Another important lesson for organizational charting can be learned from viewing the organization as a system. Every complicated electronic or servo system has:

1. A block diagram showing the main function and the over-all systems behavior.

2. A systems chart showing only those operations which directly contribute to performances.

3. A layout diagram showing physical details.

These charts are developed together.

The parallel in an organization is:

1. The functional chart showing the main operating units and the over-all behavior.

2. The systems chart showing the basic logical and quantitative operation performed.

3. The procedures chart showing the physical details of paper work and control procedures.

These charts should be developed together. Any attempt to design new procedures while neglecting to develop the functional and systems theory of the organization is bound to suffer from that lack. Also the common attempt to manage an organization from the functional point of view without developing the systems theory is afflicted by the lack of control on basic procedural costs and performance. The systems view relates basic procedures with functional behavior. Since most business corporations are more complex than a television receiver, this systems lack must be and is serious. This complexity is inherent in the control procedures of organizations and is aside from and in addition to the profound complexity of human relationships found in organizations. Indeed the relationship factor alone is so difficult that managers have been able to handle their systems problems in a non-professional manner because of the magnitude and importance of the human problems. However, it is becoming apparent that many human problems are basically systems problems in nature. Thus, we have the exciting prospect that a systems theory for organizations will permit better utilization of human qualities under more comfortable human conditions.

INTRODUCTION

The purpose of these remarks is to point out that over-all purposes of an organization and its compatability with these purposes are of great importance, even in detailed procedures design. The notion that systems design can be considered as a problem devoid of human considerations has been proven false. Even if human beings are engineered out of a system, other human beings must be on hand to maintain and operate the system. They must have a clear understanding of the purposes and the system so that they can understand the procedures (the automatic equipment). Thus, whether procedures are completely manual or completely automatic, the objectives and basic systems problems are the same. Whether they can be solved may well depend on developing new procedures, but the new procedures are about as important to organizational theory as new alloys are to automobile motor or to turbine design. The alloy may be crucial, but it cannot solve the systems problems.

Fort Wayne, January 14, 1957

PRODUCT STRUCTURE REPORT - 39 FRAME MOTOR

The usual material lists and drawings created by Engineering present model-component, assembly-component, part-material and part-feature relationships for individual models, assemblies, and parts. Manufacturing control procedures can be simplified by a knowledge of how universal these relationships are for all models, assemblies and parts within a given product line. For example, it turns out among 39 Frame Motors that shell length and base length are directly related and thus in control procedures these can be indicated by the same bits of information. On the other hand, shell length and stack height are roughly correlated but enough exceptions occur (some at customer request) so that these dimensions must be indicated separately.

Engineering material lists and drawings are mandatory for manufacturing as source documents. But when a product line has been in manufacture for some time, there develops among the direct labor, knowledge about the product line as a whole. For example, those working on end shields know there are basically about a half a dozen different wick and cap combinations. They need only to know which combination is desired in order to assemble the correct end shield. They have no need for the full engineering drawing numbers since their familiarity with the combinations is such that they will know what goes together in the various combinations. Thus they could be informed by a much simpler language such as: WICK SET E CB. This is easy to read and has some mnemonic value: it means non reversible, extended shaft, cushion ring B. Furthermore, this is part of the code which specifies both end shields used in the motor. The code for both end shields would be: SP CB. This means: non reversible, single shaft extension, open casting, disk type overload, no BX hole, no BX connector, regular oil, cushion ring A with no ground. This completely specifies both end shields and takes the place of the following information:

PULLEY END SHIELD

	PART
343C700AN-G2	323D700AD-P1
	425B116 -P1
	425B111AB-P1
	625A889 -P1
	625A890 -P1
	625A817AA-P3
	625A827AM-P1
	625A827AP-P2
	625A827AW-P1
	625A827AX-P1
	625A871AA-P1
	625A891AB-P1

OPPOSITE PULLY END SHIELD

PART

343C700AB-G2	323D700AA-P1
	425B116 -P1
	425B111AB-P1
	621A809AB-P1
	625A889 -P1
	625A890 -P1
	625A817AA-P3
	625A827AM-P1
	625A827AP-P2
	625A827AW-P1
	625A827AX-P1
	625A871AA-P1
	625A891AB-P1

Note that the Wick set code contains an E while the End Shield code does not. This is done automatically for the wick assembly station since that station must know when it is working on an extended shaft end shield of which at least one occurs in every motor. The End Shields code contains a D if the motor has a double extension shaft. Thus, by a simple pass or no pass filtering, the end shield code is broken down to be the action code for each station.

The Product Structure study begins with a study of the relationships implied by an entire product line as suggested above. It discovers those characteristics which have a broad effect on the relationships. For example, stack height and reversibility affect many parts in several of the major sub assemblies. On the other hand, totally enclosed versus open cased motors turns out to be not a useful characteristic to isolate for manufacturing control procedures. The reason for this is that many closed stator shells are used with open end shield castings. Thus, although closed end shields appear always to be accompanied by closed shells, this is not a useful characteristic. One would say that a closed end shield implies a closed shell but not conversely. But, for example, reversibility always implies double oil groove on the shaft, wound shading coil, some different and additional wicks and caps, etc. and conversely.

Other characteristics in combination will act similarly. For example, reversibility, stack height, vertical mounting, and number of poles completely determine the rotor core (aside from the aluminum end casting), the stator coil, slot insulation, winding height, shading coils and tape.

Although open versus closed casing is not a useful general characteristic, it is useful as a variable of the end shields. Useful variables are those which in combination with one another and the characteristics allow the motor to be completely specified in a simple way. For example, shells have holes on one end and some on the other and some on both and some not at all. These four combinations are most simply taken care of by specifying holes on each end separately. These two variables nicely take care of the four combinations. On the other hand, if open or closed where specified, we would still have three combinations of open to indicate: open on one end, open on the other, open on both.

The considerations suggested above entered into the chosing of characteristics and variables. Also considered were the needs of operating people and the abilities of computing equipment. For example, the code suggested above: SP CB could have been replaced by 1 2: where the other choice for 1 is 0 and the 2 could have been 1 or 3. But this is not as suggestive to the viewer and might lead to confusion among the digits. If complete automation occurs, this change can be readily made <u>within</u> the equipment. The mnemonic code is intended for use by the designers, builders, and maintance and operating people of the automatic system. It can be used on circuit and wiring diagrams. Prior to this, it can be used in present procedures in the factory.

A computing equipment consideration is the balance between interpretive equipment, number of relays and number of relay points. For example, suppose there are six choices (as with stack height) and we desire to both multiply by stack height (to obtain total number of punchings) and to indicate stack height (for printing schedules or automatically controlling production). Since a rotor stock of 30 punchings per rotor corresponds to a stator stock of 34 punchings per stator, it would appear that if rotor usage is used as the basic variable, then the stator usage must be derived by interpretation before multipication. If the simplest binary code (3 binary "bits") is used, then both usages must be obtained by interpretation and all printing would have to be emitted and selected through relay points by the equipment. A six digit binary code increases the number of relays but greatly decreases the number of points used. Thus many considerations enter into the choice of codes. It is often not best to choose the briefest code and it is usually best to have a redundant code if it is to be read by operating people.

Another feature of the product structure is a statement of historical volumes, not only of models, but of all assemblies, parts, materials, operations, machines, set ups and labor grades. This history should be updated to increase its usefulness. For example, end shield casting 750 series is no longer made and its volumes should be added to the 700 series with the same finishing operations. In a custom business history has not the full meaning found in a business where each product has many products. In this case, statistical marketing analysis is less useful. Better is a forecast of each application of each customer and the likely model he will require and the likely volume. This information, originating with salesmen and district offices can create a heavy data processing burden. Thus, manufacturing finds a heavy data processing burden to reflect model volumes into assembly, parts, materials, operations, set ups and labor grades, and marketing finds a heavy data processing burden to process salesmens estimates of future individual customer applications into a total product line forecast.

Fortunately, one of the benefits of the study of the material list information and resulting abbreviated codes is that a far more efficient data processing system can be designed. This system can be used for control procedures prior to complete automation and it can be used for research studies (before or after complete automation) by manufacturing, marketing research, engineering and cost accounting.

Two factors lead to a remarkable improvement in data processing efficiency:

(A) The use of condensed codes such as described above.

(B) The use of standard punched card equipment in a novel manner suggested by large computer techniques.

It is possible to place the complete breakdown of a 39 Frame Motor on one IBM punched card. This includes all major assemblies, variable parts and many of the variable factory operations. It also includes space for:

Customer Number

Week Number, Day Number (or other time interval)

Product Class

Volume

Stage (whether the card corresponds to an order, shipment, forecast, weekly schedule, daily schedule, cost calculation, customer historical report, etc.)

These cards, as shipment cards, are now in existence for the motors with a volume of 20 or over in the first 10 months of 1956, although the complete coding of all parts has not been finished. It is of interest to note that the variables of both end shields are coded in one column of the card. This card contains, at present, some factory operations as well as material breakdown. For example, the variable finishing operations performed on end shield castings are specified.

Such a card can be used for many purposes. For example:

(A) When used for historical analysis of the regular 39 Frame detailed shipment cards as maintained by Materials Sub Section, these cards can be sorted and listed in many ways. Several historical reports have been run off and are now available:

1. Each model summarized by week with a final total.

2. Each Winding and Test Spec summarized by week with a final total.

3. Each Product Class summarized by week with a final total.

4. Each Week broken down into stack height volumes with a total for the week (reversible and non-reversible separate).

5. Each Week broken down into Voltage with a total for the week.

6. Each Week with a sub total for every variable end shield feature with a total for the week. For example: the total quantity of BX connect -ors required each week is given. Each report required about 35 minutes to run on an IBM sorter and 407 tabulator. An ideal machine for this purpose is the IBM 407 tabulator Model IV with all extra features added.

(B) Many other reports can be run from these cards such as volume for any major assembly or combination thereof.

(C) For purposes of obtaining more information from district salesmen about individual customer future behaviour it is possible to run a report sorted by model number and then customer number. The report is separated by customer number showing the 10 months volume for each customer with subtotals for each model he purchased.

With this information before him, the salesman is better able to forecast a future volume for that customer <u>by application</u> rather than model. Thus, if he believes a new model will replace an old one, he so notes. This information is jotted down beside the listings and a copy returned to the department. The forecasted period is predetermined by the department. The notes returned to the department are key punched in the basic cards with customer numbers. Sorted, totaled and listed by the model number, this constitutes a salesmen's forecast for the product line. These cards retained and later compared with order or shipment cards for that time period will provide a comparison (made by machine) for each salesman's forecasting and each customer's predictability. In time this will result in a more factual and controlled estimate of future sales, a highly desirable development as automation increases in the factory.

The product structure project has not entered far into factory operations and much must be done to complete the coding of parts and operations in major assemblies other than the end shields. Furthermore, an IBM program for handling the cards must be established in Fort Wayne.

The following sections give the detailed results to date:

Fort Wayne, January 14, 1957

I MODEL CHARACTERISTICS AND THEIR CODES

The function of a product structure study is to reveal the exact nature of the three types of variation facing manufacturing control:

1. Variations in components and operation as revealed by all material lists, drawings, and instructions taken together.

2. Change in mix as revealed by a year of history.

3. Relative cost variations among components.

In this study, it developed that a coding of variables was desirable for several reasons:

1. It is becoming known that the drawing number codes used by Engineering to uniquely determine every product, assembly, or part among all General Electric fabrications is unnecessarily cumbersome for use on the factory floor or in manufacturing control procedure.

2. To arrive at a mix history for all products, assemblies, parts, and materials, required on automatic explosion procedure which in turn would greatly benefit from simple codes.

3. The Business Systems Project intends to design automation equipment for 39 Frame Motors. The designers will need an equipment systems language for use in designing, building, and maintaining their equipment.

Furthermore, it was seen that codes would be needed for various purposes:

1. A simple numerical code is needed to indicate the basic variations.

2. A mnemonic code is given to be used by factory people and equipment engineers. This has been done only for the motor characteristics and the end shields, so far.

3. An IBM code for an IBM machine system to be used for obtaining the historical data, for other research purposes and for its own inherent value to operating people.

Fort Wayne, January 14, 1957

The model characteristics chosen are:

	CHARACTERISTIC	CODES BINARY	DECIMAL	IBM	MNEMONIC
1.	Stack height		1-6	3-8	S
2.	Four pole instead of six pole	0,1			4 P
3.	Reversible	0,1			R
4.	Shell length		1-8	1-8	H
5.	Vertical (pulley down)	0,1			VP
6.	Vertical (opposite down)	0,1			VO
7.	Double extension	0,1			D
8.	Disk type overload	0,1			SP
9.	Thermostat overload	0,1			TH
10.	Counter clockwise rotation instead of clockwise	0,1			CCW
11.	Two speed	0,1			2 Z
12.	Three speed	0,1			3 Z

Stack height (S), polarity (4P), reversibility (R), determines the rotor and stator punchings and cores, with the exception of the wide slot rotor punchings 423 B 130 AAPI recently introduced for certain six pole motors. The two stator punchings indicated for reversible motors differ only in that 343 C 203 ADPI has a small hole in each pole area for a plastic winding retainer peg. Slot insulation, shading coils, tape, winding height and keys are also determined by S, 4P, and R. These facts are summarized on Table A. Rotor shafts are an independent variable. Shell length (H) determines oil groove to oil groove distance. Direction of rotation (R,CCW) determines the nature of the oil grooves and is recorded in the rings machined into the end of the shaft. Double extension (D) directly affects the shaft, of course. In addition, the shaft has many variable features.

Construction for vertical mounting (VP, VO) may occur for either end down or both, leaving the option to the customer. The lower end is changed in that a different thrust plate is used in the end shield, a different metal oil slinger is pressed on the shaft and a thrust washer is placed on the shaft to ride between the oil slinger and the thrust plate.

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Aside from the motor characteristics and the shaft, the only other rotor variable is the aluminum end ring casting.

Reversibility affects the wicks and end caps of the end shields, the grooves on the shaft, stator punching, shading coil, adds end punchings to protect the shad-ing coil winding, and affects the number of input leads.

Four pole motors have different punchings and winding heights. The clamp bolts are also placed through different holes in the end shields.

Shell length (H) is not determined by stack height (S) because customers may specify that different capacity motors be mounted in the same base. Shell length is correlated with base length and determines groove to groove distance on shafts.

Double extension motors require that both end caps be punched out. Oil slingers are used only with, and with all punched out end caps.

The disk type Spencer overload is mounted in the opposite pulley end shield. Special leads (Leads A and B) are spliced into the stator winding to connect the disk overload.

The thermostat overloads are Spencer or Creeper types and are tied between two poles of the stator.

Motors with overload protection are so marked on the end cap.

Direction of rotation affects the shaft oil grooves and the orientation of the stator and rotor core in assembly.

Number of speeds (2Z, 3Z) affects windings and the number of power input leads, an additional lead for each additional coil.

Name plate data is found on the Winding and Test Specifications. The same physical motor may have different test specifications and thus a different model number.

A study of Winding and Test Specifications was made by the Stator Winding Project, a copy of which is included.

II END SHIELD VARIABLES AND CODES

It was found useful to consider both end shields together. The overload, BX or leads holes are always on the opposite pulley end if they occur. Cusion rings occur on both ends if they occur (one exception was found). The codes are designed so that they readily separate without interpretation into codes for the individual end shields.

There are two basic end shield castings, closed and open. A closed end shield is always used with a closed shell (without row holes) but not conversely. It has been chosen as a variable:

	Codes	
	Binary	Mnemonic
Open	0	
Closed	1	CL

All end shield castings have a sleeve bearing, 625A890-P1 (usage = 2) inserted. The bearing is machine bored, the casting is fan stepped, and the rabbit sheered. Three additional operations may be performed: overload hole punched out, BX connector mounting holes drilled, the leads hole finished. For closed end shields the desired clamp bolt hole must be open -ed, one set for four pole and one set for six pole. (On the open casting both are open).

Operation	Binary Code	Mnemonic Code	Other
Overload hole open	1	SP	
Overload hole closed	0		
BX holes	1	BX	
No BX holes	0		
Leads hole finished	1	LH	
Leads hole not finished	0		
Closed end shield, 4 pole holes			CL,4P
Otherwise			

Fort Wayne, January 14, 1957

These variations account for all finished castings as follows:

Casting Drawing #	O'load	BX Hole	Lead Hole	Closed Casting	4 Pole Clamp Hole
323D700AA-P1	SP				
323D700AB-P1	SP	BX			
323D700AD-P1					
323D700AE-P1		BX			
323D700AG-P1			LH		
323D700AH-P1	SP		LH		
323D702AA-P1		BX	LH	CL	
323D702AB-P1				CL	
323D702AC-P1			LH	CL	
323D702AD-P1	SP			CL	CL,4P
323D702AE-P1				CL	CL,4P

The series 323D750 --- was an open casting made in 1956, but has been discontinued.

Usage --- each motor receives 2 basic castings, both closed or both open.

The BX connector is mounted by a self tapping screw.

		Binary	Mnemonic	Usage
Connector	621A817AA-P8	1	B X C	1
Screw	N106P13004B	1	B X C	1

Punched overload holes receive a cap.

		O'load	Usage
Cap	621A809AB-P1	SP	1

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-B- (Continued)

Three cushion rings find usage.

	Binary	Mnemonic	Usage
Cushion ring 425B110-P1	1	CA	2
Cushion ring 425B116-P1	1	CB	2
Cushion ring 425B120-P1	1	CC	2

The cushion ring may be grounded on the pulley or opposite end or not at all.

	Binary	Mneomic
Pulley end	1	GP
Opposite end	1	GO

If grounded, then the cushion ring and strap constitute a group number.

Group and Parts	Cushion Ring	Ground Code	Usage
425B110AA-G1	CA	GP or GO	1
Cushion Ring 425B110-P1	CA		
Strap 625A808AB-P1	CA	GP or GO	1
425B120AA-G1	CC	GP or GO	1
Cushion Ring 425B120-P1	CC		
Strap 625A808AC-P1	CC	GP or GO	1

End caps are completely determined by other variables. A different cap is required to hold the cushion ring, if it occurs. Reversible motors require a larger cap. Reversibles with cushion rings have not been made as yet. These three varieties: reversible, cushion ring, neither, may or may not be punched for an extended shaft.

End Cap	Reversible	Cushion Ring	Punched	Usage
425B111AA-P1		C		1
425B111AB-P1		C	E	1
425B111AC-P1				1
425B111AD-P1			E	1
425B111AE-P1	R			1
425B111AF-P1	R		E	1

Every end shield with punched end cap for an extended shaft also has a rubber oil slinger. Its usage on any motor is one for single extension, two for double extension.

Slinger	Extension Code	Usage
625A889-P1	D or E or DE	1 + 1 (if D)

The thrust plate adjacent to the rotor may have to support the weight of the rotor if the motor is vertically mounted. In this case, a different thrust plate is used.

Thrust Plate	Pulley Down		Opposite Down	Usage
625A871AA-P1	Not VP	and/or	Not VO	1 (if not VP) + 1 (if not VO)
625A871AD-P1	VP	and/or	VO	1 (if VP) + 1 (if VO)

The felt oil return wick varies according, as the motor is reversible or not. Two extra wicks and a spring steel wick retainer are used on reversibles. The thrust plate retainer wick, the packing wick and the inner oil well cover are standard on all motors.

Wick or Part		Reversible	Usage
Oil Return	625A827AM-P1		2 (if not R)
Oil Return	625A827AY-P1	R	2 (if R)
	625A827BB-P1	R	2 (if R)
	625A827BB-P1	R	2 (if R)
Wick Retainer	625A871AB-P1	R	2 (if R)
Washer Wick	625A827AP-P2	On All Motors	2
Packing Wick	625A827AX-P1	On All Motors	2
Retainer Wick	625A827AW-P1	On All Motors	2

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Two cases were found where low temperature oil was specified. This was added as a variable.

OIL	BINARY	MNEMONIC
Regular	0	
Heavy	1	LO

Reversible motors require more oil. There are three possibilities.

