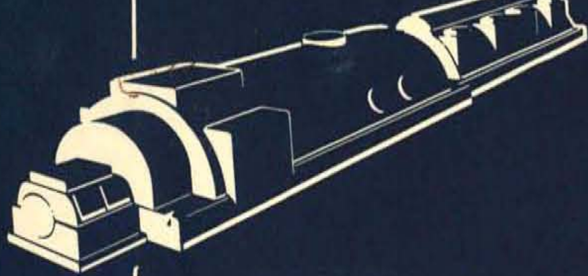

LAMINAR BUCKET PROGRAM - AN APPLICATION OF
LOGIC TABLE TECHNIQUES

R.E. May
M. Lotter

DF-59-LS-104

Sept. 21, 1959

LARGE STEAM TURBINE-GENERATOR DEPARTMENT

GENERAL ELECTRIC

SCHENECTADY, N. Y.

TG-1013 (1-52)

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Title Page

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TITLE

Laminar Bucket Program - An Application of Logic Table Techniques

ABSTRACT

This is a method of standardizing the format of data related to the engineering design and manufacturing planning of turbine buckets. The interpretation of the data and resulting solutions within a computer facility will produce drawings and labor vouchers.

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CONCLUSIONS

It appears that this technique brings within range of economic feasibility certain work formerly considered marginal for computer application. The large expansion in logic requirements associated with engineering and manufacturing planning have been reduced to tables by operating personnel. In addition to presenting a more precise statement of the problem the subsequent procedures effort, programming costs and conversion time will be reduced.

By cutting out this rectangle and folding on the center line, the above information can be fitted into a standard card file.

For list of contents—drawings, photos, etc. and for distribution see next page

INFORMATION PREPARED FOR Large Steam Turbine-Generator Department

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Introduction

Recently a review of drafting and manufacturing planning procedures for 3" laminar buckets was made in order to determine (1) if computer processing of design requirements through the drafting and planning operations was physically feasible and (2) whether substantial economies could be realized through installation of a mechanized system for drafting and planning on a broad basis within the Department. The review covered procedures from the point of release of engineering specifications to the preparation of manufacturing drawings, direct labor vouchers and material requisitions.

Procedures for processing 3" laminar bucket data were selected for review because (1) it appeared that sound conclusions could be best achieved by using an actual manufactured item as a model and (2) the 3" laminar bucket drafting and planning procedures were sufficiently complex to provide a sound test for a wide range of applications.

Recommendations

Upon completion of the review, it was concluded that a substantial portion of the bucket drafting and planning work could be processed, utilizing a table solution technique on the IBM 704. Accordingly, the following recommendations were made:

Phase I. Establish and install on the IBM 704 computer a table solution program (LOGTAB*) and related procedures to generate from engineering specifications, drafting tables and planning tables the following data required for the production of the 3" laminar buckets: (1) drawing dimensions (2) direct labor vouchers and (3) material requisitions. Utilize this program for actual production work.

* LOGTAB is a table solution technique developed into a computer program in which business logic is expressed in table form rather than as a computer program. This technique allows a reduction in computer program and operating costs and provides for compact storage of data in the form of tables and formulas.

Phase II. Establish standard drawings and mechanize drafting and planning for the following bucket designs:

a. Laminar to 3" active length
b. Laminar to 6" active length
c. Laminar vortex to 9-1/2 active length
d. Blunt laminar to 9-1/2" active length
e. Vortex to 9-1/2" active length

The standard drawings would apply to all buckets of the same configuration, regardless of dimension, and coded numbers would be provided to identify actual dimensions to be printed by the computer for each individual application.

Phase III. Upon successful completion of the above programs, extend the application to include other turbine and generator parts which lend themselves to the table solutio technique.

Clerical savings

Phase I is a pilot run to demonstrate mechanical and economic feasibility of this project It is estimated that this installation will result in reductions of clerical effort amounting to approximately one-third of a person in the Drafting Unit and one-third of a person in the Bucket Manufacturing component.

Upon completion of Phases I and II total savings of approximately $13 700 per year should be realized, consisting of $12 200 from the use of standard drawings and machine produced drawing dimensions and $1 500 from reductions in planning.

