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AUTHORITY

AFML ltr, 1 Sep 1970

AFMDC 67-8

THIRD ANNUAL REPORT OF THE

AIR FORCE MACHINABILITY DATA CENTER

John Maranchik, Jr.
Metcut Research Associates Inc.

FEBRUARY 1968

Advanced Fabrication Techniques Branch
Manufacturing Technology Division
Air Force Materials Laboratory
Research and Technology Division
Air Force Systems Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

FOREWORD

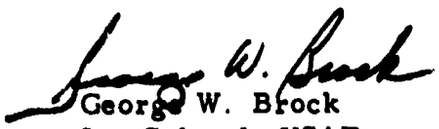
This Third Annual Report of the Air Force Machinability Data Center (AFMDC) covers work performed under Contract AF 33(615)-5262 from February 1, 1967 through January 31, 1968. The manuscript was released by the author in February 1968 for publication as an AFMDC report.

This contract with Metcut Research Associates Inc., Cincinnati, Ohio, was initiated under Manufacturing Technology Division Project 9-700, "Air Force Machinability Data Center". It is an extension of Manufacturing Technology Division Project 8-239 as indicated in our First and Second Annual Reports. The current contract is being performed under the technical direction of Mr. Max A. Guenther of the Advanced Fabrication Techniques Branch (MATF), Manufacturing Technology Division, Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio.

This project is being accomplished as a part of the Air Force Manufacturing Methods Program. The primary objective of AFMDC is to be highly specialized in the collection, evaluation, storage, retrieval and dissemination of significant data and information pertaining to all aspects of material removal processes. Recipients of these data include aerospace industry, Department of Defense (including all of the military services and their contractors), and other Government agencies, technical institutions, and nonmilitary industries in a position to assist the defense effort. In the area of material removal activity, this Center serves as the communications link for the entire technical community, both Government and industry.

Your comments are solicited on the potential utilization of the Air Force Machinability Data Center as applied to your present or future production programs.

This report has been reviewed and is approved.



George W. Brock
Lt. Colonel, USAF
Cheif
Manufacturing Technology Division

ABSTRACT

THIRD ANNUAL REPORT OF THE
AIR FORCE MACHINABILITY DATA CENTER

John Maranchik, Jr.

This is the Third Annual Report of the Air Force Machinability Data Center covering the period February 1, 1967 through January 31, 1968 (Contract AF 33(615)-5262). Three thousand seven hundred and thirty-four (3,734) documents were processed from which 27,077 cards were key punched. Currently, there are 13,101 evaluated documents and 102,250 punched cards in AFMDC files. One thousand and two (1,002) specific inquiries were answered for 485 different companies, representing 690 individuals in 96 different SIC categories. The 1,002 inquiries represent a 36% increase over the 736 processed in the previous year.

The average cost of inquiries equaled $52.66 per inquiry.

The data acquisition plant visit program was accelerated and since late 1966, 37 visitations have been made, primarily to aerospace firms.

Computer programs have been developed and made operational for storage and retrieval of all the information files in use by the Center. In addition, equations have been written and computer programs have been made operational for calculating machining costs and production rates for five major machining operations: turning, milling, drilling, tapping and reaming.

Plans for next year's effort call for augmenting current efforts and services. This includes identification of potential users of the Center and increased contact with them. This will be accomplished directly by AFMDC and through cooperation with other centers and State Technical Services Programs. This controlled effort will result in an increase in AFMDC inquiries from the current 111 per month rate to about 150 per month by the end of 1968, consistent with the increasing capability of the Center. Four data products will be prepared and made available to users. The ability of the Center to analyze and fill in gaps in accrued machining data will be enhanced by a study to determine those relationships which may exist in machining variables between various types of machining operations and work materials. The 1130 computer will provide valuable assistance in this effort.

A study will be made concerning the potential and the required mechanisms by which users of the Center may have a computer data-link with AFMDC.

PREFACE

This report covers a 12-month period of operation from February 1, 1967 through January 31, 1968. It is presented primarily in the form of individual charts which are self-explanatory with regard to organization of the Center and the results of its efforts, including costs. For each individual chart, the Appendix provides some further comments concerning various aspects of AFMDC during its third year of operation.

For a complete analysis of the progress made by the Center from its early inception to the present, the following three references should be reviewed:

"Final Report on the Design of a System for Collecting, Evaluating and Disseminating Machinability Data for Aerospace Materials", Technical Documentary Report Nr. ASD-TDR-63-572, July 1963, AD-416743.

"First Annual Report of the Air Force Machinability Data Center", AFMDC 65-2, February 1966, AD-482278.

"Second Annual Report of the Air Force Machinability Data Center", AFMDC 66-4, February 1967, AD-813037.

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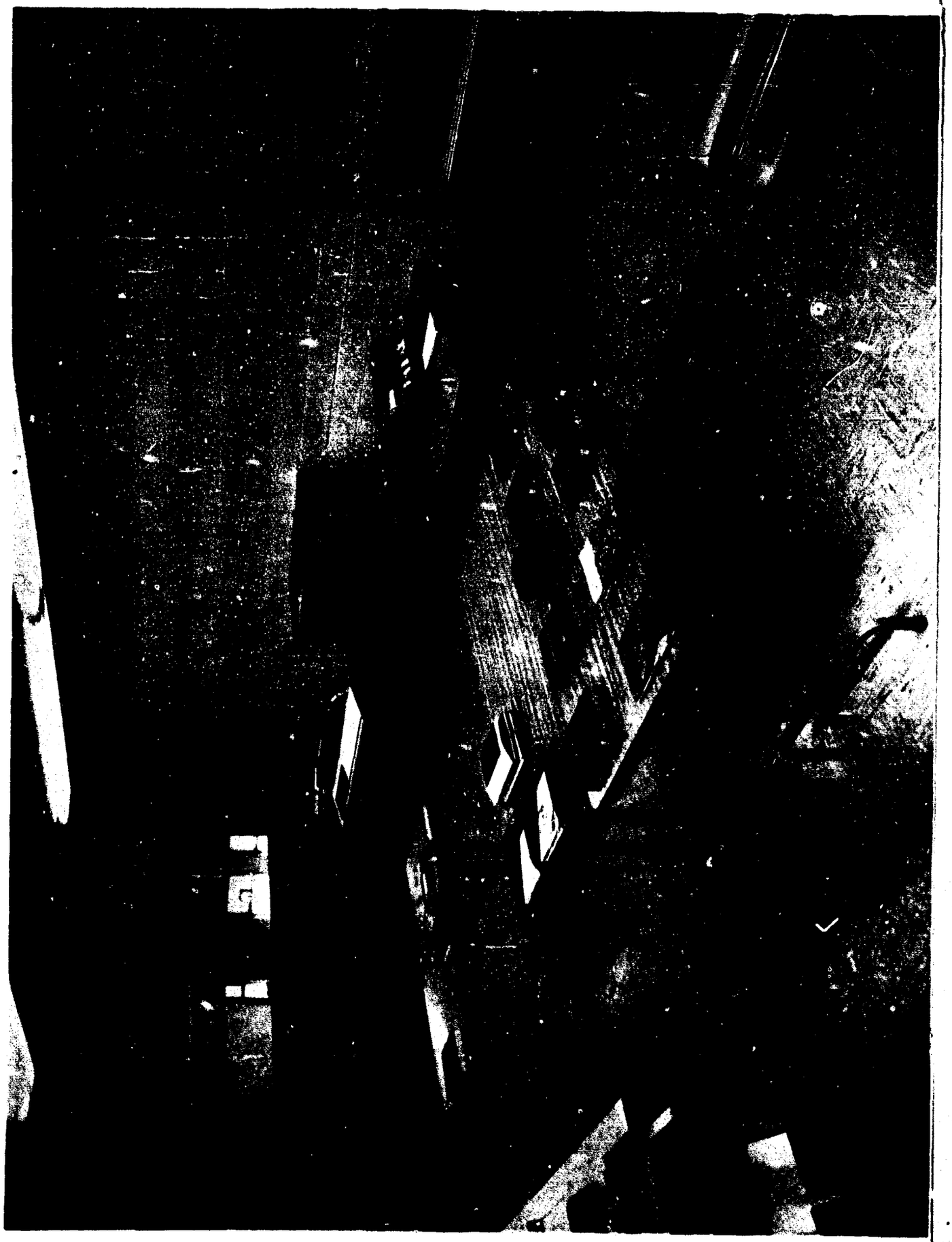


DESCRIPTION OF AFMDC

AIR FORCE MACHINABILITY DATA CENTER, 3980 Rosslyn Drive, Cincinnati, Ohio 45209. Operated for the Air Force Materials Laboratory, Manufacturing Technology Division, under Contract AF 33(615)-5262, by Metcut Research Associates Inc.

SCOPE

The Air Force Machinability Data Center (AFMDC) collects, evaluates, stores, and disseminates material removal information including specific and detailed machining data for the benefit of industry and government. Strong emphasis is given to engineering evaluation for the purpose of developing optimized material removal parameters, such as speeds, feeds, depths of cut, tool material and geometry, cutting fluids and other significant variables. Data are being processed for all types of materials and for all kinds of material removal operations such as turning, milling, drilling, tapping, grinding, electrical discharge machining, electrochemical machining, etc.

COLLECTION

AFMDC has a mechanized system in which punch cards are used to store and retrieve all types of material removal information including all significant numerical data. An IBM 1130 computing system is being used for storing and processing data from a master card and disk file and for computer decoding. The focal concept for acquisition, interrogation, or presentation of information is the specific material (with definite chemical, physical, or mechanical properties) and the specific material removal operation being used. When necessary, card source control codes may be used to retrieve original documents which are in document storage at AFMDC.

INFORMATION SERVICES

AFMDC places strong emphasis on providing specific and detailed answers to technical inquiries in the field of material removal. A User File, consisting of important users in the field of material removal, has been developed to receive information products including machining data pamphlets and tables on materials of current interest, state-of-the-art reports, technical announcements, and other appropriate items. Services are available without charge to the aerospace industry, Department of Defense (including all of the military services and their contractors), and other government agencies, technical institutions, and non-military industries in a position to assist the defense effort.

TO REQUEST MACHINING INFORMATION . . . . . .

Telephone: 513-271-8510
TWX: 810-461-2640 *or*
Write: Air Force Machinability Data Center
3980 Rosslyn Drive
Cincinnati, Ohio 45209

TO HELP US ANSWER YOUR INQUIRY, IF POSSIBLE PLEASE:

1. Identify the material being machined *(specification or tradename)*; condition, *(as cast, hot rolled, cold drawn, annealed, quenched and tempered, etc.)*; microstructure and hardness.
2. Identify the material removal operation in question *(turning, milling, drilling, tapping, surface grinding, electrical discharge machining (EDM), electrochemical machining (ECM), etc.)*.
3. Specify reasons for requiring data unless your needs are proprietary. This enables AFMDC to broaden the scope of its technical advice.
4. Specify delivery requirements.
5. Indicate to whom the inquiry reply should be sent.
6. Transmit all details concerning present practices, including feeds, speeds, cutting tool material and geometry, cutting fluids, etc., in the event your inquiry pertains to improvement of an existing machining situation.

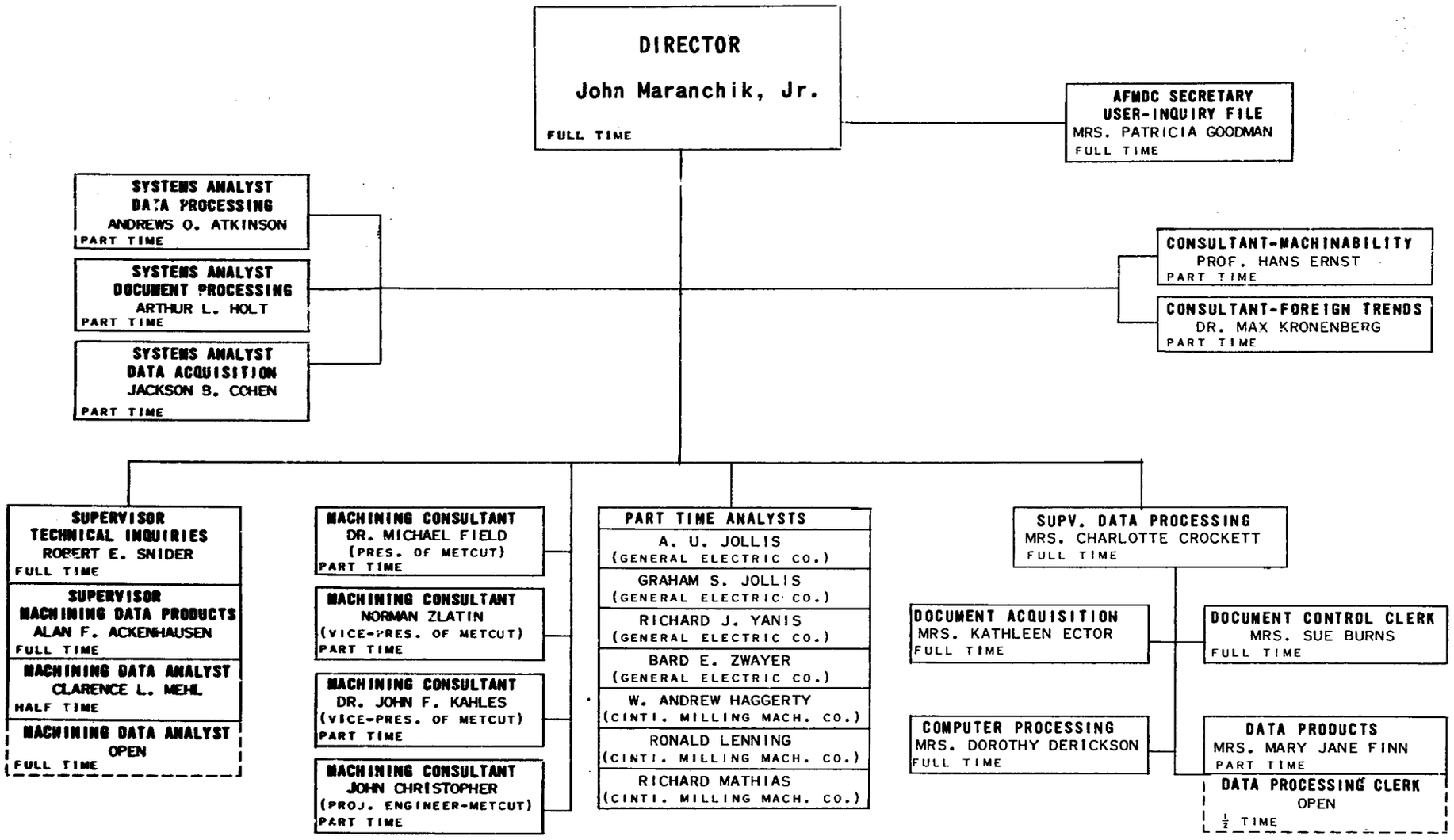
•••••••

NOTE: *Association of the names of companies and individuals with specific requests is kept confidential. However, data developed remain the property of AFMDC for dissemination as required for answering similar inquiries and for developing data products.*

SEE APPENDIX , PAGE A-1

FIGURE 1

AFMDC ORGANIZATION CHART



SEE APPENDIX, PAGE A-1

Operated for the AIR FORCE MATERIALS LABORATORY
MANUFACTURING TECHNOLOGY DIVISION *under*
CONTRACT AF 33(615)-5262,
by METCUT RESEARCH ASSOCIATES INC.

_____ FUTURE EXPANSION FOR 1968

AFMDC OPERATIONAL AREAS

At AFMDC, personnel shown in Figure 1, page 2, work in ten functional areas of operation. These are indicated below along with the numbers used for time coding purposes:

1	Administration	Administration of technical and general activities of AFMDC
2	Engineering Supervision	Technical activities including all mechanized handling of data and processing of inquiries
3	Systems Analysis	Design of the machinability data system, particularly processing
4	Machining Data Analysis	Technical evaluation of machinability data and information including Preliminary Screening
5	Data Processing	Operation of a mechanized system including a computer
6	Data Control	Superimposition and use of controls to guarantee proper operation of data processing system
7	Document Acquisition and Document Storage	Acquisition of all types of data and information for processing. Storage of documents including those which have received Final Technical Evaluation and those in process
8	Data Dissemination	Dissemination including duplication and printing
9	Machining Data Verification - Experimental Machining	Laboratory and shop work necessary for resolving highly significant and controversial data situations
0	Secretarial and Clerical	Development and execution of all procedures relating to typing and filing

SEE APPENDIX, PAGE A-2

AFMDC OPERATIONS CHART

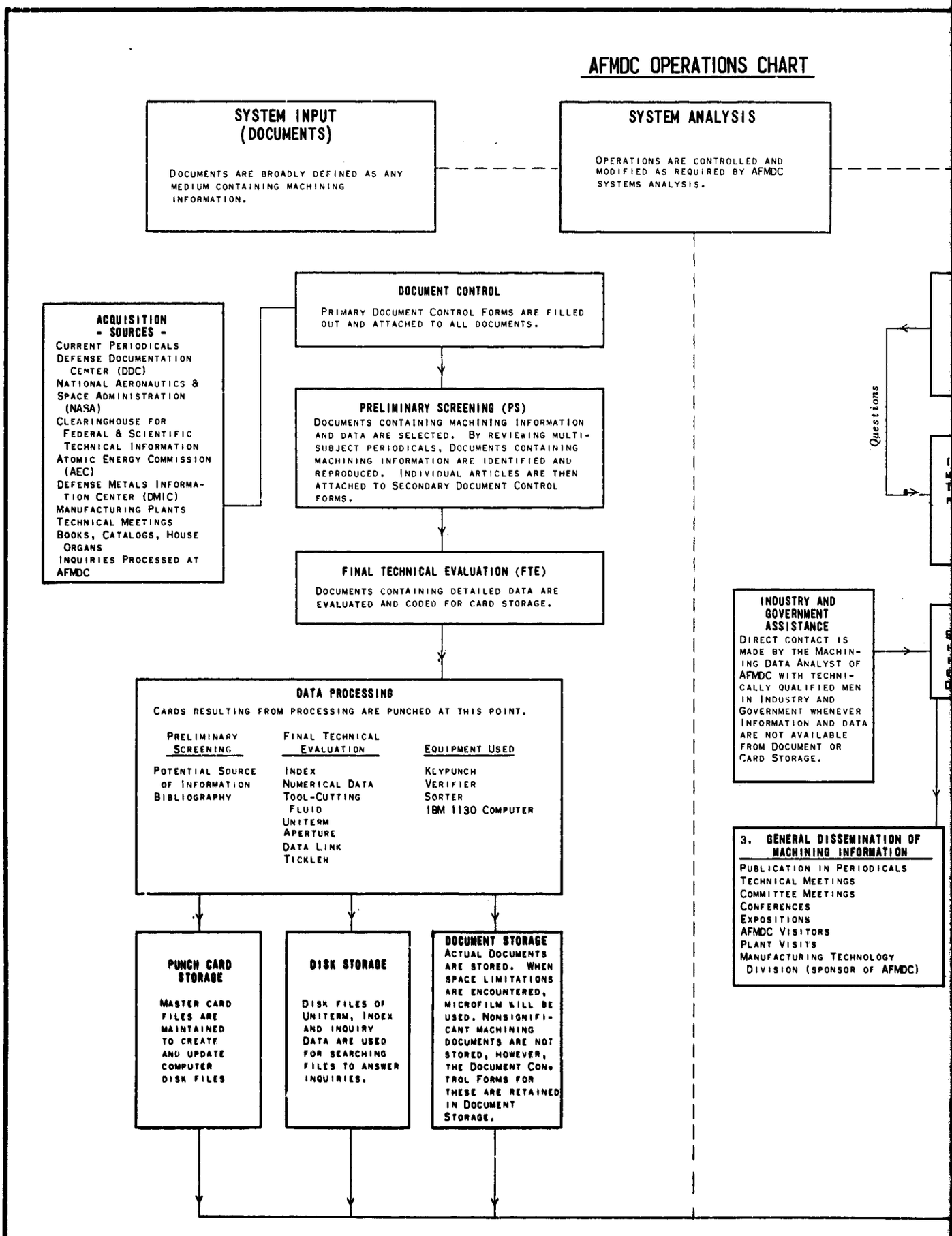


FIGURE 2

AFMDC OPERATIONS CHART

ANY

SYSTEM ANALYSIS

OPERATIONS ARE CONTROLLED AND MODIFIED AS REQUIRED BY AFMDC SYSTEMS ANALYSIS.

SYSTEM OUTPUT

CONSISTS OF:
1. ANSWERING SPECIFIC INQUIRIES.
2. PRODUCING COMPREHENSIVE DATA PRODUCTS OF SPECIFIC AND TIMELY INTEREST TO INDUSTRY AND GOVERNMENT.
3. GENERAL DISSEMINATION OF MACHINING INFORMATION.

DOCUMENT CONTROL

CUMENT CONTROL FORMS ARE FILLED TACHED TO ALL DOCUMENTS.

IMINARY SCREENING (PS)

ONTAINING MACHINING INFORMATION E SELECTED. BY REVIEWING MULTI- IODICALS, DOCUMENTS CONTAINING FORMATION ARE IDENTIFIED AND INDIVIDUAL ARTICLES ARE THEN SECONDARY DOCUMENT CONTROL

ECHNICAL EVALUATION (FTE)

ONTAINING DETAILED DATA ARE D CODED FOR CARD STORAGE.

UNCHED AT THIS POINT.

EQUIPMENT USED

KEYPUNCH
VERIFIER
SORTER
IBM 1130 COMPUTER

DOCUMENT STORAGE

ACTUAL DOCUMENTS ARE STORED. WHEN SPACE LIMITATIONS ARE ENCOUNTERED, MICROFILM WILL BE USED. NONSIGNIFICANT MACHINING DOCUMENTS ARE NOT STORED, HOWEVER, THE DOCUMENT CONTROL FORMS FOR THESE ARE RETAINED IN DOCUMENT STORAGE.

1. SPECIFIC INQUIRIES

INQUIRIES ORIGINATE FROM:
INDUSTRY
GOVERNMENT
EDUCATIONAL INSTITUTIONS
TECHNICAL SOCIETIES
INFORMATION CENTERS

Questions

Replies

INQUIRY CONTROL

INQUIRIES ARE LOGGED IN. ALL NECESSARY INFORMATION IS ENTERED ON AN INQUIRY CONTROL FORM. THE FOLLOWING CODES ARE ASSIGNED FOR CARD PROCESSING:
SIC
INQUIRY TYPE
SOURCE CONTROL *(identifies inquirer)*
SEQUENCE
DATE

REPLIES TRANSMITTED

INDUSTRY AND GOVERNMENT ASSISTANCE

DIRECT CONTACT IS MADE BY THE MACHINING DATA ANALYST OF AFMDC WITH TECHNICALLY QUALIFIED MEN IN INDUSTRY AND GOVERNMENT WHENEVER INFORMATION AND DATA ARE NOT AVAILABLE FROM DOCUMENT OR CARD STORAGE.

MACHINING DATA ANALYSIS

ENGINEERING PERSONNEL ARE ASSIGNED TO EACH INQUIRY. REPLIES ARE TRANSMITTED TO THE INQUIRER, AND THE INQUIRY INFORMATION IS ENTERED INTO THE SYSTEM AS A PRIMARY DOCUMENT.

2. DATA PRODUCTS

FIRST ANNUAL REPORT OF THE AIR FORCE MACHINABILITY DATA CENTER, AFMDC 65-2
MACHINING DATA FOR NUMERICAL CONTROL (7 INDIVIDUAL REPORT NOS. AFMDC 66-1.1 THRU AFMDC 66-1.7 COVERING TURNING, FACE MILLING, DRILLING, PERIPHERAL END MILLING, END MILL SLOTTING, TAPPING & REAMING RESPECTIVELY).
MACHINING DATA FOR NUMERICAL CONTROL AFMDC 66-1 (COMPOSITE OF ABOVE MENTIONED 7 REPORTS).
GRINDING RATIOS FOR AEROSPACE ALLOYS, AFMDC 66-2
MACHINING DATA FOR BERYLLIUM METAL, AFMDC 66-3
SECOND ANNUAL REPORT OF THE AIR FORCE MACHINABILITY DATA CENTER, AFMDC 66-4

3. GENERAL DISSEMINATION OF MACHINING INFORMATION

PUBLICATION IN PERIODICALS
TECHNICAL MEETINGS
COMMITTEE MEETINGS
CONFERENCES
EXPOSITIONS
AFMDC VISITORS
PLANT VISITS
MANUFACTURING TECHNOLOGY DIVISION (SPONSOR OF AFMDC)

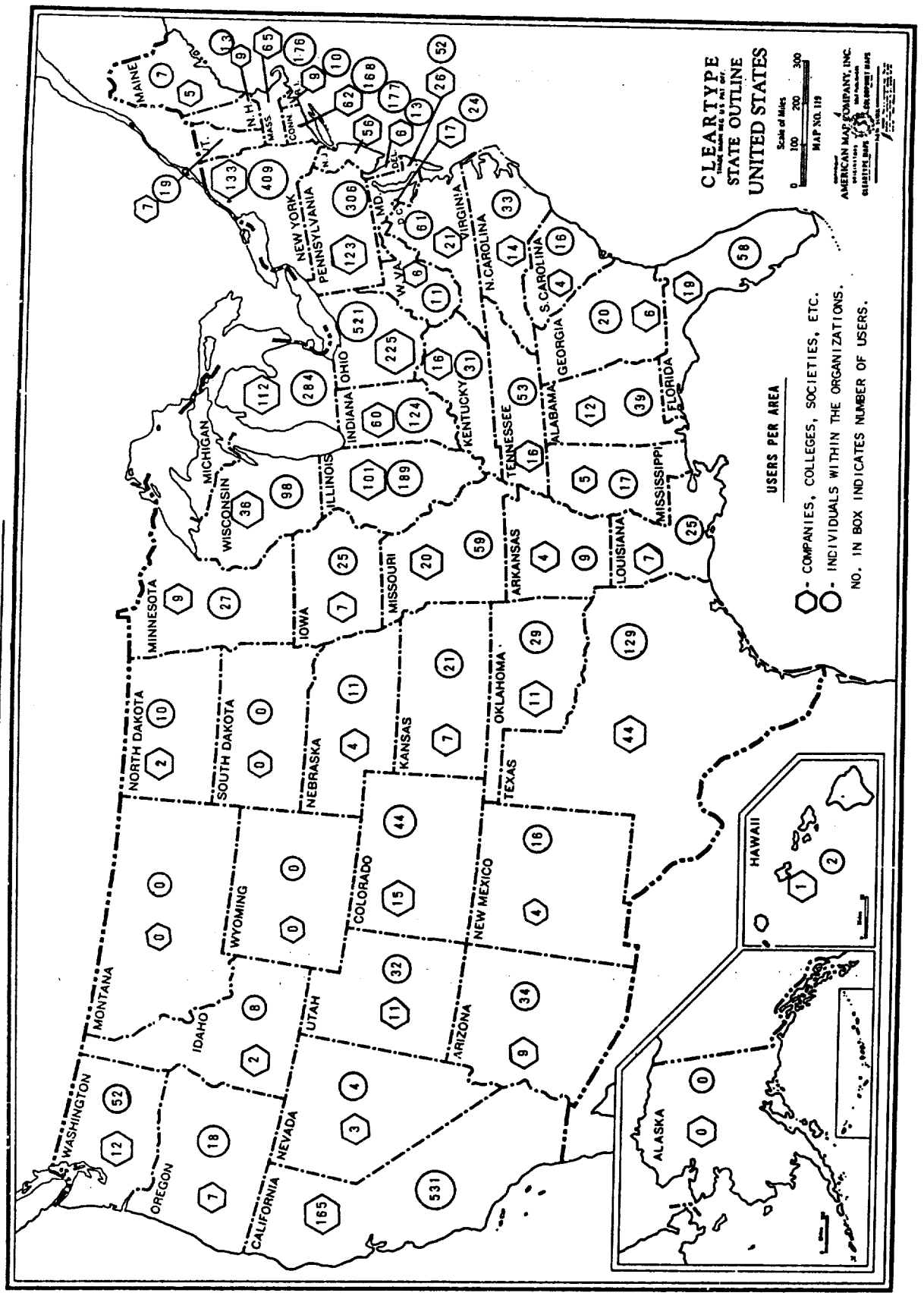
USER FILE

THE USER FILE CONSISTS OF:
MAJOR MISSILE AND AEROSPACE MANUFACTURERS AND THEIR SUBCONTRACTORS
DEPARTMENT OF DEFENSE (INCLUDING ALL OF THE MILITARY SERVICES AND THEIR CONTRACTORS), AND OTHER GOVERNMENT AGENCIES
NONMILITARY INDUSTRIES IN A POSITION TO ASSIST THE DEFENSE EFFORT
AEROSPACE INDUSTRIES ASSOCIATION (AIA) MANUFACTURING COMMITTEE
COLLEGES AND UNIVERSITIES
INFORMATION CENTERS
TECHNICAL SOCIETIES
TRADE PUBLICATIONS
AFMDC INQUIRERS
MATERIALS ADVISORY BOARD (MAB) COMMITTEES
TOTAL - 4026 (1/31/68)

B

SEE APPENDIX, PAGE A-3

AFMDC USER FILE MAP



SEE APPENDIX, PAGE A-4

FIGURE 3

DISTRIBUTION OF AFMDC USER FILE

The basic User File was developed as indicated in Appendix, Page A-4. Names are added to the User File as a result of 1) inquirers, 2) visitors, 3) additional names submitted by current Users, 4) requests resulting from dissemination of data products, and 5) technical articles published in periodicals and announcements pertaining to the Center.