Oil Drawing #	Reversible	Low Temperature	Usage
625A817AA-P3			2
625A817AA-P4		LO	2
625A817AA-P8	R		2

END SHIELD CODING AND CHARACTERISTICS

TABLE B

END SHIELD PAIR			X Code	12	11	1	2	3	4	5	6	7 (or 5,6)	8	9		
	Opp. P. E.	P. E.	Char.	Cast.	Spen. O'Load	BX Hole	BX Conn	Leads Hole	Low Temp. Oil	110	116	120	G(ope)	G(DE)	End Caps	Clamp Holes
Drawing 343C700	AA1	AN1			SP					CA					C	
(Open	AA2	AN2			SP						CB				C	
Casting)	AB1	AN1			SP					CA					C	
	AB1	AN4			SP					CA				GP	C	
	AB2	AN2			SP						CB				C	
	AC2	AN2			SP	BX	BXC				CB				C	
	AD1	AS1			SP	BX	BXC					CC			C	
	AH1	AS1			SP							CC			C	
	AH3	AS1			SP			LH				CC			C	
	AH4	AS1			SP			LH				CC	GO		C	
	AL1	AR1			SP											
	AL1	AR3	VP		SP											
(*Cushion ring with end cap	AL1	AN2*			SP*						CB*				C*	
on pulley end only)	AL2	AR2			SP				LO							
	AM1	AN1								CA					C	
	AM2	AN2									CB				C	
	AN1	AN1	D							CA					DC	
	AN1	AN4	D							CA				GP	DC	
	AN2	AN2	D								CB				DC	
	AP1	AR1														
	AW2	AN2				BX	BXC				CB				C	
	AX1	AR1				BX	BXC									
	AY1	AS1				BX	BXC					CC			C	
	BA1	AS1										CC			C	
	BA2	AS1						LH				CC			C	
	BA3	AS1										CC	GO		C	
	BC1	AR1						LH								
	BE1	AR1				BX										
	BF1	AS1			SP	BX						CC			C	
	SA1	AS1														
(Reversible)	AG1	AT1	R												R	
343C702	AA1	AB1		CL		BX	BXC	LH								
	AC1	AD1		CL							CB					
(Closed)	AC2	AD2	4P	CL	SP						CB					4P
(Casting)	AE1	AB1		CL												
	AF2	AD1		CL				LH			CB					
	AG1	AB2	4P	CL	SP											4P

Notes on End Shields (Exceptions noted by *)

1. Four operations occur on every casting: Sheer rabbit, insert sleeve, face step machine bore.

2. On closed castings the clamp holes opened are determined by 4 pole vs. 6 pole.

3. End caps are completely specified by single vs. double extension, cushion ring or not, reversible or not.

4. Overload always on Opposite pulley end.
   BX hole " " " "
   Leads hole trim " " " "
   Cushion rings" " both ends.

5. Reversible motors get different wick, rubber oil slinger and end cap set. Vertical mounting adds thrust washer and new thrust plate.

   End shield binary code completely specifies both end shields. Code "7" can be replaced by "5" and "6". Thus 16 binary bits specifies the end shields.

CODE	Motor Characteristics	CODE	End Shield Variables
R	Reversible	1	BX hole
D	Double extension	2	BX connector
4P	Number of poles	3	Leads hole finish
VP	Vertical (pulley end)	4	Low temp oil
VO	Vertical (opp. pulley)	5 only	Cushion ring #110
VOP	Vertical (both)	6 only	Cushion ring #116
		5,6	Cushion ring #120
		8	Ring ground (O.P.E.)
		9	Ring ground (P. E.)
		11	Spencer overload
		12	Closed casting

Fort Wayne, January 14, 1957

III CORE AND WINDING VARIABLES AND CODES

Rotor cores vary with the characteristics R, S, P (reversibility, stack height, and number of poles) as indicated on Table A. A new rotor punching, 423 B 130 AAP 1 with large slots is being engineered into six pole motors. It will not replace the other punching, 423 B 112 AAP 1 in all motors. The choice between these two is thus a variable.

Rotor cores may be cast with a large or standard end ring. The standard always has fan blades. Four pole motors always use the standard end ring. The large end ring may or may not have fan blades. One kind of aluminum ingot is used. Because of variable spoilage, the amount of aluminum is not shown on material lists.

As indicated by Table A, stator punchings are determined by the characteris -tics R, S, P, with the single additional variable that reversible motors may have either punching 343 C 203 AAP 1 which has no holes for the winding peg or 343 C 203 ADP 1 which has holes for the winding peg.

Two lead point tapes occur: 623 A 112 AAP 1
623 A 302 ABP 1

Special leads (Leads A and B) are used with Spencer disk type overloads. One case was found when the stator winding is connected directly to the terminal of the overload. This is considered an exception, thus Spencer disk overload always implies leads A + B of which there are four choices. (See Table C).

Certain Creeper thermostats are covered by insulation sleeves. Table C gives the codes for the variable described above.

There is a high correlation between horsepower - voltage and the specific overload required. It is believed however that the correlation is not high enough to handle deviations on an exceptions basis. Therefore, a two digit decimal code has been assigned to specify the individual overload:

Numerical code gives individual thermostats

X in tens column - Spencer disk type

X in units column - Thermostat type

TABLE A TABLE A

CORRELATION BETWEEN DRAWING NUMBERS AND STACK HEIGHT

	Stack Height	ROTOR Drawing #	ROTOR Core	Punching	STATOR Drawing #	STATOR Core	STATOR Punching	Slot Insulation	Winding	Wind. Height	Shading Coil	Shading Coil Tape	Keys
		423B	423B	423B112AAP1	343C	423B	343C	115A902	343C	621A803AAP1	623A		625A 806DA
Four Pole	B	423B211	423B206AAG1		343C 550	423B511 AAG1	343C 202AAP1	115A902 BAP24	343C607		623A102ABP5		P5
	D	423B212	423B206AAG2		343C551	423B511ABG1	343C202AAP1	115A902BAP25	343C608		623A102ABP2		P2
	F	423B213	423B206AAG3		343C552	423B511ACG1	343C202AAP1	115A902BAP26	343C609		623A102ABP3		P3
	K	423B214	423B206AAG4		343C553	423B511ADG1	343C202AAP1	115A902BAP27	343C610		623A102ABP1		P7
Reversible	D	423B225	423B200AAG1	423B109AAP1	343C525	423B520ABG1	343C203ADP1	115A902BBP1	343C611	621A803ABP1	623A107AAG1	625 P1	P2
	H	423B226	423B200AAG5		343C526	423B521AAG1	343C203AAP1	115A902BBP3	343C612		623A107AAG3	A110 P2	P1
	B	423B227	423B200ABG2		343C527	423B522ABG1	343C203ADP1	115A902BBP4	343C615		623A107AAG4	AK P4	
Six Pole	H	423B250	423B203AAG1		343C502	423B500AAG1	343C201AAP1	115A902CAP4	343C601		623A102AAP1		P1
	D	423B251	423B201AAG1		343C500	423B500ABG1	343C201AAP1	115A902CAP2	343C603		623A102AAP2		P2
	F	423B252	423B202AAG1		343C503	423B500ACG1	343C201AAP1	115A902CAP3	343C604		623A102AAP3		P3
	M	423B253	423B200AAG9		343C504	423B500ADG1	343C201AAP1	115A902CAP6	343C606		623A102AAP4		P4
	B	423B255	423B204AAG1		343C505	423B500AEG1	343C201AAP1	115A902CAP1	343C614		623A102AAP5		P5
	D		423B291AAG1	423B130AAP1	343C500	423B500ABG1	343C201AAP1	115A902CAP2	343C603	↓	623A102AAP2		P2

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TABLE C: CORE AND WINDING CODE

VARIABLE	BINARY	DECIMAL	IBM CODE
Large end ring	0,1	-	12
Fan blades	0,1	-	11
Rotor punching with large slots	0,1	-	0
Stator punching with peg holes	0,1	-	1
Lead tape joint 623 A 302 ABP1 instead of 625 A 112 AAP1	0,1	-	2
Insulation sleeves occur	0,1	-	3
Lead A and B:	---	1,2,3,4	--
623 A 200 AAP 19			4
623 A 200 ABP 47			5
623 A 200 ABP 71			6
623 A 200 ACP 7			7

IV SHELL VARIABLES AND CODES

Shells may have complete row holes on either end, both, or neither. If the leads emerge from the shell on the end which has complete row holes, then one of these holes is used as a leads hole. The leads may emerge through an end shield. Ordinarily if the leads emerge through the shell, they will emerge from the right side (looking at the opposite pulley end with the shell weld down). If BX connector holes are drilled, they are placed above and below the hole used as a leads hole:

Shell

BX Holes

Leads Hole

Drain holes may occur on either end, both or neither. They do not occur if complete row holes occur on either end.

Table D gives the codes for these variables.

Fort Wayne, January 14, 1957

TABLE D: SHELL CODES

VARIABLE	BINARY	IBM CODE
Complete row holes pulley end	0,1	9
Complete row holes opposite end	0,1	8
Drain hole pulley end	0,1	7
Drain hole opposite end	0,1	6
Leads hole in shell	0,1	5
Leads hole in pulley end	0,1	4
Leads hole in left side	0,1	3
Conduit box or BX Hole	0,1	2
Conduit box instead of BX Connector	0,1	1

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V CORDS AND LEADS VARIABLES AND CODES

Input current wires may be separate (leads) or they may be bound together (cords). Style and current rating varies. A round or rectangular bushing is used according as the cord or leads are taken out an end shield or the shell. Reversibility and Multiple Speed determines the number of wires which are brought out. Each lead or wire of a cord may be cut to a different over all length. The ripback of a cord on the motor end may vary but the various wire lengths and stripping are the same on the motor end. The ripback of a cord on the outboard end varies in length and the various wires may have different lengths. The amount of stripping, the presence of a terminal and the kind of terminal varies from wire to wire or lead to lead on the outboard end.

The assigning of codes which will reveal the basic operations on leads and cords must be left to the operations analysis. The code assigned here is a two digit decimal code to identify the complete leads or cord.

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VI BASE VARIABLES AND CODES

Base length (denoted by the part number of the drawing number) is determined by Shell length (H).

Height variations are denoted by the suffix letters or sub number.

There are four basic types of bases, including mounting holes locations.

Two group numbers for Strap and Parts were found and they differ only in the nut:

GROUP	PARTS
633 A 308 AAG 1	N 218 P 15 B 11 623 A 307 AAP 1 N 37 P 15 D 12 B
633 A 308 AAG 1	N 218 P 15 B 11 623 A 307 AAP 1 N 37 P 15 D 17 B

Table E gives the codes for these variables.

Fort Wayne, January 14, 1957

TABLE E: BASE CODES

VARIABLE	DECIMAL	IBM CODE	H
Style;	1,2,3,4		
112 C 905		9	
112 C 909		8	
112 C 911		7	
343 C 914		6	
Height:	1,2,3,4		
AA		5	
AB		4	
AC		3	
AD		2	
Strap Nut N 37 P 15 D 17 B instead of N 37 P 15 D 12 B		1	
Part number is determined by Shell length:			
1			H
2			H
3			H
4			H
5			H
6			H
7			H

Fort Wayne, January 14, 1957

VII SHAFT VARIABLES AND CODES

Shafts are all made from the same rod stock. They vary in length from 6" to 16" in $\frac{1}{4}$" increments, with a few exceptions. The distances between oil grooves is determined by shell length. Direction of rotation determines the orientation of the grooves. Shafts are made for single or double extention and the extension length varies from 1" to 7". Flats and key slots may occur on either extension and they vary in location and length. The shaft may be necked down. One exception noted was a double extension shaft which is threaded and bored. Coding for shafts to reveal the various operations must be left to the operations analysis. The code assigned here is a 2 decimal digit code which specifies the complete shaft.

Fort Wayne, January 14, 1957

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VIII CONDENSED CARD DESIGN AND MACHINE PROGRAM

The machine in mind in the following is the IBM 407, Model IV, although most of the remarks apply with the smaller machine. There are several unusual features in the IBM techniques employed:

1. In keypunching any drawing number, only those characters are punched which vary within 39 Frame. Thus model KSP39HG568AX is punched as PH568AX.

2. Information of a binary nature, such as reversible vs. non reversible, can be punched in the card as a high punch over other decimal information. Thus the third character of the model code is a number and over it a Y or 12 punch denotes that the motor is reversible.

3. Information of a binary nature may also be punched in a card column which is entirely devoted to binary punches. These punches can then be separated by the machines' digit selector.

4. Header cards are employed to add desired information in connection with any particular run with the cards. For example, if the full model name is desired on a particular listing, the characters KS39G may be taken from the header card, the variable characters PH568AX are taken from the detail card and the combination is printed as KSP39HG568AX. The header card information is stored in the IBM 407 tabulator and cleared when a new header card is read.

5. The operations performed by the tabulator are considerably determined by the header card which card program the tabulator. Thus, several different reports can be run with the same machine board. For example, factory schedules for end shield, shafts, rotor cores, stator cores, windings, stator assembly, rotor assembly, bases final assembly can all be run off the same board by use of various header cards. The header card would contain the mnemonic codes which are selected by the detail cards and printed on the schedule corresponding to the detail card. Thus, on the header card for end shield would be the characters CL. If a particular motor used the closed end shield casting, this would be denoted by a Y or 12 punch in column ____ of the detail card for that motor. The Y or 12 punch would throw a selector which

would pass the "CL" to the print sheets for printing on the end shield schedule. Also the selector would cause the counter corresponding to the Y or 12 punch to add in the quantity for that motor. Then at the bottom of the schedule would appear the total quantity of all motors in that schedule requiring closed end shields. This would be identified by the characters CL printed beside it. Table F contains the details of the card design. At the left hand of the table is a description of the coding when the card column is used in the ordinary way:

1. Letters A-R, or

2. Letters S-Z or decimal numbers plus possible X or Y punches denoting other information

At the right hand is a description of the coding when the card column is used in a binary sense. It will be obvious from an inspection how the column is used.

The mnemonic code has been used on the table to indicate when the corresponding hole has been punched. Thus R, in column 3, means that a Y punch in column 3 indicates that the motor is reversible. The "208 volts" shown in column 8 means that a Y punch in column 8 indicates a 208 volt motor. Arrows are drawn upward in columns which may contain letters A-R because these columns can contain no other information. Column 7, for example, contains either no alphanumerical information or it contains the letter "X" which is a "0" and a "7". Thus other information may be put in above it. In this case, a Y in column 7 indicates that an overload device is used on the motor. It happens that this is exactly what the letter "X" denotes, but it was found desirable to have this information in both forms.

Characteristics are coded as high punches. Variables are always in binary columns. Different runs are thus able to feed different binary columns into a digit selector and inspect for a different set of variables. If desired, the characteristics could also be placed in a binary column.

TABLE F

CONDENSED IBM CARD DESIGN

CARD COLUMN	1	2	3	4	5	6	7	8	9	10	12	13	14	15
Ordinary Coding Y or 12 Punch and Description			R	CCW			SP or TH	208 Volts	230 Volts	D	2W	3W		
X or 11 Punch and Description														
Alphanumeric Punches	P	H	5	6	8	A	X	1	6	5	1	3	2	A
Description	Model Name							Horsepower		RPM	Winding & Test Specs			

CARD COLUMN	17	18	19	20	21	22	23	24	25	26	27	28	29	27	28	29
Ordinary Coding Y or 12 Punch and Description													VO			VP
X or 11 Punch and Description																
Alphanumeric Punches	O	A	D	1	O	2	E	1	1	O	A	P	1	O	A	1
Description	Rotor				Stator					Opposite End Shield				Pulley End Shield		

CARD COLUMN	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
Ordinary Coding Y or 12 Punch Description					Old Finish										
X or 11 Punch and Description															
Alphanumeric Punches	0	4	B	3	7	6	8	1	1	3	9	9	8	8	3
Description	Base				Clamp Screw		Outline				Customer Number				

CARD COLUMN	45	46	47	48	49	50	51	52	53	54	55	56	57	Binary Code
Ordinary Coding Y or 12 Punch Description		4P	CL SP					SP	TH					12 11 0
X or 11 Punch and Description			BX BXC LH LO											1 2 3 4
Alphanumeric Punches	B	6	CA	3				1	6	3	2			5
Description	App.	S	CB CC GO GP End Shields	H	Shell	Base	Core	Overload		Cord or Lead		Shaft		6 7 8 9 Description

CARD COLUMN	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Ordinary Coding Y or 12 Punch and Description	Presently free																						Lead Cord
X or 11 Punch and Description																							
Alphanumeric Punches													0	1	0	9	4	1	7	3	F	1	3
Description													Volume					Week		Day	Stage	Deck Number	

Fort Wayne, February 5, 1957

IX DISCUSSION OF IBM REPORTS

Two basic kinds of cards have been used to date:

(1) The Condensed Cards

(2) The Assembly - Component Master Cards

The Condensed Card has been used to record the shipped volumnes by week (taken from Shipping Cards prepared by Mr. Phil Nearing) of all motors with volume of 20 units or over in the first ten months of 1956. Three models with total unit volume of 302 were missed in this listing:

KSP39MG362X	74
KSP39HG398AX	84
KSP39HG769A	144
	302

KSP39FG733BX with volume of 112 was also not included. It will not be made again. The others should be added.

On page 4 is a description of the listings made so far from the Condensed Cards used to record 1956 history. Additional runs can be made with any IBM tabulator.

The Assembly-Component Master Cards give the components of the various assemblies:

	Eng. Drawing No.	Card Column
(1)	Assembly Drawing No. (without Group No.)	1-9
(2)	Assembly Group No.	23-24

(3) Component Drawing No. 10-21

(4) Component Usage in Assembly 25-26

Not all rotor, stator, end shield, and winding and test specs were punched. A preliminary list of model condensed cards were punched, sorted by each of the major assemblies, and listed. Only those major assemblies on the list were punched onto Assembly-Component Cards. However, this preliminary listing did not include many models in the eventual 1956 historical deck. Thus a number of major assemblies required for the motors with volume of 20 or over are not indicated. Perhaps 5-15% of the assemblies are not listed.

The Component Cards were sorted by assembly and listed with a count made of the components in each assembly. They were also sorted by component and listed with a count of the number of assemblies using each component. The final listings made of these cards included several corrections which were made to the material lists as a result of the Study. Relatively few errors were found in the Material Lists. The final listings were made so that different devices could be separated for easier look up.

Fort Wayne, February 5, 1957

X RESEARCH PROBLEMS

The Product Structure Study begins with two concurrent phases:

(1) Conferences with product engineering to record their knowledge of the product line as a whole.

(2) Key punching of material lists for models and assemblies.

These phases are mutually dependent and complementary.

The first model cards punched simply contain the variable information from the model material list. The cards are sorted by every feature and listed. This reveals correlations between major assemblies and other features of the motor. For example, much of the correlation involving stack height as shown in Table A were revealed from those listings.

The assembly-component cards are punched and chains of relationships determined, plotted, and studied. For example, it was found that the same shell length may occur with two different stack heights. Such facts are revealed by relating parts to assemblies, assemblies to major assemblies, major assemblies to other major assemblies, the other major assemblies to their components, etc. There are no set means or procedures to reveal these relationships nor any fixed format for displaying them. In this study, they are shown by Tables A, B, C, D, and E. The listing of assembly-component relationships sorted by component are of some novelty to the product engineers and they suggest many variables.

As the Study proceeds, it will become clear which variables are independent and which should be considered control characteristics.

The cards punched from the model and material lists are modified as the Study progresses. For example, it was found that the end caps depend on D, R, and C (the presence of cushion rings: CA, CB, or CC) and so there is no need to retain a code for end caps. As the parts and operations for any major assembly are identified, appropriate codes are assigned and punched into the model cards. Thus, unnecessary information is dropped and new information is added. In this way, the condensed card evolves.

To continue the work, the following steps are recommended:

(1) About a dozen model material lists (kept under separate clip) included notes which indicated modifications to one or two of the major assemblies. That is, a new assembly number was not created when the model was designed. Rather, a similar existing assembly was indicated with a modification noted. These changes have not been made in the lists.

(2) By including 10-15 additional models, all motors with volume of 10 or over can be included. Ten is the volume below which complete engineering documents are not made. This cut would thus match engineering practice.

(3) Shipments for November and December of 1956 should be punched.

(4) Marketing should be consulted to determine which motors have been superceded by others for the same application and/or the same customer.

(5) The missing major assemblies (for all of 1956) should have assembly component cards punched and new listings made.

(6) The study of shafts, cords, overloads, and winding should continue and codes placed in the condensed cards.

(7) As condensed codes are placed in the cards for any major assembly, the 1956 condensed cards (sorted by week number) should be run, making accumulations by week for each part and operation. A card should be summary punched for each week and major assembly. The summary cards are then listed separately to print on one tabulator sheet (about 12 inches of printing) the volume of the parts and/or operations for that particular assembly by week. This type of listing was not done during the study.

(8) Experimentation with placing the mnemonic codes on header cards and the automatic rapid printing of factory schedules appears very valuable. Weekly and daily master schedules and schedules for individual foremen can be printed. The possible value of this development for General Electric manufacturing control seems very high.

(9) The coding of variables was done to greatly simplify the multiplications necessary in extending assembly volumes by part usage to get part volumes. So simple are these multiplications that it would waste time to put the cards through a multiplier such as the 602A, 604, or 650. The wiring should be done for a tabulator.

(10) The IBM 407, Model IV is ideal for this work. Although the IBM 402 or 403 can be used if certain features are added (Special Programming and Co-Selectors), the 407 contains storage to hold the mnemonic codes and it contains 120 type bars. The additional type bars may be considered a mixed blessing since the print of the 407 is smaller than the 402.

(11) With the historical analysis of the various assemblies, parts, and operations on summary punched cards, it is impossible to make inventory cost studies.

By adding costs and cycle times, dynamic studies of various inventory policies can be carried out to arrive at near optimum policies. The IBM 650 at Fort Wayne would be useful in making these studies.

(12) The condensed card can be extended to cover all operations, materials, machines, setups, and labor grades. It will afford a base for many studies to improve manufacturing control procedures.