Phases I and II represent only a small portion of the total drafting and planning effort in the Department. The long range goal of this project is to make substantial reductions of drafting and planning costs on a Department-wide basis through mechanization. Experience gained in Phases I and II of this project will provide a base for the extended studies.

Benefits - Long Range

Drafting and planning

1. Reduced drafting and planning cycle time. With existing procedures the normal cycle time for the production of completed drawings averages approximately thirty-seven weeks, and the planning of labor is estimated at an additional six weeks. It is expected that with a weekly computer run the normal cycle time will be reduced approximately forty-two weeks.

2. Improved flexibility and control in design or planning changes. With the present system approximately 150 alteration notices per week are processed. In many instances these require new drawings, new labor vouchers and new material requisitions. The proposed system would retain drawing and voucher data within the computer until shortly before the work is scheduled to be performed, and as a result most alteration notices could be processed internally under computer program control before drafting and production paperwork is issued.

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3. Minimum cost design and planning. It is expected that cost information now incorporated into the program will be utilized at a future date to select minimum cost design and planning when such alternates are available.

4. Improved communication. The proposed procedure will eliminate communication delays and resulting errors by processing the entire job within the computer. Storage of data on a computer file will provide a single source from which each function can draw information. Maintenance of the file will automatically up date all records eliminating the necessity for a separate filing activity by each participating function.

5. Mechanized input for inventory control, production ordering, factory scheduling and cost accounting. It is expected that at a future date mechanized procedures will be required for these functions. The data generated from the drafting and planning program would be retained on magnetic tape and used directly as input to these other functions eliminating manual keypunch operations. It is possible that the magnetic tape record would replace the present parts list for a substantial portion of the business operation.

Other benefits

1. Reduced procedures effort and computer programming costs. The table solution technique contained in the LOGTAB computer program, which was developed as a result of this project, provides a new tool for reducing procedures effort and computer programming costs associated with business data processing by reducing requirements for procedures flow charts, block diagrams and manually coded computer programs. With LOGTAB, business logic is expressed in the form of tables or formulas and input data is processed against these tables or formulas to produce the required output. Changes in the business logic can be made by introduction of new tables or formulas which can be prepared by operating personnel in a form acceptable by the computer. This new technique brings within the range of economic feasibility certain work formerly considered marginal for computer application.

2. Compact data storage. The proposed program provides a means for storing drawing, planning and certain cost information in the form of low volume basic specifications which can be expanded into the desired output at the time required for production or information purposes. In the case of the 3" laminar bucket, 150 digits of basic input information is exploded into approximately 1 500 digits of output. This principle can be applied to the storage of product structures and to any other types of information which can be expressed in terms of basic elements. Application of this technique to large volume, low reference files can increase considerably the savings to be realized from electronic data processing.

Conversion program

The following program for conversion to the recommended routines has been suggeste

Phase I. Mechanize drafting and planning for 3" laminar buckets

Conversion is already under way. The detailed conversion schedule is shown on Exhibit A.

Phase II. Mechanize drafting and planning for laminar buckets to 6" active length; laminar vortex, blunt laminar and vortex buckets up to 9-1/2" active lengtl

From the experience obtained during Phase I together with certain tables used in Phase data for Phase II buckets will be translated into logical table format for computer input and the existing computer program will be modified to accommodate the extended application. Standard drawings will be established for Phase II buckets and drafting and planning will be converted to the electronic data processing system. Responsibility for installation will remain with the same individuals as in Phase I and due dates for completion will be established upon completion of Phase I.

Phase III.

Upon successful completion of Phases I and II, extend the application to include other turbine and generator parts which lend themselves to the table solution technique.

A detailed review will be required to determine the extent to which the table solution technique can be applied ultimately, but it is expected that a major portion of the drafting and planning data required for production work can be mechanized.

There are of course no plans to mechanize drafting and planning which is based on intuitive decisions, nor does it appear feasible at this time to mechanize drafting work for other than production drawings. Likewise no attempt would be made to pick up past drawings.

Procedures personnel will contribute to the effort by formalizing a method for determining the physical and economic feasibility of extended applications. Out of this it is expected that a training program will be evolved which will enable operating personnel to (1) gather data for the logic tables and (2) establish detailed operating routines.

An estimated completion date for this phase will be determined after detailed plans have been developed.