GENERAL CONCENTRATION OF USERS BY NUMBERS

STATES	ORGANIZATIONS	TOTAL NO. ORGANIZATIONS	STATES*	INDIVIDUAL	TOTAL INDIVIDUAL USERS
4	0	0	4	0	0
21	1-10	117	21	1-25	310
13	11-25	201	8	26-50	269
3	26-50	106	8	51-125	557
4	51-100	243	6	126-300	1,123
6	OVER-100	859	4	OVER-300	1,767

AREA CONCENTRATION OF ORGANIZATIONS

West Coast (3 states) - 184 companies
North Midwest (5 states) - 534 companies
Northeast (5 states) - 439 companies

These figures indicate that 75% of User companies lie in 25% of the United States.

The total User File (4,026), can be broken down as follows:

Company Users (Individuals)	3,122
Companies	1,238
College Users (Individuals)	734
Colleges	185
Societies, Centers, etc. (Individuals)	170
Societies, Centers, etc.	103

*Includes Washington, D.C.

SEE APPENDIX, PAGE A-4

SEE APPENDIX, PAGE A-8

COMPUTER INPUT AND OUTPUT FLOW CHART

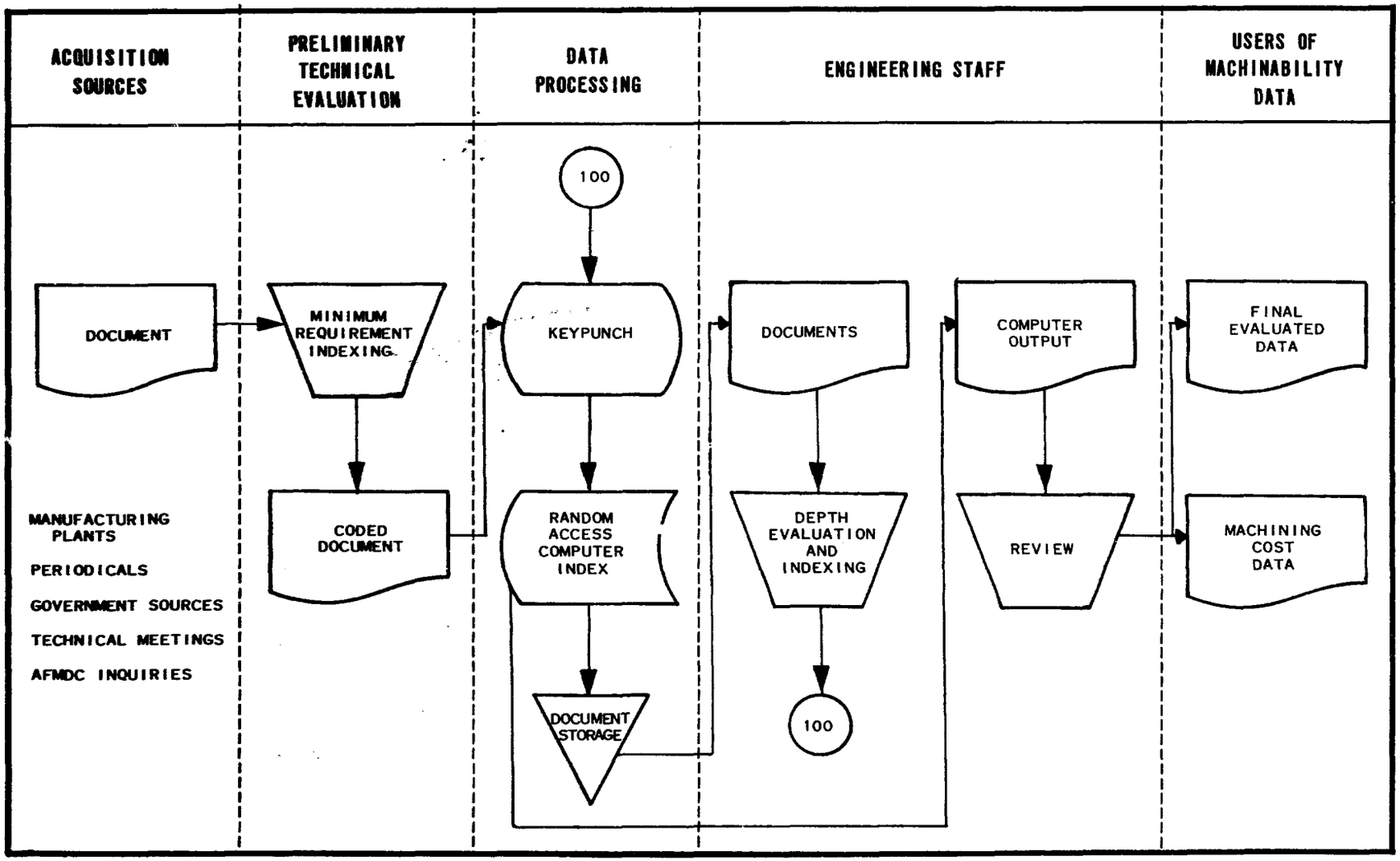


FIGURE 4

DATA CODE FORMS FOR FINAL TECHNICAL EVALUATION

OPERATION (check one)			
✓001	006	017	
002	008		
004	012		
005	016		

DATA CODE FORM #1-1

Date 12-15-69

Coded by C.R.M.

CONTROL CODES			
DATA SOURCE CODE	M/A/C/S	YEAR	INDEX
95	002	66	001

HARDNESS	MATL COND	HT TRT	MATL GROUP	MATERIAL DESCRIPTION	PART CONFIG.	PART TOL	TOOL MATL	MACHINE TOOL TYPE	MACHINE TOOL SIZE	MACHINE TOOL MFR.	MACHINE TOOL MOD	MACHINE TOOL HP	MACHINE TOOL AGE	MACHINE TOOL C	MACHINE TOOL M	CARD	FROM	TO	CODE
C29	01	03	01	INC 0718	2223	4	C	34 16	34 91	22	02	00	20	20	30	62	1	02	01	09	1
								34													1
								34													1
								34													1
								34													1
								34													1

CUTTING SPEED ft. min.	FEED in./rev.	DEPTH OF CUT inches	TOOL LIFE minutes	WEARLAND inches	SEQ NO.	CODE
0150	02247	03034	10150	00347	XXXX	
00125 1	00009 1	00060 1	00010 1	00015 1	02 1	3
00110 2	00009 2	00060 2	00015 2	00015 2	04 1	3
00098 3	00009 3	00060 3	00030 3	00015 3	06 1	3
00090 4	00009 4	00060 4	00045 4	00015 4	08 1	3
5	5	5	5	5	1	3
6	6	6	6	6	1	3

SURFACE FINISH ins	UNIT HP HP/cu. in.				SEQ NO.	CODE
2020 50	25 33 47	47	50	47	XXXX	
1	02000 1	1	1	1	03 2	3
2	02000 2	2	2	2	05 2	3
3	02000 3	3	3	3	07 2	3
00110 4	02000 4	4	4	4	09 2	3
5	5	5	5	5	2	3
6	6	6	6	6	2	3

OPERATION CODE

001	SINGLE POINT TURNING
002	FACING CUT TURNING
004	THREADING
005	MULTI-EDGE CHASER
006	TRACING or CONTOUR
008	CHAMFER
012	BOX TOOL TURNING
016	CENTERLESS
017	MULTI-POINT TURNING

SIDE 1

TOOL - CUTTING FLUID #1

TOOL STYLE	*BACK RAKE°	*SIDE RAKE°	END REL°	SIDE REL°	*ECEA°	*SCEA°		NOSE RADIUS inches	CHIP-BREAKER TYPE	CHIP-BREAKER WIDTH-in.	CHIP-BREA...R DEPTH-in.	TOOL MATERIAL TRADE DESIGNATION	TOOL MATERIAL MFR.	CUTTING FLUID MFR.	CUTTING FLUID TYPE	CUTTING FLUID CONCENTRATION	SEQ NO.	CODE
11 16	00	05	05	05	15	15		032	2	0083	0150	C2	KBI	100	3	0200	01	3
		0																3
		0																3
		0																3
		0																3
		0																3

COLUMN 1 (TYPE)
1 - SOLID
2 - BRAZED INSERT
3 - THROWAWAY INSERT

COLUMN 2 (SHAPE OF INSERT)
0 - NONE
1 - SQUARE
2 - TRIANGLE
3 - ROUND
4 - PENTAGON
5 - DIAMOND
6 - HEXAGON

COLUMN 3 (LOCKING METHOD)
1 - CLAMPING
2 - PIN LOCK

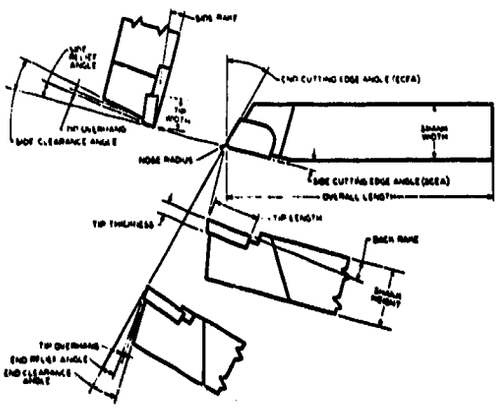
COLUMN 4 & 5 (SHANK SIZE OF HOLDER OR TOOL BIT)
IF TOOL IS SQUARE CODE BY 1/16th's
IF TOOL IS RECTANGLE CODE BY 1 6th's ON WIDTH; 1/16th's ON DEPTH
IF TOOL IS ROUND BORING BAR CODE BY 1/16th's ON DIAMETER
Examples:
SQUARE - 16 : 1" x 1" SQUARE
RECTANGLE - 64 : 6/8" x 4/4" - 3/4" x 1"
ROUND - 8 : 1/2" DIAMETER

COLUMN 6
1 - RIGHT HAND CUTTING
2 - LEFT HAND CUTTING
3 - END CUTTING
4 - BORING
5 - ROLLER TURNING
6 - CUTOFF
7 - PLANING
8 - SHAPING

COLUMN 32 (CHIPBREAKER)
1 - MECHANICAL
2 - GROUND
3 - NONE
4 - MOLDED

COLUMN 33 (CHIPBREAKER TYPE)
1 - ANGULAR
2 - PARALLEL
3 - GROOVE
4 - 45° ANGULAR
5 - REVERSE ANGULAR

* Circle appropriate plus or minus sign.

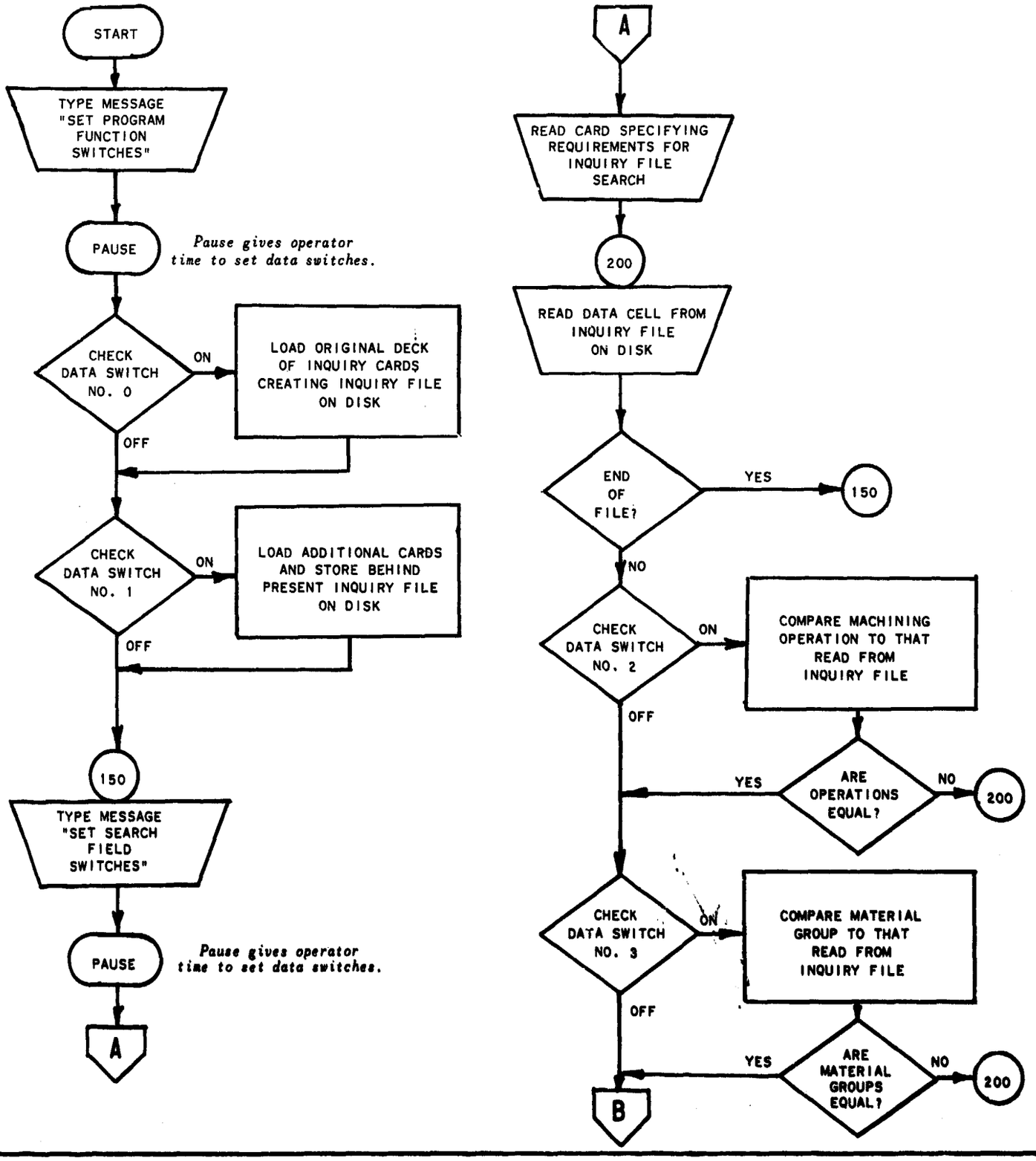


SIDE 2

FIGURE 5

SEE APPENDIX, PAGE A-8

FLOW CHART FOR FORTRAN PROGRAM TO STORE, ADD OR

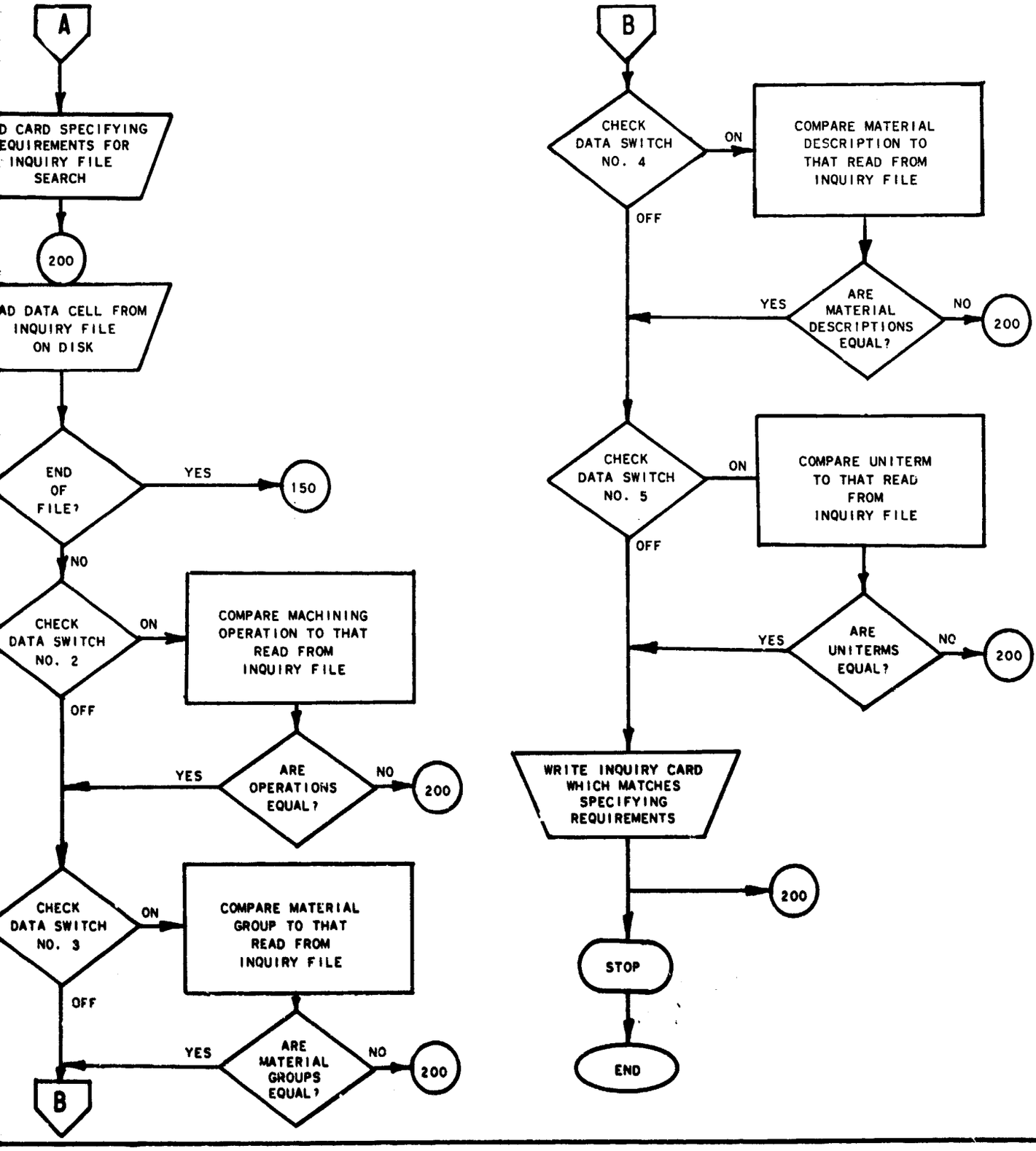


SEE APPENDIX, PAGE A-8

A

B

RT FOR FORTRAN PROGRAM TO STORE, ADD OR SEARCH INQUIRY FILE



B

FIGURE 6

INQUIRY FILE SEARCH

SEE APPENDIX, PAGE A-9

CONTROL ON DATA SWITCH NO. 5 - UNITERM, CUT FLUID

OPER	MG	MAT DESCRP		UNITERMS	SIC	CO		SEQ	DATE
0	0		0	CUT FLUID					
170	301	INCOX750	1	CUT FLUID	3541	41	11	63	2015
0	0		14	CARB TOOLSCUT FLUID	3610	42	11	97	3035
0	301	WASPALOY	2	CUT FLUID TOOL GEOM	3722	79	11	112	3045
0	0		14	CUT FLUID STRESS -CORROSION	2911	82	11	119	3125
1	301	INCOX750	13	CUT FLUID	3722	35	11	138	3185
85	301	INCOX750	13	CUT FLUID	3722	35	1	138	3185
55	301	INCOX750	13	CUT FLUID	3722	35	1	138	3185
1	301	INCO722	13	CUT FLUID	3722	35	1	138	3185

SET SEARCH FIELD SWITCHES

CONTROL ON DATA SWITCHES NOS. 3, 4 & 5 - MATL GRP, 301; MATL DESCRIP, INCO X750; UNITERM, CUT FLUID

10

OPER	MG	MAT DESCRP		UNITERMS	SIC	CO		SEQ	DATE
0	301	INCOX750	0	CUT FLUID					
170	301	INCOX750	1	CUT FLUID	3541	41	11	63	2015
1	301	INCOX750	13	CUT FLUID	3722	35	11	138	3185
85	301	INCOX750	13	CUT FLUID	3722	35	1	138	3185
55	301	INCOX750	13	CUT FLUID	3722	35	1	138	3185

SET SEARCH FIELD SWITCHES

CONTROL ON DATA SWITCHES NOS. 2, 3, 4 & 5 - OPERATION, 005 (DRILLING); MATL GRP, 301; MATL DESCRIP, INCO X750; UNITERM, CUT FLUID

FIGURE 7

OPER	MG	MAT DESCRP		UNITERMS	SIC	CO		SEQ	DATE
85	301	INCOX750	0	CUT FLUID					
85	301	INCOX750	13	CUT FLUID	3722	35	1	138	3185

OUTPUT OF PRELIMINARY TECHNICAL EVALUATED DATA

OPER	HDN	MC	HT	MTG	MAT DESCRIP	TM	SOURCE CONTROL CODE
085				301			
085	C48	01	61	301	INCO718	C	229012 G640001401011
085	C35	01	00	301	RENE41	HS	502002BD640001243451
085	C34	01	00	301	INCOX750	HS	732002Eb631288228371
085	C51	03	61	301	UD500	C	807011 &640001401011
085	C40	01	61	301	UD700	HS	8110021D602001279961
085	C35	03	60	301	RENE41	HS	8110021D602001219211
085	C25	03	00	301	WASPALOY	HS	811006TB620001262741
085	C39	03	61	301	RENE41	HS	817004 &650001401011
085	C34	01	60	301	INCO901	C	817012 G670001092571
085	C41	03	61	301	RENE41	HS	817012 G670001092571
085	C37	03	60	301	INCOX750	HS	817012 G670001092571
085	C41	00	61	301	RENE41	HS	911001MB611101234351
085	C35	01	67	301	INCOX750	C	917000 &590001401021
085	C33	01	00	301	INCOX750	HS	922004MB641001277781
085	C27	03	00	301	INCOX750	HS	922004MB641001275761
085	B89	03	00	301	HASTX	HS	922004MB641001253541
085	C35	00	00	301	HASTX	HS	922004MB641001249501
085	C36	01	04	301	INCO100C	C	950010EB660005267721
085	C39	01	61	301	RENE41	HS	950010EB660005249591

SEE APPENDIX, PAGE A-9

11

FIGURE 8

OUTPUT OF UNITERM FILE SEARCH

TOOL GEOM
085 301

TOOL GEOM TRBL SHOOTMACHG -TECHNIQUES 487000 G660001 01 4
110 004 085 040 125 301 487000 660001

TOOL STDS MACH TOOL-AUTOMATIC NC TOOL GEOM TOOL DESGN500000 &580001 01 4
001 085 055 155 020 030 100 301 051 500000 580001

TOOL GEOM 505000 G640006 01 4
085 301 505000 640006

TOOL GEOM CUT FLUID FEED RATE 506000 G630006 01 4
020 085 100 301 506000 630006

TOOL GEOM DRL GRNDG DEEP HOLE TOOL HLDR 512000 G610007 01 4
085 020 100 040 045 050 301 512000 610007

TOOL GEOM MACHG -TECHNIQUESTOOL DESGNTAP SPECS 605000 G590001 01 4
085 110 300 281 076 301 605000 590001

TOOL GEOM TORQUE THRUST TOOL FAILR 605003 G640001 01 4
085 301 605003 640001

TOOL GEOM STD SPEC FOREIGN 624002 G550001 01 4
001 085 301 624002 550001

MACHG DATATOOL GEOM MACHG -TECHNIQUES 677000 G600001 01 4
085 301 677000 600001

TOOL GEOM DRILL -THEORY CUT FLUID-EFFECT 734007 G660001 01 4
085 301 734007 660001

DRL GRNDG CUTTER -GRNDG -SPECS TOOL GRNDGTOOL GEOM 803004 &510013 01 4
085 055 225 301 803004 510013

TOOL GEOM TORQUE THRUST SPIRAL PT 810001 &570001 01 4
085 301 810001 570001

SHEAR -ANGLE TOOL GEOM CUT FORCE 810006 G510001 01 4
001 056 085 301 810006 510001

MCHNBLTY -RATING TOOL GEOM TOOL LIFE CUT FLUID 811000 &620001 01 4
001 085 056 075 070 110 100 301 811000 620001

DRL GRNDG CUTTER -GRNDG -SPECS TOOL GRNDGTOOL GEOM 803004 &510013 01 4
085 055 225 301 803004 510013

FIGURE 9

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SEE APPENDIX, PAGE A-9

SEE APPENDIX, PAGE A-10

OUTPUT OF FINAL TECHNICAL EVALUATED DATA

MACHINING OPERATION	MATERIAL GROUP	MATERIAL DESCRIPTION	HEAT TREAT CONDITION	MATERIAL HARDNESS	A F M D C DATA SOURCE	INDEX STATUS	INDEX CLASS	
TURN, SINGLE PNT	301	INCO718	SOLUTIONED	ROCK C29				INQUIRY
TURN, SINGLE PNT	301	INCO718	SOLUTIONED	ROCK C29	950002 660019	EB		AFMDC

TOOL GEOMETRY (SEE CHART)	TOOL STYLE	BACK RAKE DEG	SIDE RAKE DEG	END RELF DEG	SIDE RELF DEG	ECEA DEG	SCEA DEG	NOSE RADIUS INCHES	CHIP BREAKER TYPE	CHIP BREAKER WIDTH INCH	CHIP BREAKER DEPTH INCH	
	11 161	00	0 05	05	05	15	15	0.032	*****	*****	******	AFMDC

TOOL MATL-FLUID MATERIAL	CUTTING FLUID TRADE NAME	CUTTING FLUID DESCRIPTION	CUTTING FLUID CONCENTRATION	
C2 K68	NOT REPORTED	WATER SOLUBLE OIL -LIGHT DUTY	1 TO 020	AFMDC

NUMERICAL DATA CUT SPEED FT/MIN	FEED IN/REV	DEPTH CUT INCH	TOOL LIFE MIN	WEAR LAND INCH	SURF FIN RMS	UNIT H P HP/CUIN			
125.	0.009	0.060	10.	0.015	******	2.000	******	******	******	AFMDC
110.	0.009	0.060	15.	0.015	******	2.000	******	******	******	AFMDC
98.	0.009	0.060	30.	0.015	******	2.000	******	******	******	AFMDC
90.	0.009	0.060	45.	0.015	110.	2.000	******	******	******	AFMDC

FIGURE 10

COST AND PRODUCTION RATE FOR MILLING

INSERTED TOOTH - CARBIDE TIP OR HSS BLADE

DATA SET NO.	WORK MATERIAL	HARD NESS	TOOL MATL	CUT SPD F/M	FEED/ TOOTH IN	TOOL LIFE IN/TH	FEED COST $	RAPD TRAV $	LOAD UNLD $	SET-UP $	CUTR CHNG $	BODY DEPR $	CUTR SHPN $	BLAD RSET $	BLAD COST $	GRND WHL. $	TOTAL COST $/PC.	PROD RATE PC/HR
101	WASPALOY	302	C-2	142	0.005	12.0	0.47	0.03	0.44	0.08	0.16	0.01	1.33	0.12	0.19	0.03	2.86	7.3
102	WASPALOY	302	C-2	92	0.005	24.0	0.73	0.03	0.44	0.08	0.08	0.01	0.66	0.06	0.09	0.01	2.19	6.4
103	WASPALOY	302	C-2	74	0.005	17.0	0.91	0.03	0.44	0.08	0.11	0.01	0.94	0.08	0.13	0.02	2.75	5.5

FIGURE 11

THROWAWAY INSERT

DATA SET NO.	WORK MATERIAL	HARD NESS	TOOL MATL	CUT SPD F/M	FEED/ TOOTH IN	TOOL LIFE IN/TH	FEED COST $	RAPD TRAV $	LOAD UNLD $	SET-UP $	INDX INST $	BODY DEPR $	INSERT COST $	TOTAL COST $/PC.	PROD RATE PC/HR
201	WASPALOY	302	C-2	142	0.005	12.0	0.47	0.03	0.44	0.08	0.09	0.03	0.20	1.34	7.8
202	WASPALOY	302	C-2	92	0.005	24.0	0.73	0.03	0.44	0.08	0.04	0.03	0.10	1.45	6.6
203	WASPALOY	302	C-2	74	0.005	17.0	0.91	0.03	0.44	0.08	0.07	0.03	0.14	1.70	5.7

14

SOLID HIGH SPEED STEEL CUTTER

DATA SET NO.	WORK MATERIAL	HARD NESS	TOOL MATL	CUT SPD F/M	FEED/ TOOTH IN	TOOL LIFE IN/TH	FEED COST $	RAPD TRAV $	LOAD UNLD $	SET-UP $	CUTR CHNG $	CUTR DEPR $	CUTR SHPN $	GRND WHL. $	TOTAL COST $/PC.	PROD RATE PC/HR
301	WASPALOY	302	M-2	32	0.011	20.0	0.41	0.03	0.44	0.08	0.04	0.07	0.34	0.04	1.45	8.7
302	WASPALOY	302	M-2	29	0.011	60.0	0.45	0.03	0.44	0.08	0.01	0.02	0.11	0.02	1.16	8.6
303	WASPALOY	302	M-2	25	0.011	113.0	0.53	0.03	0.44	0.08	0.00	0.01	0.06	0.01	1.16	8.1

SEE APPENDIX, PAGE A-10

COST STUDY ANALYSIS OF IBM 1130 COMPUTER

The following statistics are based on

1. Fifteen time studies performed on fifteen inquiries comparing IBM 1130 Computer Processing versus IBM Series 50 Configuration Processing.
2. 500 calculations for production rates and machining costs.

