}$ [L_1 = FINAL VALUE OF "L" (.50L OR .333L) USED TO SOLVE FOR "f"]

THEN REFER TO CHART BELOW:

PLATE PART	SECTION MODULUS	THK OF RIB(S)
P21A	0 - 2.47	.312
	2.48 - 2.92	.375
	OVER 2.92	SEE MDG SECT
P21B	0 - 3.07	.375
	3.08 - 3.98	.500
	OVER 3.98	SEE MDG SECT

ABOVE FORMULAS BASED ON FOLLOWING SYMBOLS:
- T = BASE PLATE THK (IN.)
- H = INSIDE HEIGHT OF TANK (IN.)
- P = TEST PRESSURE (PSI) SEE TABLE #1
- W = TANK WIDTH (IN.)
- L = TANK LENGTH (IN.)
- C = .0322 FOR OIL
  .0562 FOR PYRANOL

25 & 27

CORE SIZE	BUMPER PIN 744A211 P__	K_1	K_2	WINDOW WIDTH (WW) 8 OR LESS M=	WINDOW WIDTH (WW) OVER 8 M=	H=
9 - 10	21	9	4.20	$K_2 + \frac{WW}{2}$	$K_2 + WW - 2$	$\frac{K_1}{2} + 5.50$
10 - 11	21	10	4.60			
11 - 12	21	11	5.20			
12 - 13	22	12	5.60			
13 - 14.50	22	13	6.30			
15 - 16	23	15	7.13	$K_2 + 5$		
16 - 17.50	22	16	7.83	$K_2 + WW - 2$		

GIVE "D" DIM WHEN (2) RIBS ARE REQUIRED. "D" = .166 X INSIDE TANK LENGTH, ROUNDED OFF TO NEAREST .10 INCREMENT

A = "A" ON P21A OR 21B + 13
K = "K" ON P23A OR 23B

LAYOUT NO.	#1 = 744A207 P110 #2 = 744A207 P108	LAYOUT NO.	#1 = 744A207 P110 #2 = 744A207 P108	LAYOUT NO.	#1 = 744A207 P110 #2 = 744A207 P108	LAYOUT NO.	#1 = 744A207 P110 #2 = 744A207 P108
1-2	1	3-22	1	7-3	1	9-28	1
1-5	1	3-25	1	7-4	1	9-33	2
1-6	1	3-26	1	7-5	1	9-36	2
1-13	1	3-27	1	7-7	1	9-37	2
1-14	1	3-28	1	7-8	1	9-40	2
1-17	1	3-29	1	7-13	1	11-3	2
1-18	1	3-30	1	7-15	1	11-12	2
1-21	1	3-37	1	7-16	1	11-13	2
1-22	1	3-40	1	7-17	1	11-16	2
1-25	1	3-41	1	7-19	1	11-17	2
1-26	1	3-44	1	7-20	1	11-20	2
1-29	1	5-1	1	7-25	1	11-33	2
1-30	1	5-3	1	7-27	1	11-36	2
1-41	1	5-4	1	7-28	1	11-37	2
1-42	1	5-5	2	7-37	1	11-40	2
3-2	1	5-7	1	7-40	1	13-17	2
3-3	1	5-8	1	9-1	1	13-20	2
3-4	1	5-13	1	9-3	1	13-33	2
3-5	1	5-15	1	9-4	1	13-36	2
3-6	1	5-16	1	9-5	1	13-37	2
3-7	1	5-17	1	9-7	1	13-40	2
3-8	1	5-19	1	9-8	1		
3-13	1	5-20	1	9-9	1		
3-14	1	5-25	1	9-11	1		
3-15	1	5-27	1	9-12	1		
3-16	1	5-28	1	9-13	1		
3-17	1	5-37	1	9-15	1		
3-18	1	5-40	1	9-16	1		
3-19	1	5-41	1	9-17	1		
3-20	1	5-44	1	9-20	2		
3-21	1	7-1	1	9-25	1		

INFORMATION REQUIRED TO USE THIS DWG:
1. TOTAL WEIGHT
2. LAYOUT NO.
3. INSIDE TANK DIMENSIONS - HEIGHT, WIDTH, & LENGTH
4. BASE EXTENSION - INSIDE OF TANK OVER BASE PLATE
5. OIL OR PYRANOL?
6. OPER & VACUUM PRESS.
7. CORE SIZE & WINDOW WIDTH

INFORMATION REQUIRED FROM ENG
1. INSIDE TANK DIMENSIONS - HEIGHT, WIDTH, & LENGTH
2. OIL OR PYRANOL?
3. CORE SIZE & WINDOW WIDTH
4. LAYOUT NO.
5. OPER & VACUUM PRESS
6. TOTAL WEIGHT

TABLE #1

PRESS.		
OPER	VAC	TEST
3	5	4.50
3	FULL	15
5	5	6.50
7.50	FULL	15
5	5	6.50
7.50	5	9
7.50	FULL	15

REVISIONS: 1 CHG "K" TO "N" ON P23 "A" SYMBOL TO "C" IN FORMULAE; 2 CHG L TO L_1 PER SECT MODULUS FORMULA & ADD NOTE (L_1); 3 ADD DATA TO C.G. CHART; 4; 5 CHG'S; 6 CHG [illegible]

MADE BY Oct 7, 1957 — ROME — 422C207

DO NOT CHG WITHOUT C.A.P. APPROVAL — PRINTS TO IA CAP ONLY — COMPUTER DWG

5 P-177-15 6

Exhibit 7

various business operating tasks in contrast to the accepted practice of nearly 100% file reference for everything. It was immediately evident that there were many potential advantages from the use of regeneration. These included: file reduction, search elimination, and often a substantial increase in access speed.