39 FRAME MOTOR

CONTROL ELEMENTS

BC	Conduit Box
BH	Base Height
BL	Base Length
BS	Base Style
BW	Bar Width
BX	Connection
CG	Ground Clip
CP	Creeper Overload
CR	Cushion Ring
D	Direction of Rotation
DC	Disc Type Overload
DH	Drain Hole
DR	Drilled Hole
EB	Clamp Bolt Beyond Shell
EC	Closed End Shield
EV	Extra Ventilation
FL	Free Length, Customer End
FN	Fan
HP	Horse Power
IF	Internal Flat
KY	Keyway
L	Length of Shaft
LL	Location of Leads on Stator
JT	Lead Joint Tape
LT	Base Latch
ML	Middle Length
ND	Necked Down Shaft
OE	Opposite Pulley End Extension
OF	Length of OPE Flat
OI	Oil Heavy
OR	Overload Rating
P	No. of Poles
PE	Pulley End Extension
PF	Length of Pulley End Flat
PN	Paint
R	Reversibility
S	Stack Height
SC	Ventilation Hole
SD	No. of Speeds
SL	Leads Bushing
SZ	Wire Size
TC	No. of Turns per Coil
TS	Stripback Lgth. Customer End
TW	Type of Leads
V	Voltage
VO	Vertical Mount OPP PE down
VP	Vertical Mount PE down

39 FRAME SYSTEMS PROJECT

PRODUCT STRUCTURE SUMMARY OF ASSEMBLIES AND PARTS

SHOWING VARIABLES AND THE CONTROL ELEMENTS WHICH DETERMINE THEM

			CONTROL ELEMENTS	REMARKS
I.	Motor Assembly - Test - Pack			
	A. 1.	Base	BL, BS, BH	Length, Style, Height
	2.	Latch	CR, LT	Two Styles
	B. 1.	BX Connector	BX	0 or 1
	2.	BX Connector Screws	BX	0 or 2
	C. 1.	Clamp Bolts - Length	S,P, EV, EB	Always 4
	2.	Clamp Bolt Nuts		Standard - 4
	D. 1.	Conduit Box	BC	0 or 1
	2.	Conduit Box Cover	BC	0 or 1
	3.	Conduit Box Cover Screw	BC	0 or 2
	4.	Conduit Box Mounting Screws	BC	0 or 2
	E.	Data, Name Plate, P.E.		Varies with Model
	F.	Data, Name Plate, O.P.E.	OE	Standard
	G.	Paint	PN	Standard
	H.	Test Specifications		Varies with Model
	I.	Packaging	BL, BS, BH, L, OE	
II.	Rotor Assembly			
	A.	Shaft		
	1.	PE Extension Lgth.	PE, R	Longer for Reversible
	2.	OPE Extension "	OE	
	3.	PE Flat "	PF	
	4.	OPE "	OF	
	5.	Groove to Groove Lgth.	P,S,EV	
	6.	Direction of Groove	D,R	
	7.	Rotation ~~of~~ Rings	D,R	
	8.	Lgth. of Shaft	L	Overall length is sum of PE,OE and Groove to Groove Lgth.
	9.	Keyway	KY	
	10.	Necked Down	ND	
	11.	Non-Std Chamfer	ND	
	12.	" " Flat Ht.	ND	
	13.	" " Increment	R	
	14.	Drilled Hole	DR	
	15.	Internal Flat	IF	

		CONTROL ELEMENTS	REMARKS
B.	Rotor Core		
1.	Punching		
a.	Configuration	P, BW	(BW - Bar Width)
b.	Quantity	S	
2.	Assembly		
a.	Skew Angle	S, P, BW	
b.	Length	S	(Length:No. Punching)
c.	End Ring	FN	
C.	Slinger		
1.	Style	VO or VP	If VO or VP, Qty - 1 Std. for horiz. mtg.
2.	Location	P	
D.	Textolite Thrust Washer	VO or VP	
E.	Rotor Core Location	P,R,PE	
III.	Stator Assembly		
A.	Stator Core		
1.	Punching		
a.	Configuration	P,R	
b.	Quantity	S	4 more than Rotor Core
2.	Assembly		
a.	Length	S	
b.	Key Length	S	
c.	No. Keys	P	
d.	Araldite Varnish		Standard

		CONTROL ELEMENTS	REMARKS
B.	Stator Winding		
1.	Shading Coil Length	S,R	
2.	Shading Coil Location	D,R	
3.	Quantity of Sh. Coils	P,R	
4.	Shading Coil Varnish		Standard
5.	Shading Coil Insulation	R	
6.	No. Coils	P, SD, R	
7.	No. Leads	SD,R	(SD=No. of Speeds)
8.	Location of Leads	LL	
9.	Overload	DC,CR, OR	(DC = Disc, CR = Creeper OR = Rating)
10.	Overload Leads A+B	DC	
11.	Overload Location	LL,CR	
12.	Lead Joint Tape	JT	2 Types
13.	Tying Cord		Standard
14.	Winding Ht.	P	
15.	Fiber End Punching	R,P	
16.	Sleeve Insulation	R	For Shading-Coil Leads
17.	Overload Wedge	AR,P,S	To hold Creeper O.L.
18.	Rev.Shading Coil Leads	R	
19.	Winding Retainer Pin	P	P gives Qty. & Length
20.	No. Turns per Coil	TC	
21.	Wire Size	SZ	
22.	Wt of Wire	TC,P,SZ	
23.	Leads		
	a. Quantity	SD,R	
	b. Type	TW	
	c. Lead Wire Size	V, HP	
	d. Color	SD,R, TW	
	e. Free Lgth. Cust. End	TS(?)	Each Lead may differ
	f. Middle Length	ML	Good for all Leads
	g. Strip-back - Cust. End	TS	
	h. Bushing Dwg. No.	SL, SD, R, TW	
	i. Lead Clamps	TW,SD, R	1 or 2
	j. Tape	TW	
	k. Terminals		
	1. Quantity	SD,R	
	2. Dwg. No.	TS	May be different for each lead
	l. Insulating Sleeve		
	1. Quantity	SD, R	0 or 1 per eyelet
	2. Dwg. No.	TS	

			CONTROL ELEMENTS	REMARKS
	C.		Stator Shell		
		1.	Length	S, P, EV	
		2.	Vent Holes	SC	
		3.	Leads Holes	SL, SC	
		4.	BX or Conduit Box Holes	BX or BC	
		5.	Draw Holes	DH	
		6.	Leads Hole Location	LL	IF, SC or BX, BC
	D.		Stator - Shell Assembly	P	
IV.	End Shield				
	A.		Casting	EC	Always 2, open or cl.
	B.		Sleeve Bearing		Standard
	C.		O. L. Hole	DC	Only on OPE End Shield O.L. Hole only with disc
	D.		O. L. Hole Location	LL	Opposite Leads, OPE End
	E.		BX Holes	BX, LL	BX - Yes
	F.		Clamp-Bolt Holes Location	P	
	G.		Overload Cap	DC	0 or 1
	H.		Cushion Rings	CR. CG	
	I.		Ground Clip	CG	0 or 1
	J.		End Cap	CR, R	
		1.	Quantity Punched	OE	1 or 2
	K.		Rubber Oil Slinger	OE	1 or 2
	L.		Thrust Plate	VO, VP	Special for down end
	M.		Oil Return Wick	R	Qty. -2, on R has 3 Separate Pieces
	N.		Wick Retainer Quantity	R	0 or 2
	O.		Washer Wick		Standard
	P.		Packing Wick		Standard
	Q.		Retainer Wick		Standard
	R.		Oil		
		1.	Style	OI	Regular or heavy
		2.	Quantity	R, OI	Both ends
	S.		Oil Well Cover		Standard
	T.		Cover Sealing Compound		Standard

PRODUCT STRUCTURE - IBM RUN INDEX

The index sheets immediately following are a complete list of all IBM runs made in the course of the product structure study.

Punched cards were prepared from Model and Parts lists for the active models in the 39 frame line. These cards were sorted in many ways to prepare the runs listed so that the relationships between parts and assemblies could be determined.

The actual punched cards and tabulations of these cards are filed with the Project records.

BOOK I.

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BOOK II.

INDEX

BOOK II.

INDEX - (continued)

FACTORY AUTOMATION

Factory Automation

Our general approach to factory automation was to investigate the feasibility of automating the production line without any major changes in product design or in the production processes used. For example, the use of a sectional shaft in place of the present single-piece shaft was not considered within the present scope of the project, even though the former might result in significant manufacturing economies in an automated plant. Likewise chemical milling was not considered to replace mechanical milling.

Within the range of present process and product design, however, serious effort was made to think of new and better ways of producing the motor, especially ways readily adaptable to automation. The stator winding problem was presented to three outside engineering firms to see if they could propose more automatic and better ways of solving the problem. Similarly, the shaft manufacturing problem was presented to one outside engineering firm.

This section includes the significant information from these studies. The stator winding problem, as presented to the outside firms, is included, along with summaries of their reports. Next, the shaft problem is presented, along with a summary of the outside firms reports. In addition, a brief commentary on these reports is included, to show ideas of directions in which equipment cost savings might be realized.

Also included in this section are four write ups on other ideas for producing and designing the motor. While one of these reports did not result directly from Project work, it was felt that it presented ideas which fitted in well with the factory automation aspect of the Project, and has thus been included in this section.

In evaluating our work in the area of factory automation, two points stand out. First, we feel that the major cost savings will result from the integrated office-factory information flow, and in the control of factory operations, not from the physical processes themselves. This conclusion was almost inherent in our approach which minimized consideration of new processes, and our results seemed to confirm our expectations. Secondly, we expected to run into some difficulty in trying to automate the present product design which calls for some operations based on manual dexterity and other human characteristics -- and again our expectations were confirmed. The studies by the outside engineering firms, plus our own analysis, leads us to the conclusion that the "optimum" long-range approach is to redesign the product for fully automatic production. An example might be the sectional shaft mentioned above, made up of a group of standardized sections (manufactured continuously) and "glued" together, to meet the requirements for shaft length, extensions, flats, grooving for rotation, etc. Trying to automate the present shaft seems to lead to a "roomful" of transfer equipment and processing stations, in order to achieve the necessary varieties and quantities of shafts. While such a large system might turn out to be economically feasible, it certainly does not appear to be optimum.

STATOR WINDING

STATOR WINDING PROJECT

OBJECTIVES OF STUDY AS PRESENTED TO OUTSIDE FIRMS

To study the problem of how to wind the stators of the various models of motors included in the line under consideration completely automatically. By "Completely automatically" is meant that the equipment will receive all material necessary for the operation, stator, wire, insulation material etc. as indicated in the following paragraphs, will locate the stator, make the insulator and insert same in stator as required, locating the windings and lead exits as required in relation to the bolt holes, will prepare the ends of the wire to be picked up by another piece of equipment for attaching the external leads, and will splice the thermostat as required into the coil circuit and locate thermostat between the proper poles and deliver the finished stator to some transfer device for movement to the next operation. The transfer device is not a part of this study. The equipment to do this operation will not require the attention of any operator in its normal operation, nor any set-up to change from any model of stator to a different model, nor to replace spools of wire. New spools of wire may be assumed to be delivered to the de-reeling unit with a wire end projecting in such a manner that it can be picked up. The equipment is to pick up the end of the wire, thread itself and continue operations automatically. The equipment is to be operated and controlled remotely from mechanized office equipment which will continuously feed order data to the manufacturing equipment, describing the model to be made and the quantity of each run. The equipment may consist of a single piece of equipment, or it may be a number of pieces of equipment as required either for the purpose of handling the variables which it must accomodate, or for productive capacity purposes. In general the philosophy of this equipment should be that it will be able to make a large annual volume of stator windings in considerable variety, without requiring set-up changes to go from one model to another, and on a cycle basis such that stators can be produced as required, in the quantities indicated on the production data sheets furnished, without the necessity of making long runs and accumulating inventory in wound stators.

STATOR WINDING PROJECT

Suggested Form Of Recommendations As Presented To Outside Firms

It is intended that this study shall remain purely in the engineering concept stage; that the results of the study shall be described in a written report, supplemented by such sketches and light line layouts as are considered necessary to convey all of the principal motions of the equipment, and the basic relations of the different parts of the equipment, the movement of material, and the manner in which each requirement of the operation will be met and checked, or insured. No detailing is required, no models need be made, and it is not necessary that the engineering concepts be tried and proven methods, but only that they be well considered and reasonable from both a mechanical and an electrical point of view. It is recognized that limiting the scope of the development work on the equipment concept in this manner may result in the suggestion of machine concepts which could conceivably require revision before conversion into metal, and possibly further revision after such conversion. Thus the emphasis is on the basic concept of a method, and the basic principles and motions of the equipment on which the method concept relies. In addition it is desired that an approximation of the productive capacity, both in terms of speed of the equipment, and in terms of the variety of output which each unit of the equipment could handle, be submitted, together with an area estimate as to the overall investment cost.

STATOR WINDING PROJECT

NATURE OF STUDY

The study is to concern itself with the winding of the main stator coils. The pole shading coils are not to be included. The pole shaders may either be a wound form or they may be a solid piece of metal. In either case it may be assumed that the pole shaders and the pole shader insulation will be in place on the stator when the stator is delivered to the main coil winding operation. The operation to be studied will consist of receiving the stator, minus the outer, perforated, shell, locating it in the coil winding machine, inserting and holding the slot insulations, and continuously winding the main coil. Alternate poles, in all cases, are to be wound in opposite directions. The operation is subject to numerous variables and requirements.

1. The windings may be a single coil for a single speed motor, ending up with two leads.

2. For a two speed motor, there will be two coils, the second wound on top of the first. In this case there will be three leads: the starting end of the wire of the first coil, the finishing end of the wire of the second coil, and a third lead, consisting of the finishing end of the wire of the first coil joined together with the starting end of the wire of the second coil. (All windings on any given pole must always be in the same direction, for both two and three speed motors.)

3. For a three speed motor there will be three coils, wound one upon another. In this case there will be four leads, the starting wire of the first coil, the finishing wire of the third coil, the finishing wire of the first coil attached to the starting wire of the second (as above) and the finishing wire of the second now attached to the starting wire of the third.

4. In the two speed motor the wire diameters for the two coils will normally be different sizes. In the three speed motor the wire diameters of the first and second coils will be the same size in about 50% of the cases, but the third coil will usually be of a different diameter wire.

5. The number of poles to be wound will be either four or six.

6. The winding operations must commence in relation to the four bolt holes through the stator used for securing the end plates. In the six pole forms these four holes are in two pairs, the pairs 180° apart from each other, and the two holes of each pair 70° apart from each other. In the 4 pole forms the four holes are equally spaced 180° apart. The location of each hole is approximately in the center of the base of a pole, so as not to interfere with

the flux pattern, and they cannot be relocated to any position which does not meet this condition. It is preferable not to consider moving or rearranging them at all. It must be possible to start and finish the winding operation between any two poles of either the four or six pole stators. Thus the exit point of the leads with relation to the bolt holes may be between any two of the poles, but this relation will always be specified for any given model of motor. Also the leads may exit from either end of the stator, but this too will be constant for any given model of motor.

7. It is not mandatory that each pole be wound in the conventional manner, i.e. that the wire be wound <u>around</u> the pole, but it is mandatory that current must flow in the same direction through all of the wires passing through any given space between two adjacent coils, and that this direction of flow, in adjacent spaces, must be in opposite directions. i.e. if current flows from center out in slot No. 1, it must flow toward center in slot No. 2, out in slot No. 3, in in slot No. 4 and so on. Thus the wire might pass over the outer end of pole No. 1, diagonally across the space between pole No. 1 and pole No. 2 over the inner end of pole No. 2, diagonally across the space between pole No. 2 and pole No. 3, over the outer end of pole No. 3 and so on. This would increase the pile-up and thus the thickness of the layers of wire over the outside end of every other pole, at both ends of the stator, and would thus increase the overall length of the motor. The length dimension over the coil windings is a controlled dimension and is specified on winding height drawings which will be furnished. Therefore it is not a desirable method. However, it is permissable to consider this method or its equivalent as possibilities. Other winding methods may also be considered, so long as they accomplish the objectives as set forth herein and in the various specifications attached hereto.

8. A thermostat capsule must be installed in the stator as part of the operation. The wire of the primary coil has to be broken between two poles, so that the thermostat can be connected in series with the winding. The thermostat is then pushed into the appropriate slot between the poles. The selection of the slot for locating the thermostat must be such that when the motor is mounted with the leads coming out at the proper position, the thermostat will be positioned in one of the two topmost slots, so that heat rising from the motor will pass over, and not away from, the thermostat. The coil wire does not have to be broken at the point where the thermostat is located, though it is desirable to have the break so located, but the coil wire may be broken elsewhere, so long as the thermostat is located as specified. The manner in which the thermostat wires are joined to the coil wire ends is not specified, however there must be a good electrical joint and the entire motor must subsequently pass a "rain test" in which water is sprayed on the assembled motor at a rate equivalent to a rainfall of one inch per hour.

9. These motors may be required to run either clockwise or counter clockwise. However, this direction of rotation is determined by the position of the single pole shader, and can be alternated by inverting the stator. The motor may also be reversible, in which case a different stator accomodating two pole shaders is used. In all these cases the winding of the main coils is not affected by the direction of rotation of the motor, except that the location of the exit point of the leads and the location of the thermostat must be maintained as heretofore outlined.

10. The loop of wire between each pole winding, which exists on the sample motors, is not a design requirement, and may be omitted, It is a function only of the present method of winding the coil.

11. The slot insulation pieces should be made at the coil winding machine and inserted in place. The insulation must be such that all parts of the main windings shall be at least 1/16", through air or over surface, from any ground, (the pole shader is considered ground) for a 115 v. motor, similarly this clearance requirement is 3/32" for a 230 v. motor. Experience has shown, with the present type of insulator, that it is necessary to hold the insulator in place until at least several turns of the winding have been made. in order to keep the insulation in the correct location to insure adequate clearance at both ends of the insulators, which now project beyond the slots at both ends, to afford this electrical clearance. Other methods of insulation may be considered, so long as they meet the requirements specified and have a dielectric equivalent to the present insulator. The present insulator is a rag paper .025" thick; however, this thickness is for stiffness purposes. A thickness of .015" would provide a satisfactory dielectric. Thermoplastic material substitutions would probably not be suitable because the insulators must currectly be capable of withstanding temperatures of 150°C. In the future this requirement is expected to go up to a peak of 200°C, average of 175°C. In the reversible 6 pole forms there is an insulation piece, similar to the laminations of the stator, placed over each end of the stator stack. It may be assumed that these parts will be available for magazine or similar feeding into the coil winding operation.

12. Means for maintaining constant tension on the wire while winding will be required to control stretching. Elongation of the wire by stretching, however, is of lesser significance than the number of turns, which must be the controlling factor. Elongation of the wire and consequent reduction of cross section, is permissable to the extent of a 5% increase over nominal in the electrical resistance of the wire.

13. The leads coming out of the coil (or coils of multi-speed motors) must be so prepared that they can be picked up mechanically by the equipment which will attach the external leads. In other words the ends of the coil wire must be left in a consistent pattern and location, accessible to a following piece of equipment which performs succeeding operations.

14. The outside and inside diameters of all stators are constant.

15. The "Stack height" of the laminations forming the stator core will vary from 1/2" to 3" in 1/4" increments, a total of eleven different stack heights.

16. All of the above stack heights come in either the four or six pole form.

17. The lamination shapes vary only as follows:

All four pole non-reversible motors the same lamination
All six pole non-reversible motors the same lamination
All six pole reversible motors the same lamination
(There are no four pole reversible motors)

18. Since the amount of copper in any given stator slot determines, basically, the torque characteristics of the motor, and since there is considerable variation in the wire diameters used, the No. of windings which may be specified should be considered as potentially completely variable as follows:

For single speed motors, between 30 and 800 turns per pole.
For multi-speed motors, between 2 and 200 turns per coil, per pole.

19. The wire which will be used is Heavy Formvar enameled (polyvinyl acetate) or equivalent, G.E. Spec. B22F2 (Copy of which will be furnished.) The wire diameters to be used are as follows: .0100 .0113 .0126 .0142 .0159 .0179 .0201 .0226 .0253 .0285 .0320 .0339 .0380 .0403 .0427 .0453 .0480

20. When the coil winding has been completed, a shaping, or forming operation on the windings around each pole at both ends is required to maintain the winding heighth dimension and to insure that the required electrical clearances will be established properly. Tape is then applied around the windings at each end, so that the clearances will not be lost due to movement of the wires resulting from vibration during operation. The leads where the thermostat is connected are tied back by string for the same reason. These operations, or some other operations, accomplishing the same purpose must also be performed.

21. The number and variety of motor models which are to be considered a part of this study are enumerated in the tabulations which are furnished under separate cover as part of the reference data. This variability will be furnished initially in several ways as follows: by wire diameter, by stack length, and by model number, each category separated into four pole non-reversible, six pole non-reversible and six pole reversible. Each list will show for each motor model whether single, two or three speed by indicating the number of coils to be wound on the stator under the column which specifies the wire sizes to be used.

STATOR WINDING PROJECT

The following material was sent to outside firms.

1. Set of stator winding prints

2. Set of stator winding specifications

3. Set of material and parts lists for wound stators

4. Sets of IBM breakdowns of product mix as described in section (21)* (The product mix indicated in these breakdowns, together with the lot sizes indicated, may be considered as usable representations of the mix and lot sizes which the equipment under investigation will have to produce. The total quantity, however, should be extended, proportionately to a total annual volume of approximately 1,250,000 motors.)

5. Set of winding height specification prints.

6. Prints of slot insulators, insulator lamination for 6 pole reversible motor, and insulator material specification.

7. A sample wound stator.

8. General Electric Spec. #B22F2 (Heavy Formvar Wire.)

If, after review of this material, and preliminary consideration of the problem, additional data is required, or conferences are desired with General Electric personnel, contact should be made with Mr. Burt Grad, General Electric Co. 1635 Broadway, Building 18-1, Fort Wayne, Indiana.
Phone: Eastbrook 7431, Extension 658.