Inquiry Processing

Average number of inquiries processed per month=	75
Percentage of Inquiries requiring searches=	57%
Inquiries per month for which searches are performed are 57% x 75 =	43
Average cost for processing inquiries with the IBM Series 50 Configuration=	$70.09
Average cost for processing inquiries with the IBM 1130 Computing System=	$48.92
Average savings for processing an inquiry using the IBM 1130 Computer=	$21.17
Inquiry processing savings per month = 43 x $21.17=	$910.31
Savings per month in sorting and handling of Index files = 50 hrs. x $8.16 per hr.=	$408.00
Savings per month in sorting and handling of Inquiry files = 5 hrs. x 8.16 per hr.=	$40.80
Total savings per month=	$1,359.11
Additional cost per month for IBM 1130 Computer=	$306.00
Savings per month =	$1,053.11
Savings per year, 12 x $1,053.11=	$12,637.32

Calculations For Production Rates and Machining Costs

In preparing a data product pertaining to Calculations for Production Rates and Machining Costs, 500 calculations were required:

Time per calculation using desk calculator=	15 min.
Time per calculation using IBM 1130 Computer=	0.3 min.
Savings per calculation=	14.7 min.
Time Savings = 500 x 14.7 x 7350 min.=	122.5 hrs.
Cost Savings = 122.5 x $8.16 =	$999.60

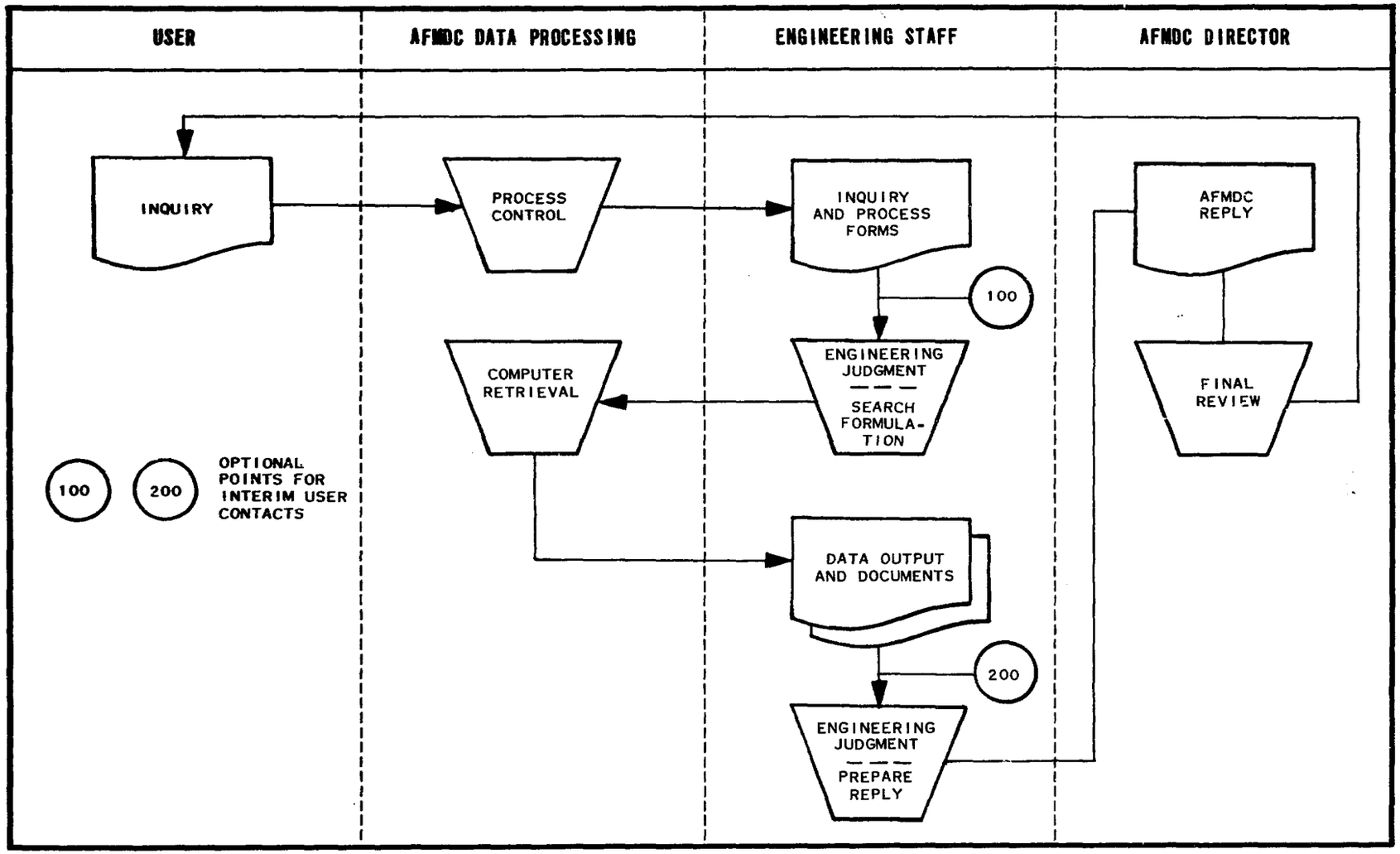
Summary of Cost Savings:

Inquiry Processing Savings=	$12,637.32
Calculations Savings=	$999.60
Savings for one year of operation=	$13,636.92

SEE APPENDIX, PAGE A-11

FIGURE 12

INQUIRY PROCESSING FLOW CHART



SEE APPENDIX, PAGE A-11

TYPICAL INQUIRY INPUT AND RESPONSE

INQUIRY FORM (IF-1)

SOURCE CONTROL CODE: SIC 3721 | CO. 0232 | DIV. 01 | INDV. 02
AUXILIARY CONTROL CODE: *EQUIPMENT 10495 | DATE 07217 | TYPE 02
INQUIRY RECEIVED BY: RES
ANALYST ASSIGNED: RES
ANSWER APPROVED BY: JM
REPLY REQUIRED BY: 7-26-67
TYPE OF INQUIRY: Letter

INQUIRY IDENTITY

COMPANY: Gemini Manufacturing Corp. DIVISION: Mfg. Engrg.
ADDRESS: 17820 Davidson Road, Hunter, Missouri 56114
INDIVIDUAL: R. A. Johnson TITLE: Manager - Mfg. Engrg.
PHONE: 545-??1-6400 DATE: 7-21-67 Already on IF [x] Put on IF [ ]

INQUIRY ABSTRACT (USE REVERSE SIDE IF NECESSARY)

Requested Face Milling, End Milling and Drilling Recommendations for Inco 718 Forgings in the Aged Condition at Rockwell C 47.

DETAILED DESCRIPTION

MACHINE OPERATIONS: 056 070 085
WORKPIECE
HARDNESS: C47
CONDITION: 01
HEAT TREATMENT: 61
MAT'L. GROUP: 301
MAT'L. DESCRIPTION: INCO718
CONFIGURATION:
TOLERANCE:
CUTTING TOOL MAT'L. & MFR.:
CUTTING FLUID, MFR. & %:
REMARKS:

MACHINE TOOL
TYPE: SIZE:
MANUFACTURER: MODEL:
AGE: CONDITION:
MODIFICATION:

MACHINING VARIABLES
SPEED: FEED: DEPTH OR WIDTH OF CUT:
SURFACE FINISH: TOOL LIFE:
TOOL GEOMETRY:
OPERATION DESCRIPTION:

AIR FORCE MACHINABILITY DATA CENTER

3980 ROSSLYN DRIVE • CINCINNATI, OHIO 45209

Telephone 513-271-6640
TWX 810-827-1755

July 24, 1967

Mr. R. A. Johnson
Manager, Manufacturing Engineering
Gemini Manufacturing Corporation
17820 Davidson Road
Hunter, Missouri 56114

Subject: Request for Face Milling, End Milling and Drilling Recommendations for Inco 718 Forgings in the Aged Condition at 47 R_c --
Contract AF 33(615)-5262

Thank you for your subject inquiry of July 20, 1967. In response to your request we are pleased to furnish the following information:

Face Milling:

Carbide

Cutting Speed:	70 feet/minute
Feed:	.006 inches/tooth/revolution
Tool Material:	C-2
Tool Geometry:	AR: 0° ECEA: 5° RR: 7° Cl: 10° CA: 45°
Cutting Fluid:	Highly Chlorinated Oil

HSS

Cutting Speed:	25 feet/minute
Feed:	.010 inches/tooth/revolution
Tool Material:	T-15
Tool Geometry:	AR: 0° ECEA: 5° RR: 30° Cl: 10° CA: 45°
Cutting Fluid:	Highly Chlorinated Oil

End Milling - Slotting:

Cutting Speed:	35 feet/minute		
Cutter Diameter:	1/2"	3/4"	1-2"
Feed (in. /tooth):	.0015	.002	.003
Tool Material:	T-15, M33, M34 or M36		

OPERATED FOR THE AIR FORCE MATERIALS LABORATORY, MANUFACTURING TECHNOLOGY DIVISION, UNDER CONTRACT AF 33(615)-5262 BY BATTELLE RESEARCH ASSOCIATES INC., CINCINNATI, OHIO

We want to ... for your future machining

AIR FORCE MACHINABILITY DATA CENTER

Robert E. Snider

Robert E. Snider, Supervisor
Technical Inquiries

RES/pg

FIGURE 13

ANALYSIS OF INQUIRIES BY STATE

October 1, 1964 - January 31, 1968

10 STATES LEADING IN INQUIRIES			
STATES	**COMPANIES**	**INDIVIDUALS**	**NO. OF INQUIRIES**
CALIFORNIA	93	165	232
CONNECTICUT	34	50	77
ILLINOIS	65	88	131
INDIANA	40	64	82
MASSACHUSETTS	40	63	96
MICHIGAN	60	88	143
NEW JERSEY	37	73	109
NEW YORK	72	118	166
OHIO	196	359	649
PENNSYLVANIA	75	112	153
TOTAL	712	1180	1938
OTHER STATES SUBMITTING INQUIRIES			
ALABAMA	4	4	4
ARIZONA	5	10	13
ARKANSAS	1	1	1
COLORADO	5	13	18
DISTRICT OF COLUMBIA	6	8	11
DELAWARE	2	14	21
FLORIDA	12	21	39
GEORGIA	2	7	9
IOWA	8	10	14
KANSAS	6	10	12
KENTUCKY	12	20	28
LOUISIANA	2	5	6
MAINE	3	4	5
MARYLAND	17	22	32
MINNESOTA	7	9	10
MISSISSIPPI	2	2	2
MISSOURI	8	26	48
NEBRASKA	1	1	1
NEW HAMPSHIRE	4	4	5
NEW MEXICO	2	7	14
NORTH CAROLINA	4	4	9
OKLAHOMA	3	10	15
OREGON	4	5	7
RHODE ISLAND	4	4	6
SOUTH CAROLINA	1	1	2
TENNESSEE	9	18	34
TEXAS	15	20	24
UTAH	4	4	6
VERMONT	4	4	6
VIRGINIA	13	17	24
WEST VIRGINIA	7	7	12
WASHINGTON	6	19	27
WISCONSIN	15	21	30
TOTAL	198	332	495
TOTAL FOR ALL STATES	910	1512	2333

FIGURE 14

SEE APPENDIX, PAGE A-12

SUMMARY OF SPECIFIC INQUIRIES BY TYPE OF INQUIRY

October 1, 1964 - January 31, 1968

		10/1/64 to 1/31/66	2/1/66 to 1/31/67	2/1/67 to 1/31/68
		NO. OF INQUIRIES		
1.	RECOMMENDATIONS FOR A SPECIFIC MACHINING SITUATION. *Typical Example:* Requested recommendations for turning Waspaloy in the solution treated and aged condition.	73	116	180
2.	STARTING RECOMMENDATIONS FOR AN EXTENSIVE GROUP OF MACHINING SITUATIONS. *Typical Example:* Requested machinability data on AM-350, S-816, HS-25, HS-31, Inconel X-750, Unitemp M-252 and Hastelloy R-235.	118	264	330
3.	INFORMATION PERTAINING TO NEW MACHINING PROCESSES, EQUIPMENT AND TOOLS. *Typical Example:* Requested information on the manufacturer of equipment called "Liquid Lathe."	45	27	78
4.	COORDINATION AND POTENTIAL USE OF AFMDC. *Typical Example:* Requested detailed information on services available from AFMDC.	77	29	40
5.	VISITS TO THE CENTER. *Typical Example:* Visited to coordinate with AFMDC to determine services available and to review System details.	60	78	56
6.	*REQUESTS FOR SPECIFIC DOCUMENTS, REPORTS, BOOKS, PAPERS, ETC. *Typical Example:* Requested a list of reports available for machining of titanium. Also wanted cost of each report.	70*	71*	116*
7.	GENERAL INFORMATION SUCH AS SAFETY PRACTICES, NAMES OF FIRMS HAVING CERTAIN MACHINING CAPABILITIES, TOOL MATERIAL PROPERTIES, ETC. *Typical Example:* Requested the names of people to contact in the fields of metal removal such as EDM, ECM, ECG, EDG, USM, CHM, EBM, LBM, Abrasive Machining and Hot Machining.	48	30	18
8.	REQUESTS FOR BIBLIOGRAPHIES AND ABSTRACTS. *Typical Example:* Request for bibliographies with abstracts covering use of ceramic tools and abrasives in machining various materials.	12	4	11
9.	STATE-OF-THE-ART INFORMATION AND REPORTS. *Typical Example:* Suggestions for important manufacturing programs for the next five years in the field of material removal. Supply problem, approach and approximate funds.	14	8	20
10.	SPECIAL INQUIRIES AND REPORTS FOR U.S. AIR FORCE, MANUFACTURING TECHNOLOGY DIVISION. *Typical Example:* Requested a report on the progress during the last five years in machining of titanium and hard to machine materials - state of the art.	12	4	2
11.	EVALUATION, TRANSLATION AND REVIEW OF REPORTS, BOOKS, PAPERS. *Typical Example:* Requested an evaluation of a report published in Electro-Technology, October 1964, concerning adaptive control possibilities.	14	12	9
12.	REQUEST FOR INFORMATION ON BERYLLIUM. *Typical Example:* Request for information on machinability data for beryllium using ECM, EDM, and other methods.	11	15	14
13.	COMPARISON OF ONE PROCESS OR MATERIAL WITH ANOTHER. *Typical Example:* Requested a comparison of the machining of Inconel W with Inconel X in both solution treated and solution treated and aged conditions, primarily in turning but also drilling and milling if possible.	15	13	14
14.	INFORMATION PERTAINING TO CUTTING FLUIDS. *Typical Example:* Requested cutting fluid recommendations for titanium and a wide variety of high temperature alloys and stainless steels.	15	22	16
15.	INFORMATION ON MACHINABILITY RESEARCH. *Typical Example:* Requested machining information on the effect of work diameter on tool life, mathematical correlations of the various machining processes and the means of predicting the surface quality in milling.	11	37	77
16.	INFORMATION PERTAINING TO ESTIMATING COST, SETTING TIME STANDARDS, AND PRODUCTION RATES IN MACHINING. *Typical Example:* Requested information including formulas that could be used to predict production rates and costs.		6	21
		595	736	1002

* *This total does not include requests for published data products such as AFMDC reports.*

SEE APPENDIX, PAGE A-12

FIGURE 15

GENERAL ANALYSIS OF INQUIRIES

FEBRUARY 1, 1966 - JANUARY 31, 1968

TYPE OF INQUIRY	NO. OF INQUIRIES	
	2/1/66-1/31/67	2/1/67-1/31/68
ONE OPERATION ON ONE MATERIAL GROUP	90	160
ONE OPERATION ON A VARIETY OF MATERIAL GROUPS	50	63
SEVERAL OPERATIONS ON ONE MATERIAL GROUP	215	242
SEVERAL OPERATIONS ON SEVERAL MATERIAL GROUPS	124	170
UNITERM LINKED WITH AN OPERATION AND/OR GROUP	126	111
GENERAL MACHINING CONCEPTS (UNITERM)	131	256
TOTAL	736	1,002

ANALYSIS OF INQUIRIES BY MATERIAL GROUP

FEBRUARY 1, 1966 - JANUARY 31, 1968

MATERIAL GROUP	NO. OF INQUIRIES	
	2/1/66-1/31/67	2/1/67-1/31/68
PLAIN CARBON & LOW ALLOY STEELS	177	262
ULTRA HIGH STRENGTH & TOOL STEELS	171	204
CAST IRON	33	36
STAINLESS STEELS	173	278
NICKEL ALLOYS	29	19
MARAGING STEELS	66	77
HIGH TEMPERATURE ALLOYS	254	327
TITANIUM ALLOYS	234	222
REFRACTORY ALLOYS	130	155
BERYLLIUM ALLOYS	46	60
ZIRCONIUM ALLOYS	7	22
ALUMINUM, MAGNESIUM, ZINC, LEAD & COPPER ALLOYS	80	86
PRECIOUS & RARE METALS	3	12
POWDER METALS	2	2
NONMETALLICS INCLUDING CERAMICS, PLASTICS, GRAPHITE & COMPOSITES	57	131
TOTAL	1,482	1,893

FIGURE 18

SEE APPENDIX, PAGE A-13

ANALYSIS OF INQUIRIES BY TYPE OF MACHINING OPERATION

FEBRUARY 1, 1966 - JANUARY 31, 1968

OPERATION	NO. OF INQUIRIES	
	2/1/66-1/31/67	2/1/67-1/31/68
CONVENTIONAL CHIP REMOVAL		
TURNING	367	499
BORING	48	52
MILLING (GENERAL)	10	30
FACE MILLING	290	375
END MILL SLOTTING	285	371
PERIPHERAL END MILLING	145	178
SLAB MILLING	6	20
THREAD MILLING	7	23
ALL OTHER TYPES OF MILLING	15	20
DRILLING	332	464
GUN DRILLING	7	24
REAMING	203	311
TAPPING	254	357
GEAR CUTTING	3	18
BROACHING	28	77
ROUTING	4	17
BANDSAWING	10	64
HACKSAWING	15	21
TOTAL	**2,029**	**2,921**
CONVENTIONAL GRINDING		
GENERAL GRINDING	27	33
SURFACE GRINDING	171	317
CYLINDRICAL GRINDING	89	193
INTERNAL GRINDING	15	38
CENTERLESS GRINDING	6	19
GEAR GRINDING	2	15
THREAD GRINDING	8	16
ABRASIVE MACHINING	4	17
ABRASIVE BELT GRINDING	7	17
ABRASIVE CUTOFF	12	21
HONING	1	15
TOTAL	**342**	**701**
ALTERNATE MACHINING METHODS		
ELECTRICAL DISCHARGE MACHINING	50	50
ELECTROCHEMICAL MACHINING	43	44
ELECTROCHEMICAL GRINDING	11	27
CHEMICAL MACHINING	26	59
PHOTOCHEMICAL MACHINING	1	2
ULTRASONIC MACHINING	4	15
ELECTRON BEAM MACHINING	5	10
LASER MACHINING	3	20
ION BEAM MACHINING	1	1
ABRASIVE JET MACHINING	0	3
ELECTRO-STREAM	0	4
TOTAL	**144**	**236**
MISCELLANEOUS		
BURNISHING	1	8
CONTROLLED ENERGY MACHINING	0	1
SUB-ZERO MACHINING	3	7
HOT MACHINING	1	1
POLISHING	2	6
THREAD ROLLING	0	3
FLAME CUTTING	1	2
TOTAL	**8**	**28**
TOTAL	**2,523**	**3,885**

SEE APPENDIX, PAGE A-13

FIGURE 17

FIGURE 18

ANALYSIS OF UNITERM TYPE INQUIRIES

FEBRUARY 1, 1966 - JANUARY 31, 1968

UNITERM*	NO. OF REQUEST	
	2/1/66-1/31/67	2/1/67-1/31/68
SURFACE INTEGRITY	27	92
NUMERICAL CONTROL	57	68
CUTTING FLUID	69	61
SURFACE FINISH	33	59
DISTORTION	27	34
CUTTING TOOLS - GENERAL	3	22
TOLERANCE	5	16
G. RATIO	11	15
CERAMIC TOOLS	3	14
SUPER HARD HIGH SPEED STEEL	5	11
ADAPTIVE CONTROL	1	10
RESIDUAL STRESS	8	10
TITANIUM CARBIDE	2	8
PRECISION MACHINING	1	6
TOOL SURFACE TREATMENT	1	5
CARBIDE TOOLS	1	4
TIME STANDARDS	2	3
TOTAL	256	438

* *Partial list - 17 most active uniterms*

SEE APPENDIX, PAGE A-14

AIR FORCE MACHINABILITY DATA CENTER

SUMMARY OF SPECIFIC INQUIRIES BY SIC* NUMBER

February 1, 1967 - January 31, 1968

SIC MAJOR GROUP NO.	SIC INDUSTRY NO.		NUMBER OF INQUIRIES BY SIC INDUSTRY NO.	NUMBER OF INQUIRIES BY SIC MAJOR GROUP NO.	% OF TOTAL
91		FEDERAL GOVERNMENT		58	5.8
	9100	U.S. Department of Defense	2		
	9100	USAF - Wright Field	14		
	9100	USAF - Andrews Air Force Base	1		
	9100	USAF - Arnold Air Force Base	1		
	9100	USAF - Tinker Air Force Base	9		
	9100	U.S. Army	7		
	9100	U.S. Navy	9		
	9100	U.S. Marines	2		
	9100	National Aeronautics & Space Administration	4		
	9100	Defense Supply Agency	1		
	9190	BSDA Department of Commerce	1		
	9190	U.S. Department Of The Interior	1		
	9190	U.S. Department of Justice	1		
	9190	U.S. Liaison Office NATO Bullpup Program	1		
	9190	National Bureau of Standards	1		
	9190	Small Business Administration	1		
	9190	Taft Engineering Center	1		
	9190	Chicago Procurement Detachment	1		
92		STATE GOVERNMENTS		5	.5
	9200	State of Illinois	1		
	9200	California State Prison	3		
	9200	State of West Virginia, Department of Commerce	1		
19		ORDNANCE AND ACCESSORIES		1	.1
	1951	Small Arms	1		
27		PRINTING, PUBLISHING, AND ALLIED INDUSTRIES		8	.8
	2721	Periodicals: Publishing, Publishing and Printing	8		
28		CHEMICALS AND ALLIED PRODUCTS		22	2.2
	2821	Plastics Materials, Synthetic Resins, & Nonvulcanizable Elastomers	4		
	2823	Cellulosic Man-Made Fibers	1		
	2824	Synthetic Organic Fibers, Except Cellulosic	2		
	2833	Medicinal Chemicals and Botanical Products	15		
29		PETROLEUM REFINING AND RELATED INDUSTRIES		12	1.2
	2911	Petroleum Refining	9		
	2992	Lubricating Oils and Greases	3		
30		RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS		1	.1
	3079	Miscellaneous Plastics Products	1		
31		LEATHER AND LEATHER PRODUCTS		2	.2
	3121	Industrial Leather Belting and Packing	2		

ndard Industrial Classification Manual (SIC), Executive Office of the President, Bureau of the Budget, 1967.

SEE APPENDIX, PAGE A-14

FIGURE 18

SIC MAJOR GROUP NO.	SIC INDUSTRY NO.		NUMBER OF INQUIRIES BY SIC INDUSTRY NO.	BY SIC MAJOR GROUP NO.	% OF TOTAL
32		**STONE, CLAY, GLASS AND CONCRETE PRODUCTS**		8	.8
	3229	Pressed and Blown Glass and Glassware	2		
	3291	Abrasive Products	5		
	3299	Nonmetallic Mineral Products	1		
33		**PRIMARY METAL INDUSTRIES**		65	6.5
	3312	Blast Furnaces (including coke ovens), Steel Works, & Rolling Mills	5		
	3313	Electrometallurgical Products	1		
	3321	Gray Iron Foundries	1		
	3322	Malleable Iron Foundries	1		
	3323	Steel Foundries	15		
	3331	Primary Smelting and Refining of Copper	2		
	3332	Primary Smelting and Refining of Lead	5		
	3334	Primary Production of Aluminum	1		
	3339	Primary Smelting & Refining of Nonferrous Metals	9		
	3341	Secondary Smelting, Refining & Alloying of Nonferrous Metals and Alloys	11		
	3362	Brass, Bronze, Copper, Copper Base Alloy Castings	4		
	3369	Nonferrous Castings	4		
	3391	Iron and Steel Forgings	6		
34		**FABRICATED METAL PRODUCTS, EXCEPT ORDNANCE, MACHINERY, AND TRANSPORTATION EQUIPMENT**		44	4.4
	3429	Hardware	4		
	3431	Enameled Iron and Metal Sanitary Ware	1		
	3443	Fabricated Plate Work	17		
	3451	Screw Machine Products	4		
	3452	Bolts, Nuts, Screws, Rivets and Washers	2		
	3461	Metal Stampings	6		
	3494	Valves & Pipe Fittings, Except Plumbers' Brass Goods	9		
	3499	Fabricated Metal Products	1		
35		**MACHINERY, EXCEPT ELECTRICAL**		213	21.2
	3511	Engines and Turbines (Except Aircraft)	11		
	3522	Farm Machinery and Equipment	13		
	3531	Construction Machinery and Equipment	1		
	3534	Elevators and Moving Stairways	1		
	3537	Industrial Trucks, Tractors, Trailers and Stackers	1		
	3541	Machine Tools, Metal Cutting Types	71		
	3542	Machine Tools, Metal Forming Types	2		
	3544	Special Dies and Tools, Die Sets, Jigs and Fixtures	3		
	3545	Machine Tool Accessories and Measuring Devices	33		
	3548	Metalworking Machinery, Except Machine Tools	4		
	3554	Paper Industries Machinery	2		
	3561	Pumps, Air & Gas Compressors, & Pumping Equipment	9		
	3562	Ball & Roller Bearings	5		
	3564	Blowers, Exhaust & Ventilating Fans	3		
	3566	Mechanical Power Transmission Equipment, Except Ball & Roller Bearings	2		
	3569	General Industrial Machinery and Equipment	4		
	3574	Calculating & Accounting Machines	8		
	3576	Scales and Balances, Except Laboratory	1		
	3579	Office Machines	1		
	3585	Air Conditioning & Refrigeration Equipment	2		
	3591	Machine Shops, Jobbing and Repair	36		
36		**ELECTRICAL MACHINERY, EQUIPMENT AND SUPPLIES**		87	8.7
	3611	Electric Measuring Instruments & Test Equipment	5		
	3621	Motors and Generators	8		
	3622	Industrial Controls	16		
	3629	Electrical Industrial Apparatus	1		
	3641	Electric Lamps	12		
	3642	Lighting Fixtures	1		
	3643	Current-Carrying Wiring Devices	2		

FIGURE 10 (cont.)