Review of drafting and planning procedures for manufacture of 3" laminar buckets

Phase I. Mechanize drafting and planning for 3" laminar buckets

Conversion schedule

	Estimated completion date	Responsibility
a. Write and test generalized logical table solution program (LOGTAB) for IBM 704	9/1/59	Manager - Computational Research
b. Complete writing detailed computer flow charts for 3" laminar bucket table solution program	9/1/59	Manager - Computational Research
c. Develop procedure for converting planning and drafting tables into a form suitable for computer input	9/1/59	Manager - Office Procedures
d. Make conversion of 3" laminar bucket planning and drafting tables into form suitable for computer input	9/15/59	Manager - Office Procedures
e. Install procedure for converting engineering data for 3" laminar buckets into the recommended form for computer input	10/17/59	Manager - Office Procedures
f. Write and test IBM 704 computer program for processing 3" laminar bucket drafting and planning data	11/17/59	Manager - Computational Research
g. Accumulate and check test data. Fifty rows of the laminar class currently to be machined will be selected for this purpose. The proper procedure would be to complete an Input Data Form for each row and submit it to Computational Research Unit which would make the computer run and distribute the output. The vouchers and the standard dimension form will be audited. The appropriate operating unit will be responsible for the validity of all data.	11/17/59	Superintendent - Bucket and Diaphragm Manufacturing Manager - Steam Path Drafting

Exhibit A

	Estimated completion date	Responsibility
h. Establish standard drawing for 3" laminar bucket	11/17/59	Superintendent - Bucket an Diaphragm Manufacturin Manager - Steam Path Dra
i. Establish procedure for maintaining both planning and drafting logical tables	12/4/59	Manager - Computational Research
j. Develop and install procedures to integrate computer voucher output with present system	12/4/59	Manager - Office Procedu
k. Complete conversion of 3" laminar bucket drafting and planning to the electronic data processing system	12/31/59	Superintendent - Bucket an Diaphragm Manufacturin Manager - Steam Path Dra

Exhibit A

EXAMPLE:

The following is a discussion in depth of the approach used to realize the objectives. To limit the detail description involved only a meaningful number of the total calculations required are completed.

A word about the notation before proceeding -- Numbers within a circle (50) refer to a dimension on the standard drawing. Each processing step is broken down by INPUT__________; INTERROGATE TABLE__________ where reference is made to a standard format (table) of data which is dependent on the bucket design; each table is written in an acceptable format for keypunching; SOLUTION__________ where reference is made to the unique result obtained from the table. As required a sub-routine calculation is also included in the processing.

Processing steps 1-4 apply to drafting calculations required for drawing dimensions. Steps 5-6 apply to manufacturing machining operations done on a milling machine on a piecework basis. Certain logic requirements not pertinent to the main thought are included in the appendix.

INPUT

Turbine	118306	↑
Shop Order	170-3010	
Standard Dwg.	152L000	Record
Drawing	823B939	Information
Stage	5	
Cost Code	U07	↓
Material Spec	B50A332A	↑
Vane Section Number	106D722-12	
Tenon Section Number	362B324-11	
No. of Spaces	124	
Dvt. Number	50	Design
Dvt. Head Height	.545	Parameters
Active Length	1.650	
Pitch Radius	18.246	
Wheel Clearance Radius	16.385	
Wheel Clearance	.010	↓

Table 1

DVT NO	=	)00048(1)(	)00049(1)(	)00050(1)(	)00051(1)(
AA		.090	.110	.150	.230
Dim 6		0.704	0.874	1.275	3.190
Dim 48		1.000	1.250	1.875	3.875
G		0.500	0.578	1.000	2.562
UHW		.335	.425	.430	.800
		** Step 2	** Step 2	** Step 2	** Step 2

Table 2

VSD No VSD No (2)	= =	)000106( )D72210(	)000106( )D72211(	)000106( )D72212(	)000106( )D72213(
E		.379	.471	.349	.429
VS THK		.490	.583	.407	.501
Dim 50		1.290	1.600	1.300	1.600
M Base		.790	.828	.572	.704
J		.045	.033	.024	.033
		** Step 3	** Step 3	** Step 3	** Step 3