One problem that arose was in the consideration of the use of formulas versus look-up procedures. The fact that we operate in a discrete world tends to make many of our decisions also discrete. The very nature of our approach to standardization and the nature of human beings who have conceived the physical systems as well as some of the physical laws to do with electricity and magnetism all seem to lead toward the idea of step or discrete solutions. So while formulas are "ideal" for full regeneration the nature of the world is such that we will have to provide for ranges and logical choice among certain specifications in order to determine the appropriate output characteristics.

Regeneration as a principle seems to be applicable in virtually every area of our business. We are able to use this principle in product design, operation planning, quality planning, cost determination, production scheduling, customer promising, vendor selection, etc. The difference between the regenerative and the file reference approach is often the scope of the answer given once the question is stated. In file reference we typically have a complex set of answer compilations for a complex set of coded specifications. In regeneration though, we tend to have a series of individually simple answers each for a relatively simple set of input parameters. This seems to be closer to the true nature of the kind of problems that we deal with in a manufacturing business. Typically, in determining each characteristic of a part the designer could not have taken into account more than a nominal number of factors. The ability to determine the value of a particular characteristic as a function of just a few variables gives the regenerative approach its great strength. This also eliminates much of the redundancy which we currently have to handle.

Let's look at one approach that has been taken on regenerative work. Instead of starting with a model number think about starting with the customer specifications themselves; and instead of calling out the drawing numbers of the various parts we define the characteristics that make up each of the parts. It can be shown that these characteristics can be determined as a function of the initial customer specifications. We would specify the logic under which various values for each parts characteristic will be selected and specify the logic by which these various parts characteristics will be combined in order to satisfy some product demand. This can be thought of as the extreme of the multiple-level system. Even though we have assigned selected discrete values (stored in tables) and even though no individual value was created that had not before been explicitly stated by the systems designer, nevertheless, the particular combination which was developed could be far different from any one originally envisaged by the product designer.

I believe that this conveys the fact that regenerative systems seem to have an approach about them which is mentally quite different from normal reference systems. In general, the regenerative approach in some way has information stored in a "where used" manner. This is in contrast to the historical file reference where the information is stored based upon hierarchies of identification. We might say that this is the case where the information is looking for a place to be used instead of the higher level list calling out the information required in a particular case.

The extreme of this is of course seen when formulas are used instead of the logical selection of discrete values. In this case, we simply substitute in the appropriate formula the input parameter values and by going through the appropriate arithmetic, relational or logical operations we are able to determine the value which should be assigned to this variable. The simplest type of formula (those which are purely arithmetic in nature) tends to give a continuous band of answers. Obviously, this can be reduced to integer values and then through a second layer of logical decision can be converted to appropriate standards.

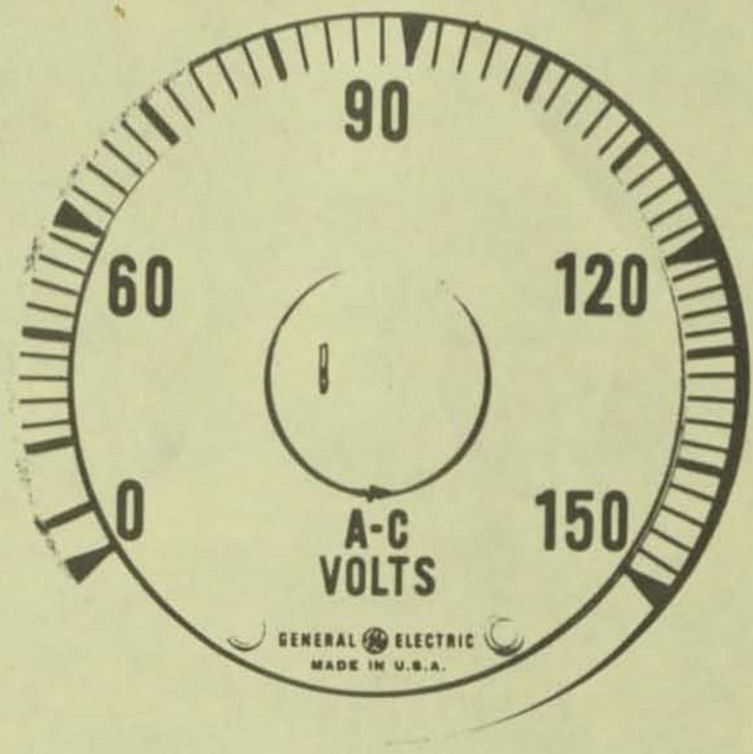
One point that's probably worth clarifying is that the concept of regeneration should be clearly separated from that of generation. It is really quite unimportant how the information is created in the first place -- whether it be by machine or by human. The question is whether these answers once generated should be stored for later re-use or whether we should go through the generation process over again each time the question is raised. Generation has to do with the solving of a new problem. Regeneration describes this re-solving of a problem which has been solved before.

I don't think there are any pat answers as to when it pays to do computer generation against manual generation and when it pays to do what degree of regeneration. I think that it is evident that factors such as: file size, type of computer, frequency of re-use of file information, frequency of change, need for permanent records, spare parts requirements, complexity of decision logic and need for human interpretation would all be involved.

It is also true that regeneration is not a necessary, basic requirement for efficient computer processing. However, it so happens that today's computers do have a substantial advantage in their computational in contrast to their file retrieval speed. Random access files are still expensive and quite slow. Tape memory systems are only well adapted to data which can be handled sequentially. Even with the present concept of consolidated files digital computers do not lend themselves to fast random extracting with automatic decision making. It is conceivable,of course,that some time in the future this internal computer balance may change as we might find very efficient, low cost filing techniques. Nevertheless, even in these cases it would certainly be desirable to consider at what level the information should be stored and to what extent we should store the answers as in a single level or multiple level assembly list system.