SIC MAJOR GROUP NO.	SIC INDUSTRY NO.		NUMBER OF INQUIRIES BY SIC INDUSTRY NO.	BY SIC MAJOR GROUP NO.	% OF TOTAL
36		**ELECTRICAL MACHINERY, EQUIPMENT AND SUPPLIES (cont.)**			
	3661	Telephone and Telegraph Apparatus	1		
	3662	Radio and Television Transmitting Apparatus	29		
	3679	Electronic Components & Accessories	12		
	3694	Electrical Equipment For Internal Combustion Engines	3		
37		**TRANSPORTATION EQUIPMENT**		289	28.8
	3711	Motor Vehicles	6		
	3714	Motor Vehicle Parts and Accessories	3		
	3721	Aircraft and Missiles	174		
	3722	Aircraft Engines & Engine Parts-Missile Engines	65		
	3729	Aircraft Parts & Auxiliary Equipment-Missile Parts	40		
	3731	Ship Building and Repairing	1		
38		**PROFESSIONAL, SCIENTIFIC, & CONTROLLING INSTRUMENTS; PHOTOGRAPHIC & OPTICAL GOODS; WATCHES & CLOCKS**		17	1.7
	3811	Engineering, Laboratory, Scientific Instruments	7		
	3821	Mechanical Measuring & Controlling Instruments	4		
	3842	Orthopedic, Prosthetic, and Surgical Appliances and Supplies	2		
	3861	Photographic Equipment and Supplies	2		
	3871	Watches, Clocks, and Parts Except Watchcases	2		
39		**MISCELLANEOUS MANUFACTURING INDUSTRIES**		2	.2
	3911	Jewelry, Precious Metal	2		
48		**COMMUNICATION**		3	.3
	4811	Telephone Communication (wire or radio)	3		
50		**WHOLESALE AND RETAIL TRADE**		8	.8
	5082	Construction & Mining Machinery & Equipment	7		
	5091	Metals and Minerals	1		
60		**BANKING**		2	.2
	6025	National Banks, Members of the Federal Reserve System	2		
73		**MISCELLANEOUS BUSINESS SERVICES**		53	5.3
	7311	Advertising Agencies	5		
	7391	Research, Development & Testing Laboratories	45		
	7392	Business, Management & Consulting Services	3		
82		**EDUCATIONAL SERVICES**		67	6.7
	8211	Elementary and Secondary Schools	4		
	8221	Colleges, Universities, & Professional Schools	46		
	8231	Libraries & Information Centers	16		
	8242	Vocational Schools	1		
86		**NONPROFIT MEMBERSHIP ORGANIZATIONS**		21	2.1
	8621	Professional Membership Organizations	21		
89		**MISCELLANEOUS SERVICES**		13	1.3
	8911	Engineering and Architectural Services	13		
01	0001	**INDIVIDUALS**	1	1	0.1
		TOTALS		1002	100.0%

FIGURE 18 (cont.)

FIGURE 20

POTENTIAL FOR AFMDC SERVICES TO INDUSTRY

STATISTICAL SUMMARY OF METALWORKING PLANTS PARTIAL LIST FROM DUN & BRADSTREET METALWORKING, DIRECTORY 1967-68				AFMDC SUMMARY OF INQUIRIES FOR 8 SIC GROUPS OCTOBER 1, 1964 - JANUARY 31, 1968	
STANDARD INDUSTRIAL CLASSIFICATION (SIC) NUMBER & INDUSTRY CLASSIFICATION	MAJOR PRODUCT MANUFACTURED NO. OF COMPANIES*	NO. OF INDIVIDUALS	MINOR PRODUCT MANUFACTURED NO. OF COMPANIES	NO. OF AFMDC INQUIRERS	COMPANIES
MAJOR GROUP 37 - TRANSPORTATION EQUIPMENT SIC INDUSTRY NO.					
3721 - Aircraft & Missiles	74	22,197	7	440	40
3722 - Aircraft Engines & Parts	119	185,333	69	234	26
3723 - Aircraft Propellers & Propeller Parts	13	11,284	12	-	-
3729 - Aircraft Parts & Auxiliary Equipment	589	189,521	380	70	43
MAJOR GROUP 33 - PRIMARY METAL INDUSTRIES	3,669	1,360,594	2,442	163	64
MAJOR GROUP 34 - FABRICATED METAL PRODUCTS, EXCEPT ORDNANCE, MACHINERY & TRANSPORTATION EQUIPMENT	10,241	1,296,147	6,842	93	45
MAJOR GROUP 35 - MACHINERY, EXCEPT ELECTRICAL	9,933	1,941,820	7,345	494	248
MAJOR GROUP 36 - ELECTRICAL MACHINERY, EQUIPMENT & SUPPLIES	4,793	1,893,661	2,966	149	57
	29,431	6,900,557	20,063	1,634	523

* *20 or more employees*

SEE APPENDIX, PAGE A-14

SEE APPENDIX, PAGE A-15

AIR FORCE MACHINABILITY DATA CENTER

GOVERNMENT AGENCIES AND SERVICES SUPPORTED DIRECTLY AND INDIRECTLY BY AFMDC INQUIRIES

February 1, 1967 - January 31, 1968

CATEGORY

A.	TOTAL INQUIRIES FOR THE PERIOD FEBRUARY 1, 1967 THROUGH JANUARY 31, 1968	1002
B.	INQUIRIES BY ACADEMIC AND COMMERCIAL SOURCES NOT IDENTIFIABLE WITH GOVERNMENT PURPOSES	57
C.	INQUIRIES IDENTIFIED AS SUPPORTING GOVERNMENT PURPOSES	945
D.	DIRECT INQUIRIES BY GOVERNMENT AGENCIES (*USAF, NASA, etc.*)	71
E.	INQUIRIES BY CONTRACTORS IDENTIFIED DIRECTLY WITH SPECIFIC GOVERNMENT SERVICES OR AGENCIES (*USAF, NASA, etc.*)	386
F.	INQUIRIES BY COMPANIES IDENTIFIED INDIRECTLY WITH SPECIFIC GOVERNMENT SERVICES OR AGENCIES (*USAF, NASA, etc.*)	488

	AIR FORCE	U.S. NAVY	U.S. ARMY	AEC	NASA	TOTAL
D. DIRECT INQUIRIES BY GOVERNMENT AGENCIES	28	11	11	17	4	71
E. INQUIRIES BY CONTRACTORS IDENTIFIED DIRECTLY WITH SPECIFIC GOVERNMENT SERVICES OR AGENCIES *(USAF, NASA, etc.)*	338	10	3	5	30	386
F. INQUIRIES BY COMPANIES IDENTIFIED INDIRECTLY WITH SPECIFIC GOVERNMENT SERVICES OR AGENCIES *(USAF, NASA, etc.)* TOTAL OF 488; DISTRIBUTION BY RATIO OR PROPORTION OF INQUIRIES COUNTED IN E ABOVE.	434	5	5	5	39	488
C. TOTAL TECHNICAL INQUIRIES ASSISTING GOVERNMENT PURPOSES	800	26	19	27	73	945

FIGURE 21

COMPANIES & AGENCIES SUBMITTING INQUIRIES TO AFMDC

October 1, 1964 - January 31, 1968

ABEX CORPORATION, MAHWAH, N.J.
ABORN, DR. ROBERT H., MILLINGTON, N.J.
ACF INDUSTRIES, INC., ALBUQUERQUE, N.M.
ACCURATE BUSHING COMPANY, GARWOOD, N.J.
ACRALOC CORPORATION, OAK RIDGE, TENN.
ADAMAS CARBIDE CORP., KENILWORTH, N.J.
ADKINS & HUMINIK, ALEXANDRIA, VA.
AEROJET-GENERAL CORPORATION, AZUSA, CALIF.
AEROJET-GENERAL CORPORATION, CLAREMONT, CALIF.
AEROJET-GENERAL CORPORATION, DOWNEY, CALIF.
AEROJET-GENERAL CORPORATION, SACRAMENTO, CALIF.
AEROJET-GENERAL CORPORATION, DAYTON, OHIO
AERONCA INC., MIDDLETOWN, OHIO
AEROPROJECTS INC., WEST CHESTER, PA.
AEROQUIP CORPORATION, JACKSON, MICH.
AEROQUIP CORPORATION, VAN WERT, OHIO
AEROSPACE CORPORATION, SAN BERNARDINO, CALIF.
AEROSPACE RESEARCH APPLICATIONS CENTER, BLOOMINGTON, IND.
AMERICAN INSTITUTE OF MINING METALLURGICAL & PETROLEUM ENGINEERS, NEW YORK, N.Y.
AIR FORCE HEADQUARTER, WASHINGTON, D.C.
AIR FORCE REPRESENTATIVE, THE MARTIN CO., DENVER, COLO.
AIRESEARCH MANUFACTURING COMPANY, PHOENIX, ARIZ.
AIRESEARCH MANUFACTURING COMPANY, LOS ANGELES, CALIF.
ALLEGHENY-LUDLUM STEEL CORP., DUNKIRK, N.Y.
ALLEGHENY-LUDLUM STEEL CORP., PITTSBURGH, PA.
ALLIANCE TOOL COMPANY INC., ST. LOUIS, MO.
ALLIED CHEMICAL CORP., MORRISTOWN, N.J.
ALLIS-CHALMERS MANUFACTURING COMPANY, MILWAUKEE, WISC.
ALLIS-CHALMERS MANUFACTURING COMPANY, NORWOOD, OHIO
ALTAMIL CORPORATION, CHAMBERS AIRCRAFT DIV., SHELBYVILLE, IND.
ALUMINUM COMPANY OF AMERICA, LAFAYETTE, IND.
ALUMINUM COMPANY OF AMERICA, PITTSBURGH, PA.
ALUMINUM SMELTERS RESEARCH INSTITUTE, CHICAGO, ILL.
AMERICAN AIRLINES INC., TULSA, OKLA.
AMERICAN BOSCH ARMA CORPORATION, SPRINGFIELD, MASS.
AMERICAN BRAKE SHOE COMPANY, ELYRIA, OHIO
AMERICAN CYANAMID COMPANY, SANFORD, ME.
AMERICAN HELLER CORPORATION, DETROIT, MICH.
AMERICAN INSTITUTE OF AERONAUTICS, LOS ANGELES, CALIF.
AMERICAN LAUNDRY MACHINERY INDUSTRIES, CINCINNATI, OHIO
AMERICAN MACHINE & FOUNDRY CO., YORK, PA.
AMERICAN MACHINIST, CLEVELAND, OHIO
AMERICAN SAW & MANUFACTURING COMPANY, EAST LONGMEADOW, MASS.
AMERICAN SOCIETY FOR METALS, METALS PARK, OHIO
AMERICAN SOCIETY OF TOOL & MANUFACTURING ENGINEERS, DEARBORN, MICH.
AMERICAN TOOL WORKS, CINCINNATI, OHIO
AMERICAN WELDING & MANUFACTURING CO., WARREN, OHIO
AMES LABORATORY, AMES, IOWA
AMETEK INC., SELLERSVILLE, PA.
AMMUNITION PROCUREMENT & SUPPLY AGENCY, JOLIET, ILL.
AMPCO METAL INC., MILWAUKEE, WISC.
AMPHENOL CORPORATION, CHICAGO, ILL.
ANDERSON BROTHERS MANUFACTURING CO., ROCKFORD, ILL.
ANDREWS AIR FORCE BASE, WASHINGTON, D.C.
ANOCUT ENGINEERING COMPANY, ELK GROVE VILLAGE, ILL.
APEX CORPORATION, INDIANAPOLIS, IND.
API CORPORATION, MIAMI, FLA.
ARGONNE NATIONAL LABORATORY, ARGONNE, ILL.
ARIZONA, UNIVERSITY OF, TUCSON, ARIZ.
ARKWIN INDUSTRIES INC., WESTBURY, N.Y.
ARMCO STEEL CORPORATION, BALTIMORE, MD.
ARMCO STEEL CORPORATION, CINCINNATI, OHIO
ARMCO STEEL CORPORATION, MIDDLETOWN, OHIO
ARMCO STEEL CORPORATION, TORRANCE, CALIF.
ARMSTRONG BLUM MFG. COMPANY, CINCINNATI, OHIO
ARMY PROCUREMENT DISTRICT, CHICAGO, ILL.
ARO, INC., ARNOLD AIR FORCE STATION, TENN.
ARROW GEAR COMPANY, DOWNERS GROVE, ILL.
ARROWSMITH TOOL & MFG. CORP., LOS ANGELES, CALIF.
ASTROSYSTEMS INTERNATIONAL INC., ROCKAWAY, N.J.
ATLANTIC RESEARCH CORPORATION, GAINSVILLE, VA.
ATLANTIC RICHFIELD COMPANY, PHILADELPHIA, PA.
ATLAS ALLOYS, CLEVELAND, OHIO
AUTOMATION ACCESSORIES INC., CINCINNATI, OHIO
AUTOMATION ACCESORIES INC., DAYTON, OHIO
AUTOMATION INDUSTRIES INC., ABILENE, TEX.
AUTOMOTIVE SERVICENTER INC., BALTIMORE, MD.
AVCO CORPORATION, STRATFORD, CONN.
AVCO CORPORATION, RICHMOND, IND.
AVCO CORPORATION, WILMINGTON, MASS.
AVCO CORPORATION, COLDWATER, OHIO
AVCO CORPORATION, NASHVILLE, TENN.
AVEY MACHINE TOOL COMPANY, COVINGTON, KY.
AVILDSEN TOOL & MACHINES INC., NEW YORK, N.Y.

BACHAN MANUFACTURING CO., POMPANO BEACH, FLA.
BACKER TOOL & DIE, CINCINNATI, OHIO
BADGER, F. SIDNEY, WOODLAND HILLS, CALIF.
BADGETT & SMITH ASSOCIATES INC., CINCINNATI, OHIO
BAKER OIL TOOLS INC., LOS ANGELES, CALIF.
BALDWIN-LIMA-HAMILTON, BURNHAM, PA.
BATTELLE MEMORIAL INSTITUTE, COLUMBUS, OHIO
BATTELLE MEMORIAL INSTITUTE, RICHLAND, WASH.
BATTELLE MEMORIAL INSTITUTE, LOS ANGELES, CALIF.
BAUSCH & LOMB INCORPORATED, ROCHESTER, N.Y.
BDSA DEPARTMENT OF COMMERCE, WASHINGTON, D.C.
BEECH AIRCRAFT CO., WICHITA, KAN.
BELL HELICOPTER COMPANY, FT. WORTH, TEX.
BELL & HOWELL RESEARCH CENTER, PASADENA, CALIF.
BELLOWS-VALVAIR CORPORATION, CINCINNATI, OHIO
BELOIT CORPORATION, BELOIT, WISC.
BELOIT EASTERN CORPORATION, DOWNINGTON, PA.
BENDIX CORPORATION (THE), DETROIT, MICH.
BENDIX CORPORATION (THE), SOUTHFIELD, MICH.
BENDIX CORPORATION (THE), KANSAS CITY, MO.
BENDIX CORPORATION (THE), TETERBORO, N.J.
BENDIX CORPORATION (THE), SIDNEY, N.Y.
BENDIX CORPORATION (THE), YORK, PA.
BENDIX CORPORATION (THE), SOUTH BEND, IND.
BENEDICT-MILLER INC., LYNDHURST, N.J.
BENNET TECHNICAL SERVICES INC., CINCINNATI, OHIO
BENRUS WATCH COMPANY, WATERBURY, CONN.
BERCO MANUFACTURING COMPANY, WATERBURY, CONN.
BERYLLIUM CORPORATION OF AMERICA (THE), READING, PA.
BERYLLIUM CORPORATION OF AMERICA (THE), HAZELTON, PA.
BESLY-WELLES CORPORATION, SOUTH BELOIT, ILL.
BESLY-WELLES CORPORATION, CINCINNATI, OHIO
BETHLEHEM STEEL CORPORATION, BETHLEHEM, PA.
BIGGER COMPANY, C. M., READING, OHIO
BLACK & DECKER MFG. CO., TOWSON, MD.
BLISS COMPANY, E. W., SOUTH PORTLAND, ME.
BOEING COMPANY (THE), WICHITA, KAN.
BOEING COMPANY (THE), NEW ORLEANS, LA.
BOEING COMPANY (THE), RENTON, WASH.
BOEING COMPANY (THE), SEATTLE, WASH.
BOEING COMPANY (THE), PHILADELPHIA, PA.
BOEING COMPANY (THE), AUBURN, WASH.
BOMAR COMPANY, CINCINNATI, OHIO
BOOZ ALLEN APPLIED RESEARCH INC., NEW YORK, N.Y.
BORG-WARNER CORPORATION, FREMONT, OHIO
BORG-WARNER CORPORATION, CHICAGO, ILL.
BOSTROM CORPORATION, MILWAUKEE, WISC.
BRAD FOOTE GEAR WORKS INC., CICERO, ILL.
BRANDS MACHINING COMPANY, PORTLAND, PA.
BRASS & BRONZE INSTITUTE, CHICAGO, ILL.

BRIDGEPORT, UNIVERSITY OF, BRIDGEPORT, CONN.
BRIGGS & STRATTON CORPORATION, MILWAUKEE, WISC.
BRIGHAM YOUNG UNIVERSITY, PROVO, UTAH
BROOKS & PERKINS INC., DETROIT, MICH.
BROWN & ROOT INC., HOUSTON, TEX.
BROWN & SHARPE MANUFACTURING CO., DAYTON, OHIO
BRUBAKER TOOL CORPORATION, MILLERSBURG, PA.
BRUNSWICK CORPORATION, MUSKEGON, MICH.
BRUSH BERYLLIUM COMPANY (THE), HAYWARD, CALIF.
BRUSH BERYLLIUM COMPANY (THE), CLEVELAND, OHIO
BRUSH BERYLLIUM COMPANY (THE), ELMORE, OHIO
BUCKEYE FOUNDRY COMPANY, CINCINNATI, OHIO
BUDD COMPANY, NEWARK, DELA.
BUERK TOOL & MACHINE CORPORATION, BUFFALO, N.Y.
BUHR MACHINE TOOL COMPANY, DETROIT, MICH.
BULLARD COMPANY,(THE), BRIDGEPORT, CONN.
BUNKER-RAMO CORPORATION, CLEVELAND, OHIO
BURGESS-NORTON MANUFACTURING CO., GENEVA, ILL.
BURGMASTER CORPORATION, CINCINNATI, OHIO
BURNDY CORPORATION, NORWALK, CONN.
BURSON MARSTELLER ASSOCIATES, NEW YORK, N.Y.

CADILLAC GAGE COMPANY, ROSEVILLE, MICH.
CALIFORNIA STATE PRISON, SAN QUENTIN, CALIF.
CALIFORNIA GENERAL INC., CHULA VISTA, CALIF.
CAMCAR SCREW & MANUFACTURING CO., ROCKFORD, ILL.
CAMERON IRON WORKS, HOUSTON, TEX.
CARBORUNDUM COMPANY (THE), NIAGARA FALLS, N.Y.
CARLISLE CHEMICAL WORKS INC., READING, OHIO
CARNEGIE INSTITUTE OF TECHNOLOGY, PITTSBURGH, PA.
CARPENTER STEEL COMPANY (THE), READING, PA.
CARR TOOL COMPANY, NORWOOD, OHIO
CARRIER AIR CONDITIONING CO., SYRACUSE, N.Y.
CATERPILLAR TRACTOR COMPANY, DECATUR, ILL.
CATERPILLAR TRACTOR COMPANY, PEORIA, ILL.
CAVITRON ULTRASONICS, INC., LONG ISLAND, N.Y.
CDS ENGINEERING INC., SANTA CLARA, CALIF.
CEEMCO, CINCINNATI, OHIO
CELANESE FIBERS COMPANY, NARROWS, VA.
CENTRAL MACHINE WORKS, INDIANAPOLIS, IND.
CENTRO CORPORATION, DAYTON, OHIO
CENTRAL FABRICATORS INC., CINCINNATI, OHIO
CHAMBERLAIN MANUFACTURING CORPORATION, WATERLOO, IOWA
CHANDLER EVANS INC., WEST HARTFORD, CONN.
CHASE BRASS & COPPER CO., SOLON, OHIO
CHASE MANHATTAN BANK, NEW YORK, N.Y.
CHICAGO CUTTING DIE COMPANY, CHICAGO, ILL.
CHICAGO PROCUREMENT DETACHMENT, CHICAGO, ILL.
CHRYSLER CORPORATION, NEW ORLEANS, LA.
CHRYSLER CORPORATION, DEARBORN, MICH.
CHUCKING MACHINE PRODUCTS INC., FRANKLIN PARK, ILL.
CINCINNATI LATHE & TOOL COMPANY, CINCINNATI, OHIO
CINCINNATI MILLING MACHINE COMPANY (THE), CINCINNATI, OHIO
CINCINNATI MINE MACHINERY CO., CINCINNATI, OHIO
CINCINNATI SHAPER COMPANY, WHITEWATER, OHIO
CINCINNATI SUB-ZERO PRODUCTS INC., CINCINNATI, OHIO
CINCINNATI, UNIVERSITY OF, CINCINNATI, OHIO
CITRUS COLLEGE, AZUSA, CALIF.
CLEARINGHOUSE FOR FEDERAL SCIENTIFIC & TECHNICAL INFORMATION, SPRINGFIELD, VA.
CLEVELAND AUTOMATIC MACHINE TOOL CO., CINCINNATI, OHIO
CLEVELAND PNEUMATIC TOOL CO., (THE), CLEVELAND, OHIO
CLEVELAND TWIST DRILL COMPANY, CLEVELAND, OHIO
CLEVITE CORPORATION, CLEVELAND, OHIO
CMCO PRODUCTS INC., CINCINNATI, OHIO
COALT INFORMATION CENTER, COLUMBUS, OHIO
COLLINS RADIO COMPANY, CEDAR RAPIDS, IOWA
COLLINS RADIO COMPANY, DALLAS, TEX.
COLT INDUSTRIES INC., BELOIT, WISC.
COMSTOCK & WESCOTT INC., CAMBRIDGE, MASS.
CORD-RENN COMPANY, CINCINNATI, OHIO
CONTINENTAL AVIATION & ENGINEERING CORP., DETROIT, MICH.
CONTINENTAL AVIATION & ENGINEERING CORP., TOLEDO, OHIO
CONTINENTAL COPPER & STEEL CO., BRAEBURN, PA.

CONTINENTAL-EMSCO COMPANY, GARLAND, TEX.
CONTINENTAL MOTORS CORPORATION, MUSKEGON, MICH.
CONTINENTAL TOOL COMPANY, DETROIT, MICH.
CONTROLS COMPANY OF AMERICA, JACKSONVILLE, ARK.
CONVER STEEL & WIRE CO. INC., NEW YORK, N.Y.
COORS CO., INC., H. F., INGLEWOOD, CALIF.
COORS PORCELAIN COMPANY, GOLDEN, COLO.
CORHART REFRACTORIES COMPANY, BUCHANNON, W. VA.
CORNELL AERONAUTICAL LABORATORY INC., BUFFALO, N.Y.
CORNING GLASS WORKS, CORNING, N.Y.
CORPLAN ASSOCIATES, CHICAGO, ILL.
CRAFTNEEDS INC., CINCINNATI, OHIO
CRANE CO., NEW CASTLE, PA.
CRUCIBLE STEEL COMPANY OF AMERICA, CINCINNATI, OHIO
CRUCIBLE STEEL COMPANY OF AMERICA, PITTSBURGH, PA.
CUMMINS ENGINE COMPANY INC., COLUMBUS, IND.
CURTISS-WRIGHT CORP., CALDWELL, N.J.
CURTISS-WRIGHT CORP., WOOD-RIDGE, N.J.
CURTISS-WRIGHT CORP., BUFFALO, N.Y.
CUSTOM TOOLING CO., CINCINNATI, OHIO
CYCLOPS CORPORATION (UNIVERSAL CYCLOPS), BRIDGEVILLE, PA.

DALMO VICTOR COMPANY, BELMONT, CALIF.
DATA INFORMATION GATHERING SERVICE, PALO ALTO, CALIF.
DAVEWOOD SUPPLY COMPANY, ROCKFORD, ILL.
DAYTON MALLEABLE IRON CO., DAYTON, OHIO
DAYTON RESEARCH INSTITUTE, UNIVERSITY OF, DAYTON, OHIO
DEERE & COMPANY, MOLINE, ILL.
DEFENSE CERAMIC INFORMATION CENTER, COLUMBUS, OHIO
DEL MACHINE & WELDING WORKS INC., HOUSTON, TEX.
DEPUY MANUFACTURING COMPANY, WARSAW, IND.
DETROIT BROACH & MACHINE CO., ROCHESTER, MICH.
DEUTSCH COMPANY, LOS ANGELES, CALIF.
DIAMOND ALKALI COMPANY, PAYNESVILLE, OHIO
DIAMOND, TOOLS & ABRASIVES INC., JUPITER, FLA.
DIAMONITE PRODUCTS MANUFACTURING CO., SHREVE, OHIO
D-K PRODUCTS (DIV. SYMINGTON WAYNE CORP.), CHICAGO, ILL.
D-M-E CORPORATION, DETROIT, MICH.
DO-ALL COMPANY, DES PLAINES, ILL.
DOVER CORPORATION, LOUISVILLE, KY.
DOVER CORPORATION, CINCINNATI, OHIO
DOW CHEMICAL COMPANY (THE), DENVER, COLO.
DOW CHEMICAL COMPANY (THE), GOLDEN, COLO.
DOW CHEMICAL COMPANY,(THE), MIDLAND, MICH.
DREW CHEMICAL CORPORATION, BOONTON, N.J.
DREXEL INSTITUTE OF TECHNOLOGY, PHILADELPHIA, PA.
DUMORE COMPANY, RACINE, WISC.
DUNCAN MANUFACTURING CO., CINCINNATI, OHIO
DUPONT DENEMOURS & CO. INC., E. I., WILMINGTON, DEL
DUPONT DENEMOURS & CO. INC., E. I., MARTINSVILLE, V
DYNA-TECH INC., DECATUR, ALA.

EASTERN KENTUCKY UNIVERSITY, RICHMOND, KY.
EASTMAN KODAK COMPANY, ROCHESTER, N.Y.
EATON YALE & TOWN INC., SOUTH EUCLID, OHIO
EATON YALE & TOWN INC., SAGINAW, MICH.
ECIVRES INC., NORWOOD, OHIO
EDMUNDS MANUFACTURING CO., FARMINGTON, CONN.
EIS AUTOMOTIVE CORPORATION (THE), MIDDLETOWN, CONN.
EITEL-MCCULLOUGH INC., SAN CARLOS, CALIF.
ELANO CORPORATION, XENIA, OHIO
ELASTIC STOP-NUT CORP. OF AMERICA, UNION, N.J.
ELECTRIC STORAGE BATTERY COMPANY (THE), PHILADELPHIA, PA.
ELECTRICAL MACHINING INC., CINCINNATI, OHIO
ELECTRO-JET TOOL COMPANY, CINCINNATI, OHIO
ELECTRONIC SPECIALTY COMPANY, PORTLAND, ORE.
ELLIOTT COMPANY, JEANNETTE, PA.
ELOX CORP. OF MICHIGAN, TROY, MICH.
EMERSON ELECTRIC COMPANY, LOS ANGELES, CALIF.
EMERSON ELECTRIC COMPANY, ST. LOUIS, MO.
EMI, CINCINNATI, OHIO
ENGINEERING SOCIETIES LIBRARY, NEW YORK, N.Y.
ENTWISTLE MANUFACTURING CO., PROVIDENCE, R. I.

FIGURE 22 (cont.)

Erie Industries Inc, Ferndale, Mich.
Ernst, Hans, Clearwater, Fla.
Esarbe Manufacturing Co. Inc., Ft. Lauderdale, Fla.
Esco Corporation, Los Angeles, Calif.
Esso Research & Engineering Co., Linden, N.J.
Euclid Machine Co., Inc., Indianapolis, Ind.
Ex-Cell-O Corporation, Lima, Ohio

Fafnir Bearing Company (the), New Britain, Conn.
Fairchild Hiller Corporation, Rockville, Md.
Fairchild Hiller Corporation, Farmingdale, L.I., N.Y.
Fairchild Precision Metals Products, El Cajon, Calif.
Fansteel Metallurgical Corp., No. Chicago, Ill.
Fellows Gear Shaper Company (The), Springfield, Vt.
Ferguson Machine Company, Toledo, Ohio
Ferris State College, Big Rapids, Mich.
Ferrotherm Co., Cleveland, Ohio
Fiberite Corporation, Winona, Wisc.
Firestone Tire & Rubber Co. (The), Akron, Ohio
Firewel Company Inc. (The), Buffalo, N.Y.
Fischer Governor Company, Marshalltown, Iowa
Flick-Reedy Corporation, Bensenville, Ind.
FMC Corporation, San Jose, Calif.
Ford Motor Company, Dearborn, Mich.
Ford Motor Company, Metal Stamping, Dearborn, Mich.
Ford Motor Company, Livonia, Mich.
Ford Motor Company, Fairfax Plant, Cincinnati, Ohio
Ford Motor Company, Sharonville Plant, Cincinnati, Ohio
Frankford Arsenal, Philadelphia, Pa.
Franklin Balmar Corporation, Baltimore, Md.
Franklin Electric Co., Inc., Bluffton, Ind.
Franklin Oil Corporation, Bedford, Ohio
Fuller Merriam Company, West Haven, Conn.
Fyr-Fyter Company (The), Newark, N.J.
G & O Tool & Die Company, Beechgrove, Ind.
Galm Company, Kenneth J., Indianapolis, Ind.
Gardner Machine Company, South Beloit, Ill.
Gar-Kenyon Instruments Inc., Brewster, N.Y.
Gebel Industries, Cincinnati, Ohio
General Dynamics Corp., San Diego, Calif.
General Dynamics Corp., Groton, Conn.
General Dynamics Corp., New York, N.Y.
General Dynamics Corp., Ft. Worth, Tex.
General Electric Company, Phoenix, Ariz.
General Electric Company, Pleasantown, Calif.
General Electric Company, San Jose, Calif.
General Electric Company, Daytona Beach, Fla.
General Electric Company, Bloomington, Ill.
General Electric Company, Ft. Wayne, Ind.
General Electric Company, Louisville, Ky.
General Electric Company, Everett, Mass.
General Electric Company, Lynn, Mass.
General Electric Company, Detroit, Mich.
General Electric Company, Warren, Mich.
General Electric Company, Kapl, Schenectady, N.Y.
General Electric Company, Schenectady, N.Y.
General Electric Company, Syracuse, N.Y.
General Electric Company, Utica, N.Y.
General Electric Company, Waterford, N.Y.
General Electric Company, Cincinnati, Ohio
General Electric Company, Cleveland, Ohio
General Electric Company, Dayton, Ohio
General Electric Company, Erie, Pa.
General Electric Company, King of Prussia, Pa.
General Electric Company, Philadelphia, Pa.
General Electric Company, Valley Forge Space Technology Center, Philadelphia, Pa.
General Electric Company, Burlington, Vt.
General Electric Company, Rutland, Vt.
General Electric Company, Waynesboro, Va.
General Electric Company, Somersworth, N.H.
General Electric Company, Sunnyvale, Calif.