Note: ** Step 3 means unconditional transfer; in this case to a sub-routine

PROCESSING

Step 1. Input Dvt No -- 50

Interrogate Table 1

Solution: AA = .150

Dimension (6) = 1.275

Dimension (48) = 1.875

G = 1.000

UHW = .430

Step 2. Input Vane Section Number -- 106D722-12

Interrogate Table 2

Solution: E = .349

VS THK = .407

Dimension (50) = 1.300

M Base = .572

J = .024

Step 3. Sub-Routine Calculation for Tied-in Edge versus Chamfer Edge (Reference Appendix)

Input from Step 2

Output from Step 6 (Appendix)

Sub-Routine

Vane Clearance Back of Dovetail (55) = [(19) - E]

(55) = .400 - .349 = .051

Bucket Thickness (57) = [M Base + VS THK + (55)]

(57) = .572 + .407 + .051 = 1.030

Tied-in Edge Test = (57) - (26)

A = 1.030 - .881 = .149

Perform: Test A > .125 Answer = Yes = Tied-in Edge

Table 3

Dim 50	(=	1.000	1.300	1.300
Dim 5	(=	2.999	1.999	1.999
A	(=	.999	.124	.999
61		.062	0	.062
62		.094	0	.094
64		.125	0	.125
65		.125	.047	.125
66		.062	.062	.062
67		.062	.062	.062
		** Step 5	** Step 5	** Step 5

Table 4

Spec	=	)0000B5(	)0000B5(	)0000B5(	)0000B5(
Spec (2)	=	)0A332A(	)0A332A(	)0A332A(	)0A332A(
Dvt SD	=	Angle	Angle	No	No
TEN	=	Rect	Prof	Rect	Prof
Dvt NO	=	46	46	46	46
		47	47	47	47
		50	50	50	50
		53	53	53	53
OP 1		023	023	023	023
OP 2		025	021	022	024
		**Table 5	**Table 5	**Table 5	**Table 5

Table 5

OP	=	021	022	023	024
A		2.21	2.21	2.21	2.21
B		4.125	4.125	4.125	4.125
C		.75	.75	.75	.75
S/U		8.60	8.60	4.50	8.60
		**Tab. 6	**Tab. 6	**Tab. 6	**Tab. 6

Table 6

Spec	=	)0000B5(	)0000B5(
Spec(2)	=	)0A125 (1) (	)0A332A(
DVT NO	(=	99	99
Feed 1		.750	1.125
Feed 2		.750	1.125
D		4.5	10.
		**Step 6	**Step 6

Step 4. Input Dim (50) From Step 2

Active Length Dim (5) = 1.650

A = .149 From Step 3

Interrogate Table 3

Solution: Dimension (61) = .062 (65) = .125

(62) = .094 (66) = .062

(64) = .125 (67) = .062

Step 5. Input Thickness (T) of Mat'l = 1-1/8

Material Spec = B50A332A

(Previously calculated) Dvt Sides = No

Tenon Section Number = 362B324-11 (Prof)

Dvt No = (50)

Interrogate Table 4

Solution: Manufacturing Operation (Op 1) = 023

(Op 2) = 024

Note: 023 -- Means Rough Mill Slot and Tenon

024 -- Means Finish Mill Slot and Tenon

Interrogate Table 5

Solution: A = 2.21

B = 4.125

C = .75

Set Up for 023 = 4.50

Set Up for 024 = 8.60

Interrogate Table 6

Solution: Feed 1st Cut = 1.125

Feed 2nd Cut = 1.125

D = 10

Step 6. Sub-Routine Calculation of Direct Labor Voucher. Input from Step 5.

$$\$/C = \frac{A}{N}\left[\frac{NT + B}{F} + C\right]$$

$$N = \frac{D}{T}$$

$$N = \frac{10}{1\text{-}1/8} = 8$$

$$\$/C = \frac{2.21}{8}\left[\frac{(8)\ 1.125 + 4.125}{1.125} + .75\right] = 3.43$$