It would seem that file maintenance with a highly regenerative system would be significantly easier then with a pure file reference system. First, many of the changes which are presently made with files do not have to be made at all with the regenerative system since many of these file changes are required simply to post new combinations of existing answers. Second, when a change does occur there will typically be fewer places to correct since there is a lower redundancy in information storage. It should no longer be necessary to maintain "where used" files, since the appropriate sets of tables will enable you to trace back to the causative elements of any decision so that if a particular dimension were changed it should be reasonably evident as to what scope of products this change will influence.

Regeneration does not necessarily require the use of structure tables. For example, most of the present uses of the regenerative principle do not use structure tables at all, but rather depend upon the use of formulas and some automatic programming technique such as FORTRAN, COMTRAN, or even machine language code. These systems still gain many of the advantages of regeneration. The use of structure tables then should be considered quite independently from the use of regeneration. However, one major advantage of the structure table approach to regeneration is the ease and simplicity with which the responsible engineer or operational planner is able to express his logic in a form convenient to him and yet directly acceptable to the digital computer. In general, as the various automatic programming techniques become better developed it will become less and less necessary to introduce a programmer between the systems engineers and the computer itself and if Decision Structure Tables are used, the programmer may well be entirely eliminated.



"BEFORE"
FIG 22

tariff walls or sharp import quotas? During the past four years we have been working intensively on three more positive ways of establishing industrial leadership.

First, innovation - we have to provide the amount of research required to develop new products and then to introduce these new products rapidly and efficiently so as to maintain competitive position.

We must give prompt and reliable delivery of high quality products, offering customer oriented features, backed up by dependable, economic field service.

But most important, we must re-establish cost leadership. The only logical way to do this is through increased productivity which means fewer direct and indirect labor hours per unit of product. This increased productivity comes not from sweat shop techniques but from designing a product for producibility, from best shop layouts, from best methods, from using the most modern factory and office equipment and, particularly, from planned integrated automated systems.

Recent figures on industrial productivity show how slowly we have improved since World War II. The average increase in productivity per year since 1950 has been approximately 2%. In contrast, Germany has increased its productivity by more than 5% a year in the same period. 1958 was the first good omen when U. S. productivity increased by over 6%, this in spite of a significant reduction in industrial output. It was analysis of this data that caused

General Electric's Services' organizations ~~to~~ attempt ~~the~~ design ~~of~~ an advanced automatic system, one that would be able to respond more efficiently and more economically to incoming customers' orders.

Certain general objectives were established in order to accomplish this task: ~~(SLIDE A-1)~~

1. The new system ~~should~~ be economically practical and technically feasible; it should be broadly applicable to many departments of ~~the Company~~.

2. The system should be multi-functionally integrated and provide a close linkage between the office and factory.

3. It ~~should~~ be designed with bold innovation in order to break the historically accepted business systems patterns.

~~We~~ hoped through research to develop new concepts and tools for use in designing such new systems.

~~We~~ hoped to develop new criteria for technically and economically sound approaches to automation that would help ~~us~~ determine which particular new techniques should be used in specific businesses.

~~We~~ wanted to provide a foundation for future ~~General Electric~~ progress through research and development.

continue (A)

To pick an initial area for this exploration, ~~we~~ They analyzed some of the current weaknesses of industrial systems. ~~(SLIDE A-1)~~

1. Typically, delivery cycles are quite long when compared to the product's cost. This is particularly true of manufacturing cycles in relation to the actual processing time. Work-in-process inventories are correspondingly excessive. ~~(SLIDE A-3)~~

2. Indirect labor costs are increasing steadily. Many factories even joke about the fact that they can't make a shipment until the paper weighs as much as the product.

3. A third area is the high redundancy of information used in factory paperwork. For example, on a line of shafts used by a successful motor manufacturing department ~~manufacturer~~, it was found that some three hundred different drawings had been prepared over the course of two years to take care of each minor variation. ~~and that~~ On each of these drawings there was some sixty to seventy fields of information. Of these fields, better than 80% were completely fixed. For every shaft only 20% were truly variable.

With these and other significant problems in mind, ~~we~~ They sought the areas of an industrial business system that would have the greatest impact in these areas of opportunity. ~~We called~~ This heart of the business process was called the Main Line System. ~~Possibly~~ A review of the steps included in this Main Line System will give a clearer understanding of the particular scope of this project.

The present Main Line System starts with a customer's order. This specifies what the customer wants in functional terms, such as size, color, rating and other product requirements. A typical order then goes through certain conventional steps. ~~(See Exhibit I)~~ (See Exhibit I)

1. It is edited to eliminate ambiguities and to put the order into the proper, most usable, internal form.

2. Then this order is engineered and drafting prepares documents needed, namely blueprints, bills of material, etc.

3. Based upon this design information, the manufacturing engineers then perform the operational planning on how to make the product and what the time allowances should be for the various labor and machine operations.