General Electro-Mech Corp., Buffalo, N.Y.
General Motors Corporation Defense Research Lab., Santa Barbara, Calif.
General Motors Corporation, Delco Remy Division, Anderson, Ind.
General Motors Corporation Guide Lamp Division, Anderson, Ind.
General Motors Corporation, Indianapolis, Inc.
General Motors Corporation, Munice, Ind.
General Motors Institute, Flint, Mich.
General Motors Corporation, Warren, Mich.
General Motors Corporation, Harrison, N.J.
General Motors Corporation, Frigidaire Division, Dayton, Ohio
General Motors Corporation, Inland Manufacturing Dayton, Ohio
General Motors Corporation, Milwaukee, Wisc.
General Precision Aerospace Technical Information Center, Little Falls, N.J.
General Precision Incorporated, Binghamton, N.Y.
General Precision Incorporated, Pleasantville, N.Y.
General Transducer Company, Santa Clara, Calif.
Geometric Tool Company, New Haven, Conn.
George's Screw Products, Franklin Park, Ill..
Gisholt Corporation, Madison, Wisc.
Glidden Company (The), Baltimore, Md.
Goddard Space Flight Center, Greenbelt, Md.
Goldman & Company, Harvey, Dearborn, Mich.
Goodrich Company, B. F., Akron, Ohio
Goodyear Aerospace Corporation, Akron, Ohio
Goulds Pumps Inc., Seneca Falls, N.Y.
Graham Research Laboratory, Pittsburgh, Pa.
Gray Company, G. A., Cincinnati, Ohio
Great Lakes Research Corporation, Elizabethton, Tenn.
Great Lakes Steel Corporation, Detroit, Mich.
Greenfield Tap & Die, Greenfield, Mass.
Greenleaf Corporation, Hagerstown, Pa.
Griffin Wheel Company, Chicago, Ill.
Griko Chemical Products Inc., Newark, N.J.
Griswold-Eshleman Company (The), Cleveland, Ohio
Grumman Aircraft Engineering Corp., Bethpage, L.I. N.Y.
Gulf Coast Technical Institute, Gulfport, Miss.

H & C Supply Corporation, Rochester, N.Y.
Hall Planetary Co. of Philadelphia, Philadelphia, Pa.
Hamilton Standard, Windsor Locks, Conn.
Hamilton Tool & Machine Co., Kenilworth N.J.
Harnischfeger Company, Escanaba, Mich.
Harris-Intertype Corporation, Cleveland, Ohio
Harvard Business School, Cambridge, Mass.
Harvey Aluminum Sales Inc., East Orange, N.J.
Hastings Manufacturing Co., Hastings, Mich.
Hater Industries, Cincinnati, Ohio
Heald Machine Company, Worcester, Mass.
Hendriksen, Erik, Downey, Calif.
Hercules Inc., Allegany Ballistics Lab., Cumberland, Maryland
Herkert Products Company, Chicago, Ill.
Hesston Corporation, Hesston, Kan.
Hill, George M., Oxford, Ohio
Hinkle Brothers Inc., Clarksburg, W. Va.
Hirschmann Corporation, Roslyn Heights, N.Y.
Hobart Manufacturing Company, Troy, Ohio
Hoffman Brothers Jewelry Co., Tunxsutawney, Pa.
Hoke Inc., Cresskill, N.J.
Holley Carburetor Company, Warren, Mich.
Holley Carburetor Company, Clare, Mich.
Holyoke Machine Company, Holyoke, Mass.
Honeywell Inc., St. Petersburg, Fla.
Honeywell Inc., New Brighton, Minn.

FIGURE 22 (cont.)

HONEYWELL INC., MINNEAPOLIS, MINN.
HOUGHTON COMPANY, E. F., CINCINNATI, OHIO
HOUGHTON COMPANY, E. F., CLEVELAND, OHIO
HOUSTON, UNIVERSITY OF, HOUSTON, TEX.
HUCKTROL INC., KINGSTON, N.Y.
HUGHES AIRCRAFT COMPANY, CULVER CITY, CALIF.
HUGHES AIRCRAFT COMPANY, EL SEGUNDO, CALIF.
HUGHES AIRCRAFT COMPANY, LOS ANGELES, CALIF.
HUGHES AIRCRAFT COMPANY, TUCSON, ARIZ.
HUGHES TOOL COMPANY, CULVER CITY, CALIF.
HUMBLE OIL & REFINING CO., HOUSTON, TEX.
HYDRAULIC RESEARCH & MANUFACTURING CO., BURBANK, CALIF.
HYDRODYNE ENGINEERING COMPANY, SANTA ANA, CALIF.
HYSTER COMPANY, PORTLAND, ORE.
HYSTER COMPANY, DANVILLE, ILL.

IIT RESEARCH INSTITUTE, CHICAGO, ILL.
ITT CANNON ELECTRIC INC., LOS ANGELES, CALIF.
ILLINOIS INSTITUTE OF TECHNOLOGY, CHICAGO, ILL.
ILLINOIS, STATE OF, SPRINGFIELD, ILL.
ILLINOIS, UNIVERSITY OF, URBANA, ILL.
INDUSTRIAL NUCLEONICS CORP., COLUMBUS, OHIO
INGERSOLL MILLING MACHINE CO. (THE), ROCKFORD, ILL.
INGERSOLL RAND COMPANY, PHILIPSBURG, N.J.
INGERSOLL RAND COMPANY, PRINCETON, N.J.
INGERSOLL RAND COMPANY, PAINTED POST, N.Y.
INSTITUTE OF GAS TECHNOLOGY, CHICAGO, ILL.
INTERNATIONAL BUSINESS MACHINES CORP., LEXINGTON, KY.
INTERNATIONAL BUSINESS MACHINES CORP., ROCKVILLE, MD.
INTERNATIONAL BUSINESS MACHINES CORP., ENDICOTT, N.Y.
INTERNATIONAL BUSINESS MACHINES CORP., KINGSTON, N.Y.
INTERNATIONAL BUSINESS MACHINES CORP., OWEGO, N.Y.
INTERNATIONAL BUSINESS MACHINES CORP., POUGHKEEPSIE, N.Y.
INTERNATIONAL BUSINESS MACHINES CORP., YORKTOWN HEIGHTS, N.Y.
INTERNATIONAL BUSINESS MACHINES CORP., DAYTON, OHIO
INTERNATIONAL GLASS COMPANY, NEW YORK, N.Y.
INTERNATIONAL HARVESTER COMPANY, CHICAGO, ILL.
INTERNATIONAL LEAD ZINC RESEARCH ORGANIZATION INC., NEW YORK, N.Y.
INTERNATIONAL NICKEL CO., INC. (THE), NEW YORK, N.Y.
INTERNATIONAL NICKEL CO., INC. (THE), SUFFERN, N.Y.
INTERNATIONAL NICKEL CO., INC. (THE), DAYTON, OHIO
INTERNATIONAL NICKEL CO., INC. (THE), HUNTINGTON, W. VA.
ION PHYSICS CORPORATION, BURLINGTON, MASS.
IOWA STATE UNIVERSITY OF SCIENCE & TECHNOLOGY, AMES, IOWA
IOWA, UNIVERSITY OF, IOWA CITY, IOWA
IRON AGE, PHILADELPHIA, PA.

JANSSEN MANUFACTURING COMPANY, WAYNESVILLE, OHIO
JARVIS CORPORATION, PORTLAND, CONN.
JARVIS CORPORATION, GREENWOOD, S.C.
JERDEN MANUFACTURING COMPANY, INDIANAPOLIS, IND.
JET PRODUCTS CORPORATION, SAN DIEGO, CALIF.
JONES & LAMSON, SPRINGFIELD, VT.
JONES & LAUGHLIN STEEL CORP., INDIANAPOLIS, IND.
JORDON VALVE, CINCINNATI, OHIO

KDI COMPANY, CINCINNATI, OHIO
KAISER AEROSPACE & ELECTRONICS, SAN LEANDRO, CALIF.
KANSAS STATE COLLEGE OF PITTSBURGH, PITTSBURGH, PA.
KARL & SONS, WILLIAM, MIDDLE VILLAGE, N.Y.
KEARNEY & CO., INC., A.T., CHICAGO, ILL.
KEARNEY & TRECKER, MILWAUKEE, WISC.
KEMETRIC COMPANY, SUNNYVALE, CALIF.
KENNAMETAL INC., CINCINNATI, OHIO
KENNAMETAL INC., BEDFORD, PA.
KENNAMETAL INC., LATROBE, PA.
KENNEDY SPACE CENTER, KENNEDY SPACE CENTER, FLA.
KENT STATE UNIVERSITY, KENT, OHIO
KERNS MANUFACTURING CO., LONG ISLAND CITY, N.Y.
KING FIFTH WHEEL COMPANY, MOUNTAINTOP, PA.
KINSEY,COMPANY, E. A., CINCINNATI, OHIO
KLIK INDUSTRIES, HARTFORD, CONN.
KLINE MANUFACTURING CO., WESTERVILLE, OHIO
KOBE INC., HUNTINGTON PARK, CALIF.
KOEHRING CO., HPM DIVISION, MT. GILEAD, OHIO
KOPPERS COMPANY INC., BALTIMORE, MD.
KREISLER INDUSTRIAL CORP., EAST PATTERSON, N.J.
KRESS CORPORATION, CLEVELAND, OHIO
KRONENBERG, DR. MAX, CINCINNATI, OHIO
KUNTZ COMPANY, J. R., DAYTON, OHIO

LADISH COMPANY, CUDAHY, WISC.
LANCASTER METAL PRODUCTS, LANCASTER, OHIO
LASALLE STEEL COMPANY, HAMMOND, IND.
LATROBE STEEL COMPANY, LATROBE, PA.
LAVALLEE & IDE INC., CHICOPEE, MASS.
LAVIN & SONS, INC., R, CHICAGO, ILL.
LAWRENCE AVIATION INDUSTRIES, INC., NEW YORK, N.Y.
LAWRENCE RADIATION LABORATORY, LIVERMORE, CALIF.
LEAR SIEGLER COMPANY, GRAND RAPIDS, MICH.
LEBANON STEEL FOUNDRY, LEBANON, PA.
LEBLOND MACHINE TOOL COMPANY, R. K., CINCINNATI, OHIO
LEHIGH UNIVERSITY, BETHLEHEM, PA.
LELAND-GIFFORD COMPANY, WORCESTER, MASS.
LENNOR ENGINEERING COMPANY, CHICAGO, ILL.
LESSELLS AND ASSOCIATES, WALTHAM, MASS.
LINAIR ENGINEERING, DANIA, FLA.
LING-TEMCO-VOUGHT, INC., DALLAS, TEX.
LING-TEMCO-VOUGHT (LTV AEROSPACE) WARREN, MICH.
LING-TEMCO-VOUGHT (LTV ELECTROSYSTEMS), GREENVILLE, TEX.
LINK BELT COMPANY, INDIANAPOLIS, IND.
LINK BELT COMPANY, PHILADELPHIA, PA.
LIQUID DYNAMICS, CHICAGO, ILL.
LITTLE CO., INC., ARTHUR D., CAMBRIDGE, MASS.
LLOYD PRODUCTS COMPANY, CINCINNATI, OHIO
LOCKHEED AIRCRAFT CORPORATION, BURBANK, CALIF.
LOCKHEED AIRCRAFT CORPORATION, PALO ALTO, CALIF.
LOCKHEED AIRCRAFT CORPORATION, REDLANDS, CALIF.
LOCKHEED AIRCRAFT CORPORATION, SUNNYVALE, CALIF.
LOCKHEED-GEORGIA COMPANY, MARIETTA, GA.
LODGE & SHIPLEY COMPANY (THE), CINCINNATI, OHIO
LONGYEAR COMPANY, E. J., MINNEAPOLIS, MINN.
LORD MANUFACTURING COMPANY, ERIE, PA.
LOUD COMPANY, H. W., POMONA, CALIF.
LUBRX PRODUCTS INC., NORTH ATTLEBORO, MASS.
LUNKENHEIMER COMPANY, CINCINNATI, OHIO

MS&R INC., IRWIN, PA.
MACHINE DESIGN, CLEVELAND, OHIO
MACHINECRAFT, INC., BALTIMORE, MD.
MACHINERY, BIRMINGHAM, MICH.
MACHINING TECHNOLOGY CORPORATION, SO. WINDSOR, CONN.
MACKLIN COMPANY, JACKSON, MICH.
MADISON INDUSTRIES, PROVIDENCE, R.I.
MAFFITT TOOL & MACHINE COMPANY, ST. LOUIS, MO.
MAGNA MACHINE COMPANY, CINCINNATI, OHIO
MALLEABLE FOUNDERS SOCIETY, CLEVELAND, OHIO
MANHATTAN RAYBESTOS COMPANY, CORINTH, KY.
MANSFIELD PHOTO ENGRAVING, MANSFIELD, OHIO
MAREMONT COMPANY, SACO, ME.
MARLIN-ROCKWELL COMPANY, PLAINVILLE, CONN.
MARQUARDT CORPORATION (THE), VAN NUYS, CALIF.
MARQUARDT CORPORATION (THE), OGDEN, UTAH
MARQUETTE METAL PRODUCTS CO., CLEVELAND, OHIO
MARSHALL SPACE FLIGHT CENTER, HUNTSVILLE, ALA.
MARTIN COMPANY, DENVER, COLO.
MARTIN COMPANY, ORLANDO, FLA.
MARTIN COMPANY, BALTIMORE, MD.

FIGURE 22 (cont.)

MARTIN COMPANY, WHEELING, ILL.
MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASS.
MASSEY-FERGUSON INC., DETROIT, MICH.
MASTER CHEMICAL CORPORATION, PERRYSBURG, OHIO
MASTER MANUFACTURING CO. INC., HUTCHINSON, KAN.
MATERIALS DEVELOPMENT INC., PROSPECT, KY.
MATERIALS IN DESIGN ENGINEERING, NEW YORK, N.Y.
MATERIALS TESTING LABORATORY, LOS ANGELES, CALIF.
MAYNARD & COMPANY, INC., H.B., PITTSBURGH, PA.
MCCULLOCH CORPORATION, LOS ANGELES, CALIF.
MCDONNELL DOUGLAS CORP., LONG BEACH, CALIF.
MCDONNELL DOUGLAS CORP., SANTA MONICA, CALIF.
MCDONNELL DOUGLAS CORP., ST. LOUIS, MO.
MCDONNELL DOUGLAS CORP., HUNTINGTON BEACH, CALIF.
MCGRAW-EDISON COMPANY, PITTSBURGH, PA.
MCGRAW-EDISON COMPANY, COLUMBUS, OHIO
MCGRAW-EDISON COMPANY, SO. MILWAUKEE, WISC.
MCGREGOR MANUFACTURING CORP., TROY, MICH.
MCKINNEY INC., HARRIS D., PHILADELPHIA, PA.
MCMELLON BROTHERS, INC., STRATFORD, CONN.
MEAD CORPORATION, CINCINNATI, OHIO
MEASUREGRAPH COMPANY, ST. LOUIS, MO.
MECHANICAL SUPPLIES COMPANY, CINCINNATI, OHIO
MELPAR INC., FALLS CHURCH, VA.
MEMCOR INC., HUNTINGTON, IND.
MENASCO MANUFACTURING COMPANY, BURBANK, CALIF.
MENASCO MANUFACTURING COMPANY, FT. WORTH, TEX.
MERCER ALLOYS CORPORATION, GREENVILLE, PA.
MERCER MACHINE COMPANY, INDIANAPOLIS, IND.
METAL FINISHING SERVICE, CHICAGO, ILL.
METAL LUBRICANTS COMPANY, CHICAGO, ILL.
METAL-MATION INC., SOUTH BEND, IND.
METALORE, EL SEGUNDO, CALIF.
METAL POWDER INDUSTRIES FEDERATION, NEW YORK, N.Y.
METALWORKING MAGAZINE, BOSTON, MASS.
METALWORKING NEWS, CINCINNATI, OHIO
METCUT RESEARCH ASSOCIATES INC., CINCINNATI, OHIO
METEM CORPORATION, HANOVER, N.J.
MICHIGAN TECHNOLOGY UNIVERSITY, HOUGHTON, MICH.
MICHIGAN TOOL COMPANY, DETROIT, MICH.
MICHIGAN, UNIVERSITY OF, ANN ARBOR, MICH.
MIDDLE COUNTRY CENTRAL SCHOOL DISTRICT 11, CENTEREACH, N.Y.
MIDWEST RESEARCH INSTITUTE, KANSAS CITY, MO.
MIDWEST TECHNICAL SERVICES, INC., CINCINNATI, OHIO
MINIATURE PRECISION BEARINGS, INC., KEENE, N.H.
MINNESOTA MINING & MANUFACTURING CO., ST. PAUL, MINN.
MODERN MACHINE SHOP, CINCINNATI, OHIO
MOHAWK TOOLS, INC., MONTPELIER, OHIO
MONSANTO RESEARCH CORPORATION, DAYTON, OHIO
MONSANTO RESEARCH CORPORATION, MIAMISBURG, OHIO
MONSANTO RESEARCH CORPORATION, HARTFORD, CONN.
MONTGOMERY CO., H. A., DETROIT, MICH.
MOOG, INC., EAST AURORA, N.Y.
MOREHEAD STATE UNIVERSITY, MOREHEAD, KY.
MORFORM TOOL COMPANY, CINCINNATI, OHIO
MORGEN DESIGN, INC., CINCINNATI, OHIO
MORRIS & COMPANY, E. K., CINCINNATI, OHIO
MORRIS MACHINE CO. INC., INDIANAPOLIS, IND.
MORSE TWIST DRILL & MACHINE CO., CHICAGO, ILL.
MORSEAR TOOLS INC., CINCINNATI, OHIO
MOSLER LOCK COMPANY, MILFORD, OHIO
MOTOROLA INC., SCOTTSDALE, ARIZ.
MUSKEGON TOOL INDUSTRIES INC., MUSKEGON, MICH.

NASA, SCIENTIFIC & TECHNOLOGY INFORMATION FACILITY, BETHESDA, MD.
NASA, LANGELY RESEARCH CENTER, HAMPTON, VA.
NASA, LEWIS RESEARCH CENTER, CLEVELAND, OHIO
NATIONAL BERYLLIA CORPORATION, HASKELL, N.J.
NATIONAL BUREAU OF STANDARDS, BOULDER, COLO.
NATIONAL CASH REGISTER COMPANY, DAYTON, OHIO
NATIONAL FORGE COMPANY, IRVINE, WARREN COUNTY, PA.
NATIONAL LEAD COMPANY OF OHIO, CINCINNATI, OHIO
NATIONAL LEAD COMPANY OF OHIO, FERNALD, OHIO
NATIONAL SCREW MACHINE PRODUCTS ASSOCIATION, CLEVELAND, OHIO
NATIONAL WATER LIFT COMPANY, KALAMAZOO, MICH.
NAVAL AIR ENGINEERING CENTER, PHILADELPHIA, PA.
NAVAL AIR REWORK FACILITIES, SAN DIEGO, CALIF.
NELCO CUTTER COMPANY, MANCHESTER, CONN.
NEUMAN & COMPANY, H., SKOKIE, ILL.
NEVILL, C. R., INDIANAPOLIS, IND.
NEW BRITAIN MACHINE CO. (THE), NEW BRITAIN, CONN.
NEW ENGLAND METALLURGICAL CORPORATION. S. BOSTON, MASS.
NEW ENGLAND RESEARCH APPLICATION CENTER, STOORRS, CONN.
NEW YORK STATE UNIVERSITY OF BINGHAMTON, BINGHAMTON, N.Y.
NOBLE INC., NORMAN, CLEVELAND, OHIO
NORDEN COMPANY, NORWALK, CONN.
NORTH AMERICAN ROCKWELL CORP., ANAHEIM, CALIF.
NORTH AMERICAN ROCKWELL CORP., CANOGA PARK, CALIF.
NORTH AMERICAN ROCKWELL CORP., EL SEGUNDO, CALIF.
NORTH AMERICAN ROCKWELL CORP., INGLEWOOD, CALIF.
NORTH AMERICAN ROCKWELL CORP., LOS ANGELES, CALIF.
NORTH AMERICAN ROCKWELL CORP., NEOSHO, MO.
NORTH AMERICAN ROCKWELL CORP., COLUMBUS, OHIO
NORTH AMERICAN ROCKWELL CORP., TULSA, OKLA.
NORTH CAROLINA STATE UNIVERSITY, RALEIGH, N.C.
NORTH HARTFORD HIGH SCHOOL, PYLESVILLE, MD.
NORTHEASTERN UNIVERSITY, BOSTON, MASS.
NORTHROP NORAIR, HAWTHORNE, CALIF.
NORTHROP VENTURA, NEWBURY PARK, CALIF.
NORTON COMPANY, WORCESTER, MASS.
NRC EQUIPMENT CORPORATION, NEWTON, MASS.
NUCLEAR METALS, INC., WEST CONCORD, MASS.
NUMERICAL CONTROL & COMPUTER SERVICES, CLEVELAND OHIO
NU TEC ENGINEERING CORPORATION, WARREN, MICH.
NU-TOOL SAW SERVICE, INC., DETROIT, MICH.

OK TOOL COMPANY, MILFORD, N.H.
OAKES CORPORATION, E. T., LONG ISLAND, N.Y.
OBERG MANUFACTURING COMPANY, INC., FREEPORT, PA.
OHIO STATE UNIVERSITY (THE), COLUMBUS, OHIO
OKLAHOMA STATE UNIVERSITY, STILLWATER, OKLA.
OLIN DIXSON CORPORATION, COFFEEVILLE, KAN.
OLIVER MACHINERY COMPANY, GRAND RAPIDS, MICH.
ONTARIO CORPORATION, MUNCIE, IND.
OREGON TECHNICAL INSTITUTE, KLAMATH FALLS, ORE.
OTIS ELEVATOR COMPANY, YONKERS, N.Y.
OWENS-ILLINOIS, INC., COLUMBUS, OHIO

PACIFIC SCIENTIFIC COMPANY, ANAHEIM, CALIF.
PACKER CONSULTING ASSOCIATES, NAPERVILLE, ILL.
PANDA PRODUCTS, CINCINNATI, OHIO
PEABODY INDUSTRIES, PEABODY, MASS.
PECK, PAUL H., BROCKTON, MASS.
PENN NUCLEAR CORPORATION, PENN, PA.
PENNSYLVANIA STATE UNIVERSITY, UNIVERSITY PARK, PA.
PENTA TECHNICAL COLLEGE. PERRYSBURG, OHIO
PESCO PRODUCTS, BEDFORD, OHIO
PHELPS-DODGE-COPPER PRODUCTS CORP., ELIZABETH, N.J.
PHILADELPHIA NAVAL SHIPYARD, PHILADELPHIA, PA.
PHILCO CORPORATION, LAWNDALE, CALIF.
PHILCO CORPORATION, NEWPORT BEACH, CALIF.
PICATINNY ARSENAL, DOVER, N.J.
PIPE MACHINERY COMPANY, CLEVELAND, OHIO
PITTSBURGH PLATE GLASS CO., PITTSBURGH, PA.

FIGURE 22 (cont.)

PLANET PRODUCTS CORPORATION, CINCINNATI, OHIO
POINT PARK COLLEGE, PITTSBURGH, PA.
POLYMET CORPORATION, CINCINNATI, OHIO
PRATT & WHITNEY AIRCRAFT, EAST HARTFORD, CONN.
PRATT & WHITNEY AIRCRAFT, NORTH HAVEN, CONN.
PRATT & WHITNEY AIRCRAFT, WEST PALM BEACH, FLA.
PRATT & WHITNEY CORPORATION, W. HARTFORD, CONN.
PRATT & WHITNEY CORPORATION, CUDAHY, CALIF.
PRECISION CASTPARTS CORP., PORTLAND, ORE.
PRECISION MACHINE & TOOL, INC., VANDALIA, OHIO
PRECISION MECHANICS INC., CINCINNATI, OHIO
PRESTOLITE COMPANY (THE), DECATUR, ALA.
PRISOCK ASSOCIATES, JOHN, CINCINNATI, OHIO
PROCTER & GAMBLE COMPANY, CINCINNATI, OHIO
PRUYNE COMPANY, SAN DIEGO, CALIF.
PURDUE UNIVERSITY, WEST LAFAYETTE, IND.

RGF CORPORATION, ELWOOD, IND.
RADIO CORPORATION OF AMERICA, CAMDEN, N.J.
RADIO CORPORATION OF AMERICA, PRINCETON, N.J.
RADIO CORPORATION OF AMERICA, LANCASTER, PA.
RADIO ENGINEERING LABORATORIES, LONG ISLAND, N.Y.
RAYTHEON COMPANY, WALTHAM, MASS.
RAYTHEON COMPANY, WAYLAND, MASS.
RAYTHEON COMPANY, BRISTOL, TENN.
REACTIVE METALS, INC., NILES, OHIO
REDSTONE ARSENAL, U.S. ARMY MISSILE COMMAND, REDSTONE ARSENAL, ALA.
REGENTS OF THE UNIVERSITY SYSTEM OF GEORGIA, ATLANTA, GA.
RELIANCE ELECTRIC COMPANY, ASHTABULA, OHIO
REMINGTON ARMS COMPANY, INC., BRIDGEPORT, CONN.
REPUBLIC STEEL CORPORATION, CLEVELAND, OHIO
RESOURCES DEVELOPMENT CORPORATION, EAST LANSING, MICH.
REX CHAINBELT, INC., DOWNERS GROVE, ILL.
REYNOLDS METALS COMPANY, RICHMOND, VA.
RIDINGS, JAMES A., PITTSBURG, KAN.
ROCK ISLAND ARSENAL, ROCK ISLAND, ILL.
ROHR CORPORATION, CHULA VISTA, CALIF.
ROLLWAY BEARING COMPANY, SYRACUSE, N.Y.
ROMA CORPORATION, INDIANAPOLIS, IND.
ROOTS-CONNERSVILLE, BLOWER DIV., CONNERSVILLE, IND.
RUST-LICK INC., BOSTON, MASS.
RYERSON & SON, INC., JOSEPH T., CHICAGO, ILL.