The purchase order which is being sent under separate cover is to include costs of all engineering work, travel costs and other expenses incident to the project.

* Preceding Page

Stator Winding Project

Summary of report of

Sheaffer Tool & Die
Division of
W.A. Sheaffer Pen Co.

This conception deals with the Automatic Insulation Assembly and winding of practically any combination of one, two, or three speed motors. Any combination of the nineteen different wire sizes called for in the motor specifications may be used and the motors may be four or six pole type. Primary consideration has been given to both low and high production volume throughout this study. The various sequences are to be actuated by the proper impulse from tape or standard business machine cards which have been punched for numerical positioning control.

It will be possible to check at each station of the machine for continuity, resistance, grounds, etc. If, at any station a reject part is detected, that part will be rejected. Through a feed back circuit from each rejecting station, a special pulse or signal will add one more unit to the original order, so it will not come up short at the end of a run. Rejected parts will be returned to a central point where they will be torn down and salvaged parts returned to their proper turret for reprocessing.

The molded insulator parts in their various styles are stored in cylindrical indexing units. These units which are on a larger turret will index around until the correct style insulator is in position to be dropped into the pallet on the transfer table upon a pulse or signal from the machine director.

The same method as above is used to store and drop the various size stators and front insulator parts onto the pallets of the transfer table.

As these pallets with the stators assembled with their insulators, move intermittently down the line, the winders select the correct wire size and then wind one pole only, first wrapping approximately six turns around the coil fastening post, then winding the correct number of turns, and then again wrapping six turns around the other coil fastening post, thus completing one coil winding.

As the pallet with the assembled stator moves to the next station, it is automatically indexed to a new pole and the above winding cycle is repeated. These operations are repeated at each station until all poles are wound. At the last station, the leads are attached and the complete winding is given an electrical continuity resistance and ground check and ejected from the line.

All of the various operations to control the above machines are to be programmed from standard business machine cards and magnetic tape, using record-playback techniques and servo-principles.

Stator Winding Project

Summary of Report of Arlin Products Inc.

A. Inasmuch as General Electric Co. has several styles of units to be wound; it is our recommendation that each unit have a separate winding station.

B. Stations to be banked and ready to perform the job of winding.

C. A special flow belt to be constructed so that any and all stators will flow down same as they come off production assembly lines.

D. Machine to be installed on this conveyor to detect and flow proper stator to proper station.

E. Each station to have a small bank of parts waiting and to individually act in the following manner:

1. Part is indexed and positioned into winding fixture.
2. Winding fixture to proceed to wind stator — finish same and to again repeat for the next stator.
3. Each bank of stator winders to act individually.
4. O.K. wound sections to be discharged to "take away" flow belt systems for further processing.

F. The Winding Machine to consist of an arrangement for counting the proper turns and winding them on the stator.

Sequence of Operation of Stator Winder Section:

1. Part is positioned in winder clutch mechanism.
2. Insulation is automatically inserted.
3. Special winding machine to finish job of winding.
4. The Winding Machine.

   Fancy electronic counters are not needed as the job is a relatively slow one. Therefore, a simple mechanical counting system is in order.

The O.D. of all Stators is usually plus or minus .0015" or so, in size so that this leads to a precision clutch for holding.

Actual winding of the wire in the machine should be done by a controlled finger type unit. The Stator should not be oscillated — only the controlled finger holding the wire, which is unwinding from a large spool, should be oscillated into proper motion. Wire is held in small especially designed opening (nylon) and played out automatically as stator sections are contour wound.

Motion of this winding action must be precision and can be supplied by a direct cam action or an electronic servo-mechanism. For the present, mechanical action is recommended.

Simplicity is the keynote if this is to be a successful machine.

Stator Winding Project

(The summary of the report of Barnes Engineering, Multra Corp., Stamford, Connecticut will be forwarded when received)

STATOR WINDING PROJECT

Summary of Report of

Multra Corporation
Subsidiary of
Barnes Engineering Co.

Since it is fairly obvious that more than one machine is required for the desired production, it is possible to remove one of the many variables in the desired equipment by arranging the permanent setup so that a machine or machines handle each variation of one of the variables. To be more specific, there are three different lamination shapes, 4-pole, 6-pole non-reversible, and 6-pole reversible. Thus, any one machine can be so arranged that it handles only one of these three basic lamination shapes, and will not be required to handle any other.

This assembly facility has been considered to be made up of four identical machine groups merely as a convenient method of arriving at a typical picture. In the construction of the facility it may well be considered preferable to group the four (three might suffice) 4-pole machines side-by-side, the four 6-pole reversible machines side-by-side, and the sixteen 6-pole non-reversible machines together.

The assembly work is to be done as an "in-line" type operation. The "in-line" method was selected over the rotary index type machine for several reasons:

(a) The area required by the "in-line" machine will be less.
(b) An indexing table would be larger and heavy.
(c) The supply conveyor arrangement would be superior.
(d) The "in-line" type machine allows access to both sides of the assembly and its carrier.

The stators are to be placed upon carriers which are a permanent part of the conveyor. These carriers are to be rotary, such that the stators can be turned about their own axis to any desired position. In general this would be any one of four positions for the 4-pole stators, and any one of six positions for the 6-pole stators. The carriers are to be rotated, and held in position by stationary mounted actuators, such as air cylinders.

Since there are eleven different stack heights of stator cores, the carriers must be adjustable with respect to this height. The method provides that the upper face of the core always will be at the same level, maintained by catches, and that the variation will be on the bottom side. The carriers are self adjustable since the mounting plate is spring loaded, and is pushed down to the level required by any particular stack height.

In the mounting plate of the carrier are studs located in the same arrangement as the four bolt holes through the stator core. These studs serve to locate the stator core in the proper orientation, and to maintain it thus throughout the assembly operation.

The stator laminations are not symmetrical due to the positions of the bolt holes and shader poles. Thus, inverting a stator core produces a second pattern. Also, the fact that the leads must exit fromeither end of the stator produces two additional patterns, or an apparent total of four patterns. However, upon closer examination it is found that any of these four arrangements can be achieved by inverting the stator core before winding, and then winding always from the same side, which is to say, always have the leads exit from the same side.

The slot insulation pieces are to be made at the machine, and then inserted into place.

The width of the insulation piece in its developed state is constant for each laminations shape. Only the length, or height, varies depending upon the stack height of the stator core to be wound. Thus, the insulation pieces are to be made from the desired material in the form of strip stock, whose width is the width of the final insulator.

The insulators are to be punched out, two punching operations being required for each piece. In this manner any desired length of insulator may be had merely by varying the length of stock feed between punching strokes.

It is proposed that the design of the motor be altered to include a terminal strip to which the ends of all wires will lead, and be attached. This innovation will provide several advantages.

The pole which is undergoing the winding operation is always in the same position. When one coil has been completed the carrier is indexed to bring the next adjacent pole into the winding position. In the same way the carrier is to be indexed before winding to bring that pole which is to be first wound into winding position. Likewise before winding, and again after all coils have been wound the carrier is to be indexed to bring the terminal strip into position for the wire connections to be made to its posts.

Each machine has a rotary inventory wheel or turntable upon which each size wire required for that particular machine will be carried. The wire reel is transferred from the shuttle conveyor to the turntable at the point of tangency between table and conveyor. Each wire size, or course, has its particular position on the table. The turntable can be rotated (rotated rather than indexed to save time) to bring any wire position tangent to either the shuttle conveyor or the assembly conveyor. Thus, wire is placed on the turntable from the shuttle conveyor and is then moved to the stator.

Since the unit which imports the winding motion is fixed, and since the unit which carries the wire is not only movable, but also selective, it is not feasible to attempt any permanent link between these two elements. The motion unit need never touch the wire itself, provided all guides, pulleys, etc., over which the wire must pass are a part of the wire position on the turntable. This, of course, obviates the necessity of complicated rethreading, since each wire size has its own set of guides, and remains threaded at all times.

SHAFT

OUTLINE MOTOR SHAFT SPECIFICATIONS

AS PRESENTED TO OUTSIDE FIRMS

Material	Steel B4HIB Cold drawn, Standard bar quality.
Major Diameter	.5000/.4997 to be ground max. .002, rejects possible.
Shaft Length	5" to 17" (1/32" increments)
Shaft Extension	0" to 7" (Single or double extensions)
Oil Grooves	2" to 6" apart (1/8 increments) Grooves have .543" lead Grooves run clock-wise or counter clock-wise Grove is arc. - .030/.020 wide by .006/.002 deep There may be auxiliary grooves - refer prints
Chamfer on Shaft End	Constant as indicated
Identification Groove	Arc. .030"/.020" wide by .010/.005 deep Refer prints for number and location

Eccentricity of shaft extensions when turning on bearing surfaces not to exceed .0005 TIR.

Shaft Flats	May be located at either end of shaft of both may be at intermediate positions. Double flats must be within 15^{o} of each other. Inside end of end flats have 1" radii or 15^{o} chamfer. Intermediate flats have step ends. Flats may be of any length up to 4". Flats may be of any depth up to .1875" Pin holes up to .250" diameter may be drilled thru shaft at flat at right angles to flat surface.
Shaft Drilling	Shaft may have either or both ends drilled with up to a 1/4" hole up to 2" deep. (5 different size holes - depth in 1/32" increments)

Shaft Keyways	May be located in shaft at either or both ends and at intermediate positions. Keyway may be .1875" in width by .1875" deep by up ro 4" long. End of keyway to have 1" radius. (6 keyway widths)
Step Shafts	Shafts may be turned to second diameter (as little as .250" diameter) for length up to 5" in 1/8" increments at either or both ends. Steps are chamfered at 15°, 20°, or 30°.
Weekly Production	30,000 with complete variation. Production to be run in batches of as little as three or as many as 10,000.

Summary of Report of Engineering Service Inc. of America

Design concept to produce all types of motor shafts automatically by the use of an I. B. M. card to set up and control all equipment. The basic equipment is composed of three machines, #1 Special Machine, #2 Altered Standard Machine and #3 Special Machine.

The #1 Special Machine is composed of three units in one. #1 Inspect bar for size, #2 Cut Identification Grooves, chamfer and cutoff, #3 Roll Oil Grooves. — (See Sketches #1 and #2).

The #2 Altered Standard Machine to Centerless Grind the major diameter on all shafts. — (See sketch #1).

The #3 Special Machine is composed of a series of stations to do all secondary operation on shafts — such as turn down ends, flats, steps, keyways, drill holes and burr. — (See sketches #2 thru #16).

Machine #1 to be the controlling factor in governing the rate of production of the shaft. The cut identification grooves, chamfer and cutoff station to be the longest requiring approximately 4 seconds per shaft. The other operation done by the #1 Machine requires much less time and therefore are always waiting on the cutoff station. The weekly production at 37 hours per week with 90% efficiency at a rate of one shaft every four seconds is 29,970 shafts per week.

The #2 Altered Machine is also faster than the #1 Machine cutoff station so it will be waiting on the #1 Machine cutoff station.

The #3 Machine which handles four shafts at a time will require about 15 seconds from station to station or will be one second faster than the #1 cutoff station.

In cases where there are three or less shafts at the end of a batch that are being run, the counter at the preload station will stop the #1 Machine long enough so it will not get ahead of the #3 Machine. There is a possibility of a 12 second loss of time between each batch of shafts that are run.

GENERAL COMMENTARY

ON

AUTOMATIC MANUFACTURING EQUIPMENT PROPOSALS

SUBMITTED BY

OUTSIDE FIRMS

B. Grad
3/15/57

STATOR WINDINGS

Apropos Schaeffer Tool and Die's (Mr. Long) presentation, certain other ideas seems worthwhile to note down. Basically, the system appears to be far overdesigned for the needs. Conceptually however, some interesting ideas were presented, especially the molded insulation with the terminal inserts connected by etched wiring in the molded plastic. The biggest single item of cost however in the proposal ($2,461,000) is for the de-reeling units. Since 18 of these were required in order to handle spooled wire, a suggestion was made as to using a barrel type of wire storage. Each would give the equivalent of 10 to 20 reels and would therefore make it possible to avoid an automatic welding system. It might be possible to arrange some sort of a clip-on or hook-on device at the bottom of the drum which would ride into a stop coming out of the drum; and this would stop the wire, turn on a light, and have a manual welding procedure performed to permit continuous reeling without the necessity of re-threading. This would not be fully automatic, but would accomplish about 90% of the objective.

Of the other costs, the two biggest items were the winding control and test units and the actual winding units themselves. These totalled to $574,000. The concept presented of winding one pole at a time requires 18 machines to wind every possible case including the two speed and three speed on in-line basis. This seems quite expensive and is wasteful. It seems more logical to provide for some type of re-cycling of the two and three speed motors through a standard six winding units which have six winding control and test units. This would reduce the basic cost of the winding machines by approximately two-thirds of the price to something under $200,000. Yet by proper adjustment of machine speed and by taking advantage in the machine cycle time of the variable number of turns required, it should still be possible to produce an output substantially better than ten to fifteen thousand a week on these six machines.

Another possibility here would be to adjust the winding speed to the size of wire being wound. In other words, with heavy wire it is conceivable that winding can be done faster without any danger of stretching, but with the smaller wires the breaking danger becomes higher, and the speed should be lowered. By effective scheduling techniques, it should be possible to still keep this winding line well balanced so that it would, with a minimum buffer, be able to operate to the rest of the line. This concept of an independent winding area does not seem illogical. Since it has about the highest on-machine operational time per unit, it should be possible to isolate it so that the rest of the line might go on a fixed plan basis. It is also one of the most highly variable components and the only other way in which the variability can be taken out is to allow a great deal of excess time for each operation.

With these two changes, the cost of the total system would be reduced to approximately \$400,000 which starts to bring it into the range of feasibility. Another suggestion for elimination of cost would be in the parts supply turrets. To have stator cores coming in already keyed seems like introducing an unnecessary set of variations. There are theoretically 18 possible cores which might have to be stored on the line and even in practical sense probably 10 to 12. By having the punchings come in directly, mounted on some sort of rod or center device, it should be possible by using these 3 feed "tubes" to have the punchings available at the point of usage ready for metering and keying. It is also conceivable that something similar to this might well be done for the molded plastic insulating and terminal pieces. There might be a standard top piece for each of the three basic punching forms and therefore we could directly move these over on a center mounting device. These could be nested one into another, thereby making the amount of space occupied a minimum. For the other end, it might be possible to have the molded plastic made in one length or two lengths taking care of either the maximum or average conditions, and cut off any variance to fit a particular stator.

Another thought which might be useful would be to have the top piece go a full 3/4 of an inch to handle the minimum punching and then two styles of bottom pieces; the first 3/4 inch so that in combination we could handle anything between 3/4 inch and 1 1/4 inch and 1 1/2 inch piece which in combination with the original 3/4 inch top piece could handle from 1 1/2 inch to 2 inches. With some concept like this it would be quite possible to reduce the cost for parts supplies to a substantially lower figure. The three turrets which cost a total of \$75,000 might well find their total cost reduced to \$15 to \$20,000 range.

Very little thought or work has been done on the control or direction aspect of these machines and hence, it is not possible yet to evaluate whether there is an inherent logic as to what was proposed. Nevertheless, the types of differences and changes required seem to be of a very simple binary or six stage (variable stack height) nature and therefore should be handled readily by a programming device.

Arlin Products, Inc. (Mr. Arlin) felt that the key problem lay in the basic winding machine itself. It was suggested a hydraulically operated head mechanism be used which would have speeds of in the order of 300 to 500 turns per minute. A feeling was expressed that the big area for savings lay in speeding up the winding process, and getting a more accurate lay of the wire. It seems that the wire lay might be of interest if by so doing better motor characteristics are obtained plus a reduction of the stack height. The idea presented consisted mainly of a precision winding device which would lay the wire very carefully one right next to the other. However, their winding speeds are substantially below what's being realized at present, and therefore do not seem to offer very much of a possibility. They had not thought through how the wire would be selected or how the leads operation or any of the other operations would be automated.

One other suggestion had to do with the stator itself, was that an epoxy resin might be used for the insulation on the inside of the punching surface. It was suggested that some sort of a finger device might come down into the opening, spray this material, go down and come back up again to give a thorough coating. To get the coating on the top and bottom, it was recommended that a dip process be considered.

SHAFT

In the Engineering Service, Inc. proposal, much attention was given to the necessity for control of the various different positions on the shaft. In the original outline given to this firm, tolerances and variances were set at much tighter levels than actually exist in the current motor. This was done since the specifications were prepared in advance of a detailed study of the shaft blueprints. This of course, led them toward planning an elaborate system with very tight control which might not be necessary if they have looked at the true incremental spacing of most of the parts. Nevertheless, we may evaluate this in terms of how well it fits the specifications and then secondly examine it in terms of how the specifications might have been relaxed to provide a more economical solution.

The general concept includes a reading device which would read a card containing all the dimensions. These dimensions were then to be used to position a control box to one inch, tenth of an inch, and twenty-thousandths of an inch increments. This corresponded very nicely to the way the card was designed in that it would show the dimension at the three levels: the amount of inches, the number of tenths of inches, and the number of twenty thousandths of an inch. This firm had not thought through how the cards were to be read or how the information was to be stored; they merely assumed that it could be done and that it would be available when needed. The position control boxes were designed on an exception principle in that they were set for the first part of a certain type going through and not changed until a different part was started. The individual position stops were fully independent for each machine tool along the line and were not necessarily interlocked. A counter control would be used to know when the proper quantity of parts had been made and this would then be the indication that a new card should be read in so that the position controls could be adjusted.

Though the basic concept of treating both ends of the shaft from a symmetric standpoint has certain advantages, there are certain obvious disadvantages. It is likely that certain of the characteristics cannot occur on either end, but only on the opposite pulley end for example. This might enable us to eliminate certain machines along the line. In addition, of course, the number of single extension shafts which occur in the business is quite substantial, and to have two complete sets of equipment for the 50 percent or so of our double extension shafts does not seem too realistic. A concept therefore which might reduce the cost considerably would be to re-cycle the double extension shafts through reversing their position and having the same machines perform the flat milling operations and turn-down operations on the second extension (opposite pulley end) after the pulley end extension was machined. This would in all likelihood result in a reduction of equipment cost of something over $100,000.

The total cost of the position boxes suggested here is something in the order of $100,000. It was estimated that there are approximately 120 positions which need to be controlled and on a mass production basis would cost about $700 to $800 per position box. This looks like a fruitful area for cost reduction with two major approaches. One possibility would be to directly control the motion itself instead of having a separate stop on limit. This in effect, reproduces equipment which is already in existence for producing the motion in the first place. If the motion itself were to be controlled then it would be necessary to measure continuously the actual status of the movement to compare this measurement to a standard and stop the motion when the comparison reached a zero point. Another different concept for reducing the cost would be to simplify the physical equipment needed for positioning and replace it with electronic gear which would remember the limit position, in effect setting up a small closed loop right at the machine itself. One interesting thought that came up in this regard was the possibility of having a multiple reading device, each station of which would correspond to one of these stations of the shop. Each reading device would be so designed as to read only that information which was necessary to the operation of the particular station to which it corresponded. The punched card would follow the first part through. The demand for the next card would occur only when the counter had reached a certain maximum quantity indicating that the proper number of parts had been produced. The card would go right straight through to a final hopper; it would not be controlled in the intermediate station but would pass through one station to another as the line was indexed. In effect the reading stations would be an analog of the physical factory. Cards would have an advantage in this application since the space between cards could be stretched or lengthened depending upon the quantity involved.

The question was asked if by using a two shaft at a time plan instead of a four shaft at a time plan significant savings could be made in the total cost of the equipment. It was indicated the savings would not be high but would probably be no more than 15 to 20 percent of the total system cost.

The capacity (30,000 per week on a 5 day - 1 shift basis) was excessive for the demands that are forseen for the particular motor, and therefore some exploration should be given as to whether there are not better solutions that would be available for a smaller capacity plant. The initial stations in the line looked good and the only major suggestions there were in terms of adding a straightening operation ahead of the cut to length operation.

All in all, the report by Engineering Service, Inc. was most comprehensive and complete and by having noted each of the motions they were trying to control they did a very thorough job. In the main part of the line, the major important changes that could be made might include elimination of the following operations: 3, 4, 5, 6, 7, 15, 16, and 17. Each of these operations seems to be done on a very small percentage of the total shafts produced and might well be eliminated through Marketing co-operation. There are other operations which have some likelihood of being eliminated through effective, integrated planning. These include operations: 10, 11, 12, 13, and 14.

It seems to me, in colclusion, that the total cost of the system might be significantly reduced from the proposed $350,000 to a figure more in the range of $150,000 by effective co-operation and by new concept work on the re-cycling of double extension shafts.

One other idea on shafts which was suggested by Mr. A.C. Close concerned producing standard segments of the various elements which make up a shaft and then putting these together to prepare the specific shaft required. The segments would consist of: flat, extensions, oil grooves, center sections, and possibly neck down or internal flat segments. A careful standardization of a relatively few different parts could by combination, make any shaft required. The difficulty, of course, lies in how to put these together and whether or not any significant savings would be made. It was suggested that a glued shaft or a force fit concept might be quite feasible since the total torques are not very high. However, this would require more material than the present process and might not be as economical.