Name of Part Bucket Blade Standard Dwg. 152L000

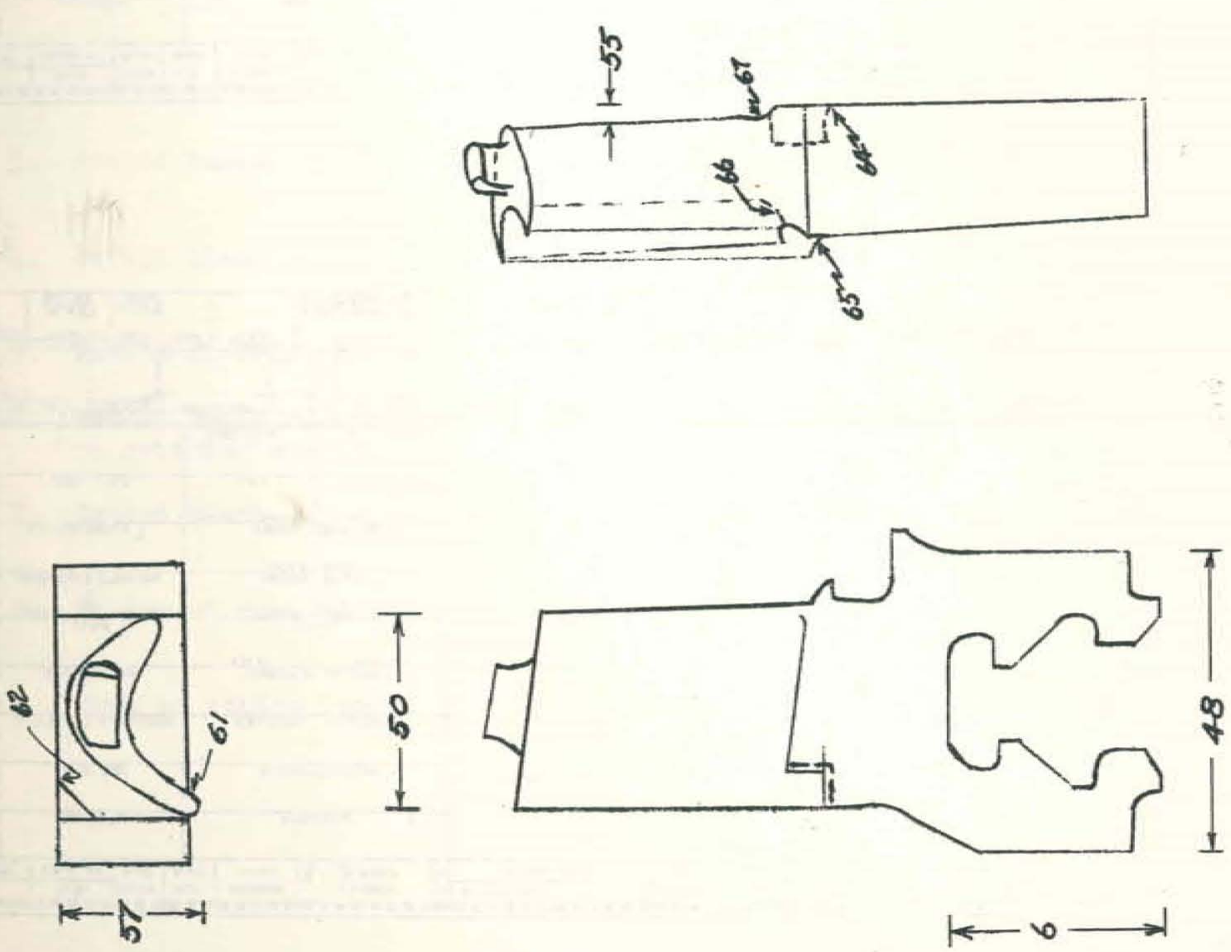
Turbine 118306 Dvt 50 Vane 106D722-12

Mat'l B50A332A Tenon 363B324-11 Stage 5

Dwg. 823B939 Qty. 124

Dimension	Part 1
6	1.275
48	1.875
50	1.300
55	.051
57	1.030
61	.062
62	.094
64	.125
65	.125
66	.062
67	.062