4. In a similar manner, the quality control planning procedures are determined, establishing

omit

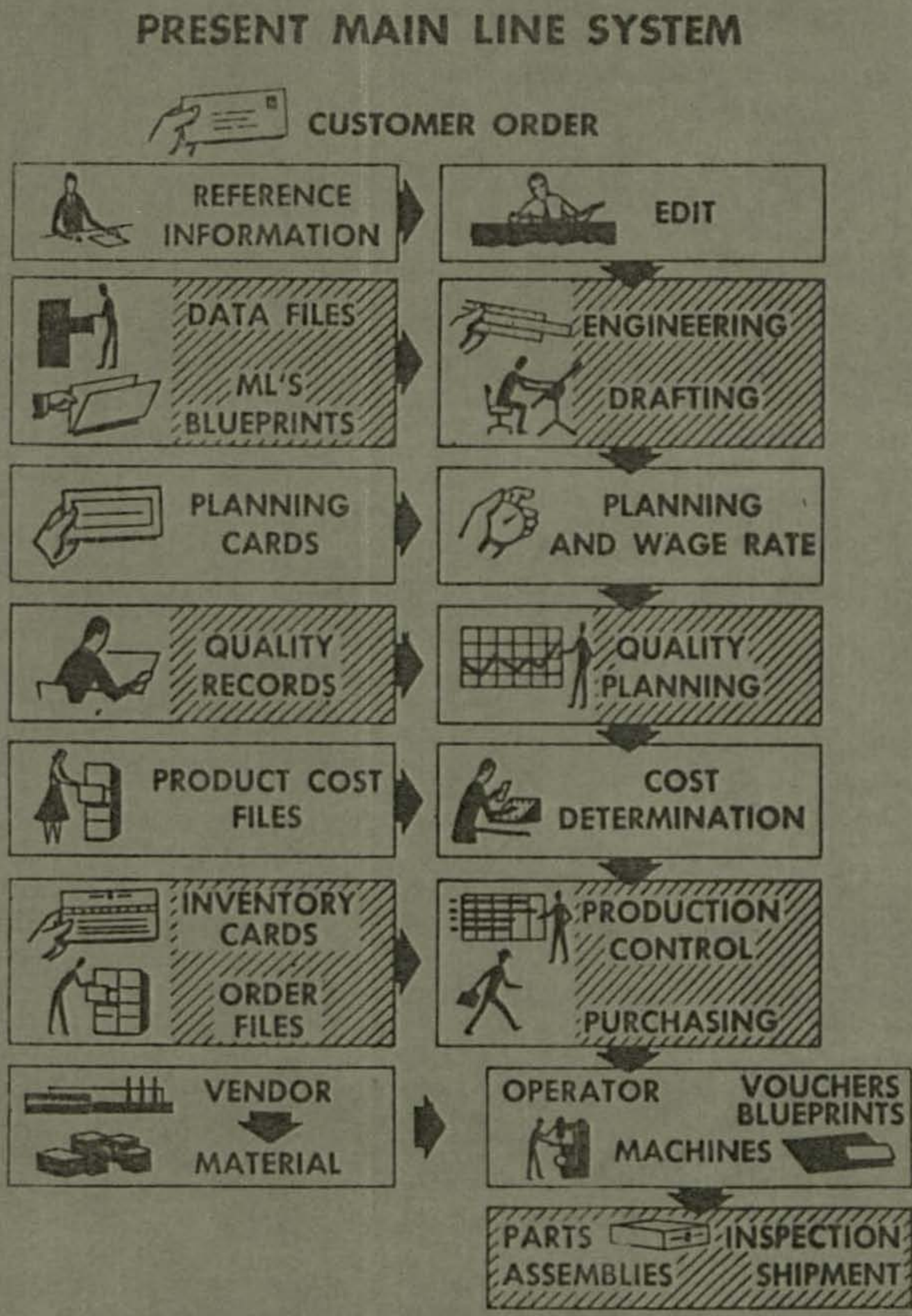


Exhibit I

standards, methods and frequency of quality analysis.

5. And then, using the existing records and files, cost information is accumulated, compiled and analyzed.

6. ~~Manufacturing~~ Production control then takes over to determine when the parts are needed as well as how many are to be purchased and made. Typically, this includes the functions of customer promising, scheduling and inventory control.

7. Finally, instructions in the form of vouchers, purchase requests, etc. along with blueprints and other necessary papers are transmitted to the factory to direct the manufacture of internally made components or to purchasing for outside material procurement.

In each of these steps, information is taken from the previous function, typically in the form of written documents, and used to produce the next document or output with the aid of information reference files: material lists, blueprints, planning cards, cost cards, (quality records) etc. In short, ~~[SLIDE A-1]~~ the Main Line System converts the customer's order into a finished product. Present systems are ~~typically~~ usually based on human-to-human ommunication with extensive file reference. The use of mechanical aids is generally still limited. The shop area is often characterized by the job-shop type facilities, high buffer stocks between operations and long manufacturing cycle times.

End E

Begin B

Substantial amounts of money are involved in the Main Line System. Normally, 100% of the direct labor and 100% of the direct material is tied up in the Main Line System. At least ~~40%~~ 40% of the indirect ~~labor and indirect~~ manufacturing expenses are also in this area. The productive raw and in-process inventories are in this category as well as approximately 80% of the [redacted] plant and equipment investment. In total, this area probably accounts for 75 to 80% of [redacted] product costs and a similar percentage of [redacted] investment. ~~(Slide A-11)~~

To perform a research and development job on these multi-functional problems, ~~it was necessary to organize~~ a multi-functional team was organized representing the various business functions: Engineering, ~~and~~ Accounting and ~~as well as~~ Manufacturing. In this particular study, Marketing and Employee Relations were not included ~~simply~~ because the particular system defined did not require their extensive contribution.