SHELL

When Schaeffer Tool and Die's representative presented the stator winding proposal it was also suggested that the shell might well be constructed from a pierced metal frame. By piercing and then expanding the metal one might get a shell equal in strength to the present one while still not leaving any openings so large that it would allow a person's finger to enter. This seems like a reasonable suggestion and should probably be investigated further.

MISCELLANEOUS

When the Arlin Products representative presented the stator winding proposal, certain questions concerning the rest of the product were raised to see if he had any other particular ideas which might be applicable. He suggested, for example, that for the shaft similar grinding operations were already being controlled with one of their standard built machines. He felt that the cost of the control and feed back equipment, would run in the order of $12,000. Much of this equipment though (about $3000 worth) has to do with the orientation of the shaft and if an oriented part could be presented to the machine, the cost would be dropped to the $8000 range. This machine would directly correspond to what was being required in the Engineering Service, Inc. study. He felt that the oil slingers offered an obvious screw machine control opportunity. The sensing as to whether or not the oil groove exists can be done with an air device; punchings can be orientated automatically if they are randomly stacked, and positioned at the rate of about one per second. The metering operation on punchings is one which they are doing on either a quantative or a displacement basis. The automatic printing of information nameplates is an operation which they are doing on automobile pistons. It was also suggested that the insulation pieces be made directly at the winding machine and that this, even though still made of paper, would be a substantial advantage.

PHYSICAL TRANSFORMATION AREA

Mark Grenier

March 17, 1957

The object of the Physical Transformation or "Making Operations" Study was to determine to what degree the manufacturing equipment and related business functions could be economically upgraded into automatic areas.

The basic approach taken was to determine the needs of the business as dictated by the product requirements. As a result, the plan called first for getting acquainted with the business and the product. This was the "What is now being done" phase.

The area of investigation called for a study of the information and process flow pattern, as well as a detailed analysis of the parts characteristics.

In addition to getting to know the product and processes, it was decided to get outside engineering work done in developing a complete automatic system for processing the shaft and performing the coil winding operation.

The information and process flow charts were simply a systematic plot of the flow of information and operations which take place in the processing of a part or assembly.

The parts characteristic study consisted of an analysis of all drawing numbers for a given part or assembly and separating the physical characteristics into fixed and variable categories. This type of arrangement established the full range of dimensions and incremental variations. In addition to providing a better understanding of the product make-up, it is intended that this information will be useful in the future in the actual design of the manufacturing equipment.

As of the conclusion of the Project, the following parts and assemblies were covered:

1. Shaft
2. Rotor Core
3. Rotor Assembly
4. Stator Core
5. Stator Winding
6. Lead and Cord

Simultaneously with the get acquainted phase of work, it was deemed necessary to initiate outside engineering studies on two key processes of the make operation. It was felt that such conceptual system studies might be valuable in gaining a new insight into the methods involved. The key processes selected were:

1. Shaft Processing
2. Stator Core - Coil Winding Process

To perform the outside engineering studies, the following engineering firms were selected:

1.	Engineering Services, Inc. Detroit 19, Michigan	Shaft
2.	Sheaffer Tool and Die Fort Madison, Iowa	Coil Winding
3.	Multra Engineering Stamford, Connecticut	Coil Winding
4.	Arlin Products Detroit, Michigan	Coil Winding

Complete reports on the engineering studies performed by the above firms are available.

The process and parts characteristics studies were designed to serve as a base of examination for the "why" phase so that logical improvements could be evolved. The information tabulated in the product structure proved that there was a logical relationship and pattern for most cases; and as a result, this information could be used to extreme advantage in planning automatic set-up and contol of equipment.

In the outside engineering studies, positive gains were made in the form of product design recommendations and processing points; in addition, there were excellent examples of the penalties incurred when some of the present product requirements and methods are extended into an automatic line without economic consideration or product re-evaluations.

During the weeks of data collection, discussion was encouraged on the over-all aspects of the manufacturing equipment problem. Some of these general topics were:

Control:

The question of over-all system control basically is centralized control vs. decentralized line or unit control. The former could take the form of a central computer directing programming information to the over-all system. This information would consist of work scheduling, setup instructions, machine cycle information and feedback information. In the alternative case, decentralized line control, the controlling action would take place independently of the other systems. It would appear that the centralized control would be a logical evolution from decentralized control.

System Design:

In order to vary cycle times and cushion against system failures due to failures of individual units, in-process buffers will probably be necessary. To determine how much buffer stock is needed, it would seem desirable to simulate factory operations by a dynamic computer model to test operating conditions and their effects. Work of this nature is being carried out in similar cases with good success.

Machine Design:

The area of machine design presents a number of important points. Some of these points are:

Variable Speed Control vs. Fixed Speed;
Automatic Set/Up vs. Manual Change;
Positioning Control Path vs. Point Control;
Performance Life Design;
Maintenance, Standardization, Automatic Adjustment

Philosophy of System Design:

The proper sequence of steps for good system design are unfortunately not always intuitively obvious. Of the number of approaches possible, one approach would be to accept existing product designs and processes as they largely exist today and build equipment around them. Although this does have many recommending features it may not solve the problem. Possibly a better approach will be directed more specifically at a change where it can be justified. This latter philosophy would discount change for change's sake but on the other hand would encourage change aimed at optimum economic advantage.

Although nothing can be definitely resolved in a general discussion of such topics as this, it seems important to be aware of them in a large project so that they may be considered at the proper time.

FRAME 39 SYSTEMS PROJECT

QUALITY CONTROL STUDY

OBJECTIVE:

A thorough understanding of both product and process measurements and their relationships to process control, product design and product quality.

APPROACH:

General: Each of the "specific studies" listed below were performed in the following manner:

1. Review available forms and reports and complete a brief survey of the activity to be studied by interviewing the supervisor.

2. Plan the information gathering phase and make a time schedule for the study.

3. Process chart the information flow using the charting techniques specified for the project, if applicable. Keep a record of date, interviewing time, person interviewed, charting time, and planning time.

4. Review the data gathered and replan if necessary.

Specific: In order to present a more concise and descriptive picture of the Quality Control function, the study was divided into the following sub-studies:

1. Quality Control Engineering
    - (a) Inspection and test planning
    - (b) Analysis of Inspection reports
    - (c) Quality audits
    - (d) Analysis of customer complaints

2. Product and Process Measurements

3. Manufacturing Loss Control Study

4. Inspection and Test
    - (a) Material identification
    - (b) Color system for gage checking periods
    - (c) Calibration of instruments and meters

SUMMARY OF QUALITY CONTROL STUDY TIME:

A total of approximately 327 hours were spent in planning and compiling the Quality Control Study. This total time may be broken down as follows:

	Hrs.	% of Total
Planning	27	8
Interviews	150	46
Meetings	18	6
Charting	132	40
Total	327	100

or by total time for each phase of the study:

	Hrs.	% of Total
Quality Control Engineering	138	42
Product and Process Measurements	145	44
Manufacturing Loss Control	15	5
Inspection and Test	29	9
Total	327	100

GENERAL RECOMMENDATIONS BASED ON STUDIES:

1. The report on Analysis of Inspection Reports shows that pertinent inspection information is being collected and processed with modern data processing equipment. Feedback of information to the Quality Control Specialist is prompt; however, the report indicates that this information reaches the Shop Foremen only after an analysis has been made by the Quality Control Supervisor. This may be several days later. Advantages of getting original information directly to Foreman might be investigated.

   It might also be an advantage to keep control charts on certain specific items so trends could be followed more accurately than is possible by noting percentages for individual days. It is difficult to keep a point of reference in mind.

2. The Product Quality Auditing function appears to be very thorough in checking on such items as inspector accuracy and adherence to procedures and standards. The report refers to inspection data points as being those activities that are audited. If this does not include test points, we would also recommend that these be audited - if not by the same person, by some other person qualified to do this work.

   A once per week audit of final product quality seems light considering the volume of production. We would also hope that this includes operational tests such as heat runs, etc.

3. Analysis of customer complaints appear to have all the necessary elements, including follow-through, to see that corrective action gave the desired results.

4. We recommend classifying tolerances on quality characteristics as minor, major or critical in regard to the requirements of both the product and the process. In this way, the preventive effort available can be directed toward the positive control of the more important quality characteristics. This classification will also have an effect on the workers producing the material by pointing out where more care should be exercised.

5. The analysis of the product and process measurements indicate a high inspection content, in some cases doing post-process sorting. We would recommend the investigation of measurements which are now made on a 100% or high percentage basis by Quality Assurance personnel, directing the study toward these goals:

   (a) Mechanizing the measurement

   (b) Integrating the measurement with the production process for the operator's use in control of the process.

R. A. Jimmo
W. H. Lewis

3/14/56

Subject: 39 Frame Systems Project
Computer Support for Product Engineering

INTRODUCTION

The problem of product engineering 39 Frame induction motors is one of the most challenging to be found within the General Electric Company. There are two important reasons for this fact: first, shaded pole motor technology defies rigorous mathematical expression; second, the commercial field is so highly competitive that the selling price cannot reflect more than a very small amount of product engineering expense.

Whether we consider Product Engineering as an entity or as a link in the integrated manufacturing system, two questions are of particular interest.

1. Can computer techniques be used to support product engineering?

2. What are the technical and economic advantages of the use of a computer in product engineering?

Since only a few days were devoted to investigating this general area, the answers to these questions cannot be stated without qualification. We have simply attempted to scope the problem, consider various approaches, and define the areas of expected gains.

PRODUCT ENGINEERING FUNCTION DEFINED

The complete Product Engineering function has been excellently process charted by Mr. Reynold King. However, for the purposes of this report, principal emphasis is placed upon the task of calculating and adjusting the physical variables of the motor such that this motor meets the required performance characteristics.

Input. The following parameters represent information which must be specified to define the motor:

Voltage
Speed or speeds
Torque at rated speed (or torque at fan operating speeds)
Minimum allowable efficiency
Minimum dip torque ratio
Direction of rotation (or reversible)
Allowable temperature rise

All of the above items are not always specified by the customer, and under certain circumstances the value will be established by the engineer, marketing, or industry standards.

Physical Variables. In order to obtain desired motor performance, the engineer manipulates many physical variables. Due to the interdependence of these variables, the task of actually designing a motor is an iterative procedure. The following list contains several items which are normally considered constants; however, each is truly a variable, and ideally we would know the quantitative relationship of its influence upon the motor's characteristics.

Number of poles
Stack height
Stator winding turns per pole
Stator winding wire size
Rotor bar size and bar material
Rotor end ring
Rotor skew
Shading coil conductor size
Shading coil conductor span
Pole chamfer
Length of air gap
Magnetic material and punching thickness

Except for the first five of the above items, these variables are normally fixed by design engineering for a given motor line.

Characteristics. After establishing the specification of each of the physical variables, the product engineer must determine the following characteristics:

Speed - torque curve (at least at points of rated, breakdown, dip, starting).
Stator winding full load amperes
Watts loss
Efficiency
Dip torque ratio
Stator winding resistance
Power factor
Reactor speed control data
Temperature rise
Overload device required
Weights

The specification of each of the physical variables and the determination of the resulting motor characteristics defines the product engineering function as considered in this report.

COMPUTER SUPPORT

A careful study of the process chart prepared by Mr. King reveals that the existing procedure of product engineering can be conveniently programmed for a computer. However, since this existing procedure utilizes the straight-forward method of ratioing against tested reference models, it is very doubtful that a mechanization of the procedure would offer either technical or economic gains. The only justification for such mechanization would be to allow product engineering to provide the required link in a fully integrated data processing system.

It is of much more interest to consider what new methods of calculation are available through a high speed computer. If new methods do present themselves, it is possible that the technical and economic gains usually associated with data processing can be realized.

Two possible approaches to the electro-magnetic design are feasible. The first is the equivalent circuit presently being developed at Ft. Wayne for the shaded pole motor. The second is the extensive collection of test data for the purpose of writing emperical formulae (this also is receiving close attention at Ft. Wayne). Either approach would add considerably to the technological understanding of the motor and would result in closer control of product quality. However, again it is highly probable that mechanization of the procedure would be justified only when complete integrated data processing was the objective. (An extremely complex equivalent circuit could change this statement.)

Of considerably greater potential gain is a computer program to determine the temperature rise. While good methods of heat transfer calculation exist for motors, these methods are extremely complex and time consuming when attempted by hand. A digital computer motor design program using any appropriate electro-mechanical procedure but using also a fairly accurate calculation of temperature rise would do several things:

1. Lower the cost. Due to the fact that temperature rise calculations are not made at present, and due to the absence of accurate heat run data, there can be little doubt that an excessive amount of material must be engineered into the product in order to insure against test failures.

2. Improve product quality. Heat transfer is an extremely deceptive field, and often the best of judgement is not correct. It is possible that some motors are operating above standard temperatures.

3. Close the loop of design procedure. Design of electrical machinery is normally an iterative process of adjusting variables to obtain the optimal compromise between electro-mechanical characteristics and thermal properties. With no method available to determine temperature rise, the designer cannot take advantage of refinements in the electro-magnetic formulation which might normally indicate possible savings in material.

The heat transfer problem is not one which will be solved readily by empirical data. The difficulties of measuring temperature rises in test are well known, and are compounded by the fact that the customer's actual installation can seldom be duplicated.

It would appear that the first step toward a solution of the thermal problem would be the setting of NEMA or ASA standards for heat runs. If the allowable temperature rise could be stated for a well defined set of conditions, one of several analytical approaches could be used to give reasonably accurate results. These approaches would be lengthy and undesirable as parts of hand procedures, but the computer program would be completely practical.

In beginning the actual heat transfer study preparatory to writing a computer program, reference should be made to the following:

DQF-56-MC-3 and DQF-56-MC-8 discuss the uses of computers in solving and reducing the equivalent thermal circuit for induction motors.

Solution of Transcient and Steady State Temperature Distribution Problems on the IBM-704. This is a memorandum by J. M. Butler of Turbine-Generator

Engineering.

No attempt will be made here to detail the probable computer program which would mechanize product engineering. At this time it should be sufficient to establish these facts:

1. Without a heat transfer calculation, the program becomes one of solving equations with little reiteration.

2. With a heat transfer calculation included, the program becomes an iterative process (one for which a digital computer is ideally suited).

3. In either case, it is likely that empirical equations will be completely satisfactory for the success of the program, and I would like to suggest that work towards obtaining these equations be increased.

CONCLUSION

Several approaches to the electro-magnetic design of shaded pole induction motors are capable of being programmed conveniently for a computer. However, such programs would offer little technical or economic advantage unless they also included a reasonably accurate temperature rise calculation. Presently known methods of determining heat transfer in rotating machinery are too complex to be justified in a hand calculation for 39 Frame motors. However, the potential gains offered by such a calculation can be realized by the use of a computer.

Without adequate standards for heat run conditions, the 39 Frame motor engineer has little opportunity to take advantage of design ability in working toward optimum specification of the physical variables. Similarly, the absence of thermal standards will limit the effectiveness of any computer program.

D. M. Bouton
Systems Engineer
Computer Department

SECOND REPORT ON SPECIALTY MOTOR MANUFACTURING

SUBJECT. THE ULTIMATE INDUCTION MOTOR (AS SEEN IN "56")

INTRODUCTION

This report is basically concerned with motor design for manufacture. It summarizes and shakes down much of the work now in development to set a definite pattern and to define an ultimate goal, where possible. The basic consideration is of shell type motors. An additional consideration of chemical process (glued) motors is made. In each case the motor is considered a part at a time and then on an overall basis.

SHAFT

The ultimate is a centerless ground straight thru shaft because such a shaft:

a. Has the lowest material cost
b. Has the lowest manufacturing cost
c. Can be made most accurately, if straightened on a Kane & Roach before grinding.
d. Requires the lowest total equipment cost, if equipment utilization is high.

The shaft should be grooved for reversible rotation, so that a single manufacturing set up and procedure can be used for all flanges.

The lengths of shafts and flats should be standardized for minimum set up and maximum machine capacity. These lengths must be within some established machine capability.

ROTOR AND STATOR LAMINATIONS

The laminations should be designed to be punched to size in a scrapless die, because this will yield:

a. The lowest material cost
b. The lowest manufacturing cost
c. The lowest equipment cost
d. The most accurate punchings

The use of scrapless dies makes necessary four small flats at 90 degrees on the sides of the punching. The stator to shell holding power is not impaired, since the stator is secured by the araldite dip as well as the press fit.

ROTOR CASTING AND FINISHING

The rotor must be of a closed slot design to eliminate turning the O.D. Also, the rotor must be cast flashless and sprueless to eliminate turning.

The rotor may require reaming or boring for shrink fit size on small shaft diameters. In a boring operation the rotor would be chucked on the O.D. so that the boring operation would be:

a. Faster than O.D. turning
b. More concentric than O.D. turning
c. More accurate in diameter and straighter than reaming
d. Not as fast as reaming

THE ULTIMATE INDUCTION MOTOR CONT:

ROTOR SPIRAL

To accurately spiral a stack of rotor punchings is a difficult manufacturing achievement. The greater the spiral, the more difficult the achievement of an acceptable spiral becomes and the more variable the motor performance becomes even with rotors within acceptable spiral limits. No good method has been conceived to mechanically achieve a very high rotor spiral. They must be made by hand.

ROTOR SLOT FOR SHADED POLE

The most logical standardization would seem to be two rotor punchings. One small slot punching for high start torque multi-speed motors and one large slot punching for high efficiency motors. If a compromise is attempted, the standard will probably break down into three or more rotor slot sizes.

ROTOR SHAFT ASSEMBLY

The rotor should be taken directly form anneal and shrink fitted on the shaft. The anneal temperature should be between 900 and 1000 degrees F. After the rotor is fitted to the shaft, it should be quenched as soon as possible.

The shrink fit calculation can be from as high as 800 degrees F. Assembly of small diameter shafts may require the shaft to be rapidly pressed or shot into the rotor rather than the rotor to be dropped on the shaft. This will prevent the shaft from expanding during assembly.

OIL THROWERS

The cost of screw machined steel oil throwers is excessive. Oil throwers must be of aluminum, unless they are single edge and high quantity. In this case they may be cold forged. A process may be worked out to cold forge double edge steel oil throwers. It is being worked on.

STATOR CORE CONSTRUCTION

Keyed stator construction should be used because it is:

a. The strongest construction
b. The most trouble-free construction
c. The most economical construction
d. The most readily mechanized construction

Keyed construction is not applicable to excessively thin stator yoke design because it sets up some stresses when the keys are flattened.

Riveted stator construction yields poor quality and high rejection on large cores and, particularly, on long cores. This is because the L/D of the rivet and hole are inherently such that the rivet will buckle in the stator hole and distort the core. Also, there must remain some clearance between the rivet and the hole, which means that friction is the only force which retains the laminations in alignment. For low mass cores with low L/D rivets, riveted construction is very successful.

THE ULTIMATE INDUCTION MOTOR CONT:

STATOR CORE INSULATION

Integral insulation should be used on the stator core. This means that the windings must be redesigned both to take advantage of integral insulation and to make allowances for it. The winding machines must be retooled to clear the integral insulation wherever it interferes and conventional insulation does not, such as, between the stator teeth or pole tips.

SHADING COILS ON SHADED POLE MOTORS

Solid shading coils will be insulated and automatically inserted. Shading coil insulation is imperative for uniform motor performance. Automatic insertion requires that the punching be designed for straight shading coil entrance. This indicates a chamfered pole tip rather than a reluctance slot punching. The reluctance slot punching makes shading coil insertion very costly. All shaded pole punchings, whether chamfered or not, should be designed for straight shading coil entrance, if low cost shading coil assembly is to be achieved.

Wound shading coils for reversible motors will be insulated with heavy tape which serves two purposes;

One, it holds the coil together during the winding operation.
Two, it serves as a ground insulation.

No other system offers one part or material for both purposes. The heavy tape insulated coils will be automatically glued into the slots, so that they will not move into the bore or axially, when handling or winding. This is an important and necessary step in assembly, because it overcomes the need for two end turn fibers. One end fiber will be used to insulate the shading coil crossover from the main winding. Competitive motors use no end fibers. End fibers are expensive from a material standpoint, but they cost even more to handle.

AUTOMATIC AND SEMI-AUTOMATIC SHELL MAKING

The 39 Frame shell making system represents the most economical high production automatic system for making shells. The 39 Frame system is not completely automatic like the original Form G system, but it is more economical from an overall standpoint for quantities over 18,000 in 80 hours.

The 29 Frame system will be less automatic than the 39 Frame system, but it will be more economical for quantities of between 10,000 and 18,000 shells in 80 hours. The 29 Frame system requires somewhat lower investment and a slight increase in labor cost.

The roll and weld to size without expanding or turning process should be used if it proves successful in DeKalb. This process may work out for long motors but not for short motors. In any event, it should be used to the greatest extent possible whenever it proves usable.

THE ULTIMATE INDUCTION MOTOR CONT:

END FLANGE MATERIAL

The choice between steel and aluminum depends on the design requirement, which in turn depends on the application. The first choice is steel, provided a steel flange can be designed as a single piece with very little or no machining required.