Standard Dwg. 152L000

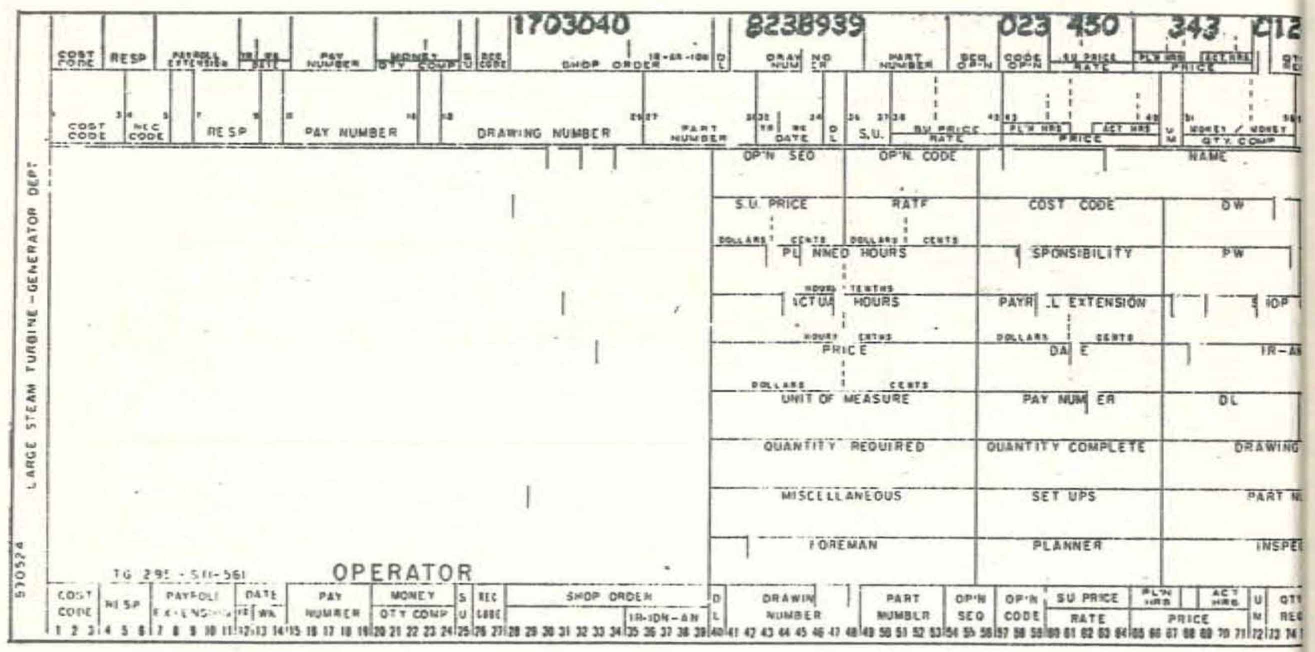


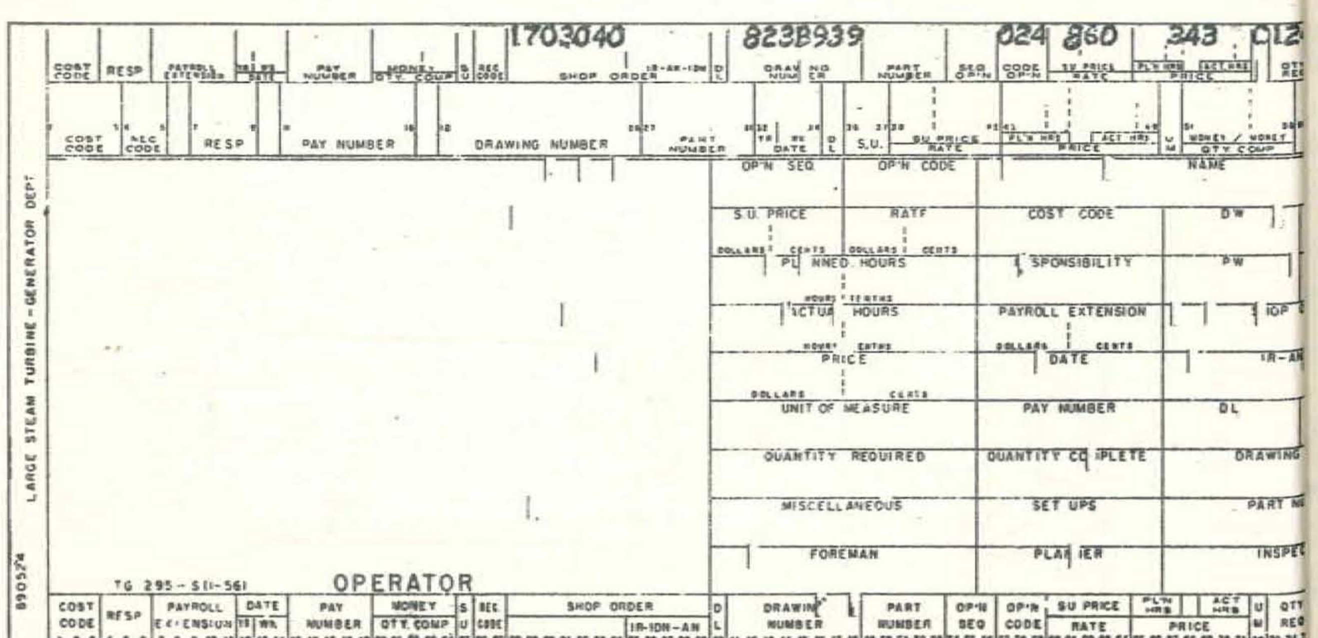
OUTPUT

Direct Labor Vouchers for Two Manufacturing Operations

023 Rough Mill Slot and Tenon

024 Finish Mill Slot and Tenon





APPENDIX

I Sub-Routine calculation for Root of Active Length Dimension (26)

Step 1. Input: Number of spaces (2) = 124

Wheel clearance radius (3) = 16.385

Dvt head height (9) = .545

Wheel clearance (10) = .010

Pitch radius (4) = 18.246

Active length (5) = 1.650

Step 2. Sub-Routine

Normal pitch at wheel rim (13A) $= \frac{2\,[(3) - (10)]\,\pi}{(2)}$

Table

13A	(=	.751	1.751	2.751
13		.065 **Step 3	.270 **Step 3	.380 **Step 3

Step 3. Arc of bucket on wheel rim (14) $= \frac{[(3) - (10)]\,2\pi}{(2)} - (13)$

Step 4. Bucket blade angle (16) $= \frac{(14)\,[57.2957]}{(3) - (10)}$

Step 5. Radius at crushing surface (18) $= (3) - (9)$

Step 6. Bucket blade 1/2 chord on crushing surface (19) $= (18) \times \text{Tangent } \frac{(16)}{2}$

Step 7. Bucket blade (20) $= (19) \times \text{Tangent } \frac{(16)}{2}$