In a decentralized company like General Electric, planning such a program is not uncomplicated. There are two types of problems that arise:

1. The integration of staff planning people into a closely knitted team is complicated by the fact

continue (B)

that there is no component in the organization responsible for multi-functional systems work. Therefore, effective work requires mutual participation of the functional services who have no common manager short of the Chairman of the Board, who is the Chief Executive Officer. Basic problems like leadership, budgets, relative functional roles, decision making, reporting, etc. were ~~could well have become~~ major problems which had to be overcome. ~~obstacles. Fortunately, the merit of the project and the integrating force of belonging to one company was sufficiently strong to overcome these natural organizational barriers.~~

2. A second problem in a large decentralized company is developing concepts in a framework that will be both understandable and meaningful to the many operating components. Because they have such a variety of products, processes and markets, that generality is elusive.

They felt ~~It was our belief~~ that an ivory tower approach would not provide an effective atmosphere for integrating systems design work nor would it particularly aid in selling any new concepts which were developed. What was needed was a real ~~live~~ business -- a "living laboratory".

Continue (B)

This selected operation had to be representative of the breadth of businesses in which General Electric engages~~; varying from lamp bulbs to large steam turbines, from silicones to guided missiles, from fractional motors to complex steel mill controls~~. Also in picking a business, they ~~we~~ wished to select one where the existing information was in sufficiently clear form to be readily usable. ~~We looked for a business with a good clear documentation, clean records~~. Since they felt that "you can't automate a mess", they ~~we~~ sought a well run business where they ~~we~~ could concentrate on advanced development rather than having to devote time to cleaning up existing problems.

They ~~We~~ also felt that by carrying on their ~~our~~ research in a particular business, the systems team would have its attention focused on specific, clearly defined problems rather than the more vague, imaginary difficulties. In this way, the creative contributions were concentrated on the areas most needing improvement.

END B

Begin D

After the multi-functional organization was completed, a clear and specific design program ~~work plan~~ was followed. The first stage was that of data gathering. This involved getting all the facts concerning present inputs and outputs, volume of devices, design variations, manufacturing facilities, historical performance, etc. This phase began in November 1958 and took approximately six months; it ~~and~~ led directly into the second phase: problem analysis. During problem analysis, all the information gathered during the first phase was digested, reviewed and an effort made to determine clear cause and effect relationship between changing external conditions and changing internal performance.

The third phase of the program was that of preliminary systems design. This achieved a first ~~verification~~ specification of what ~~may truly~~ might be called the basic system. This lasted approximately one month and brought into play the design efforts of not just the general systems designers but all the specialists in the various areas.

The fourth stage was that of detailed systems design. This refined the specifications in great detail. It clearly indicated those phases which needed to have their technological feasibility proven and those that had already been clearly demonstrated in previous work.

The fifth phase was that of construction of a prototype to demonstrate application of the new ideas. It was ~~in the vernacular,~~ a bread board model, and not yet an actual operating model.

The ~~last~~ sixth and final phase of ~~any~~ the program ~~is~~ was that of testing, training and evaluating. ~~We have been able to test this~~ The bread board model has been tested against a variety of circumstances and ~~have~~ found ~~it~~ to be very satisfactory. ~~We have been carrying out our~~ The training objective was carried out during ~~the past twelve-month period~~ 1959 along with initial evaluations of potential savings.

While these are quite conventional steps, the important new concept ~~that we felt we brought~~ in the application of the systems approach to business systems problems. ~~was the use of the scientific or engineering systems approach. This kind of technique RAND and other similar organizations have devoted to~~ military

~~systems problems.~~

NO ¶ With this systems approach, ~~we~~ they treated the entire Main Line System as though it were a big black box with only one transaction input ~~to this black box~~, the customer's order, and ~~there was~~ only a single basic output, the finished product. All that went on in between was subject to analysis and redesign. The systems approach was intended to design a new Main Line System and provide~~d us~~ an opportunity to ignore present techniques and ignore all of the conventional organizational or functional divisions of work and to really concentrate, without inhibitions, on reconceiving the solution.

End D

Beg C

~~We felt that~~ A business system~~, like military systems, would~~ ~~have~~ has five elements: ~~(Chart # 14)~~

1. It has information resources including the various decision criteria which are currently in the form of reference files.

2. It must have decision makers capable of taking the transaction inputs and matching them with the information resources to determine a course of action.

3. It must have communications channels enabling it to transmit its decisions and in turn to receive feedback info[illegible]ion concerning operating performanc[illegible]

4. It must have a physical processor which actually transforms material through the use of men, machines, and energy in accordance with the instructions given it.

5. The physical processor must have access to the physical resources of men, machines, materials and energy.

The fundamental concept in carrying out this project was the idea of vertical integration. Integration is currently a by-word, but most new work has been concerned with automating common activities like payroll, inventory control or requisition processing across many product lines or the whole business. This might be called horizontal integration. However, ~~we felt that~~ true integration should follow lines of information flow; it should cut vertically through all functions in a product line. ~~With this vertical integration, far broader opportunities for profit will be available. Why?~~ By having all the information processes linked together inside the computer, it is unnecessary for each function to duplicate the other's files. For example, cost will no longer have to maintain independent files of material lists, blueprints and planning records for every part and assembly. This elimination of file redundancy will be felt in many indirect labor activities.

Further, vertical integration of effort also has a major effect on reducing the information and physical processing time cycle. Since all of the decision-making logic needed to completely process an order is in the computer, it is reasonable to expect overnight data processing and, by having dynamic control of the whole physical process from purchasing through parts making and assembly, it is possible to reduce significantly the actual "make" cycle. This type of control should result in lower inventories, higher promises kept and better indirect labor efficiency.