Steel is many times more expensive to machine than aluminum. A relatively small amount of steel machining will run the equipment investment and the labor cost so high that aluminum will be less expensive. If a flange design in steel is such that more than one piece is required for the basic structure, the cost becomes questionable, because of the handling labor. A very small piece generally costs just as much to handle as a very large piece. Thus, a two piece flange probably requires more than twice as much labor as a single piece flange, even if one piece is only a sleeve or a cup.

Where aluminum is used, it should be designed to accommodate all functions, so that the only machining is the bearing hole. The die cast material should be used as the bearing with no insert. Such construction with end oiling seems to be proving satisfactory from recent life tests and is a major step ahead in aluminum flange design.

END FLANGE DESIGN

In all flange designs, an unmachined rabbet should be designed. With the proper design and manufacturing technique, an unmachined rabbet produces a better quality assembly than a machined rabbet and, of course, costs much less.

In the steel flange, the design should be such that the complete flange can be made in one die. The sizing operations should be incorporated within the die. The only finish operation should be the finish boring of the pressed in bearing insert.

All bearing cups, caps, washers, packing parts and the cushion ring should be designed and worked out with Manufacturing, so that all assembly can be accomplished by stacking the parts up and pressing the stack together with one stroke. This means the flange should not have to be turned over for assembly.

The bearings should have washer type wicks, which lubricate both the sleeve bearing and the thrust bearing, serve as end bump absorbers and make possible single end adjustment for motor assembly.

All cups and caps should be press fit with a solid gasket for lowest cost assembly.

All oilers should be punched holes, cast in holes at parting line, or if absolutely necessary, drilled no more than 0.2 inch. Oil tubes, if absolutely required, should be assembled with a single motion and should be snapped or crimped in place. Oil holes and tubes should be such that the complete flange assembly can be done in one station at one time and with one handling.

The flange design should be such that its assembly on the motor can be performed in a single straight motion. The flange design should not complicate the motor assembly by requiring subsequent flange assemblies after motor assembly.

THE ULTIMATE INDUCTION MOTOR CONT:

MOTOR ASSEMBLY

The motor design must be such that the motor can be assembled from one end toward the other without being turned over. This makes low assembly labor possible through proper fixtures or semi-automatic assembly. The motor design must be such that there is a basic unchangeable pattern to the steps in assembly. The application flexibility must be obtained by additions to this basic pattern, never by changes in the pattern. If basic assembly pattern changes are made, they must be made across the board, so that a new basic pattern is established. In this case the assembly equipment must be changed to accommodate the new pattern.

Motor end play should be set by adjusting the shaft shoulder in motor assembly. This adjustment can compensate for all the tolerance build-ups in the motor, except those in one flange. The adjustment can be done automatically. This is the simplest and lowest cost method of end play adjustment at this time.

The flange thrust bearing and the felt parts must not be too loose radially, because the shaft must slide through the thrust washer, felt, bearing and thrower in a smooth single motion. Hand location could double the assembly labor.

The flanges should not be too tight a fit in the shell. In the 39 Frame a large percentage of tight motors resulted from excessive flange interference in the borematic and the shell. This interference caused the flanges to spring slightly.

The clampbolt nuts should be square for ease in handling and locating.

The motor leads should be reasonably short. If long leads are required, a plug in at the motor should be developed. To be economical, the plug in must be capable of going through stator treatment. Any assembly after treatment is too costly.

MOTOR FINISH

Motors which go inside customer's enclosure should use the araldite treatment as a shell finish and the aluminum flanges should be left unfinished. The end caps should be plated, sprayed or araldite dipped, whichever is lower cost and works with Dewey Almy. Steel flanges can be araldite dipped or plated before bearing assembly. Any motor, which must be painted, must be painted as a motor and not as parts.

GENERAL PHILOSOPHY OF ULTIMATE SHELL MOTOR

1. A minimum of machining operations. Example (bearing bore and shaft cut off only).
2. A maximum of punch press operations.
3. Each part made complete and ready for assembly or sub-assembly in one sequential line of operations.
   Example (laminations, shells, shafts and flanges).
4. All windings connectionless with coil wires to plug.
5. No metal cutting or forming operations of any kind on sub-assemblies or assemblies.
6. All sub-assemblies and assemblies by press, snap or bend.
7. All sub-assemblies and assemblies such that operator care and skill are not required. Care and skill should be built in the machine not the operator.

Following this general philosophy greatly increases the possibility of an automatic factory.

SECOND REPORT ON SPECIALTY MOTOR MANUFACTURING

.THE ULTIMATE INDUCTION MOTOR CONT:

CHEMICAL PROCESS MOTOR OR GLUED MOTOR

Here the above discussion applies to all parts, except, the shell and flanges. The shell and flanges are replaced by two brackets. The brackets should be of steel unless complexity of bearings and/or customer's mounting, connections, etc., dictate die casting to reduce the number of parts.

*I Air Gap Spacing
1. The development of a wax shim of air gap thickness, which can be applied to the rotor or stator and will melt out during the chemical assembly process has been adequately successful for pilot operation.
2. With the wax shim applied to either the rotor or stator, the rotor and stator assembly is held in a vertical position in the assembly fixture.
3. A fixture has been built, which will hold the rotor and stator assembly in such a manner that no cocking force is applied to the bearings in the end brackets.

*II Bracket Gluing
1. The system of bracket gluing thru holes in the bracket has been developed to a point satisfactory for pilot operation. Satisfactory equipment and glue is now available for purchase.
2. Gluing thru holes in the bracket is not satisfactory for some lines of motors with very short stator stackings, because the overlap of the bracket on the stator is not long enough to provide an adequate spread of the glue between the bracket and the stator.
3. A new bracket gluing process is being developed for short stack stator motors. The present concept is to make this process similar to the operation of the Dewey Almy machine.

III Basic Advantages of the Chemical Process Motor
1. More economical square or rectangular punchings can be used.
2. Less space per HP is required in one diametral dimension.

*IV Basic Disadvantage
Fairly costly process equipment is required to get a reasonable cost.

V General Comments
1. The chemical process motor is not inherently lower cost than the ultimate shell motor.
2. There are many places where it has advantages over a shell motor, but it has no across-the-board advantage.

VI A detailed report on this subject is available

*Changed

L.W. Wightman
(Rev. 3/14/57)

MISCELLANEOUS

Miscellaneous

This section includes several brief papers describing various aspects of the Project, including:

a. Original time schedule for the Project;

b. History of the Project, through March 15, 1957;

c. Time and cost summaries of the Project, through February 22, 1957;

d. Definition of types of Department personnel used on the Project;

e. A brief discussion of an idea on a universal sample motor;

f. A "brainstorming" type analysis of market potential, product leadership, possible design variations and cost characteristics;

g. A brief discussion on how to study the sociological impact of automation;

h. A list of periodicals and books used by the Project.

ORIGINAL TIME SCHEDULE FOR THE PROJECT

1956

August 1 to October 15	Initial planning and organization of study.
October 15	Begin data gathering and process charting.

1957

February 15	Complete the data gathering.
February 15 to June 1	Analysis of data and decision areas.
June 1 to December 31	Conceptual design of the new system.
	Review conceptual design with Department Management.
	Design of new system and preparation of a technologically and economically feasible proposal.
	Present plans to Department and Company Management. Submit Appropriation Request; request authority to proceed with implementation.

1958 - 1959

January, 1958 to Spring 1959	Assuming approval of plans, implementation of the first phase of new system; initial equipment installed and working.
Summer, 1958	Begin discussions of plans with management of other Departments, to inform them of this approach to automation.

1959 - 1961

Fall, 1959 to Summer, 1961	Completion of implementation of new system; all components installed and working.

BRIEF HISTORY OF THE PROJECT:

June, 1955	Project originally conceived as an integrated factory-office automation project.
September, 1955	Proposal for performing the Project presented to Manufacturing Services Management.
December, 1955	Presentation of Project concept and plans to other functional Services, soliciting their participation.
March-June, 1956	Interviewing the Managements of Candidate Departments, where the Project could be performed.
July, 1956	Selection of Specialty Component Motor Department, as place where study would be conducted.
August 6-10, 1956	Development of long range plans for Project, by Manufacturing Services personnel, SCM Department representatives and consultant.
August 13-17,1956	Development of initial plans for data gathering phase and beginning of data gathering in Fort Wayne. Beginning of development of information process charting technique.
September 13 & 14	Finalized plans for data gathering phase.
October 1-5, 1956	Presentation of course on electronic data processing for SCM Department Management and Project team members from all functions.
October 8 on	Data gathering activities in the Manufacturing area built up rapidly.
November 1, 1956	Meeting with Section Managers, SCM Department initiating active participation of other four functional areas.
November 15 on	Data gathering activities in other functional areas built up rapidly. Participation by other functional Services and other outside consultant began.
	Weekly Planning Meetings began (on Tuesdays) for all Senior Analysts.
	Weekly Progress Meetings began (on Thursdays) for all Project team members.
November 27, 1956	Presentation of Project plans and progress to Integrated Procedures Council, at Fort Wayne.
December 13, 1956	Second major meeting with Sectional Managers SCM Department. Project objectives and methods discussed and clarified.
February 15, 1957	Conclusion of Data Gathering Phase with the Specialty Component Motor Department.
March 15, 1957	Completion of Summary Report on Project objectives, techniques and ideas.

TIME AND COST SUMMARY – SEPT. 1, 1956 – FEB. 22, 1957

SPECIALTY COMPONENT MOTOR DEPARTMENT

Direct Costs	1956 Acct. 374	1956 Billed to. mfg. service	1956 Net	1957 Acct. 374	1957 Billed to. mfg. service	1957 Net	Total Net
Salaries	4987	1973	3014	6803	3713	3090	6 104
Office Equipment	2762	676	2086	--	--	--	2 086
Tel., Tel., & Travel.	1636	1232	404	617	617	--	404
Rearrangement	1051	1051	--	20	20	--	
Office Sup., Tech. Serv.	936	936	--	1188	1188	--	
Misc. (rent etc.)	319	47	272	378	26	352	624
Summary	11691	5915	5776	9006	5564	3442	9 218
Less office equipment which will be applied							2 086
Net direct cost to SCM development							7 132

Diverted Costs	1956 hrs.	1956 @ $5/hr.	1957 hrs.	1957 @ $5/hr.	Total
Employee Relation	175	875	326	1630	
Engineering	468	2340	459	2295	
Marketing	208	1040	60	300	
Finance	600	3000	310	1550	
Manufacturing	720	3600	170	850	
Summary Diverted Costs	2171	10855	1325	6625	17 480
Grand Total - all costs -Specialty Component Motor Dept.					24 612

TIME AND COST SUMMARY - MAR. 1, 1956 through FEB. 22, 1957

SERVICES COMPONENTS

195~~7~~6

Mfg. Services direct to Acc't 1179 - includes SCM billing		70 670	
Less est. accrual reductions		7 500	
			63 170
	Man-hrs	@$10/hr	
Mfg. Engineering Service	160	1 600	
Outside Firm Study	---	5 000	
Quality Control Service	255	2 550	
Materials Service	170	1 700	
Accounting Service	300	3 000	
			13 850
			77 020

1957

Mfg. Services - Direct to Acc't 1179 - includes SCM billing		6 018	
Plus Unpaid Contingent Obligations			
SCM Billing		3 134	
Computer Rent		500	
Canning, Sisson and Associates		4 151	
Walter L. Murdock		1 900	
			15 703
	Man-hrs	@$10/hr	
Mfg. Engineering Service	656	6 560	
Quality Control Service	8	80	
Materials Service	126	1 260	
Accounting Service	200	2 000	
			9 900
		Total Services	102 623

DEFINITION OF TYPES OF PERSONNEL TO BE PROVIDED:

LIAISON MAN	A high caliber person who knows the product and the manufacturing problems associated with the product. He should show a high level of interest in the concept of automation and the use of electronic data processing equipment. He will head up the Department's participation in the Project, including analysis of data gathered and the design of the new system. He will carry a fair share of the administrative responsibilities of the Project and will act as a Senior Analyst for his function.
SENIOR ANALYST	A high level operating or staff man, preferably at subsection manager level, who will represent his function on the Project team. He will supervise the activities of the Analysts under him. He will participate in the analysis of the data which has been gathered, and in the design of the new system. Ability to think logically is quite important to this work. There should be one Senior Analyst from each function and Project activities will require about 20% to 75% of his time.
ANALYSTS	Gemerally, a non-supervisory level person who will gather data for the Project. May be MTP, BTC, or similar trainees. The work often involves interviewing other employees and discussing details of their jobs. Beyond this human relations aspect, the ability to think logically is quite important.

CONCEPT WHICH MAY LEAD TO A UNIVERSAL SAMPLE

One of the prime difficulties today in developing a more efficient method of calculating motor design is the lack of effective data concerning how a motor will actually work in the customer's application. These difficulties are primarily not dimensional, but rather performance characteristic in terms of torque, heat, vibration, and noise. To accumulate this data we now have an extensive sample building program. 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 the operating results. This process involves the expenditure of time and money in the factory 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 occasion cost us orders, it was suggested that a standard motor be built, possibly with variable mountings and with certain external variable controls which will permit the motor to perform in a number of different ways. For example, there could be an external reactor which would produce the effect of a variation in the number of ampere-turns in the windings of the motor. There should be a method of applying different voltages externally through a switching device. The heat problem could be analyzed by taking temperature readings from the motor and by measuring the flow of air over the motor in the application. It's possible that some simple devices (such as pitot tubes and thermocouples) might be directly attached to the motor to record the air flow as well as the temperature. The noise frequency might be measured through varying the second and third harmonics of the field by varying the speed of the motor. To simulate the different heating effects in the performance of a smaller motor, it might be possible to have heating elements built into the shell of the motor itself. 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.

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 first contact visit or very shortly thereafter, to make running tests to show the customer specifically what the needs were, to see clearly what his performance requirements would be, and to enable us to design an optimal motor for the particular application.

SYSTEMS PROJECT - 39 FRAME SHADED POLE MOTORS

MISCELLANEOUS NOTES ON POSSIBLE CHANGES IN FACTORY PROCESSES AND PRODUCT DESIGN

BY: T. L. STALEY

Steel for laminations is most economically purchased in coiled lengths of sheet material in the width range 36" to 48". The method currently in use for production of magnetic core punchings involves slitting $34\frac{1}{4}$" widths into six strips 5 5/8" wide and then punching these strips on progressive dies into a pair of rotor and stator punchings at each press stroke. This process results in 75% material utilization in terms of a round blank - the size of the stator punching outside diameter.

A method permitting nesting the punchings and overlapping the stator outside diameters in the layout on the sheet would reduce the gross amount of material required for laminations by 15% or a little more. It would seem that a "C"-Type punch press, equipped with a progressive die, having guide pins only at the die end set nearest the back of the "C", could be equipped with a feeding device - manipulating the payed-off coil end of sheet 39" wide so that the nested and overlapping pattern would be obtained. This would accomplish the better material utilization, eliminate the slitting operation, and retain the single punching operation feature of the progressive die method. The progressive die method would then become more economical than the blank and repunch method.

Examination of financial data shows that in 1956, 37.2% of the income from 39 Frame shaded pole motors sales was spent for direct materials to build them. This looks quite high when compared to the average of 22.2% for the Specialty Component Motor Department during the three years (1952 to 1954) before the 39 Frame became an appreciable factor in production.

This observation is perhaps interesting, but of little value unless, it prompts finding a way to reduce the amount of material required. The 39 Frame motor is built with windings including all of the magnetic material in each pole - in all of the winding turns on that pole. This results in energy losses and backward torque components that are high in comparison with the energy losses and backward torque components in a machine built with the winding turns distributed along the pole face in a manner designed to distribute the magnetic flux sinusoidally along that pole face. The shading coils remain short circuited during running conditions although their purpose is to obtain starting torque, not to improve running operation. The currents circulating in the shading coils during running conditions result in energy losses which would not be present if a device for open circuiting them upon reaching running conditions were provided.

It is the writer's estimate, that shaded pole motors could be built employing the 30 Frame - 36 slot punching length and would operate at about 50% energy efficiency at full load compared to 35% for the presently built motors. The main windings would be distributed over three coils per pole in six pole motors, and over four coils per pole in four pole motors. The shading coils would be wound in the same slots as the main windings and would be short circuited and open circuited by a switch and centrifugal mechanism. The switch and centrifugal mechanism would be the same as those now used on KH and KC types of 30 frame motors.

SOCIOLOGICAL IMPACTS OF AUTOMATION

The automated plant which could be built as a result of the systems study will present some new concepts of management-employee relations. The difference between the classes of functions involved in the new system and those involved in our present system will probably call for entirely new organizational patterns, channels of communication, and types of management controls.

A study of these changes should be made in connection with the systems project to facilitate the transition from the system which is in operation today to that system which is being designed for the future.

The results of such a study will be essential to management in carrying through this transition. These results will point the way to the type of organization which will be most effective in an automated business, the types of people required to operate the business, where the people will come from and how they can be trained for the new jobs. The study should help management achieve the best possible utilization of the abilities of employees and develop some means of motivation for these employees. The question of the impact of automation on society and the community, and how to best utilize the community, should be answered in this study. Unless these things are taken into consideration, the task of the systems project team will not be fully accomplished.

We believe that a study should be made, as part of the systems project, to point out the ways in which management can utilize a knowledge of human behavior to help achieve the ultimate in an automated operation.

PROPOSALS

A. Initial Investigation

With the help of the project team members, an identification should be made of the classes of functional changes which will take place in the move to automation. One of the changes should be selected for an initial study. This initial study could be made in several areas where a similar change has taken place, and the best solutions to the problems involved should be noted. Some measure of the responses of employees to the change could be devised to help in the selection of "best" solutions to problems. The results of this initial study should point up the effectiveness of utilizing this method.

B. Enlarging the Study

If the results of the initial study indicate the validity of this method, the study should proceed. A selection should be made, again by the project team members of those areas of change which will be most significant. Each area should be studied in a manner similar to the initial study.

It is expected that from this enlargement of the study will come some preliminary plans for employee and community orientation programs,selection and training methods, management techniques, payment plans, organization patterns and channels of communication which will be necessary to achieve the transition to automation.

SUGGESTED PERIODICALS FOR AUTOMATION BACKGROUND

Automation - Penton Publishing Co.

Automation Service - R. Hunt Brown

Automatic Control - Reinhold Publishing Corp.

Business Week - McGraw-Hill Publishing Co., Inc.

Computers and Automation - Berkeley Enterprises Inc.

Control Engineering - McGraw-Hill Publishing Co., Inc.

Data Processing Digest - Canning, Sisson and Associates

Factory Management And Maintenance - McGraw-Hill Publishing Co., Inc.

Flow - Industrial Publishing Group

Fortune - Time Inc.

Instruments And Automation - Instruments Publishing Co., Inc.

Journal of the American Institute of Industrial Engineers

Journal of the Association for Computing Machinery

Journal of the Institute of Management Sciences

Journal of the Operations Research Society of America

Library Service Bulletin - G.E. Co.

Machine Design - Penton Publishing Co.

Programmer, The - Remington Rand

Publications of the American Standards Association

Publications of the Bureau of Standards

Steel - Penton Publishing Co.

ADDITIONAL REFERENCES

Books

"Electronic Computers and Management Control" - Kozmetsky and Kircher

"Electronic Data Processing for Business and Industry" - Richard Canning

"Office Automation" - R. Hunt Brown

ACTIVITY STUDIES

SUGGESTED ACTIVITIES - EMPLOYEE RELATIONS

Application Routine

Processing a job applicant from his entrance to the employment office to the beginning of the "engagement routine". Includes interviews, aptitude testing, reference checks, medical exam, identification picture.

Employee Benefits

Processing of insurance claims, initiation of retirement, death claims, absence investigation.

Engagement Routine

Orientation, engagement sign-up, forms processing and initiation of the initial employment folder.

Personnel Counseling

Outline of routines and sources of information used in discussion and solution of employee problems.

Removal Routine

From the initiation of the removal record to the end of the removal process for termination of employment.

Safety

The investigation of accidents and resulting preventitive measures.

Salary Administration

Additions, transfers, removals, salary changes for salaried personnel.

Suggestions

Processing of suggestions submitted through the formal suggestion plan.

Transfer and Upgrading

Transfers within a section, between sections or departments and transfers involving changes in job grade and lack-of-work transfers.

Wage Administration

Assignment of rates and codes, reporting of wage information, evaluation of new jobs for non salaried employees.

SUGGESTED ACTIVITIES - FINANCE

Accounts Payable

Processing and payment of invoices from external and allied works vendors. Computation of transportation charges, discounts and billing adjustments.

Budgets and Measurements

Data collection, analysis, summary and reports of projected costs and margin. Comparison of results obtained with budget and historical data.

Cost Accounting

Computation and allocation of manufacturing costs. Maintenance of standard data for analysis of variance. Evaluation of input and output of inventory. Preparation of forecasts of labor, IME and tool costs.

Customer Billing

Render invoices to customers, billing adjustments, bill collection scheduling.

Expense Accounting

Payroll distribution, IME reports, balance sheet, internal invoices, appropriations, warranty and reserve accounting, engineering expense, clearing accounts.

General and Tax Accounting

Summary of operations, preparation of financial statements, reserves for depreciation, processing and computing government, state and local taxes and company assesments.

Gross Payroll and Timekeeping

Administration of wage payment plans for hourly and piecework labor, record time worked, output and earnings.

Gross to Net Payroll

Control employee master files, employee benefit deductions, employee collections. Provide reports of deductions and collections to employee, management and government.