SKF INDUSTRIES, TIMONIUM, MD.
S&S MACHINERY COMPANY, BROOKLYN, N.Y.
SAE STEELS, INC., HUDSON, OHIO
SAN JOSE STATE COLLEGE, SAN JOSE, CALIF.
SANDERS ASSOCIATES, NASHUA, N.H.
SANDIA CORPORATION, ALBUQUERQUE, N.M.
SATEC CORPORATION, GROVE CITY, PA.
SAUNDERS & CO. INC., ALEXANDER, COLD SPRING, N.Y.
SCHELLENS TRUE CORPORATION, IVORYTON, CONN.
SEATTLE UNIVERSITY, SEATTLE, WASH.
SEIFREAT-ELSTAD MACHINERY CO., CINCINNATI, OHIO
SETCO INDUSTRIES INC., CINCINNATI, OHIO
SEYBOLD COMPANY, CINCINNATI, OHIO
SHEAFFER PEN COMPANY, W. A., FT. MADISON, IOWA
SHEFFER CORPORATION (THE), CINCINNATI, OHIO
SHEFFIELD CORPORATION (THE), DAYTON, OHIO
SHWAYDER CHEMICAL METALLURGY CORP., DETROIT, MICH.
SIKORSKY AIRCRAFT, STRATFORD, CONN.
SILICONICS INC., OAKMONT, PA.
SINCLAIR REFINING COMPANY, CHICAGO, ILL.
SINCLAIR REFINING COMPANY, COLUMBUS, OHIO
SMALL BUSINESS ADMINISTRATION, CHICAGO, ILL.
SNAP-ON-TOOLS COMPANY, KENOSHA, WISC.
SONNET TOOL & MFG. CO., HAWTHORNE, CALIF.
SOUTH CHESTER CORPORATION, LESTER, PA.
SOUTH SHORE TOOL & DEVELOPMENT INC., MENTOR, OHIO
SOUTHERN AUTOMATICS INC., CINCINNATI, OHIO

SOUTHERN ILLINOIS UNIVERSITY, CARBONDALE, ILL.
SOUTHWEST RESEARCH INSTITUTE, SAN ANTONIO, TEX.
SPECIAL MACHINE COMPANY, ROCKFORD, ILL.
SPERRY RAND CORPORATION, CLEARWATER, FLA.
SPERRY RAND CORPORATION, DETROIT, MICH.
SPERRY RAND CORPORATION, JACKSON, MISS.
SPERRY RAND CORPORATION, TROY, MICH.
SPERRY RAND CORPORATION, BRISTOL, TENN.
SPERRY RAND CORPORATION, SALT LAKE CITY, UTAH
SPINDLETOP RESEARCH, LEXINGTON, KY.
SPRINGFIELD ARMORY, SPRINGFIELD, MASS
ST. JOSEPH LEAD COMPANY, MONACA, PA.
STANDARD OIL COMPANY-OHIO (THE), CLEVELAND, OHIO
STANDARD PRESSED STEEL CO., JENKINTOWN, PA.
STARK INDUSTRIAL SUPPLY COMPANY, CANTON, OHIO
STATHAM INSTRUMENTS, OXNARD CALIF.
STEEL MAGAZINE, CLEVELAND, OHIO
STERLING FAUCET COMPANY, MORGANTOWN, W. VA.
STERLING GRINDING WHEEL CO., TIFFIN, OHIO
STERLING INSTRUMENT, MINEOLA, N.Y.
STEVENS INSTITUTE OF TECHNOLOGY, HOBOKEN, N.J.
STRASMANN MACHINERY CORPORATION, LONG BEACH, CALIF.
STUART OIL CO., LTD., D. A., CHICAGO, ILL.
STUDEBAKER CORPORATION, DUNBAR, W. VA.
STYRE/PAK, NEWTON, IOWA
SUN OIL COMPANY, CINCINNATI, OHIO
SUN OIL COMPANY, MARCUS HOOK, PA.
SUN SHIPBUILDING & DRY DOCK CO., CHESTER, PA.
SUNDSTRAND CORPORATION, SUNDSTRAND AVIATION, ROCKFORD, ILL.
SUNDSTRAND CORPORATION, SUNDSTRAND MACHINE TOOL CO., BELVIDERE, ILL.
SYLVANIA ELECTRIC PRODUCTS, INC., SALEM, MASS.
SYLVESTRE SCREW COMPANY, PROVIDENCE, R. I.
SYSTEMS RESEARCH LABS., DAYTON, OHIO

TRW INC., CLEVELAND, OHIO
TRW INC., DANVILLE, PA.
TRW INC., LEBANON, TENN.
TAFT ENGINEERING CENTER, CINCINNATI, OHIO
TAYLOR FORGE INC., CHICAGO, ILL.
TECHNICAL CONSULTANTS INC., HUNTINGTON, W. VA.
TECHNICAL EQUIPMENT SALES CO., CINCINNATI, OHIO
TECHNICAL & TRADE TRAINING CENTER, WESTBURY, N.Y.
TECUMSEH PRODUCTS COMPANY, ANN ARBOR, MICH.
TELEDYNE INC, WAH CHANG, GLEN COVE, N.Y.
TELEDYNE INC., ALLVAC METALS, MONROE, N.C.
TELEDYNE INC., FIRTH STERLING, PITTSBURGH, PA.
TELEDYNE INC., VASCO, LATROBE, PA.
TELEDYNE INC., AUTOMATED SPECIALTIES, CHARLOTTESVILLE, VA.
TELEFLEX INC., NORTH WALES, PA.
TELETYPE CORPORATION, SKOKIE, ILL.
TENNESSEE, UNIVERSITY OF, KNOXVILLE, TENN.
TEXACO INC., BEACON, N.Y.
TEXACO INC., CINCINNATI, OHIO
TEXAS INSTRUMENTS INC., DALLAS, TEX.
TEXAS, UNIVERSITY OF, AUSTIN, TEX.
THERM INC., ITHACA, N.Y.
THIOKOL CHEMICAL CORP., DENVILLE, N.J.
THOMPSON COMPANY, JOHN R., WASHINGTON, D.C.
TIMKEN ROLLER BEARING COMPANY, CANTON, OHIO
TINKER AIR FORCE BASE, OKLAHOMA CITY, OKLA.
TIPP MACHINE & TOOL INC., TIPP CITY, OHIO
TIPPETT INCORPORATED, CHICOPEE FALLS, MASS.
TITANIUM METALS CORPORATION OF AMERICA, NEW YORK, N.Y.
TITANIUM METALS CORPORATION OF AMERICA, TORONTO, ONIO
TOOL SALES & SERVICE, CINCINNATI, OHIO
TOOL STEEL GEAR & PINION CO. (THE), CINCINNATI, OHIO

FIGURE 22 (cont.)

TOULON HIGH SCHOOL, TOULON, ILL.
TOWNSEND COMPANY, SANTA ANA, CALIF.
TRIJB STROHM CORPORATION, PLAINVIEW, N.Y.
TRI INDUSTRIES INC., TERRE HAUTE, IND.
TRI-D CORPORATION, PLAINVILLE, CONN.
TRU-CUT MACHINE CORPORATION, CINCINNATI, OHIO
TYCO LABORATORIES, WALTHAM, MASS.
TYLER CORPORATION, BENSON, MINN.

UTD CORPORATION, ATHOL, MASS.
U.S. ARMY, PRODUCTION ENGINEERING DIVISION, FT. BELVOIR, VA.
U.S. ARMY, EDGEWOOD ARSENAL, EDGEWOOD ARSENAL, MD.
U.S. ARMY, PRODUCTION EQUIPMENT AGENCY, ROCK ISLAND, ILL.
U.S. ARMY, WEAPONS COMMAND, ROCK ISLAND, ILL.
U.S. ATOMIC ENERGY COMMISSION, WASHINGTON, D.C.
U.S. BAIRD CORPORATION, STRATFORD, CONN.
U.S. DEFENSE SUPPLY AGENCY, CINCINNATI, OHIO
U.S. DEPARTMENT OF DEFENSE, N. ARLINGTON, VA.
U.S. DEPARTMENT OF THE INTERIOR, ROLLA, MO.
U.S. DEPARTMENT OF JUSTICE, WASHINGTON, D.C.
U.S. MARINE CORPS., CHERRY POINT, N.C.
U.S. NAVAL AVIONICS FACILITY, DEPARTMENT OF NAVY, INDIANAPOLIS, IND.
U.S. MISSILE CENTER, MUGU, CALIF.
U.S. NAVAL ORDNANCE LAB., WHITE OAK, MD.
U.S. NAVAL ORDNANCE TEST STATION, CHINA LAKE, CALIF.
U.S. NAVAL POST GRADUATE SCHOOL, MONTEREY, CALIF.
U.S. NAVAL UNDERWATER ORDNANCE STATION, NEWPORT, R.I.
U.S. STEEL CORPORATION, MONROEVILLE, PA.
UNION CARBIDE CORPORATION, INDIANAPOLIS, IND.
UNION CARBIDE CORPORATION, KOKOMO, IND.
UNION CARBIDE CORPORATION, PADUCAH, KY.
UNION CARBIDE CORPORATION, OAK RIDGE NATIONAL LAB, OAK RIDGE, TENN.
UNION CARBIDE CORPORATION, Y12 PLANT, OAK RIDGE, TENN.
UNITED AIRCRAFT CORPORAT SYSTEMS CENTER, FARMINGTON, CONN.
UNITED AIR LINES, SAN FRANCISCO, CALIF.
UNITED STATES BORAX & CHEMICAL CORP., NEW YORK, N.Y.
UNITED STATES LIAISON OFFICE, APO, N.Y.
UNITED STATES TIME CORPORATION, WATERBURY, CONN.
UNITED TECHNOLOGY CENTER, SUNNYVALE, CALIF.
UNIVAC, ROSEVILLE, MINN.
UNIVERSAL-CYCLOPS SPECIALTY STEEL, BRIDGEVILLE, PA.
UNIVERSAL TECHNOLOGY CORP., DAYTON, OHIO
UNIVERSAL VALVE COMPANY, INC., ELIZABETH, N.J.
UTAH, UNIVERSITY OF, SALT LAKE CITY, UTAH
UTAH STATE UNIVERSITY, LOGAN, UTAH

V.I. JEWELRY MANUFACTURING CORP., NEW YORK, N.Y.
VALERON CORPORATION (THE), LOS ANGELES, CALIF.
VALERON CORPORATION (THE), INDIANAPOLIS, IND.
VALERON CORPORATION (THE), DAYTON, OHIO
VALUE PROGRAM FOR INDUSTRY, SCHENECTADY, N.Y.
VAN STRAATEN CHEMICAL COMPANY, CHICAGO, ILL.
VARO INC., SANTA BARBARA, CALIF.
VEEDER-ROOT INC., ALTOONA, PA.
VERMONT AMERICAN CORPORATION, LOUISVILLE, KY.
VIKING FORGE & STEEL COMPANY, ALBANY, CALIF.
VINCO CORPORATION, DETROIT, MICH.
VIRGINIA POLYTECHNIC INSTITUTE, BLACKSBURG, VA.
VITRO CORPORATION OF AMERICA, WEST ORANGE, N.J.
VOGT MACHINE CO. INC., HENRY, LOUISVILLE, KY.
VR/WESSON COMPANY, CINCINNATI, OHIO

WALKER COMPANY, O.S., WORCESTER, MASS.
WALKER GRINDING COMPANY, SANTA BARBARA, CALIF.
WALMET CORPORATION (THE), PLEASANT RIDGE, MICH.
WALMET CORPORATION (THE), SUMMITT, N.J.
WALTCO ENGINEERING COMPANY, GARDENA, CALIF.
WARNER-SWASEY COMPANY (THE), CLEVELAND, OHIO
WARNER-SWASEY COMPANY (THE), LAHR DIVISION, CLEVELAND, OHIO
WARREN PUMPS, INC., WARREN, MASS.
WATERTOWN ARSENAL, WATERTOWN, MASS.
WATERVLIET ARSENAL, WATERVLIET, N.Y.
WAYNE STATE UNIVERSITY, DETROIT, MICH.
WEATHERHEAD COMPANY (THE), DAYTON, OHIO
WEBCO MACHINE PRODUCTS, INC., CLEVELAND, OHIO
WEINMAN PUMP MANUFACTURING CO. (THE), COLUMBUS, OHIO
WEST MILTON PRECISION TOOL CO., VANDALIA, OHIO
WEST VIRGINIA, STATE OF, DEPARTMENT OF COMMERCE, CHARLESTON, W. VA.
WESTERN ELECTRIC COMPANY, INC., OMAHA, NEB.
WESTERN ELECTRIC COMPANY, INC., GREENSBORO, N.C.
WESTERN ELECTRIC COMPANY, INC., PRINCETON, N.J.
WESTERN ELECTRIC COMPANY, INC., NEW YORK, N.Y.
WESTERN GEAR CORPORATION, EVERETT, WASH.
WESTERN RESERVE UNIVERSITY, CLEVELAND, OHIO
WESTINGHOUSE AIR BRAKE COMPANY, PEORIA, ILL.
WESTINGHOUSE ELECTRIC CORP., SUNNYVALE, CALIF
WESTINGHOUSE ELECTRIC CORP., BUFFALO, N.Y.
WESTINGHOUSE ELECTRIC CORP., BLAIRSVILLE, PA.
WESTINGHOUSE ELECTRIC CORP., HOMEWOOD, PA.
WESTINGHOUSE ELECTRIC CORP., PHILADELPHIA, PA.
WESTINGHOUSE ELECTRIC CORP., PITTSBURGH, PA.
WHEELABRATOR CORPORATION, MISHAWAKA, INC.
WHITE COUNTY MACHINE SHOP, MONTICELLO, INC.
WHITIN MACHINE WORKS, WHITINSVILLE, MASS.
WHITTAKER CORPORATION, LA MESA, CALIF.
WHITTAKER CORPORATION, WEST CONCORD, MASS.
WILLIAMS RESEARCH & ENGINEERING CO., WALLED LAKE, MICH.
WISCONSIN, UNIVERSITY, MADISON, WISC.
WISCONSIN STATE UNIVERSITY, PLATTEVILLE, WISC.
WITHROW COMPANY, ARTHUR C., LOS ANGELES, CALIF.
WOLVERINE BRASS WORKS, GRAND RAPIDS, MICH.
WORLD TOOL & ENGINEERING CO., MINNEAPOLIS, MINN.
WRIGHT-PATTERSON AIR FORCE BASE, MANUFACTURING TECHNOLOGY DIVISION, WRIGHT-PATTERSON AFB, OHIO
WRIGHT-PATTERSON AIR FORCE BASE FOREIGN DISCLOSURE OFFICE, WRIGHT-PATTERSON AFB, OHIO
WRIGHT-PATTERSON AIR FORCE BASE FOREIGN TECHNOLOGY OFFICE, WRIGHT-PATTERSON AFB, OHIO
WYMAN-GORDON COMPANY, NORTH GRAFTON, MASS.
WYMAN-GORDON COMPANY, WORCESTER, MASS.

XEROX CORPORATION, ROCHESTER, N.Y.

ZENITH MANUFACTURING COMPANY, OAK PARK, MICH.
ZIMNEY CORPORATION, MONROVIA, CALIF.

FIGURE 22 (cont.)

SUMMARY OF SPECIFIC INQUIRIES BY COMPANIES MAKING 5 OR MORE REQUESTS

October 1, 1964 - January 31, 1968

Aerojet-General Corporation (6)*	24
Aeronca Inc.	5
Aerospace Research Application Center	10
Airesearch Manufacturing Co. (2)*	5
Allis-Chalmers Manufacturing Company (2)*	13
Altamil Corp.	7
American Society for Metals	10
American Society of Tool & Manufacturing Engineers	6
Argonne National Laboratory	7
Armco Steel Corporation (4)*	7
Avco Corporation (5)*	18
Battelle Memorial Institute (3)*	26
Bendix Corporation (The) (7)*	35
Boeing Company (The) (6)*	35
Bomar Company	5
Brush Beryllium Co. (The) (3)*	8
Burndy Corporation	5
Carborundum Company	9
Caterpillar Tractor Company (2)*	5
Cincinnati Lathe & Tool Company	7
Cincinnati Milling Machine Co. (The)	52
Cincinnati Shaper Company	6
Cincinnati, University of	6
Continental Aviation & Engineering Corp. (2)*	8
Corning Glass Works	9
Crucible Steel Company of America (2)*	6
Curtiss-Wright Corp. (3)*	50
Dow Chemical Company (3)*	9
DuPont deNemours & Co., E. I. (2)*	22
Electrical Machining Inc.	5
Elliott Company	8
Ford Motor Company (5)*	13
General Dynamics Corp. (4)*	19
General Electric Co. (27)*	175
General Motors Corp. (11)*	22
Glidden Company (The)	5
Goodyear Aerospace Corporation	10
Grumman Aircraft Engineering Corp.	14
Hamilton Standard	11
Holley Carburetor Company (2)*	13
Honeywell, Inc. (3)*	9
Hughes Aircraft Company (4)*	9
Illinois, University of	8
Ingersoll Rand Corp. (3)*	11
International Business Machines Corp. (8)*	15
International Nickel Co. Inc. (The)(4)*	17
Jerden Manufacturing Company	7
Kennametal Inc. (3)*	9
Kronenberg, Dr. Max	5
LeBlond Machine Tool Company, R. K.	12
Lockheed Aircraft Corporation (5)*	31
Machine Design	5
Marquardt Corp. (The) (2)*	6
Martin Company (4)*	34
Massachusetts Institute of Technology	5
Massey-Ferguson Inc.	5
Menasco Manufacturing Company (2)*	5
Metalworking Magazine	5
Metcut Research Associates Inc.	29
McDonnell Douglas Corp. (4)*	35
Monsanto Research Corporation (3)*	6
Morehead State University	5
National Lead Co. of Ohio (2)*	16
New England Research Application Center	8
North American Rockwell Corp. (8)*	59
North Carolina State University	5
Norton Company	6
Pennsylvania State University	6
Philco Corporation (2)*	5
Planet Products Corp.	9
Pratt & Whitney Aircraft (3)*	6
Radio Corporation of America (3)*	5
Reactive Metals Inc.	8
Rock Island Arsenal	13
Rohr Corp.	8
Sandia Corp.	11
Southern Illinois University	8
Sperry-Rand Corp. (4)*	5
Sundstrand Corp., Sundstrand Aviation	13
Sylvania Electric Products Company	12
TRW Inc., (3)*	36
Teledyne Inc., (5)*	11
Therm, Inc.	13
Thiokol Chemical Corp.	10
Tinker Air Force Base	13
Tool Sales & Service	8
Union Carbide Corporation (4)*	29
Vermont American Corp.	6
Wayne State University	20
Western Electric Co., Inc. (4)*	5
Westinghouse Electric Corp. (6)*	20
Wright-Patterson Air Force Base (3)*	46
Wyman-Gordon Company (2)*	8
Xerox Corp.	5

SEE APPENDIX, PAGE A-15

FIGURE 23

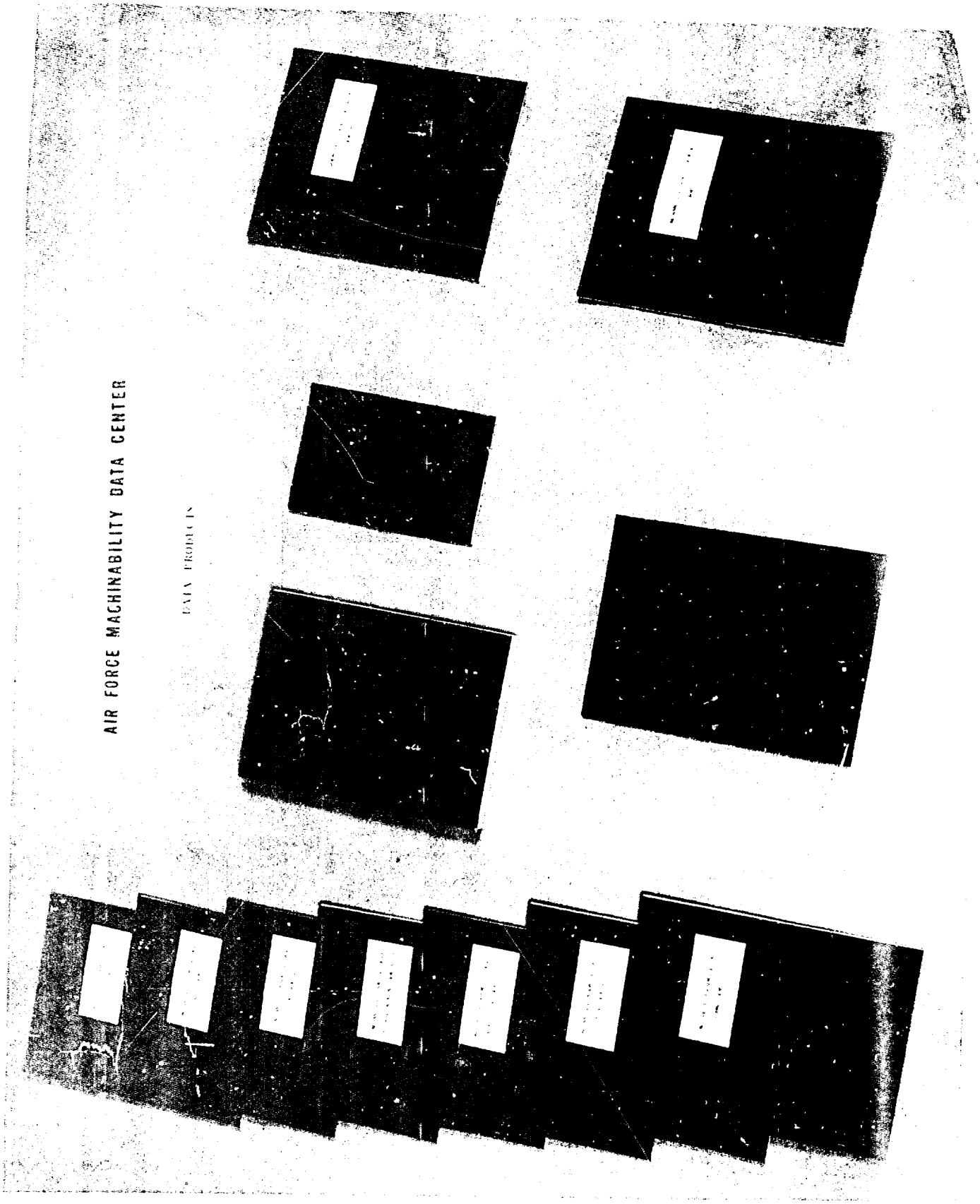


FIGURE 24

SEE APPENDIX, PAGE A-16

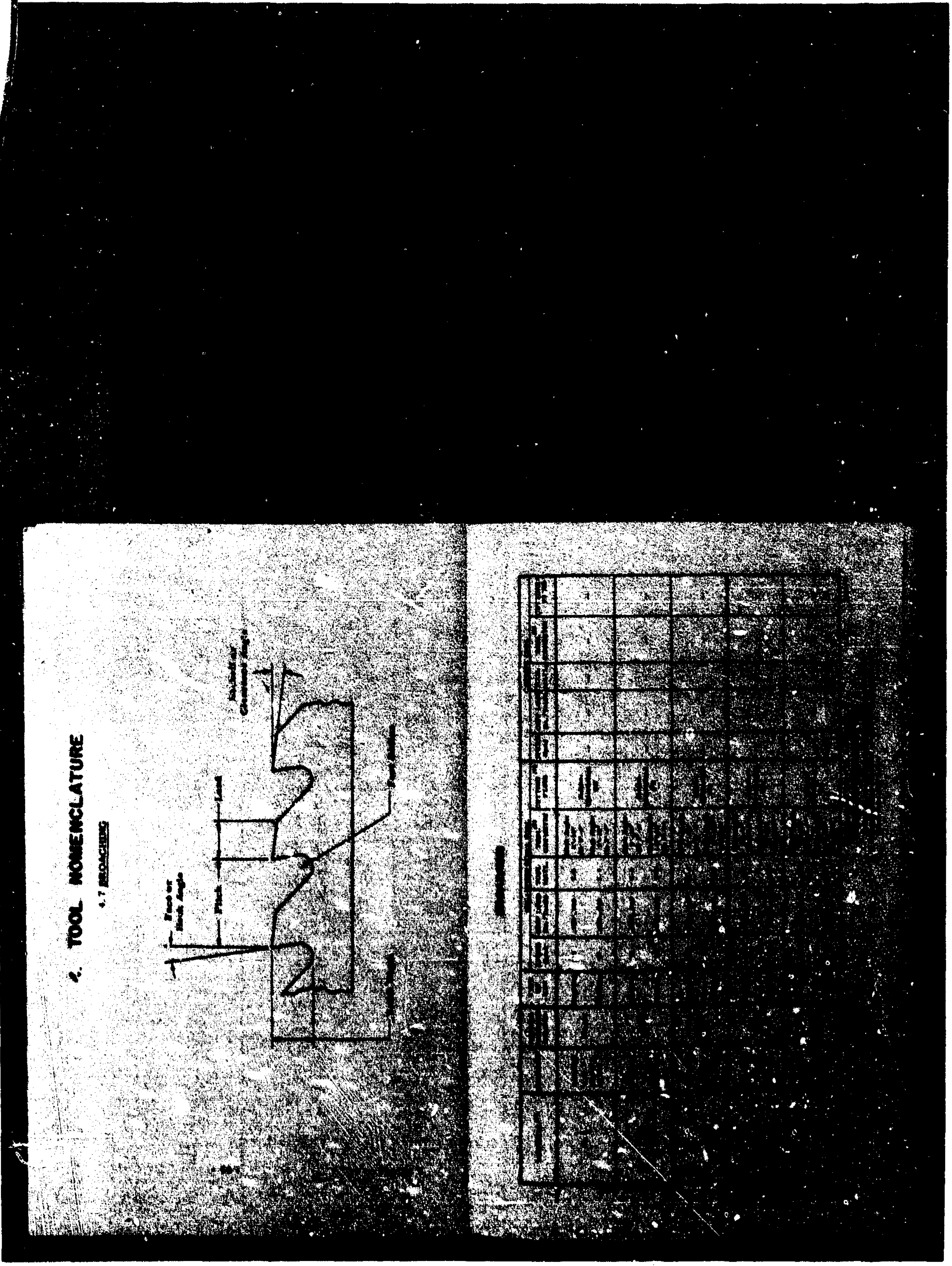


FIGURE 25

SEE APPENDIX, PAGE A-18

TYPICAL FORMATS FOR DATA PRESENTATION

FIGURE 20

TURNING

MATERIAL	CONDITION & MICROSTRUCTURE	BHN	TOOL MATERIAL: TRADE NAME	TOOL MATERIAL: INDUSTRY GRADE	TOOL GEOMETRY: BR°	SR°	SCEA°	ECEA°	RELIEF°	NOSE RADIUS in.	CUTTING FLUID	DEPTH OF CUT in.	FEED ipr	TOOL LIFE END POINT in.	TOOL LIFE - minutes vs SPEED-feet/minute R=Recommended Speed
HIGH TEMPERATURE ALLOYS - NICKEL BASE WROUGHT - *(cont.)* INCONEL 718	SOLUTION TREATED & AGED AUSTENITIC	45 R_c	-	T15 HSS	0	15	15	15	5	.032	52	.080	.007	.060	3 / 40
INCONEL 718	SOLUTION TREATED & AGED AUSTENITIC	45 R_c	K8	C-2	0	5	15	15	5	.032	11 1:20	.080	.009	.015	10 / 123 ; 15 / 117 ; 29 / 90

PERIPHERAL END MILLING

MATERIAL	CONDITION & MICROSTRUCTURE	BHN	TOOL MATL.: TRADE NAME	TOOL MATL.: INDUSTRY GRADE	CUTTER TYPE	DIA. in.	NO. TEETH	FLUTE LENGTH in.	UP OR DOWN MILLING	TOOL GEOMETRY: HELIX ANGLE°	RR°	CHAMFER	ECEA°	END REL.° / PERIPH. REL.°	CUTTING FLUID	DEPTH OF CUT in.	WIDTH OF CUT in.	FEED ipt	TOOL LIFE END POINT in.	TOOL LIFE/CUTTER inches work travel vs SPEED-feet/minute R=Recommended Speed
HIGH TEMPERATURE ALLOYS - NICKEL BASE WROUGHT *(cont.)* INCONEL 718	SOLUTION TREATED & AGED AUSTENITIC	42 R_c	-	M2 HSS	SOLID HSS	.750	4	2	DOWN	30	10	45° x .060"	1	3 / 7	11 1:20	.125	.750	.001	.012	24 / 11

DRILLING

MATERIAL	CONDITION & MICROSTRUCTURE	BHN	DRILL MATL.: TRADE NAME	DRILL MATL.: INDUSTRY GRADE	TYPE DRILL	DRILL SIZE: DIA. in.	LENGTH in.	FLUTE LENGTH in.	DRILL GEOMETRY: TYPE POINT	HELIX ANGLE°	POINT ANGLE°	LIP RELIEF°	CUTTING FLUID	DEPTH OF HOLE in.	FEED ipr	DRILL LIFE END POINT in.	DRILL LIFE NO. OF HOLES vs SPEED-feet/minute R=Recommended Speed
HIGH TEMPERATURE ALLOYS - NICKEL BASE WROUGHT *(cont.)* INCONEL 718	SOLUTION TREATED AUSTENITIC	245		T15 HSS	TWIST	.250	2.5	1.375	CRANK-SHAFT	29	118	7	53	.5 THRU	.002	.015	21 / 25

SEE APPENDIX, PAGE A-10

SEE APPENDIX, PAGE A-18

DESCRIPTION & DISTRIBUTION OF AFMDC DATA PRODUCTS

August, 1965 - January, 1968

DESCRIPTION & CONTENT	DISTRIBUTION		
	USER FILE & DIRECT INQUIRIES	NO. SOLD	TOTAL
AFMDC 65-1, MACHINING DATA FOR TITANIUM ALLOYS, AUGUST 1965 Turning, Face Milling, End Mill Slotting, Peripheral End Milling, Drilling, Reaming, Tapping, Broaching and Surface Grinding for Commercially Pure Titanium, Alpha & Alpha-Beta, and Beta Alloys.	4,108	1,442	5,550
AFMDC 66-1 , MACHINING DATA FOR NUMERICAL CONTROL, DECEMBER 1966 Contains all the data originally printed in the 7 individual reports, AFMDC 66-1.1 through 66-1.7 listed below. *(See Notes).*	149	512	661
AFMDC 66-1.1, MACHINING DATA FOR NUMERICAL CONTROL-TURNING, JUNE 1966 Free Machining Plain Carbon Steels, Plain Carbon Steels, Free Machining Alloy Steels, Alloy Steels, Ultra-High Strength Steels, Tool Steels-Hot Work, Stainless Steels, Titanium Alloys, High Temperature Alloys, Refractory Alloys, and Nonmetallics.	1,091	80	1,171
AFMDC 66-1.2, MACHINING DATA FOR NUMERICAL CONTROL-FACE MILLING, AUGUST 1966 Alloy Steels, Ultra-High Strength Steels, Tool Steels-Hot Work, Stainless Steels, Titanium Alloys, High Temperature Alloys, Refractory Alloys, and Nonmetallics.	1,081	26	1,107
AFMDC 66-1.3, MACHINING DATA FOR NUMERICAL CONTROL-DRILLING, AUGUST 1966 Alloy Steels, Ultra-High Strength Steels, Tool Steels-Hot Work, Stainless Steels, Titanium Alloys, High Temperature Alloys, Refractory Alloys, and Nonmetallics.	1,080	13	1,093
AFMDC 66-1.4, MACHINING DATA FOR NUMERICAL CONTROL-PERIPHERAL END MILLING, SEPTEMBER 1966 Alloy Steels, Ultra-High Strength Steels, Titanium Alloys, High Temperature Alloys, and Refractory Alloys.	1,080	2	1,082
AFMDC 66-1.5, MACHINING DATA FOR NUMERICAL CONTROL-END MILL SLOTTING, SEPTEMBER 1966 Alloy Steels, Ultra-High Strength Steels, Tool Steels-Hot Work, Stainless Steels, Titanium Alloys, High Temperature Alloys, and Refractory Alloys	1,063	2	1,065
AFMDC 66-1.6, MACHINING DATA FOR NUMERICAL CONTROL-TAPPING, NOVEMBER 1966 Alloy Steels, Ultra-High Strength Steels, Tool Steels-Hot Work, Stainless Steels, Titanium Alloys, High Temperature Alloys, Refractory Alloys, and Nonmetallics.	1,060	-	1,060
AFMDC 66-1.7, MACHINING DATA FOR NUMERICAL CONTROL-REAMING, NOVEMBER 1966 Ultra-High Strength Steels, Titanium Alloys, High Temperature Alloys, and Refractory Alloys,	1,060	-	1,060
AFMDC 66-2, GRINDING RATIOS FOR AEROSPACE ALLOYS, JUNE 1966 Surface Grinding of Alloy Steels, Ultra-High Strength Steels, Tool Steels, Stainless Steels, Titanium Alloys, High Temperature Alloys, Refractory Alloys and Nonmetallics.	695	156	851
AFMDC 66-3, MACHINING DATA FOR BERYLLIUM METAL, JUNE 1966 This booklet covers problems involved in machining beryllium, in addition to specific data for 10 conventional operations and 4 alternate machining methods.	724	305	1,029
TOTALS	13,191	2,538	15,729

FIGURE 27

DATA ACQUISITION PLANT VISIT PROGRAM

Thirty-seven plants were visited in late 1966 thru January 1968 for the purpose of acquiring machining data from them on a regular basis. Emphasis was placed on visiting aerospace firms. Visits to all plants were very satisfactory and there was general interest in this project. Nearly all the plants are taking steps to make necessary arrangements for transmitting data. Over 200 reports of high data yield have already been received from several firms. Followup is planned in the form of correspondence and periodic visits.