A second principle is the need for discovering a ~~logical pattern~~ a logical structure or pattern which formally displays and relates the various decisions such as those in product design, facilities operation and factory scheduling. In manufacturing planning, for example, by focusing attention on each variation in method or elemental time standard, ~~you can spotlight~~ cause and effect relations can be spotlighted to aid in making ~~and thereby make~~ improvements. By organizing the multitude of detail into a clear, easy to understand framework, it shows what design characteristics control the various manufacturing process elements making clear the simplification and standardization opportunities. The use of logical decision patterns in a business should reduce direct labor and direct material through the powerful analytical insights they make possible.

An analogy to vertical integrated planning might be drawn from the design of a number of railroads in different states or countries which interconnect at various terminal points. The engineers from the individual companies building the roads and the countries planning to continue G

use the roads had better decide in advance certain basic problems like gauge of track, weight limits for bridges, clearances, motive power, signaling techniques, etc. If this type of integrated planning is not done, the result can be virtual chaos. Vertical integrated planning provides the single gauge approach to business systems design.

Another new concept was to use computers in the way that they are best qualified to work. It is certainly not true that computers should be programmed to do work the way humans have in the past. We needed to create bold, advanced, computer oriented techniques. We must have

Another basic concept was to design the system designed with the computer in mind. Although computers and humans perform many of the same tasks, their relative efficiencies and economic advantages are quite different. To arbitrarily make the computer follow the same routines, the same steps, the same processes as humans is illogical. Rather, the basic system should be reconceived and redirected to obtain maximum performance from the electronic computing equipment.

It was also quite an insight to think about the system as being directed solely toward the ultimate user, ignoring all the intermediate functional outputs that have so commonly become identified with our data processing system. The only purpose of having any operating outputs from a system is to cause someone to take action, to cause a buyer to purchase materials, an operator to make parts, etc. The intermediate transformations and hence the intermediate outputs are not essential systems elements but are only a reflection of the particular data processing techniques currently in use.

The results of ~~this type of~~ work have ~~been quite exciting. We~~ can now automatically convert a customer's order into parts of a specially designed product, performing all of the Main Line System's steps inside the computer. This automatically provides all of the factory's action documents; purchase orders, operator instructions, quality instructions, punched paper tapes to run numerically controlled machines, customer promises, bills of material, stock order recommendations, withdrawal notices, shipping papers, etc.

As a result of this Project, many new techniques were developed to help the various General Electric departments design integrated, automatic systems. For example, new techniques have been developed for decision analysis. New techniques have been conceived for part and product representation and identification. New ideas have been formulated for computer programming. All of these concepts taken together have changed ~~our viewpoint entirely as to~~ the economic feasibility of installing integrated, automated business systems.

~~We~~ feel that there are many benefits from these concepts. In order to clarify them ~~for you, I should like to describe~~ the nature of each function in the computer and some of the resultant benefits.

The determination of "What to Build" is the key role of engineering ~~and we believe that~~ the requisition engineering activities

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can now be computerized. The computer can translate a customer's wants into the specific details of the materials, parts and assemblies needed to satisfy those wants. In addition, this computerized process can avoid the necessity of having to create many of the documents and records with which we have become too familiar. Outstanding savings can be realized in the preparation of model lists, bills of material, blueprints, etc.

Included in the benefits from this engineering advance should be substantially reduced engineering time and cost through the elimination of many of the routine steps which humans now take. There should be lower drafting expense through eliminating many of the tasks which drafting has historically performed. A clear, logical statement of the engineering scope of a product line should make it easier to obtain an optimal level of standardization. A properly designed computerized engineering system should be easier to change and be more flexible.

With knowledge of the product design details, manufacturing engineering is then in a position to determine the best routing, work methods and time standards. ~~We have found that~~ Much of this work on "How to Build" the product can also be completely taken over by the computer. The possibility of automatically preparing accurate operational descriptions coupled with correct time standards for every job certainly has considerable appeal.

Another intriguing area is in the communication of the computer with numerically controlled machine tools. Three new features should have wide application.

1. A single program tape controls an automatic machine for the entire day.
2. Machined parts are automatically identified as an integral part of the program.
3. Computers are used to automatically generate machine tool programs.

"Tape-for-a-Day" Machine Tool Control. Typically, users of numerically programmed machines have achieved repetitiveness in operations by cycling a loop of punched paper tape. Thus, if ten pieces are required, the operator glues the back-end of the tape to the front and allows the looped tape to run around ten times. In this system, the same objective is accomplished by providing ten machine tool control programs in a single length of tape. Further, the same length of tape also includes a program for all other pieces to be manufactured by the machine that day. Thus, one length of paper tape provides an integrated, sequenced control program for a numerically controlled machine tool for the entire day.

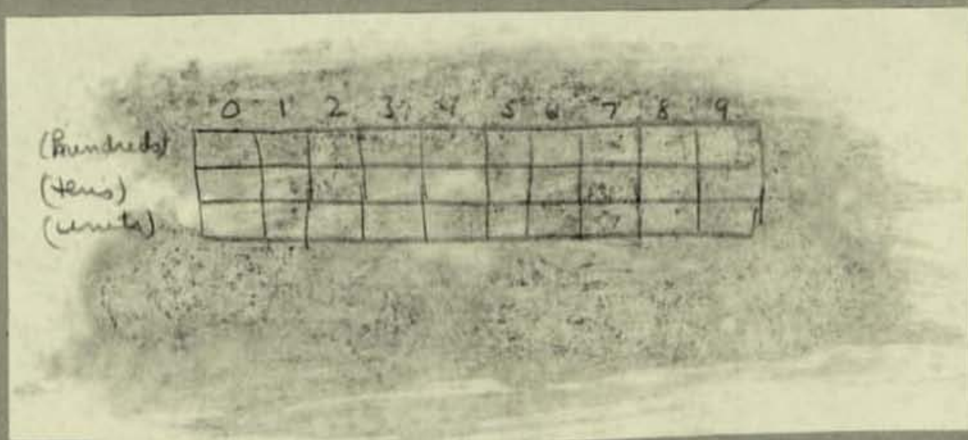
Machined Parts Automatically Identified. Parts processed on numerically controlled equipment are sometimes identified in a secondary manual operation. This can be avoided by introducing an identification step in the machine tool program. For example, parts continues ¶

can be identified with shop identification numbers by spotting a shallow blind hold in a code matrix stamped on the part itself:

	1A	2	6	51	62	64	75
●							

identification hole →

A more suitable, generalized version of this code matrix idea would be:



(include) Computer Generated Machine Tool ~~Programs~~. The generation of numerical machine tool programs was done on an electronic computer. This, of course, facilitates developing the "tape-for-a-day". While electronic computers are not essential, mechanizing the production of punched paper tapes (or cards) to run automatic machines improves accuracy and reduces cost.

Among the other benefits is ~~shorter~~ reduced planning time since the computer takes over a former manual job. There would also be reduced planning costs since computers can do this job for less money than humans and probably, most important, more accurate planning and time standards should result because of the computer's ability to follow the exact instructions ~~you've~~ given. That it has been,

Quality Control ~~can follow a very similar pattern; the key questions here are~~: at what point to inspect or test, the quality evaluation method, appropriate time standards, frequency of evaluation, and criteria for acceptance or rejection. Here again we have found that a computer program can be prepared which will perform all of these tasks automatically. This would, in effect, determine how to evaluate the product and its components. Included in the benefits are fewer quality corrections through having the proper balance between quality failure and quality appraisal costs. There should be fewer complaints through a careful analysis of customers' needs and product characteristics. There should also be lower quality costs through the integrated planning of quality control along with engineering design and manufacturing operation planning.

Cost accounting offers another opportunity. The objective was to determine ~~appropriate~~ product costs for quotation work or for cost standards to be used for comparison with actual costs. We find again that cost standards can be automatically developed and that a computer properly programmed can also be used for establishing work-in-process inventory value. Through this cost work, it should be ~~able~~ possible to obtain better cost analyses by having all the facts at our finger tips when they are needed. It would be far easier to maintain up-to-date costs because of the potential simplicity in storing the cost information. There should be reduced ~~expense of~~ cost determination through the use of a computer to replace human effort.

The next area of production control is particularly intriguing ~~over~~. Each of the previous steps in the computer portion of the integrated Main Line System have all dealt with tangible product characteristics; what to build from engineering, how to build from operation planning, etc. In contrast, production control, the final element of the computer portion of the Main Line System, develops a fourth dimension by determining the time and sequence in which main line activities take place.

Production control is interested in when things happen. It has the responsibility of actually carrying out at the right time the data processing and decision-making calculations necessary to support each function. Production control is concerned with the time inter-relationships of all customer orders. It is responsible for economically satisfying these customers' requirements considering the actual status of the shop.

Production control provides the scheduled release of the factory's action documents:

- purchase requests
- punched tape for automatic machine programs
- operator instructions [illegible] [illegible]ke and assemble products

quality instructions for inspecting and testing

shipping papers to deliver the customer's

product

In this integrated system the computer should daily schedule shop operations, specify operation release dates and due dates, specify specific order quantities, review inventory stock levels and issue customer promises. These orders should not be released prematurely. One key element in computerized manufacturing control is frequent feedback coupled with frequent scheduling for close shop control; using today's performance to guide tomorrow's shop decisions. In the past, a major obstacle to such tight shop control has been the mass of detailed data which had to be gathered and interpreted before any meaningful results could be obtained. Manual and even punched card techniques often sagged under this burden, but electronic computers offer the high speed, low cost calculating ability necessary to cope with this problem.

The Integrated Main Line System has daily feedback of completions ~~from each of the various areas of the shop~~. This information will be digested by the computer each night and recognized in the releases to be prepared for the following day. The parts to be started the next day will depend upon the exact status of each of the areas of the shop; whether they be behind schedule or ahead of schedule, what their status is on rush jobs and related information.

The result is a flexible system prepared to respond quickly and

Continue F

accurately to changes. Time delays in handling information are avoided and corrective actions can be initiated immediately throughout the Integrated Main Line System.

Developing ~~manufacturing~~ production control rules presents some special difficulties. For example, product performance can be proven in the laboratory, operation time standards can be checked by a stopwatch, but how can you pretest a rule for customer promising? General Electric has been instrumental in applying simulation techniques to similar business problems involving many interdependent activities that change with time. The heart of shop simulation is a computer model which realistically duplicates the behavior of the shop as it processes customer orders, making allowances for set-up and processing times, absenteeism, machine breakdowns, and the like. The specific computer model developed for the Integrated Systems Project compressed four months of shop experience into a fifteen minute computer run. As a result, it was possible to test how well various proposed sets of production control rules would meet due dates and planned cycle times without actually trying them in the shop. In addition, inventory levels, employment stability and man-machine utilization could also be evaluated and compared. ~~A series of such tests provided the basis for estimating and selecting the Integrated Production Control Rules.~~

Integrated production control offers several benefits. For example, it now seems quite practical to obtain a shorter main line information cycle -- actually less than one day. Similarly, electronic computers can be expected to lower paperwork costs. Shorter cycles in the office and factory, as well as improved scheduling techniques, will permit substantially lower inventories. These improvements should lead to shorter customer promises, improved service and potentially higher sales. Somewhat unexpectedly, indications are that these gains can be achieved while improving employment stability -- and without a sacrifice in promises kept and equipment utilization.