Orders and Sales Accounting

Account distribution for sales, cost of sales, inventory relief. Report taxes accrued and billed from sales, sales and cost data for management. Control warehouse and consigned stocks.

SUGGESTED ACTIVITIES - MANUFACTURING

Control of Unit Operations and Feedback

Information flow in foreman-dispatcher-worker relationship. Classification and definition of all control and feedback information. Progress reporting and expediting.

Customer Order Processing (Requisition Service)

Receipt and handling of customer orders, pricing, preparation of manufacturing orders, repair and return orders, cancellations and renewal parts orders.

Incoming Material Inspection

Procedure of inspection, recording of condition or quality of incoming material and reports of inspection results (may be included in 'Receiving' study).

Inspection and Testing

In-process and finished product routines of reporting quality levels, disposition of defective material, maintenance of test equipment.

Making Operations

Actual operations in the physical transformation of raw and purchased materials into finished parts and assemblies. Production equipment used in these operations.

Operation and Process Planning

Translation of new parts requirements into operating descriptions and standard times. Provision of labor, materials and equipment data for estimating; rework and extra work planning; analysis of new part drawings for tool, equipment and routing requirements; computing standard time data.

Plant and Equipment Maintenance

Procedures for handling work requests for maintenance and repair of building, equipment and facilities. Preventive maintenance scheduling. Inventory of repair parts and supplies. Operation of tool room and janitor service.

Procurement

Direct and Expense material ordering routine, Inquiry procedure, Quotation analysis, Preparation of purchase order, Vendor selection, Overcharge claims, Follow-up, Invoice checking.

Product and Process Measurement

Determination of quality characteristics of parts or assemblies; method and frequency of measurement for control of product and process quality.

Production Forecasts and Inventory Planning

Development of short-range production forecasts based on Sales Forecasts and calculation of projected inventory balances and turnover ratios.

Production Control

Master scheduling, weekly schedules, shipping estimates, work vouchers, material requirements determination, inventory record maintenance, dispatching, factory order placement, production progress feedback, schedule adjustment.

Quality Control Engineering

Manufacturing loss control, inspection and test planning, analysis of inspection reports, quality audits, customer complaints, quality costs.

Receiving

Unloading of incoming carriers, verification of receipts, damage or shortage reports, distribution of materials, receiving reports.

Salvage and Obsolete Materials

Receiving materials from manufacturing sections, maintenance of inventory records, selection of buyer, accumulation and shipping of materials.

Shipping

Accumulation of finished stock for shipment, release by Production, preparation and distribution of shipping documents, M/S Log preparation, loading outgoing carriers.

Stockkeeping

Maintenance of authorized buffer stocks of work-in-process. Authorization of stock levels. Operation of stockroom and stock areas for direct and expense materials.

Tooling

Planning, design, ordering, tool room operation, Maintenance of dies and fixtures, tool crib operation.

Traffic

Incoming and outgoing, determination of carrier and route, scheduling, minimum cost, provide required service to customer.

Warehousing

Stock authorization, replenishment, activity reports in factory and district warehouses for finished products and renewal parts.

SUGGESTED ACTIVITIES - MARKETING

Budget - Net Sales Billed

Application of market knowledge and experience and computations used in the preparation of the NSB budget.

Cancellation Routine

Receipt of instruction sheet, cancellation procedure, distribution of cancellation notices.

Customer Inquiry for Quotation

Acknowledgement, sample aurhorization, analysis of specifications, formal quotation.

District Request for Information

Request for performance data, drawings, or delivery information.

Forecasting

Application of general market trends, index patterns, sales reports and production data for forecasting of department and product line sales - short and long range.

Market Research

Selection of data for reference material, investigation of market condition, use of market surveys and reports to provide market data for forecasting and product planning.

Marketing Plans

Study of marketing activities, customer potential and projected cost estimate to determine future marketing goals, activities and sales plans.

Product Planning

Appearance, identification, cataloging, packaging, design and performance recommendations for assurance of product leadership.

Product Service

Complaints, renewal parts quotations, repair and return orders, analysis of complaints and failure reports.

Requisition Pricing

Use of original quotation, standard cost data, estimated price to determine unit selling price of product. Application of customer descounts and adjustments to arrive at net price.

SUGGESTED ACTIVITIES - EXTERNAL

These activities will not be studied and charted in detail but are considered as sources and destinations of information flow from and to the 'business'.

Apparatus Sales Division

G.E. Management

G.E. Co. (Other Departments)

Government (Federal, State, Local)

Public

Services (Accounting, Treasury, etc.)

Vendor (Including Carriers)

Union

SAMPLE

COST ACCOUNTING

SCOPE AND BOUNDARY REPORT

1. BASIC PURPOSE OF ACTIVITY:

   a. To assure proper allocation of manufacturing costs.

   b. To provide control data for analysis of activity costs.

   c. To evaluate physical inventory.

   d. To provide cost estimates and forecasts.

2. BOUNDARIES:

   Include all activities normally associated with Cost Accounting.

3. SCOPE OF STUDY:

   The study includes:

   a. Costing of input and output to inventory.

      (1) Shipments using M/S and shipping notice procedure.
      (2) Intra-department and interdepartment billing.

   b. Setting new standards for labor, material and overhead.

   c. Development of production costs.

   d. Preparation of variance reports.

   e. Costing of physical inventory.

   f. Preparation of budgets.

   g. Preparation of forecasts on direct labor, indirect manufacturing expenses, tool expenditures and cost variances.

   h. Estimating costs:

      (1) On new products and alternative designs.
      (2) For make or buy decisions.

Exhibit 3

SAMPLE

SYSTEMS PROJECT

TIME RECORD SHEET

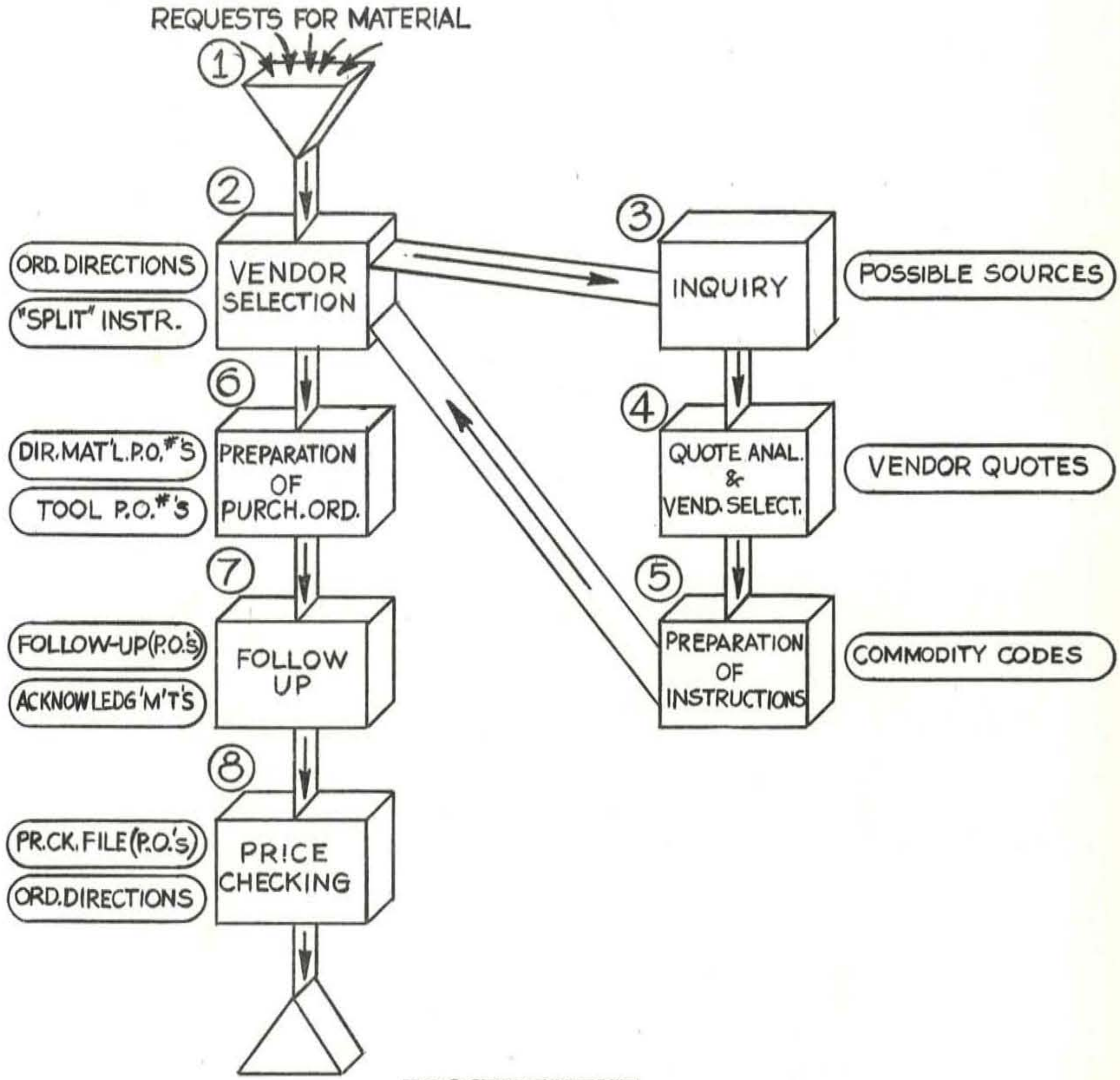
NAME OF ANALYST ________________________ WEEK NO.____________

Date	Activity	MAN HOURS SPENT *				Total
		Int'v'ws	Charting	Planning	Meeting	
Total						

* To nearest Man-Hour

SAMPLE

PROCUREMENT



PROCUREMENT

The procurement organization provides the link between the vendor and the man who desires his product. The main function of Procurement begins when the material description, quantity desired and delivery schedule is established. When this information is received by the organization; the vendor is selected, the purchase order is prepared and sent, and the transaction is followed until the material and invoice are received. When the price on the invoice has been verified and the material is in the hands of the user, the responsibility of Procurement ceases.

PROCUREMENT

(1) Requests for material may be in the form of travel order cards (for direct materials) R. M.'s (for tools, expense materials, furniture, supplies, etc.) letters, memos or verbal requests (for miscellaneous materials) or in the form of Request for Manufacturing Plant Equipment.

(2) Vendor Selection is made with the use of ordering direction cards and vendor split instructions, prepared in steps (3), (4) and (5). These directions include the vendor's name and the current price for the quantity requested.

(3) If (for a new or a low-volume material) ordering directions are not available, an inquiry is sent out to each of several possible sources, requesting their quotations.

(4) When quotations are received, an analysis is made on the basis of material price, vendors' reputation for quality and service, trade relations and other pertinent factors. The vendor is then selected.

(5) All information regarding future transactions with the vendor selected in (4) is then recorded on order direction cards and filed for use in step (2).

(6) When material description, quantity, delivery schedule and vendor information are all available, this data is entered on a purchase order and distribution is made to the vendor and copies are filed for follow-up (7) and Price checking (8).

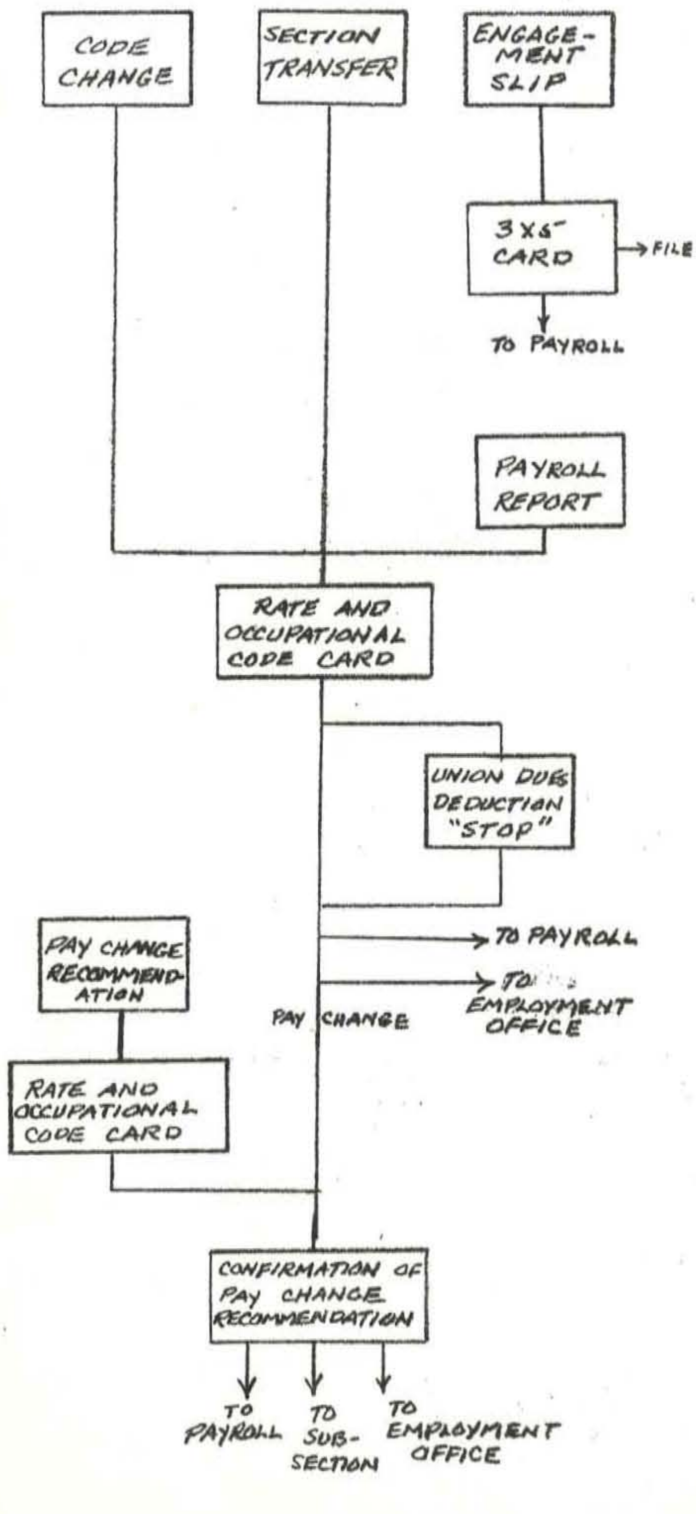
(7) All contacts with the vendor for the purpose of follow-up and expediting are made by procurement personnel who refer to the date the material is required and the date the vendor has promised delivery.

(8) When the material and invoice are received they are checked to see that the material corresponds to what was ordered and that the price is that which was agreed upon in steps (3) and (4).

If the material and price are acceptable, the invoice is passed for payment and the material is sent to the person who requested it.

SAMPLE
SUMMARY CHART

ENGAGEMENTS, TRANSFERS AND CHANGES IN PAY



CODE CHANGE NOTICE (FOR CHANGE OF OCCUPATION WITHIN A SUB-SECTION), SECTION TRANSFER, OR ENGAGEMENT OR RE-ENGAGEMENT SLIP (INCLUDES TRANSFERS FROM OTHER DEPARTMENTS) ARE CHECKED FOR CORRECT RATE AND CODE WHEN RECEIVED.

IN THE CASE OF AN ENGAGEMENT OR RE-ENGAGEMENT A 3X5 CARD IS USED TO RECORD RATE AND CODE WHILE THE ENGAGEMENT SLIP IS SENT TO PAYROLL.

AFTER PAYROLL REPORT IS RECEIVED AND PAY NUMBER IS VERIFIED, A RATE AND OCCUPATIONAL CODE CARD IS INITIATED AND RATE AND CODE ARE ENTERED ON IT.

IN THE OTHER TWO CASES, RATE AND CODE ARE ENTERED ON THE RATE AND OCCUPATIONAL CODE CARD WHICH IS ON FILE. REMOVALS, WHICH ALSO APPEAR ON THE PAYROLL REPORT, ARE RECORDED ON THE RATE AND OCCUPATIONAL CODE CARD.

IF CODE ENTRY CHANGES AN EMPLOYEE FROM ONE UNION "GROUP" TO THE OTHER A UNION DUES DEDUCTION "STOP" IS FILLED OUT AND SENT TO PAYROLL.

CODE CHANGE NOTICE IS SENT TO EMPLOYMENT OFFICE, SECTION TRANSFER IS SENT TO PAYROLL UNLESS A PAY CHANGE IS INVOLVED. IF A PAY CHANGE OCCURS ON A SECTION TRANSFER THE TRANSFER IS HELD FOR CONFIRMATION.

WHEN A PAY CHANGE RECOMMENDATION IS RECEIVED IT IS CHECKED AGAINST THE WAGE SCALE. IF IN ORDER, THE ENTRY IS MADE ON THE RATE AND OCCUPATIONAL CODE CARD.

CONFIRMATION OF PAY CHANGE RECOMMENDATION IS FILLED OUT FROM SECTION TRANSFERS AND PAY CHANGE RECOMMENDATIONS. CONFIRMATION IS SENT TO SUB-SECTION AND EMPLOYMENT OFFICE. SECTION TRANSFERS AND PAY CHANGE RECOMMENDATIONS ARE SENT TO PAYROLL

SAMPLE

FORMS ANALYSIS

A. ORIGINATING ACTIVITY Procurement

B. NAME OF FORM Purchase Order

C. PRIMARY PURPOSE To order

WHERE IS FILE LOCATED Raw Material Leader, Central Purchasing

VOLUMES PER DAY 5 (average)

HOW MANY COPIES 7

DISTRIBUTION OF COPIES 1&2, Vendor; 3&4, R.M.Leader; 5, Central Purchasing; 6, Rec.Insp; 7, Scrap

HOW PREPARED MANUALLY TYPEWRITER PUNCHED CARD OTHER

NUMBER OF DOCUMENTS IN ACTIVE FILE 30 Open orders

NUMBER OF DESIGNED ENTRIES PER FORM 12

NUMBER OF ENTRIES USED 12

EACH FIELD USED:

NAME OF INFORMATION	ESTIMATED # OF CHARACTERS	WHO INSERTS INFO ON FORM	ALPHA, NUMERIC, SPECIAL
Send Ack. & Corres. to	Varies	R.M. Leader	A-N-S
Order No. SFM	8	"	N-S
(Addressee)	Varies	"	A-N-S
Date (of P.O.)	8 (max.)	"	N-S
Deliver to (check box)	1	"	S
Broadway			
Taylor St.			
Jonesboro			
Quantity & Description	Varies	"	A-N-S
Ship (by date)	Varies	"	A-N-S
Account	9	"	N-S
By	Varies	"	A-S

SAMPLE

FILES ANALYSIS FORM
(Data Retention)

ORDERING DIRECTION CARD FILE — IBM CARD
Name of File — Type of File

1500
Volume of Records Contained

CENTRAL PURCHASING-PARTIAL FILES IN EACH SECTION
Location

BUYER
Originating Source

COMMODITY CODE NO. (10 DIGIT)
How is File Indexed

TRAVEL CARD, REQUEST FOR O.D. CARD, INVOICE
Initiating Reference

CENTRAL PURCHASING BUYERS, RAW MATERIALS CLERK
Activities using the Files

REQUIRES COMMODITY CODE KNOWLEDGE OR
CODE BOOK TO LOCATE PROPER CARD
The Ease or Difficulty in Extracting Information

NAME OF APPROVED VENDOR, UNIT PRICE
Specific Fields of Information to be Extracted

Analysis Made by A.C. CLOSE Date 3/7/57

Activity Studies

This section includes a list of the 72 major activities of the 39 - frame motor business which were studied in detail during the five-month data-gathering phase of the Systems Project. These studies are on file in the Project office and include:

Nine studies in the Employee Relations function;

Six studies in the Engineering function;

Seven studies in the Financial function;

Thirty-eight studies in the Manufacturing function;

and

Twelve studies in the Marketing function;

In all, five hundred twenty-seven Information Process Charts were prepared to describe the information processing in each of the activities.

This section also includes a portion of a representative activity study. This shows:

A Scope and Boundary Report

A Summary Chart

Examples of Process Charts

A List of Open Exits to other activities.

The Shaft Part Structure study is included to illustrate how the various parts of the motor were analyzed in terms of their fixed and variable characteristics. The key variables or control elements are indicated, as are the dependent variables which are completely determined by other characteristics of the motor. A summary of the results of this study is presented in Section II above (Product Structure).