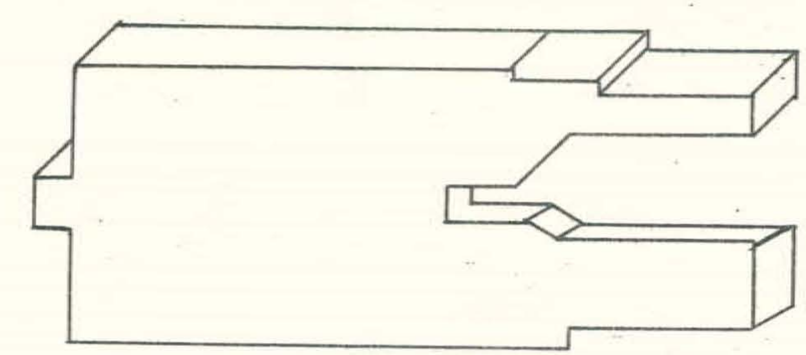
Step 8. Radius at root of vane (22) $= (4) - \frac{(5)}{2}$

Step 9. Root of active length (26) $= [(22) - (20)]\ \text{Tangent } (16)$

II Background Material for the Sub-Routine Calculation of the Direct Labor Vou

1. The operations required to convert material into a finished part have coded into a three digit number. As a result the manufacturing plann of "what to do" is transmitted to the direct labor through the code, i.e., 023 means Rough Mill Slot and Tenon.

2. The Rough Mill Slot and Tenon is a basic milling operation, using a vi for a fixture, and machining from bar stock material as indicated in the sketch.



III In the method of calculating the piecework price a standard milling machine formula is used.

A represents the timing rate

N - the number of pieces the vice will hold

D - the maximum vice jaw width

T - thickness of material

F - feed of machine

B - pre-run and over-run of cutters

C - handling time

$$\$/C = \frac{A}{N}\left[\frac{NT + B}{F} + C\right]$$