During all visits it was found essential to provide rather detailed information concerning AFMDC's organization and how it functions. Effort was made to reach directly or through responsible supervisory personnel the lower echelon manufacturing and manufacturing engineering people who need data for immediate application to machining of hardware. The effect of this approach was noted in the significant increase in inquiries received from most of the companies visited. The specific companies visited are:

Aerojet-General Corporation
Sacramento, California

American Welding & Manufacturing Company
Warren, Ohio

Argonne National Laboratory
Argonne, Illinois

Avco Corporation
Nashville, Tennessee

Beech Aircraft Corporation
Wichita, Kansas

Bell Helicopter Company
Ft. Worth, Texas

Boeing Company (The)
Wichita, Kansas

Boeing Company (The) (2)*
Seattle, Washington

General Dynamics Corporation
San Diego, California

General Dynamics Corporation
Ft. Worth, Texas

General Electric Company
Phoenix, Arizona

Giddings & Lewis Inc.
Fond Du Lac, Wisconsin

Hughes Aircraft Company
Tucson, Arizona

Hughes Aircraft Company
Culver City, California

Kaiser Aerospace & Electronics
San Leandro, California

Ling-Temco-Vought, Inc.
Dallas, Texas

Lockheed Aircraft Corporation (2)*
Burbank, California

Lockheed-Georgia Company
Marietta, Georgia

Lockheed Aircraft Corporation
Sunnyvale, California

Los Angeles Pierce College
Woodland Hills, California

Martin Company
Orlando, Florida

Menasco Manufacturing Company
Burbank, California

McDonnell Douglas Corporation
Santa Monica, California

McDonnell Douglas Corporation
St. Louis, Missouri

North American Rockwell Corporation
Anaheim, California

North American Rockwell Corporation
Downey, California

North American Rockwell Corporation (2)*
Canoga Park, California

North American Rockwell Corporation (3)*
Los Angeles, California

Northrop Norair
Hawthorne, California

Northrop Ventura
Newbury Park, California

Pratt & Whitney Aircraft
West Palm Beach, Florida

Sandia Corporation
Albuquerque, New Mexico

Solar/Div. of International Harvester
San Diego, California

Tinker Air Force Base
Oklahoma City, Oklahoma

Union Carbide Corporation
Oak Ridge, Tennessee

Western Electric Company, Inc.
Oklahoma City, Oklahoma

Westinghouse Electric Corporation
Sunnyvale, California

( )* more than one visit

SEE APPENDIX, PAGE A-17

CODE SHEET FOR PROJECT TIME CARD

(USED BY EMPLOYEES FOR RECORDING HOURS ON DAILY TIME CARDS)

DIRECT LABOR	1000
INQUIRIES	1100
ENGINEERING SUPERVISION*	1110
Inquiry Stragety and Inquiry Approval	1111
MACHINING DATA ANALYSIS	1120
Answering Inquiries	1121
DATA PROCESSING	1130
Keypunching	1131
Verification	1132
Sorting	1133
Coding	1134
Decoding	1135
Computer Processing	1136
DATA CONTROL	1140
Forms and Document Handling	1141
DATA ACQUISITION*	1150
Special Acquisition for Inquiries	1151
REPRODUCTION*	1160
Xerox	1161
Ditto	1163
Drawing	1165
SYSTEMS ANALYSIS	1170
Technical Review	1171
Cost Evaluation	1172
VISITS TO AFMDC – TECHNICAL*	1180
Manufacturing Technology Division	1181
Others	1182
ORIGINAL DATA ENTRY	1200
ENGINEERING SUPERVISION	1210
Technical Planning	1211
MACHINING DATA ANALYSIS	1220
Preliminary Screening	1221
Preliminary Technical Evaluation	1222
Final Technical Evaluation *(put Document Control No. on Daily Time Slip)*	1223
DATA PROCESSING	1230
Keypunching	1231
Verification	1232
Sorting	1233
Coding	1234
Decoding	1235
Computer Processing	1236
DATA CONTROL	1240
Forms and Document Handling	1241
REPRODUCTION	1250
Xerox	1251
Drawing or Data Sheets, etc.	1253
SYSTEMS ANALYSIS	1260
Technical Review	1261
Cost Evaluation	1262
Data Acquisition Evaluation	1263
DATA ACQUISITION – LITERATURE	1270
Industrial Contributors of Machining Reports and Case Histories	1271
Domestic Periodical Literature	1272
Foreign Periodical Literature	1273
Industrial Trade Literature	1274
Technical Institutions, Professional Societies, and Associations	1275
Publishers of Handbooks, Manuals, Books	1276
Information Centers	1277
Government Agencies	1278
Machinability Laboratories	1279
DATA ACQUISITION – BY TECHNICAL PERSONNEL	1280
Plant Visits	1281
Telephone, TWX, Telegram	1282
Letters	1283
Technical Meetings (Machinability)	1284
Technical Meetings (Information Science)	1285
Foreign Plant Visits	1286
Foreign Technical Meetings	1287
Industry Special	1288
DATA STORAGE	1290
Document File	1291
Support Information (Books, etc.)	1292
GENERAL DISSEMINATION OF MACHINABILITY DATA AND CENTER INFORMATION	1300
Publication in Technical Literature	1310
Presentation at Technical Meetings	1311
Presentation at Plants	1312
AFMDC Exhibits	1320
Newspapers (Metalworking, etc.) & Magazines	1330
User List (Technical Aspects)	1340
User List Products	1350
AFMDC Pamphlets, Announcements, etc.	1360
Special Reports (State-of-the-art, etc.)	1370
Bibliographies	1380
AFMDC SYSTEM REPORTS AND MEETINGS	1400
Monthly (MTD)	1410
Quarterly (MTD)	1420
Annual (MTD)	1430
Operations Manual	1440
Detailed Code Book	1450
AFMDC Meetings	1460
Manufacturing Technology Division and Information Branch Meetings, Reports, and Conferences	1470
Special Reports for Manufacturing Technology Division, DCD, etc.	1480
MACHINING DATA VERIFICATION - EXPERIMENTAL (Provisional - presently inactive)	1500
Planning	1501
Testing	1502
Reports	1503

Put Inquirer and Sequence numbers in Operation space on Time Card. The Inquirer No. and Sequence No. are those blocked out at the top of IF-1 as shown here:

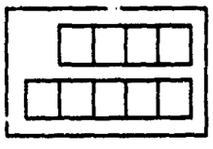


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FIGURE 28

CODE SHEET FOR PROJECT TIME CARD *(continued)*

SYSTEMS ANALYSIS - GENERAL	1600
1130 Computing System (Systems Aspects)	1610
Statistical Program for Analysis of Center Effectiveness (SPACE)	1620
1130 Computing System (Technical Aspects)	1630
INDIRECT LABOR	0000
General Repair, Cleaning, Painting	0101
Training	0102
Sickness or Excused Absence	0103
Vacation	0104
Acquisition of Major Facilities and Equipment	0105
Acquisition of Minor Equipment and Supplies	0106
Proposals and Setting Up Programs	0116
Technical Meetings and Papers (not directly related to AFMDC)	0127
General AFMDC Clerical and Office Work	0128
General AFMDC Administration	0150
Typing and Clerical on Inquiries	0151
Typing and Clerical on Original Data Entries	0152
Handling of Mail	0153
Personnel (Hiring, etc.)	0154
User File (Typing and Clerical)	0155
Visitors (Transportation, System Demonstration, General AFMDC Information)	0156
Data Processing (Time Cards, etc.)	0157
Typing and Clerical on User Products	0158
Miscellaneous AFMDC Nonchargeable Services	0159
Library-Support Information	0160

PURCHASES

For Purchases precede code by: 800

Examples:

800-1230 IBM cards for data processing, etc.
800-0000 Indirect charges such as general supplies
800-1272 Purchase of domestic periodical literature

FIGURE 20 (cont.)

AFMDC DAILY TIME SLIP

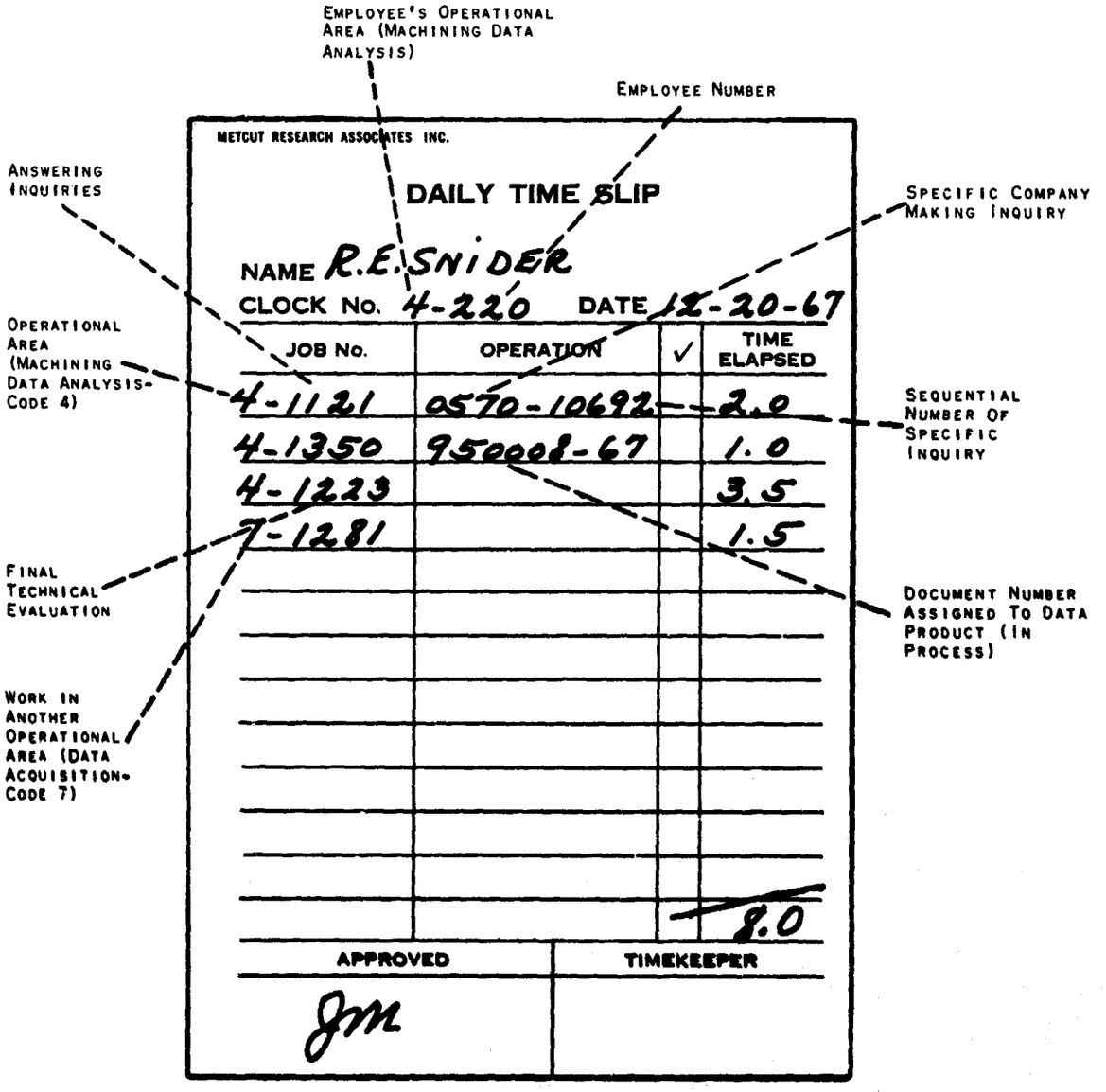

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FIGURE 20

FIGURE 10

COMPUTER PRINTOUT OF AFMDC PROJECT TIME CARDS

PROJECT CLASS	LABOR TYPE	EMPLOYEE NUMBER	EMPLOYEE INFORMATION FIRST-NAME-LAST	ELAPSED HOURS	DATE	PROJECT NUMBER-INDEX	LIST PAYROLL
5 1251	I	5 383	D DERICKSON	1.50	I 31 68	950999 68	
5 1261	I	5 383	D DERICKSON	1.00	I 31 68	950999 68	
		5 383		2.50			***
5 1156	I	5 384	C CROCKETT	4.00	I 22 68	950999 68	
5 1252	I	5 384	C CROCKETT	1.00	I 23 68	950999 68	
5 1650	I	5 384	C CROCKETT	2.50	I 30 68	950999 68	
		5 384		7.50			***
4 1121	I	4 240	A F ACKENHAUS	0.50	I 31 68	0492 10115	
4 1121	I	4 240	A F ACKENHAUS	1.50	I 31 68	0047 10129	
4 1121	I	4 240	A F ACKENHAUS	2.50	I 26 68	0039 10003	
		4 240		4.50			***
4 1223	I	4 235	C MEHL	2.00	I 29 68	950999 68	
4 1223	I	4 235	C MEHL	5.00	I 24 68	950999 68	
4 1223	I	4 235	C MEHL	8.50	I 25 68	950999 68	
		4 235		15.50			***
4 1121	I	4 220	R SNIDER	1.00	I 26 68	0062 10126	
4 1121	I	4 220	R SNIDER	1.00	I 26 68	0171 10131	
4 1121	I	4 220	R SNIDER	1.00	I 26 68	0708 10128	
4 1121	I	4 220	R SNIDER	1.00	I 26 68	0330 10127	
		4 220		4.00			***
2 1111	-	2 101	J MARANCHIK	2.00	I 29 68	950999 68	
2 1211	-	2 101	J MARANCHIK	2.00	I 29 68	950999 68	
		2 101		4.00			***
			DECK TOTAL HOURS =	58.00			

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AFMDC OPERATING COSTS

FEBRUARY 1, 1967 - JANUARY 31, 1968

INPUT COSTS		
TECHNICAL EVALUATION		$ 23,311.61
DATA PROCESSING		14,732.75
DOCUMENT ACQUISITION & REPRODUCTION		12,720.60
		50,764.96
EQUIPMENT, SUPPLIES & SERVICES		9,600.00
	TOTAL	$ 60,364.96
OUTPUT COSTS		
INQUIRIES:		
TECHNICAL EVALUATION		$ 40,337.82
DATA PROCESSING & RETRIEVAL		12,558.87
DATA ACQUISITION & REPRODUCTION		5,793.13
		58,689.82
GENERAL DISSEMINATION OF MACHINABILITY DATA & CENTER INFORMATION		6,934.32
USER LIST PRODUCTS:		
DATA PRODUCTS IN PROCESS		9,808.82
AFMDC SYSTEMS REPORT		1,183.30
SECOND ANNUAL REPORT - PREPARATION COSTS		5,418.55
SECOND ANNUAL REPORT - PRINTING COSTS		715.00
AFMDC, MTD,& INFORMATION BRANCH MEETINGS & SPECIAL MTD REPORTS		4,109.52
		86,639.43
EQUIPMENT, SUPPLIES & SERVICES		12,122.31
	TOTAL	$ 98,761.74
SYSTEMS ANALYSIS, MODIFICATION & CONTROL		
TECHNICAL EVALUATION		1,997.87
DATA PROCESSING - IBM 1130 COMPUTING SYSTEM:		
TECHNICAL ASPECTS		919.33
SYSTEMS ASPECTS		8,474.85
DATA ACQUISITION		1,972.08
OPERATIONS MANUAL & CODE BOOK REVISIONS & ADDITIONS		665.97
		12,030.20
EQUIPMENT, SUPPLIES & SERVICES		1,027.81
	TOTAL	$ 13,057.81
TOTAL ACTUAL COSTS NOT INCLUDING FIXED FEE		$ 172,784.51

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FIGURE 31

APPENDIX

Description of AFMDC (page 1)

This description of AFMDC is distributed by the Center in the form of a pink flyer (3-1/2" x 7-1/2") with the information relating to Scope, Collection, and Information Services on one side of the card and with instructions on how to request machining information from AFMDC on the other side. The pink flyer is convenient in size which makes it possible to include it in all types of mailings and to use it for handouts at meetings and for Center visitors. Various plants have also used AFMDC flyers to acquaint machining personnel with Center services.

By including detailed information on how to request machining information, it is hoped that some loss in time can be avoided and that the search strategy required will be simplified. Information shown on page 1 has also been furnished for the Air Force Materials Information Centers (AFMIC) booklet, March 1967.

AFMDC Organization Chart (Figure 1, page 2)

This Organization Chart is self-explanatory, but certain comments may be helpful toward gaining a fuller understanding of the basic plan. One of the most important aspects of AFMDC's organization relates to use of engineering personnel. These persons are professionally trained, experienced people who have the capability of judging the value of machining information for input purposes and to make technical analyses of output used for answering specific inquiries as well as developing data products.

Systems Analysts are employed on a part-time basis, with emphasis being placed in three areas: 1) Data Processing, 2) Document Processing, and 3) Data Acquisition. Consultants are used to a limited extent.

Up to the present time, almost complete emphasis on document acquisition has been given to domestic considerations. Since the foreign literature and foreign efforts relating to machinability are significant, this area has been covered by using a consultant to report on foreign trends as they may influence need for domestic cognizance.

The Organization Chart indicates requirements for employing one additional Machining Data Analyst. Since AFMDC is operated by Metcut Research Associates Inc., full advantage is taken of the capabilities of Metcut personnel not associated with AFMDC on a full-time basis. This includes Dr. Michael Field, president of Metcut, Mr. Norman Zlatin, vice-president of Metcut, Dr. John F. Kahles, vice-president of Metcut, and Mr. John Christopher, who is a project engineer in charge of experimental machining data being developed at Metcut.

Since metal removal is a very complex technical discipline, it is obvious that not all of the capability required can be centered in one organization, and therefore use has been made of part-time analysts located at several companies.

Two important areas of AFMDC systems are document acquisition and data processing. Document acquisition is responsible for acquiring input from both domestic and foreign sources covering the entire broad scope of machining information required to meet the output of the Center. Data processing is a key function required for storage and retrieval of the detailed evaluated and coded information extracted by Machining Data Analysts. Mechanical processing of data was accomplished prior to July 1, 1966, by Electrical Accounting Machine (EAM) equipment. Part of this equipment now supports the IBM 1130 computer, which is the medium for storage and retrieval of processed information.

From an information point of view, the Organization Chart also reflects handling aspects of information which do not require full-time activity. Trained competent secretarial personnel handle activities of the files pertaining to inquiries and data products. The Organization Chart indicates a requirement for a part-time data processing clerk.

Part-time Systems Analysts are used to develop required computer programs and systems evaluation of current operations. Capability of full-time engineering and data processing personnel has been developed to supplement the effort now being expended by part-time Systems Analysts.

AFMDC Operational Areas (page 3)

Each of the functional areas of operation of AFMDC has been assigned a code number from 1 through 9 and 0. These time codes are used in connection with the codes shown in Figure 28, pages 41 and 42, Code Sheet for Project Time Card. For example, a Machining Data Analyst in functional area No. 4 who is answering inquiries will use the code 4-1121. If a Machining Data Analyst in area No. 4 is performing in another operational area, such as assisting in technical aspects of document acquisition by obtaining data from industrial plants (see Figure 28, time code 1281), he will use the time code 7-1281. Since the project time card also includes his employee number and the operational area in which he functions, it is possible to determine the extent of time spent by employees in their principal assigned area as compared with time they spend in other functional areas of the Center (see actual Daily Time Slip, Figure 29, page 43). More important, the stored punched card information from the project time card is valuable in providing detailed analyses of the various cost aspects pertaining to the Center's operation.

AFMDC Operations Chart (Figure 2, page 4)

Basically the Operations Chart divides functions into two principal parts: 1) System Input, and 2) System Output. The other function shown in the heading is System Analysis and is linked to input and output to insure and measure the effectiveness of the two major functions. All sources of information are referenced as 'documents' regardless of whether they are journals, books, technical reports, data sheets, microfilm, abstracts, etc.

System Input consists of the steps shown in Figure 2 which are designed to accept any type of document from any source and process it so that each document becomes an entity within the system. The steps are set so that documents may be evaluated as to the nature of the information contained in view of the computer programs and codes which were established and are modified by System Analysis. In the preliminary screening step judgments are made by engineering personnel as to whether documents received at AFMDC have valuable machining information. The selected documents are then sent on to engineering personnel for technical evaluation and the important information is extracted and recorded using established codes and formats.

Due to the large backlog of unprocessed documents on hand at the beginning of operation of AFMDC, a decision was made to process documents through the step called Preliminary Technical Evaluation. This evaluation identified only seven parameters of a machining situation, if available, 1) machining operation, 2) material hardness, 3) material condition, 4) heat treatment, 5) material group, 6) material description, 7) tool material. At this step all documents were assigned uniterms where applicable to describe the text to the system. These uniterms, together with the source control number, are punched into card formats. Examples of computer printouts of searches made on the Preliminary Technical Evaluation and Uniterm Files are shown in Figures 8 and 9, pages 11 and 12. This mode of evaluation allowed for rapid access to documents in AFMDC storage. As of April 1, 1967, the Preliminary Technical Evaluation step was eliminated and all incoming documents selected in Preliminary Screening are routed directly to Final Technical Evaluation. In this phase of the processing all of the significant reported information for each machining situation is extracted, including numerical data and tool geometry. The extracted information is placed on the forms shown in Figure 5, page 8. These forms are given to a keypunch operator who punches cards which will be stored on the computer. A printout of this type of information is shown in Figure 10, page 13.

System output consists of the three basic types of output: 1) specific inquiries, 2) data products, and 3) general dissemination. Specific

inquiries may be submitted to AFMDC by anyone qualified as a User of AFMDC. The request may be for specific data for a machining situation or series of machining operations, state-of-the-art studies, etc. A list of the types of inquiries is shown in Figure 15, page 19.

Data products are published by AFMDC on timely subjects which are comprehensive studies and generally take the form of charts of data for one or more alloys. The charts contain all the known data for machining parameters, tool geometry, cutting fluid, tool material and other considerations directly applicable to the machining situation. When data products become available a notice is sent to every individual on the User File. Through this notice the User is made aware of information that may be applicable to his needs.

General dissemination takes the form of plant visits for coordination (see page 40), writing technical papers or preparing exhibits for presentation at meetings or presentation in the literature. AFMDC is always open to visitors and technical personnel are available to discuss various problems in detail and to show the User how AFMDC can assist his operation.

AFMDC User File Map (Figure 3, page 5)

The User File map shows the number of organizations per state and the total number of individual Users in those organizations per state. These figures include Industrial Firms, Government Agencies, Universities, Colleges, other Centers, Publishers and Societies. Four states have no Users and 21 states have 10 or less organizations. As would be expected, the heavy concentration of Users is in heavy industrial sections and the West Coast aerospace industry.

Distribution of AFMDC User File (page 6)

The basic User File was developed by using the following sources:

World Space Directory, Volume 3, No. 1 - This directory contains a large index of plants associated with the aerospace industry. An important section lists the "Major Missile and Space Manufacturers". Request forms were sent to key people in all of the company listings in this section, and provision was made in the form allowing for listing additional personnel, personnel from other divisions, and major subcontractors.

Manufacturing Committee of the Aerospace Industries Association, Washington, D. C. - This is an important aerospace group which has need for machining information in the solution of their common industry problems.

The American Society for Engineering Education (including members of the Engineering College Administrative Council, Engineering College Research Council, Technical Institute Council and Industrial

Members) - Letters were sent to the deans of all of the important colleges which have significant interest in machining through departments such as: Aeronautical Engineering; Ceramic Engineering; General Engineering; Industrial Engineering; Mechanical Engineering; Metallurgical Engineering; Pre-Engineering; Engineering Extension Groups; Control, Computer and Information Science Departments; Material and Engineering Sciences; and Technical Engineering Institutes and Engineering Research Groups oriented in disciplines of materials and material removal. Products of the Center have been helpful to college students, some of whom are already engaged in time standards work, manufacturing engineering, etc., in cooperative work programs and in summer jobs. Even more important is the fact that the training of engineers and thus their future professional performance will be influenced through AFMDC's activities.

Information Sources - Listings were compiled from "A Directory of Information Resources in the United States", National Referral Center for Science and Technology, Library of Congress, January 1965. The prime function of the Referral Center is to direct people to the proper information sources, including Centers, in the United States. Their directory contains a large listing of Centers, Technical Societies, Government agencies, etc., which in turn disseminate information to their various clientele. This directory was reviewed and selections for the User File were made.

1964 "ASM Index for the Review of Metal Literature" - This list includes societies and trade publications in the United States, and from it selections were made of those concerned with material removal.

Manufacturing Technology Division, Wright-Patterson AFB, Ohio, Report Distribution Lists - It should be noted that these distribution lists include other Departments of the Air Force, the Departments of the Army, Navy, Defense, and other Government agencies.

Inquirers - People who request information from AFMDC are termed 'inquirers'. New inquirers not already listed in the User File are added to it. Since there have been 2,333 inquiries during the 3-1/3 years operation of AFMDC, it is quite obvious that the file will grow considerably from this source alone.

Materials Advisory Board (MAB) Committee on Manufacturing Requirements for Aerospace Materials and the Ad Hoc Committee on Aerospace Manufacturing Requirements - This group was contacted because of its importance in manufacturing planning at a national level.

In order to keep the User File current, each individual on the User File is periodically contacted to ascertain whether he wishes to continue to be listed and whether there are any changes in position and address. The last such survey was accomplished in November 1967. Names are added to the User File as a result of: 1) inquirers, 2) visitors, 3) additional names submitted

by current users, 4) requests resulting from dissemination of data products, and 5) technical articles published in periodicals and announcements pertaining to the Center.