EMPLOYEE RELATIONS

Application Routine

Employee Benefits

Engagement Routine

Personnel Counseling

Removal Routine

Safety and Suggestions

Salary Administration

Transfer and Upgrading

Wage Administration

ENGINEERING

Engineering Duplication

Files Analysis

Forms Analysis

Production Engineering

Requisition Drafting

Requisition Engineering

FINANCIAL

Accounts payable

Cost Accounting

Customer Billing

Expense Accounting

Gross Payroll and Timekeeping

Gross to Net Payroll

Orders and Sales Accounting

MANUFACTURING

Communications Channels

Control of Unit Operations & Feedback

Customer Order Processing

MANUFACTURING (continued)

Files Analysis

Forms Analysis

Inspection and Test

Making Operations

- Assembly
- Lead Assembly
- Rotor
- Rotor Core
- Shaft
- Shell
- Stator Core
- Stator Winding

Manufacturing Loss Control

Operation and Process Planning

Plant and Equipment Maintenance

Procurement

Product Structure

Product and Process Measurement

Production Control

- Dispatching and Factory Order Placement
- Inventory Record Maintenance
- Master Factory Scheduling
- Requirements Determining and Planning

Production Forecasts and Inventory Estimates

Quality Control Engineering

- Customer Complaints
- Inspection and Test Planning

MANUFACTURING (continued)

Inspection Reports

Quality Audits

Quality Costs

Receiving and Receiving Inspection

Salvage and Obsolete Material

Shipping

Statistical Study

Tooling Study

Tool Crib Operation

Tool Ordering

Punch and Die Repair

Traffic Study

Warehousing

MARKETING

Budget (Net Sales Billed)

Cancellation Routine

Customer Inquiry

District Request for Information

Forecasting

Long Range

Short Range

Market Research

Market Plans

Pricing

Product Planning

Product Service

Requisition Pricing

PHYSICAL TRANSFORMATION (MAKING OPERATIONS) STUDY

SHAFTS PART STRUCTURE

OBJECTIVES

I. To flow chart shaft making process

II. To identify fixed characteristics of all shafts

III. To classify in condensed form, the minimum and maximum dimensions, and incremental spacing of dimensions, of variable characteristics of all shafts.

IV. To identify key control variables by which sny shaft can be specified.

APPROACH

I. See flow chart - material and information process chart Pages 1 and 2 attached.

II. Exhibit "B", shaft blueprint 423 B 302 AT, contains all fixed characteristics of all shafts. Dimensions and notes encircled are identical on practically all prints. The few exceptions to the standard are indicated on Exhibit "A" under "exceptions to STD."

III. Exhibit "A" shows for all shafts;

1. Drawing No.
2. Minimum and maximum dimensions of variable dimensions for all part numbers within each drawing number.
3. Increment spacing of each variable dimension.
4. Exceptions to standard.

5a. Summary of minimum and maximum dimensions for single extension shafts - Sheet No. 1

5b. Summary of minimum and maximum dimensions for double extension shafts - Sheet No. 2

SHAFTS PART STRUCTURE (continued)

6. Minimum and maximum dinensions for all shafts - Sheet No. 2.

IV. Key Control Variables.

There are four key variable inputs at shaft explosion level.

These are:

1. Oil groove to end distance, pulley end.

2. Oil groove to end distance, opposite pulley end.

3. Length of flat, pulley end.

4. Length of flat, opposite pulley end.

Groove to groove distance is already specified by shell length. Rotation has been specified and determines oil groove direction, and number of rotation identification rings. Other dimensions and specifications are standard for all shafts with a few exceptions.

Exceptions:

1. Shaft No. 423 B 307 AA is special throughout.

2. In three cases (423B301AH, 423B302AG, AM) internal flats occur, and in conjunction with 302 AG,AM, drilled holes outboard to the flats occur.

3. A keyway occurs in 423B301AD.

4. Shafts No. 423B301AG, 302 AF are necked-down, each differently.

5. There are many exceptions to the standard .25 inch increment between dimensions. However, most of the exceptions on blueprint are in dimensions of obsolete shafts for which there have been no drawing changes bringing them up to date. The remaining exceptions occur in the opposite pulley-end extension. It is this part of the shaft that absorbs any non quarter inch increments that are necessary on the design. Also, reversible shafts require an additional washer and this results in some non-standard dimension-increments between reversibles and other shafts. In general, quarter inch increments are standard on all variable dimensions.

MATERIAL AND INFORMATION PROCESS CHART

ENTRIES	MAIN LINE FLOW	EXITS	SECONDARY FLOW		RECORDS		RECORD OR FIELD		FIELDS	REMARKS
	+				DAILY PROD, SCHEDULE, BLUEPRINT, PLANNING, TOOLS, MACHINES.		ALL FIELDS ALL MACHINES			
	2				SHAFT BAR STK.		DIA. LENGTH 10' MTL. SPEC			
	S/U LATHE + 3			ON	MACHINE PROGRAM	FROM	BLUEPRINT, S/U PLAN	INSERT	LENGTH, ROTATION IDENTIF. DIA.	SET-UP MACHINE. MANY DIFFERENT SET-UPS USED. TWO CUT-OFF LATHES.
$	SR FIND 4			IN	STOCK AREA	FIND	STOCKPILE OF BAR-STOCK	BY	DATE PURCHASED, DIA, SPEC.	STANDARD BAR-STOCK
	5									
	SP 6			FROM	STOCKPILE	SEPARATE	BAR-STOCK			
	CUT TO LG. + 7			ON	BAR STOCK	FROM	MACHINE PROGRAM	INSERT	LENGTH, CHAMFER, IDENT. RING	
	8									
	9									
	AM			INTO	STOCKPILE	MERGE	SHAFT			TOTEPANS

		11									
	SP				FROM	STOCKPILE	SEPARATE	SHAFT			
		12									
	WASH +				ON	SHAFT	FROM	MACHINE PROGRAM	INSERT	FREEDOM OF FOREIGN MATTER	WASHING MACHINE. PERMANENT SET-UP
		13									
	AM				INTO	STOCKPILE	MERGE	SHAFT			TOTEPANS
		14									
		15									
S/U	COIN. MACH. +				ON	MACHINE PROGRAM	FROM	BLUEPRINT	INSERT	LOCATION & DIRECTION OF OIL GROOVES, SHAFT LENGTH	SET-UP (1) COINING MACHINE MANY SET-UPS
		16									
	SP				FROM	STOCKPILE	SEPARATE	SHAFT			
		17									
COIN	GROOVE +				ON	SHAFT	FROM	MACHINE PROGRAM	INSERT	OIL GROOVES LOCATION & DIRECTION OF OIL GROOVES	
		18									

CTD PG 2

SUBJECT CHARTED ROTOR - MAKING OPERATIONS (SHAFT MAKING OPERATIONS)

CHART BEGINS ORDER FOR SHAFTS

CHART ENDS STOCK OF FINISHED SHAFTS

CHARTED BY W.C. O'NEAL

PAGE 1 OF 5

LAST EXIT #

LAST ENTRY #

FILE CODE

DATE 1-9-56

MATERIAL AND INFORMATION PROCESS CHART

ENTRIES	MAIN LINE FLOW	EXITS	SECONDARY FLOW		RECORDS		RECORD OR FIELD		FIELDS	REMARKS
	AM 1			INTO	STOCKPILE	MERGE	SHAFT			TOTE PAN
	SP 2			FROM	STOCKPILE	SEPARATE	SHAFT			
	3									
	STRAIGHTEN + 4			ON	SHAFT	FROM	MACHINE PROGRAM	INSERT	STRAIGHTNESS	STRAIGHTENING MACHINE, PERMANENT SET-UP
	AM 5			INTO	STOCKPILE	INTO	STOCK AREA	MERGE	SHAFT BY DWG NO.	TOTE PAN STOCK
	SR FIND 6			IN	STOCK AREA	FIND	STOCKPILE	BY	DWG. NO	
S/U	GRINDERS + 7		FEEDBACK & CONTROL	ON	MACHINE PROGRAM	FROM	BLUEPRINT	INSERT	DIAMETER, LENGTH	3-IN-LINE C'LESS GRINDERS, ROUGH GRIND, SEMI-FIN ", FINISH ", AUTO-TRANSFER
	SP 8			FROM	STOCKPILE	SEPARATE	SHAFT			
	GRIND + 9			ON	SHAFT	FROM	MACHINE PROGRAM	INSERT	O.D., FINISH	

11	CHECK O.D. (≠ SPEC → MANU; = SPEC)	COM-PARE	DIAMETER	WITH	BLUEPRINT	BY	DIAMETER, PROCESS CONTROL	MANUAL INSPECTION
12	AM	INTO	STOCKPILE	MERGE	SHAFT			TOTEPAN
13	S/U MILLER +	ON	MACHINE PROGRAM	FROM	BLUEPRINT, S/U PLAN	INSERT	SHAFT LENGTH, FLAT DIMENSIONS.	MANY S/U'S, 1 MACHINE - AUTOMATIC MILLER
14	SP	FROM	STOCKPILE	SEPA RATE	SHAFT			
15	MILL FLAT +	ON	SHAFT	FROM	MACHINE PROGRAM	INSERT	FLAT DIMENSIONS.	
16	WASH +	ON	SHAFT	FROM	MACHINE PROGRAM	INSERT	FREEDOM FROM FOREIGN MATTER	WASHING MACHINE PERM. S/U.
17	INSPECT (≠ SPEC. → A REJECT; ACCEPT = SPEC)	COM-PARE	SHAFT CHARACTER-ISTICS	WITH	INSPECTION SPECIFICATION		OD, LENGTH, FLAT DIMENS., OD OF RING, STRAIGHTNESS	(INSPECT) SAMPLING PLAN
18	STORE AM	INTO	STOCKPILE	INTO	STOCK AREA BY DWG. NO.	MERGE	FINISHED SHAFT	

1. TO PAGE 5 - 7

ROTOR MAKING OPERATIONS

SUBJECT CHARTED (SHAFT MAKING OPERATIONS)

CHART BEGINS ORDER FOR SHAFTS

CHART ENDS STOCK OF FINISHED SHAFTS

CHARTED BY W.C. O'NEAL

PAGE 2 OF 5

LAST EXIT #

LAST ENTRY #

FILE CODE

DATE 1-10-56

② MINIMUM AND MAXIMUM DIMENSIONS OF PARTS FOR EACH AA TO AH GROUP

① SHAFT DWG NO.	EXT. PE Z	A	B	L	K	J	STACK HT CODE (B 3/4, D 1, F 1 1/4, H 1 1/2, K 1 3/4, M 2)
	MIN MAX	MIN MAX	MIN MAX	MIN MAX	MIN MAX	MIN MAX	MIN MAX
③ INCREMENT SPACE →	.25	.25	.25	.25	.25	NON STD	:25
423 B 301AA / 301AE (SAME SHAFT)	1.50-3.00	4.874-7.374	2.54-4.54	5.56-8.06	1.16-2.00	1.50-2.34	B M
AB / AF (SAME SHAFT)	1.50-7.00	4.874-11.124	2.54-8.04	5.81-11.81	1.16-2.50	1.50-2.84	B M
AC	1.59-2.09	5.374-5.874	2.79-3.29	6.18-6.68	1.16-1.50	1.50-1.84	B K
AD	2.00-2.00	5.874-5.874	3.04-3.04	6.56-6.56	1.50-1.50	1.84-1.84	D F
AG	2.00-2.00	5.874-5.874	3.04-3.04	6.54-6.54	1.50-1.50	1.84-1.84	D F
AH	3.50-4.00	7.624-7.624	4.54-5.04	8.31-8.31	1.50-1.50	1.84-1.84	B M
TOT. TOLERANCE	—	.020	.020	.020	—	.060	—
⑤A Σ MIN-MAX	1.50-7.00	4.874-11.124	2.54-8.04	5.56-11.81	1.16-2.50	1.50-2.84	B-M

CODE: 0=REV 1=CCW 2=CW

④ EXCEPTIONS TO STD.

SHAFT DWG NO.	ROTATION RINGS 0,1,2	INTERNAL FLAT	KEYWAY	NECKED DOWN	NON. STD. CHAMFER	NON. STD. FLAT HT.	NON. STD. INCREMENT
301AA / 301AE	1						K
AB / AF	2						
AC	0						{K N F}
AD	1		1				
AG	1			1.	1	1	
AH	2	1					

CONTINUED NEXT PAGE

NOTE :

> DIMENSIONS SHOWN ARE AT UPPER LIMITS OF TOLERANCE RATHER THAN AT NOMINAL. IE, FOR A DIMENSION $\frac{5.874}{5.854}$, 5.874 IS SHOWN ABOVE.

EXHIBIT "A"
SHEET NO. 1

SINGLE EXTENSION
423 B301AA TO 301AH

1-18-57
SHAFT BLUE-PRINT
ANALYSIS W.C.ONEAL

② MINIMUM AND MAXIMUM DIMENSIONS OF PARTS FOR EACH AA TO AW GROUP

① SHAFT DWG. NO.	Y OPE EXT. MIN MAX	Z PE. EXT. MIN MAX	A MIN MAX	B MIN MAX	L MIN MAX	XJ MIN MAX	J MIN MAX	XK MIN MAX	K MIN MAX	STACK HT CODE (B ¾, D 1, F 1¼, H 1½, K 1¾, M 2) MIN MAX
③ INCREMENT SPACE →	NON-STD.	.25	.25	.25	.25	NON-STD.	NON-STD	.25	.25	.25
423B302 AA, AL, AN (SAME SHAFT)	2.58-5.33	2.00-6.00	6.374-9.874	3.04-7.04	10.01-16.01	1.84 1.84	1.84 1.84	1.50 1.50	1.50 1.50	B M
AB	1.59 4.59	2.00-4.50	5.624-8.374	3.04-5.54	9.01-13.02	2.09-2.09	1.84-1.84	1.75-1.75	1.50-1.50	B H
AC	2.84 6.50	2.00-4.25	5.624-8.124	3.04-5.29	10.02-14.02	2.09-2.09	1.84-1.84	1.75-1.75	1.50-1.50	B H
AD	1.58 1.58	1.50-4.00	5.374-7.624	2.54-5.04	7.76-10.26	1.50-1.50	1.50-1.50	1.16-1.16	1.16-1.16	B M
AE	2.00-5.58	1.25-5.50	5.124-9.624	2.29-6.79	8.68-16.01	1.84-2.34	1.09-2.34	1.50-2.00	.75-2.00	B H
AF	4.81-4.81	3.50 3.50	7.124-7.124	4.54-4.54	13.02 13.02	2.72-2.72	1.59-1.59	2.375-2.375	1.25-1.25	D D
AG	2.28-3.28	5.00 6.00	8.624-9.624	6.04-7.04	13.02-13.02	1.34-2.09	—	1.00-1.75	—	D D
AH, AR (SAME SHAFT)	1.58-5.58	1.75-5.75	5.374-9.624	2.79-6.79	8.51-16.01	1.09-2.84	1.50-2.84	.75-2.50	1.16-2.50	B M
AJ	2.33-5.58	2.50-7.00	6.124-11.124	3.54-8.04	10.51-16.00	1.84-1.84	1.84-1.84	1.50-1.50	1.50-1.50	B M
AK	1.50-1.58	1.50-1.50	5.124-5.624	2.54-2.54	7.76-8.18	1.50-1.50	1.50-1.50	1.16-1.16	1.16-1.16	B H
AM	2.58-2.58	4.75-4.75	8.624-8.624	5.79-5.79	12.26 12.26	1.84-1.84	—	1.50-1.50	—	F F
AP	3.08-3.08	2.00-2.25	5.874-6.124	3.04-3.29	10.01-10.26	2.00-2.00	2.00-2.00	1.75-1.75	1.75-1.75	D F
AS	3.08-4.08	2.50-3.50	6.624-7.624	3.54-4.54	10.76-12.76	1.84-2.84	1.84-2.34	1.50-2.50	1.50-2.00	F H
AT	1.83-2.83	1.50-1.50	5.374-5.374	2.54-2.54	8.26-9.26	1.84-2.34	1.50-1.50	1.50-2.00	1.16-1.16	D F
AW	1.08-1.58	2.25-2.25	5.874-6.124	3.29-3.29	8.51-8.51	1.13-1.50	.88-1.25	2.00-2.00	1.75-1.75	B H
307 AA SPECIAL										
311 AA	4.33-4.33	5.00-5.00	9.624-9.624	6.04-6.04	15.01-15.01	1.84-1.84	1.84-1.84	1.50-1.50	1.50-1.50	M M
TOT. TOLERANCE	—	—	.020	.020	.020	.060	.060	—	—	
⑤a MIN-MAX Σ 302-311	1.08-6.50	1.25-7.00	5.124-11.124	2.29-8.04	7.76-16.01	1.13-2.84	.88-2.84	.75-2.50	.75-2.00	B - M
⑥ MIN-MAX Σ 301-311	1.08-7.00	1.25-7.00	4.874-11.124	2.29-8.04	5.56-16.01	1.13-2.84	.88-2.84	.75-2.50	.75-2.50	B - M

④ EXCEPTIONS TO STD

CODE: 0 = REV, 1 = CCW, 2 = CW

SHAFT DWG. NO.	ROTATION	INTERNAL RINGS 0,1,2	KEYWAY FLAT	NECKED DOWN	NON. STD. CHAMFER	NON. STD. INCREMENT	DRILLED HOLE	NON STD. FLAT HT.
423B302 AA, AL, AN	1							
AB	1					L ZB		
AC	2					L K		
AD	1					XK		
AE	1					L ZB		
AF	1			1	1	XK		1
AG	2	1					1	
AH, AR	2					XL ZB		
AJ	2							
AK	2					XK LM		
AM	2	1					1	
AP	1							
AS	1							
AT	1							
AW	2							
307 AA SPECIAL	-		1 1					
311 AA	2							

923 B 302 AA TO 311 AA
DOUBLE EXTENSION

EXHIBIT "A"
1-21-57 W. C. ONEAL
SHAFT BLUEPRINT ANALYSIS.
SHEET NO. 2

423B302AT

GENERAL ELECTRIC

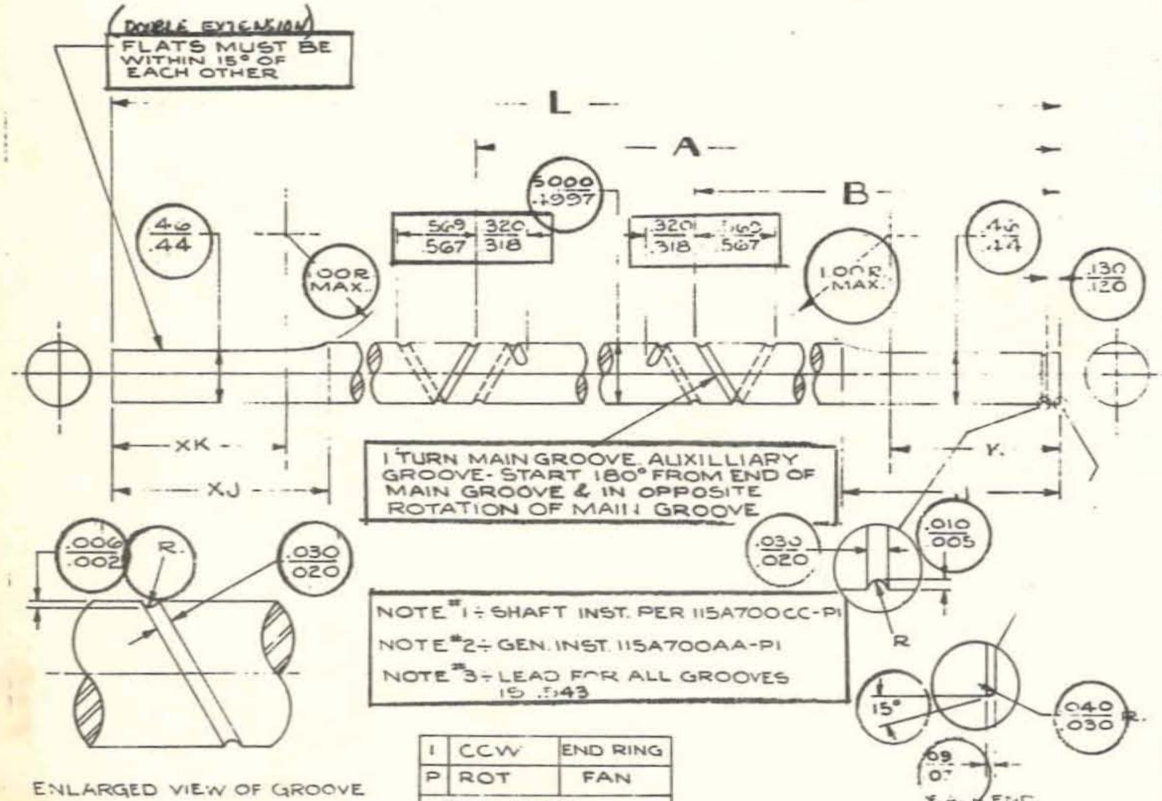
423B3C

423B302AT

SHAFT

5KSP39FG915X

P	MATERIAL	EXT PE (REF)	EXT OPPE (REF)	A	B	L	XJ	J	XK	K	STK 6P	STK 4P
1	STL-B4HIB	1.50	2.83	5.374 / 5.354	2.54 / 2.52	9.26 / 9.24	2.34 / 2.28	1.50 / 1.44	2.00	1.16	F	D
2	STL. B4HIB	1.50	1.83	5.374 / 5.354	2.54 / 2.52	8.26 / 8.24	1.84 / 1.78	1.50 / 1.44	1.50	1.16	F	D



NOTE #1 - SHAFT INST. PER 115A700CC-P1

NOTE #2 - GEN. INST. 115A700AA-P1

NOTE #3 - LEAD FOR ALL GROOVES IS .543

1	CCW	END RING
P	ROT	FAN
REF. DATA		

A — 1 400 12 (5KSP39FG935X) — Dec. 13, 1956

B44
B45
B333 (2)
B332 (PT)
B327 (PT)
F18 (6)

EXHIBIT "B"

STANDARD DIMENSIONS

J.R. Bean Nov 8, 1956
C.L. Thomas Nov. 20, 1956

FILE A39D — SPECIALTY MOTORS FORT WAYNE

423B302AT

S.P.