Of course, the only reason for all of this information is to procure the parts that are needed, on schedule, at optimum cost; and to direct the machines and operators in the factory to make the right parts at the right time. This leads directly to the concept of flexible factory automation.

Rather than visualizing automation as a long line of highly specialized machines and transfer devices, we believe, for our General Electric type of businesses, that the important aspect of automation will be the ability of machines to switch from one task to another at little or no extra cost. The inherent flexibility of the individual machine or group of machines will be a determining factor in the effectiveness and usefulness of these automatic systems concepts. With numerically controlled machines, such as are now available, the set-up cost is generally reduced to practically zero, and as those who have worked on inventory control problems will recognize, this implies that the economic lot size can be reduced to one. Hence, flexible factory automation permits direct to response to the external, customer oriented requirements and not give such such heavy consideration to the internal shop.

(SLIDE A-21)

Through This flexible factory automation, we believe that we will be able to lower direct labor costs per unit through replacing human activities, where desirable, by machine operations. Machine accuracy and set-up flexibility will reduce both scrap and rework. Integrated planning and control with the right tempo will result in shorter manufacturing cycles.

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The future of integrated systems planning is an exciting one, but some of the problems which we face are certainly significant. I would like to list some of these problems and opportunities to give you some feeling for the scope of our future work.

(SLIDE K-2)

Decentralization has many advantages, but one problem is the lack of suitable computer equipment for performing such massive data processing tasks. We find in General Electric individual locations which cannot by themselves justify either medium or large-scale data processing equipment. What should be done in these areas? Is there a possibility of combining the needs of a number of these locations to support a computer? We've discussed having a major business locate its plants on the periphery of a wheel whose hub was the plant headquarters. We have wondered about connecting these plants through wire transmissions or microwave so that the information for decision-making could be fed to the hub location for processing and the answers radiated back out to the individual plants.

In new plant location studies, we have always made a careful analysis of the size of the plant and the amount of labor available in the community, the water and power supply, etc. However, now that indirect labor exceeds direct labor in many cases, now that the major improvement opportunities are available in data processing, why should not the economic availability of electronic data processing be an essential consideration in plant site selection?

Also, we have become aware that while we have concentrated on reducing our data processing operating costs, we have given inadequate attention to the start up and maintenance costs of our computer installations. Intensive research is now required on ways to accelerate the installation of new systems and ways of reducing the cost of maintaining and modifying its programs. This compression of the innovation cycle can be a major factor in our ability to compete effectively in the future.

An interesting economics problem is posed by the impact of these automatic systems on our fixed and variable costs. With the higher investment both in factory and office equipment and the simultaneous reduction in the variable cost per unit, we have business systems and factory systems dedicated to growth, since with growth the full profit-making potential will be fully realized. What will this kind of business system mean in terms of inventory accumulation and in terms of product pricing?

It has been our experience that as the breadth of an application increases, the complexity of conceiving and installing a system grows with something like the square of the number of functions involved. (SLIDE K-3) We must establish tools and techniques for coping with this increasing systems complexity to allow our systems designers to get their mental arms around the problems.

As with any new development, there is, at least temporarily, (SLIDE K-4) an acute shortage of competent trained systems designers. These men will have to be developed by the colleges and through on-the-job courses and training. This implies the development of a body of knowledge to draw on so that systems design principles and tools may be properly taught. These systems designers must learn to extrapolate wisely from basic fundamental ideas to develop the best system that should be installed in a given plant.

Returning to the problem mentioned earlier, (SLIDE K-5) we have to face up to organizing such broad systems studies. Who in the business organization should be made responsible for determining the need for such work and for actually carrying it out? Because of the multi-functional nature of these problems, how can effective cooperation be insured, who should take the initiative? In General Electric there has been developed, over the past ten years, a clear concept of the work of a manager and the work of an individual contributor. We have carefully defined the responsibilities of each individual function of the business. In this same way, we must now analyze in detail the mortar that holds these bricks together. We must describe the kinds of people and the kinds of responsibilities that are required to constitute the most effective kind of mortar. It is even conceivable in some daily operating areas that the mortar will take over the whole operating responsibility, sort of like going from a brick building with mortar in the interstices to a concrete building, which eliminates the individual bricks entirely.

Our evaluation of new systems is generally quite inadequate. We must devote substantial research effort to deriving and determining better measurements of business performance. We have got to stop palming off the decision-making problem on intuition. We have to quit blaming the lack of progress on the intangible nature of the savings from new equipment and new concepts. As a starter, we suggest that at least three factors need to be considered: Time, Cost and Accuracy. Time includes not just elapsed time between two events such as between the receipt of an order and its delivery, but also response time; how quickly can a business change direction when external conditions require it, how quickly can it innovate? In considering Cost, we have to think not only about actual operating costs but also investment cost and modification cost. We have to stop applying broad overhead factors because the base

Omit /

of our overhead -- direct labor -- is fast disappearing.

The Accuracy factor is quite complex. It includes not only the quality of the product but our ability to meet promises, degree of employment stability, utilization of equipment, reliability of forecasts, etc.

To close, I believe that there has been one idea which alone has been more important than any of the individual techniques developed by our integrated systems planning work. It seems to be the fundamental principle underlying the success of our multi-functional team studies and clearly pointing the way to future progress. This is SYNERGISM, the sort of a situation where 1 + 1 = 3. Where two things taken together have a greater total effect than the sum of the individual items taken alone. To us "synergism" is the key that will open the door to future industrial progress. We have seen creative men of widely varying functional backgrounds agree on a common goal, forget their functional bias, forget today's conventional business system, and achieve results that are inspiring, results that are most rewarding.