Page 6 indicates that there are a total of 4, 026 individual users from a total of 1, 526 organizations.

Computer Input and Output Flow Chart (Figure 4, page 7)

The flow pattern described in this diagram gives a picture of the goals of AFMDC. All documents with detailed data are given to a Machining Data Analyst so that this data may be extracted and placed in "Data Code Forms", see Figure 5, page 8. This information is then punched on cards from which the disk files are generated.

The flow chart indicates Preliminary Technical Evaluation, a phase in document processing. While this step has been eliminated for incoming documents, it is shown because there is still a backlog in the files of documents which were processed as far as Preliminary Technical Evaluation prior to April 1, 1967.

Data Code Forms for Final Technical Evaluation (Figure 5, page 8)

Figure 5 is a photograph showing both the front and back of Data Code Forms used as an intermediate step between the original document and the punched cards used as input to disk storage. The formats are designed to handle alphameric information required for some parameters and decimal numbers for others, as well as integers. These formats and a book with codes enable the Machining Data Analyst to concisely identify the important information regarding a specific machining situation. Required decimals are set in the numerical data fields, thereby further simplifying recording of the data. These forms are then passed to the keypunch operator, who punches the information contained in them into Index, Tool-Cutting Fluid, and Numerical Data Cards.

These, plus the additional cards used by AFMDC are described as follows:

Card	Description
0 Inquiry	**The Inquiry Card is punched with the inquiry information desired and is used by matching key indices in exactly the same columns as information which would have been precoded into the System.**
1 Index	**The Index Card establishes information available in the System by preassigned data index columns and respective codes to be matched against inquiries.**

Card	Description
1 Index (cont.)	The Index Card describes the machining situation including the machining operation, specific material designation, hardness, condition, heat treatment, and broad material group. In addition to the above "minimum requirements", the Index Card also includes the part configuration code, tool material, machine tool description, and the control codes. The control codes provide information on the data source, its classification and index controls which allow for retrieval monitoring. The primary method of access into the AFMDC information decks is through the Index Card.
2 Tool - Cutting Fluid	This card defines tool size, shape, and geometry, as well as the trade name and manufacturer. It also identifies the trade name of the cutting fluid, the manufacturer, and the concentration of the cutting fluid.
3 Numerical Data	The Numerical Data Card contains actual values of machining variables, such as feeds, speeds, depth of cut, hole size, tool life, etc.
4 Uniterm (key word)	This card alphabetically describes special technical significance of a document not covered by categories included on the Index, Numerical Data, and Tool-Cutting Fluid Cards.
5 Data Link	This card provides means for eliminating the recording of data relevant to different topics or sources. Data are encoded and stored under one control code.
6 Aperture	The Aperture Card is used to store and retrieve microfilms of pertinent curves, drawings or any information best stored in a graphic manner.
7 Bibliography	The Bibliography Card set is designed to present the Source Document in a formalized, uncoded manner.
8 Potential Source of Information	This card records into the System information on contracts awarded and other work initiated or in progress which are considered potential information sources. In this manner, the card helps direct an active data acquisition program. It also serves as a card to store certain bibliographic information such as author and organization.

Card	Description
8 Visitor	This card has the same format as the Potential Source of Information Card and therefore serves not only to develop a Visitor File but can and is used to identify visitors as inquirers and/or potential sources of information.
9 Tickler	The Tickler Card is generated at the time machining information is committed to the System primarily as a review device for updating, purging, etc., but also for checking on commitments for potential sources of information. Dates for tickler review of data committed to the System are based upon the times related and shown in the Classification Code.

Flow Chart for Fortran Program to Store, Add or Search Inquiry File (Figure 6, page 9)

The flow chart of the inquiry program is an example of the storage and search techniques used by AFMDC on the IBM 1130 computer system. These programs have two basic sections: 1) to create files into which data may be stored, added to and deleted from, and 2) to set up a procedure for searching the data files. Discussion of the inquiry program follows:

1) Create data file and store additional cards to file. Console Data Switch No. 0 controls loading of a new deck of cards to create an original file. This file is created in a file protected disk area called "User Area". At the end of each month, inquiries for that month are coded and cards punched. The additional cards are then loaded at the end of the file. Console Data Switch No. 1 is used to control this function of the program. By this procedure, the Inquiry File is only one month behind any inquiry ever submitted to AFMDC.

2) Search Routine - Since the load and add functions of the program are to by bypassed, Data Switch No. 0 and Data Switch No. 1 are turned off. Control of the parameters to be matched in the search are then selected through the use of Data Switches No. 2, No. 3, No. 4 and No. 5. All or any combination may be selected by the operator as specified by the Machining Data Analyst. These Data Switches (D. S.) control matches for: Specific Machining Operation (D. S. 2); Specific Material Group (D. S. 3); Specific Material Description (D. S. 4); and Uniterm (D. S. 5). Through the use of the Data Switches the computer may be used to narrow the selection of documents if the initial search output yields too many references. This concept is fundamental to all of the search programs operated by AFMDC.

Inquiry File Search (Figure 7, page 10)

The Inquiry File which, as of January 31, 1968, contained data pertaining to 2,333 inquiries is a very important AFMDC file. Search of this file can prevent duplicate effort in answering identical inquiries or provide assistance in answering those having similarity.

Figure 7 shows the use of Data Switches described in Figure 6, page 9, as they were utilized to make broad and then selective searches on the Inquiry File. The first search was made on the uniterm, CUT FLUID, by having Data Switch No. 5 in the 'on' position. When the file was interrogated the machine selected and printed all inquiries for which the uniterm, CUT FLUID, was used. To be more selective on the second search, material group 301 (NICKEL BASE HIGH TEMPERATURE ALLOYS) and material description INCO 718 were added to the CUT FLUID uniterm on the search card. In the third search, the machining operation requirement was added so that now the search was concentrated on a specific operation, on a specific material group, one specific material description and a uniterm requirement. From this type of search, the computer finds a precise match and prints that information. The number on the right is a unique number to that inquiry so the information may be reached quite rapidly.

Output of Preliminary Technical Evaluated Data (Figure 8, page 11)

Figure 8 shows a printout of specific searches on the Preliminary Index File.

The Preliminary Index File contains six possible terms which can be searched in any combination. Preliminary Technical Evaluation is designed to identify, if available, 1) machining operation, 2) material hardness, 3) material condition, 4) heat treatment, 5) material group, 6) material description, and 7) tool material. With the exception of material condition, an engineer may set up a search strategy to interrogate the file on any combination of the other six parameters. When a match is found, the source control code will be printed and the document pulled from the file. The Preliminary Index search shown in Figure 8 was made on an operation, DRILLING (085) of NICKEL BASE HIGH TEMPERATURE ALLOYS (material group 301).

Output of Uniterm File Search (Figure 9, page 12)

The uniterm concept was designed so that technical text important to material removal operations could be stored and retrieved. Each document is assigned uniterms (keywords) which describe the nature of the text. These uniterms are punched into cards which are stored on disks.

A second card is generated indicating the machining operations and material groups associated with the given uniterm. Thus, a selective search can be made linking a particular uniterm to a specific machining operation and/or a material group.

A master list of the uniterms is contained in the code book so that search strategies may be set up. A search can be made on a single term or on two terms simultaneously. These terms may be in any position within the card set. The search shown in Figure 9 is for the Uniterm, TOOL GEOMETRY (TOOL GEOM) for a given operation, DRILLING (085) of NICKEL BASE HIGH TEMPERATURE ALLOYS (material group 301). On the right hand side of the computer printout are the source control codes for the documents containing the desired information.

Output of Final Technical Evaluated Data (Figure 10, page 13)

Figure 10 is the computer printout of decoded information which has been extracted from a document which received Final Technical Evaluation. Note that the information extracted by the Machining Data Analyst and coded on the forms in Figure 5, page 8, is now computer decoded and printed out. The first line of data describes the inquiry to the file. The second line is the AFMDC match of the inquiry search terms on the stored Index card. The succeeding lines are the retrieved Tool Geometry, Tool Material, Cutting Fluid, and Numerical Data associated with the particular machining situation described in the Index card. The coded integers stored from punched cards are matched against another file on the disk resulting in the alphameric equal being printed on the output sheet.

The headings are printed and the retrieved information in the data cell is printed in the proper location. Coded integers are matched against another file on the disk resulting in the alphameric equal being printed on the output sheet. It is anticipated that this type of printout will be used to answer some inquiries directly later this year.

Cost and Production Rate for Milling(Figure 11, page 14)

The use of data shown in Figure 10 leaves something to be desired for the manufacturing engineer. The printout gives a series of values to choose from but does not clearly indicate the economics involved. Since the major reason for having adequate data is to help minimize the cost, the logical question is which set of values will yield the minimum cost. A basic equation has been developed which considers the economics of each significant element of a machining operation and determines the production cost and production rate. The output gives the cost and production rate and the value of elements which make up the total cost. These values give the

engineer an opportunity to analyze the elements so that he may decide where the major contributors to the total cost lie and then work on the critical areas.

Equations have been written and computer programs have been developed and made operational for five major conventional chip removal operations. The particular operations are turning, milling, drilling, reaming and tapping. Available representative hard data are being processed using these computer programs in connection with a data product being developed on this subject. This data product will be completed and published about June 1968.

Cost Study Analysis of IBM 1130 Computer (page 15)

As a result of a request made by the Office of the Director of Defense Research and Engineering, Department of Defense, a cost study was conducted by AFMDC to determine the increase in effectiveness resulting from the installation of the IBM 1130 computing system. Prior to installation of the IBM 1130 computer the data processing equipment utilized was designated as an IBM Series 50 configuration. This consisted of a keypunch, verifier, sorter, collator and an electrical accounting machine.

A review was made of the various aspects of the AFMDC system and judgments made pertaining to those aspects which were affected, timewise, by conversion from the IBM Series 50 configuration to the IBM 1130 computing system. It was judged the following aspects were affected: a) inquiry processing and b) calculations for production rates and machining costs.

The statistics shown on page 15 indicate that a savings of over $13,000 for a one-year period was effected by installation of the IBM 1130 Computer. These important cost savings are the result of time saved by engineering and data processing personnel and are reinvested in the AFMDC operation. This is reflected in the continual and substantial rise in the ratio of output to input costs, thus providing more extensive services for the expended funds.

Inquiry Processing Flow Chart (Figure 12, page 16)
and
Typical Inquiry Input and Response (Figure 13, page 17)

Responses to inquiries are the most important of the services provided by AFMDC. Strong emphasis is placed on providing specific and detailed answers to technical inquiries which are transmitted by letter, telegram, telephone or by direct visitation to the Center. A high percentage of the

inquiries is made via telephone, some because of the urgency of information requirements and others due to the necessity of discussing technical details with the engineering personnel. When required, inquirers are contacted to clarify their specific needs. As indicated in Figure 12, page 16, engineering personnel impose judgments on the inquiries and establish the search strategies. Data Processing personnel perform the computer search functions and provide the printouts to the engineers. The engineers again impose engineering judgment in the selection and preparation of the information to be transmitted to the inquirer.

An inquiry form and the AFMDC response are shown in Figure 13, page 17. Note the codes within the blocks on the form which are keypunched and then stored on the computer inquiry file.

Analysis of Inquiries by State (Figure 14, page 18)

The analysis of inquiries by state, Figure 14, page 18, provides some interesting and informative statistics. AFMDC has received inquiries from 42 states and the District of Columbia. Over the period of October 1, 1964, through January 31, 1968, there have been 2,333 inquiries received and processed by AFMDC. These inquiries have originated from 910 different organizations and 1512 individuals within these organizations. It is interesting to note that 79% of the total inquiries and 78% of the company and individual inquirers were from 10 highly industrial states, as would be expected. The specific inquiry statistics for these 10 states are shown in Figure 14, page 18.

Summary of Specific Inquiries by Type of Inquiry (Figure 15, page 19)

The statistics shown in Figure 15 point out several important factors. There has been a constant and substantial rate of growth in the number of inquiries received and processed at AFMDC. The average was 37 per month during the first 16-month period of the Center's operation. This average increased to 61 per month for the ensuing year and rose to an average of 84 per month during the last 12-month period. This growth has largely been the result of multiple inquiries from prior users, new contacts from companies already on the inquiry file and contacts from companies who have not previously submitted inquiries to AFMDC. Many of the new contacts can be attributed to "word of mouth" communication of AFMDC inquirers with persons who are in the field of machining.

Another factor responsible for this growth has been the AFMDC plant visitation program and participation in technical conferences.

In addition to providing information on the varied services available at AFMDC, Figure 15 indicates trends in the nature of inquiries from October 1964 to the present. In particular, it has been noted that inquiries are becoming more specific and are concerned with more complex and difficult machining situations. The relative increase in inquiry types 1, 2, 3, 15 and 16 bears out this conclusion.

The inquirer profile has also been relatively changing. A higher percentage of inquiries are being received at AFMDC from lower echelon personnel such as manufacturing or tool engineers, industrial engineers and time standards personnel, process engineers, tool designers, shop supervisors and foremen, planners, estimators, etc. This indicates that AFMDC is achieving its objective of reaching and setting up a direct line of communication with not only management, but also with an increasing number of persons directly responsible for application of machining data and information available from AFMDC.

General Analysis of Inquiries and Analysis of Inquiries by Material Group (Figure 16, page 20)

The chart, General Analysis of Inquiries, provides perspective of the relative complexity of inquiries processed during the past two years. Of the inquiries related to given machining operations and material groups, over 75% were concerned with more than a single machining situation (one operation on one material group) for both years. Over one-third of the inquiries were of the uniterm (keyword) type.

The Analysis of Inquiries by Material Group helps to provide AFMDC with perspective of user needs, input requirements, and establishes priority and extent of detailed technical evaluation of the input. An analysis of the past two years' inquiries was made categorizing the materials involved by 15 material groups. Figure 16, page 20, shows that there has been a high level of interest for machining data on high temperature alloys, titanium alloys and refractory alloys. A high total of 814 requests was made for plain carbon and low alloy steels and ultra-high strength tool steels covering the two-year period. Information for stainless steels was in high demand as evidenced in the 451 requests. The 131 requests for machining information on nonmetallics represented a significant increase over the 57 requests processed the previous year.

Analysis of Inquiries by Type of Machining Operation (Figure 17, page 21)

Added perspective of user needs and in turn AFMDC input requirements is obtained by analyses such as shown in Figure 17. For conventional chip removal types of operations the statistics indicate that emphasis on input and detailed evaluation should be on turning, face milling, end milling, drilling, reaming, and tapping. The most significant relative increase in

interest by type of machining operation within the two years has been in broaching and in band sawing. For conventional grinding, the highest interest is shown in surface and cylindrical grinding operations. The total number of requests for all grinding operations more than doubled during the past year. The 235 requests for information on the alternate machining methods during the past year represents a substantial increase over the 144 for the previous year. These statistics are indicative of the increasing interests in these machining methods and alert AFMDC to an important area of its users' needs.

Analysis of Uniterm Type Inquiries (Figure 18, page 22)

A high percentage of the inquiries received at AFMDC are of the uniterm (keyword) type. This machining information is of the technical text type. The 17 subjects of highest interest for this type of machining information are shown in Figure 18, page 22. Very high interest has been expressed for information on surface integrity, numerical control, cutting fluids, surface finish and distortion. Very significant increased interest has developed during the two-year period for information concerning surface integrity and surface finish.

Summary of Specific Inquiries by SIC Number (Figure 19, pages 23 through 25)

An analysis of inquiries by type of industry utilizing the services of AFMDC is shown in Figure 19. The chart presents the inquiries by SIC Code, a number which references listings in the Standard Industrial Classification Manual, Executive Office of the President, Bureau of the Budget, 1967. While some SIC descriptions may appear completely commercial, an analysis of specific inquiries will indicate a close relationship to DoD requirements, as shown in Figure 21, page 27.

SIC Major Group No. 37, Transportation Equipment, is the predominant group with respect to utilizing AFMDC services. This group encompasses three significant industry users of AFMDC, namely; Aircraft and Missiles; Aircraft Engines and Engine Parts and Missile Engines; and Aircraft Parts and Auxiliary Equipment and Missile Parts. Other SIC Major Groups who provided relatively high quantities of inquiries to AFMDC during the past year are: 91 - Federal Government; 33 - Primary Metal Industries; 34 - Fabricated Metal Products Except Ordnance, Machinery and Transportation Equipment; 35 - Machinery, Except Electrical; 36 - Electrical Machinery Equipment and Supplies; 73 - Miscellaneous Business Services; 82 - Educational Services.

Potential for AFMDC Services to Industry (Figure 20, page 26)

The statistics shown in Figure 20 indicate that five major SIC Groups provide a vast potential for utilization of AFMDC services and they have been the

primary groups submitting inquiries to AFMDC. The left-hand side of the chart, Figure 20, provides a statistical summary of metalworking plants consisting of a partial SIC list taken from Dun & Bradstreet Metalworking Directory, 1967-68. The right-hand side of the chart summarizes AFMDC inquiries for the same SIC classifications.

As would be expected, the largest number of inquiries have been received from Major Group 37, Transportation Equipment. Four of the SIC Industrial Classifications within this group are: 3721 - Aircraft and Missiles; 3722 - Aircraft Engines and Parts; 3723 - Aircraft Propellers and Propeller Parts; and 3729 - Aircraft Parts and Auxiliary Equipment. A second significant source of inquiries is Major Group 35, Machinery Except Electrical. Some of the important industries included in this group are Machine Tools-Metal Cutting Types, Machine Tool Accessories and Measuring Devices and Machine Shops - Jobbing and Repairing. The statistics from Dun & Bradstreet's Metalworking Directory display a vast economic environment for AFMDC operations. Metalworking is the prime activity for five major groups alone, comprised of 9,431 companies (20 or more employees), employing 6,900,557 individuals. There are 20,063 other companies (20 or more employees), for which metalworking is a secondary activity. Dun & Bradstreet reports that 21,364 of the 38,383 listings in its Metalworking Directory perform machining operations. Although no specific statistics can be quoted, there is no doubt that there is even a larger number of firms (employing less than 20 individuals), whose major activity is machining. Considering that to date there has been a total of 910 organizations which have submitted inquiries to AFMDC speaks for itself regarding the potential increase in services that is possible to the machining industry.

Government Agencies and Services Supported Directly and Indirectly by AFMDC Inquiries (Figure 21, page 27)

The data shown in this chart are somewhat difficult to compile but by careful analysis of particular inquiries and by an analysis of the prime objectives of principal contractors at various plant locations it has been possible to show that 945 of the 1002 requests made to the Center were stimulated by Air Force, AEC, U.S. Navy, NASA, and U.S. Army projects.

Companies and Agencies Submitting Inquiries to AFMDC (Figure 22, pages 28 - 34)
Summary of Specific Inquiries by Companies Making Five or More Requests (Figure 23, page 35)

Figure 22 presents a total of 910 individual companies and divisions which have been inquirers of AFMDC, an increase of 305 organizations

during the past year. This is a comprehensive list. Figure 23 includes a summary of the 94 organizations (including the divisions) making five or more requests. This group has provided 1416 of the 2333 inquiries processed by AFMDC to date. This list reflects high interest in AFMDC information on the part of aerospace industry, as represented by companies such as Aerojet-General Corporation, The Boeing Company, Curtiss-Wright Corporation, General Dynamics Corporation, General Electric Company, Grumman Aircraft Engineering Corporation, Lockheed Aircraft Corporation, Martin Company, McDonnell Douglas Corporation, TRW Inc., and in fact Wright-Patterson Air Force Base itself.

Photograph of AFMDC Data Products (Figure 24, page 36)
Photograph of AFMDC Titanium Booklet (Figure 25, page 37)
Typical Formats for Data Presentations (Figure 26, page 38)

Planned data products have proven to be important output to AFMDC Users. In addition to providing valuable and timely data, these products serve as a direct line of communication with the Users of the Center. Excellent response has been received for the 11 data products prepared and issued to date. These products are shown in the photo in Figure 24, and the formats are displayed in Figures 25 and 26. Careful thought was given to the preparations of the products to present the machining recommendations in complete but concise form in order to make easy and effective use of them.

Description and Distribution of Data Products (Figure 27, page 39)

There were two primary means used for publicizing the data products. AFMDC prepared two separate data product announcements and sent them to the User File which now consists of 4026 individual names. The policy followed was to provide one free copy to Users who submitted a request and then charge for additional copies. The set limit of making 1000 free copies available proved to be practical inasmuch as all requests from the User File were able to be filled. A second means used for reaching persons who would have an interest in the data products was accomplished by sending copies of these documents to about 60 editors of technical periodicals. Each of these were encouraged to publish announcements of the products and print typical data sheets. This not only stimulated interest in the data products, but also in the Center's services in general. Numerous inquiries were submitted to the Center each time a periodical published the information provided by AFMDC.

The fine response for data products is indicated in Figure 27, page 39. A total of 15,729 copies were distributed, most of which were to the User File and some as direct response to inquiries. The 2538 copies sold are further evidence of the high interest and use of the data products.

Data Acquisition Plant Visit Program (page 40)

The information contained in page 40 covering this program is self-explanatory. An expansion of this type of data acquisition effort is planned for 1968 in view of the interest on the part of industry, the high yield of important data, and the contact with personnel resulting in an increase in specific inquiries.

Code Sheet for Project Time Cards (Figure 28, pages 41 and 42)
AFMDC Daily Time Slip (Figure 29, page 43)
Computer Printout of AFMDC Project Time Cards (Figure 30, page 44)

The code sheet provides the basic approach to AFMDC System Costing. Approximately 100 individual time codes are in current use. It has been simple for individuals to maintain time records because relatively few time codes are used by any one person during a given day and the use of the same codes is repeated from day to day. Figure 29, page 43, shows a Daily Time Slip which indicates the manner in which individuals record their time.

The information from these time slips is punched into cards and the information is stored in the IBM 1130 computer. Figure 30, page 44, is a computer printout of AFMDC project time cards.

Figures 31 and 32, shown on pages 45 and 46, reflect the use made of project time card data. These records are available for making even more detailed analyses when required. For example, it would be possible to analyze the cost for a particular project, such as a special report requested by DoD.

AFMDC Operating Costs (Figure 31, page 45)
AFMDC Input and Output Summary (Figure 32, page 46)

Figure 31, page 45, shows the operating costs for the past year broken down into three major groups: 1) Input, 2) Ouptut and 3) Systems Analysis, Modification and Control. The summary of these costs compared to two previous periods, as shown on page A-18, reflects the progress made by AFMDC since it began its operation.

Summary of AFMDC Operating Costs
October 1, 1964 - January 31, 1968

Operating Time Period	Input Costs	% of Total Cost	Output Costs	% of Total Cost	System Costs	% of Total Costs
Oct. 1, 1964 - Jan. 31, 1966	126,123.27	66.0	38,577.33	20.0	25,811.54	14.0
Feb. 1, 1966 - Jan. 31, 1967	99,697.76	45.5	88,154.70	41.0	29,230.40	13.5
Feb. 1, 1967 - Jan. 31, 1968	60,364.96	34.9	98,761.74	57.2	13,657.81	7.9

It is significant to note that the output costs rose from 20.0% to 57.2% over the three time periods, while the input costs decreased from 66.0% to 34.9%, and the systems costs dropped from 14.0% to 7.9%. This increased efficiency was gained through working experience, the build-up of AFMDC information files, and putting into operation the IBM 1130 computer. The net result of the relative decrease in input and systems costs has been that it allowed AFMDC to handle the continually increasing number of inquiries without sacrificing the quality of the responses and the response time period required by the inquirer. Over the three time periods inquiries have increased from an average of 37 to 84 per month.

The chart in Figure 32, page 46, presents various summaries of AFMDC input and output. As of January 31, 1968, there were 13,101 evaluated documents in AFMDC storage. The important information from these documents has been extracted, coded, and punched into 102,250 cards, and stored on the 1130 computer. Unit costs for preparation of 11 data products and for processing of inquiries are cited in Figure 32, page 46.

Future Planning (page 47)

One of the major goals of 1968 is to continue the effort to identify and make direct contacts with personnel in all echelons who can utilize machining information available from the Center. The methods used to accomplish this are outlined under Future Planning, page 47. Emphasis will be given to contractors, subcontractors and sub-subcontractors producing components for advanced aerospace vehicles. The approaches to be taken will undoubtedly stimulate inquiry activity and thereby continue the upward trend in inquiries being received by AFMDC. It is expected that the level of inquiries will

reach a monthly average of about 150 per month by the end of 1968 (the average for the past three months is 111). The program of plant visitation will be continued with increased emphasis on making the industrial user aware of the information at AFMDC which is available to him.

A considerable number of inquiries have been received from active State Technical Services Programs in Connecticut, Illinois, Indiana, Michigan, Tennessee, and West Virginia. In addition, AFMDC has directly participated in conferences and meetings conducted by the states of Illinois, Indiana and Michigan. Contacts will be made with other states which have such programs in operation or are in the process of setting up such programs. Fine coordination has been effected with the National Referral Center as well as various information centers. Communication with these centers will be maintained.

There has been substantial growth in vocational schools, as well as vocational courses offered by educational institutions. Many of these include training of students in machining who thereby become an important segment of the machining community. AFMDC will expand its services to these schools through the State Technical Services Programs and by direct contact.

Efforts on data products will be directed toward preparation of the four products listed under Future Planning since information seems to be lacking or widely scattered on these subjects.

Additional data products will be prepared as good timely information is accrued by AFMDC.

Experience has shown that there are some relationships in machining variables between the various types of machining operations and work materials, and they can be determined if careful analyses are made using substantial and reliable data. Manual analyses of this type are difficult and cumbersome. Determination of existing relationships would be very valuable for evaluation of new data and filling in gaps in accrued data. AFMDC plans to investigate these relationships. The computer resolves much of the difficulty and time required to make the subject analyses.

Preliminary discussions have been held with one aerospace firm concerning an experimental program of a computer data-link between the company and AFMDC. In this experimental program it is planned that mechanisms would be developed that would allow a firm to have direct communication with the Center's computer. This communication would make it possible for the user to directly submit and obtain an immediate response. The direct link with the user would facilitate machining information formats which would be compatible between the Center and the major users. A part of the planned program is to work out procedures whereby an organization could store its important machining data at AFMDC for its own rapid retrieval and for utilization by AFMDC for serving industry.

ECONOMIC ENVIRONMENT FOR AFMDC OPERATIONS

(Annual Costs)

Labor and Overhead Costs for Operating Metal Cutting Machine Tools in the Metalworking Industries in the United States

Total number of metal cutting machine tools in the metalworking industries (June 10, 1963, American Machinist Inventory of Metalworking Equipment) = 2,137,497

Average labor cost + overhead = $8.00 per hour
Average working day = 8 hours
Number of working days per year = 250
Average number of direct labor personnel per machine = 1

Total Cost of Labor + Overhead:
2,137,497 x $8.00 x 8 x 250 x 1 = $34,199,952,000 or about

$34,000,000,000

Based on the 1963 Inventory and actual 1964 and 1965 metal cutting machine tool shipments, American Machinist estimates that 2,500,000 machine tools were in use at the end of 1965. Using this projection, the $34,000,000,000 would be revised to $40,000,000,000.

Total Cost of Labor + Overhead:
2,500,000 x $8.00 x 8 x 250 x 1 = $40,000,000,000

$40,000,000,000

Total Shipments Including Exports of Metal Cutting Type Metalworking Machinery

$1,040,766,000 (1965)

Source: U.S. Department of Commerce

Machine Tool Accessories Industry

$971,000,000

(including small cutting tools for machine tools and metalworking machinery in the amount of $598,000,000)

Source: 1965 Census of Manufacturers
Bureau of Census

Cutting Fluids

$35,000,000

Source: "Coolant Control...a plant study plan" by B. F. Wilson, Automatic Machining, June 1965.

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	Manufacturing Technology Division Air Force Materials Laboratory Wright-Patterson Air Force Base, Ohio

13. ABSTRACT

This is the Third Annual Report of the Air Force Machinability Data Center covering the period February 1, 1967 through January 31, 1968 (Contract AF 33(615)-5262). Three thousand seven hundred and thirty-four (3,734) documents were processed from which twenty seven thousand and seventy-seven (27,077) cards were key punched. Currently there are 13,101 evaluated documents, and 102,250 punched cards in AFMDC files. One thousand and two (1,002) specific inquiries were answered for 485 different companies, representing 690 individuals in 96 different SIC categories. The 1,002 inquiries represents a 36% increase over the 736 processed in the previous year.

The average cost of inquiries equalled $52.66 per inquiry.

The data acquisition plant visit program was accelerated and since late 1966, thirty seven visitations have been made, primarily to aerospace firms.

Computer programs have been developed and made operational for storage and retrieval of all the information files in use by the Center. In addition, equations have been written and computer programs have been operational for calculating machining costs and production rates for five major machining operations, turning, milling, drilling, tapping and reaming.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Machining						
Management						
Data Center						
Information Center Costs						
Information Center Economics						
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