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UCAPP
UNION CARBIDE APT POST PROCESSOR
First Edition

AUTHORS:

RELEASED FOR ANNOUNCEMENT
IN NUCLEAR SCIENCE ABSTRACTS

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UNION CARBIDE CORPORATION
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Operating the

OAK RIDGE GASEOUS DIFFUSION PLANT • OAK RIDGE NATIONAL LABORATORY
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ABSTRACT

UCAPP, the Union Carbide APT Post Processor, is a computer program which processes the output of the APT computer system into control tapes for numerically controlled machines. It is generalized to handle a wide variety of N/C machines.

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1.0

INTRODUCTION

APT is a computer program or, more specifically, a sophisticated computer system consisting of a large collection of computer programs and a programming language for manipulating them.

It is by far the most powerful and widely used system for numerically controlled machines and is being continuously expanded and perfected by the Research Institute of the Illinois Institute of Technology and many of the APT users.

The APT language is used to describe surfaces, tools, and the sequence of motions to a computer which then calculates the coordinates of the desired path. These coordinates are then converted into a control medium such as punched tape for a specific numerically controlled machine. The last step usually requires that a special program be written for each specific machine.

The processing of the tool path coordinates, and other commands such as feedrate and auxiliary machine functions, into a machine control tape is called post-processing and the computer program which does it is called a post-processor. Many post-processors for specific machines have been written and a few have been written which will handle a variety of machines if all of them have the same type of control unit.

UCAPP, for Union Carbide APT Post Processor, is an initial effort toward a generalized post-processor that will handle a wide variety of numerically controlled machines regardless of the type of control unit. Also, it is designed to be set-up or modified with a minimum of time and effort to handle new capabilities or new type machines.

This project was started when a need developed for a post-processor to handle several types of drafting machines with different controls. The initial implementation and testing has been carried out for drafting machines but UCAPP is not restricted to any particular types of machine.

2.0

SUMMARY

An APT post-processor has been designed that is sufficiently generalized to produce control tapes for a wide variety of numerically controlled machines.

The logic is described in a manner to allow for easy implementation in different computer programming languages. The modular construction enables the post-processor to be readily expanded or contracted to fit the needs of the user or the size of the computer.

3.0

DISCUSSION

In UCAPP the basic concept of generality is achieved by incorporating a large "option" table and procedures for assigning values to these options. It is intended that the table contain all the parameters necessary to discriminate and control the significant variations among existing N/C machines and have extra space for machines or capabilities not yet available.

One important function of the option table is to identify a particular machine for which output is required on a given pass. This enables efficient and effective multiple postprocessing, utilizing only those part program statements applicable to the machine being processed. The computer then simply makes one post-processing pass for each machine.

All the values of the option table must be initialized in some manner. One could, of course, have the values preset to some "normal" and then in the part program make any necessary changes for a particular machine. Or, one could have "normal" sets for certain classes of machines where the classes are, say, types of control or type of machine such as lathes or mills. From the part-programmer's viewpoint, it may be desirable to have a preset "normal" for each machine so that, in principle, he has a specific post-processor for each specific machine. The latter case suggests that the MACHIN/ one word name statement be expanded over that now existing in APT.

In order to identify a specific machine out of a large set of machines and still have a meaningful name, the one word machine name has been expanded to a three-word name. The first word is the name of the manufacturer, the second word is the type of machine, and the third word is a model number or other in-house designation.

Some examples of the MACHIN statement are:

MACHIN/LEBLND, LATHE, NUM3

(Assuming the pre-set condition is "ON", a control tape for a LeBlond Lathe designated number 3 will be produced.)

MACHIN/GERBER, PLOTTER, VP1000, ON, CIRCUL, NOZ

(Starting at this point in the part program, and continuing until turned off, a tape for a Gerber Plotter Model VP1000 will be produced containing x and y coordinates and taking advantage of circular interpolation.)

One method of assigning options is illustrated in the MACHIN statement above. Options specified this way apply to that machine only. Another method is to use an OPTION statement such as:

OPTION/ 21, 2, 76, .025

which will set option No. 21 to the value 2 and option No. 76 to the value .025 for all "ON" machines. This requires that the part-programmer have access to a table of option numbers and their meanings though OPTION statements are needed for unusual circumstances only.

A list of all options is given in Section 7.0. A detailed list of the syntactical structure and statement types is given in Sections 5.0 and 6.0. It is expected that these lists will grow rapidly with experience, new machine requirements and increased system demands.

4.0

VOCABULARY

<u>Major word</u>	<u>code number</u>	<u>reference</u>
ARCSLP	1029	6.3.9
AUXFUN	1022	6.4.4
DELAY	1010	6.4.4
DISPLY	1021	6.7
DRAFT	1059	6.3.5; 6.4.1
END	0001	6.6.3
ERROR4	1082	6.3.10
FEDRAT	1009	6.3.8.
FINI	10	6.8
FORMAT	1081	6.8
INSERT	1046	6.7
LEADER	1013	6.4.4
LETTER	1043	6.3.7
MACHIN	1015	6.1
MESSAG	1044	6.7
OPSTOP	0003	6.4.4
OPTION	0144	6.3.4B
PARTNO	1045	6.3.1
PLOT	1041	6.3.6; 6.4.2
PPRINT	1080	6.5
PREFUN	1048	6.4.4
REWIND	1006	6.6.2
SEQNO	1019	6.3.2
STOP	0002	6.6.1
TRANS	1037	6.3.3

4.1

<u>Minor word</u>	<u>code number</u>	<u>associated major word</u>
ALL	51	MACHIN
ATANGL	1	LETTER
BLACK	0130	DRAFT
BLUE	0133	DRAFT
CIRCUL	0075	MACHIN
CTRLIN	0126	DRAFT
DARK	0137	DRAFT
DASH	0124	DRAFT
DOTTED	0125	DRAFT
DRAW	197	LETTER
ENDARC	0058	ARCSLP
GREEN	0132	DRAFT
HEIGHT	0224	LETTER
HOLRTH	195	PLOT
INCR	0066	SEQNO
INTEGR	196	PLOT
INTENS	0134	DRAFT
LARGE	7	ARCSLP
LEFT	8	ARCSLP
LENGTH	9	LETTER
LIGHT	100	DRAFT
LINEAR	0076	MACHIN
MEDIUM	0061	DRAFT, FEDRAT
NOMORE	0053	ERROR4, TRANS
NOX	14	MACHIN
NOY	15	MACHIN
NOZ	16	MACHIN
OFF	0072	MACHIN, SEQNO, DRAFT, PLOT
ON	0071	MACHIN, SEQNO, DRAFT, PLOT
PEN	0128	DRAFT
PLOTER	193	MACHIN
PROCED	0225	ERROR4
RADIUS	23	ARCSLP
RED	0131	DRAFT
RIGHT	24	ARCSLP
SCRIBE	0129	DRAFT
SMALL	26	ARCSLP
SOLID	0123	DRAFT
START	0057	ARCSLP, SEQNO
SYMBOL	194	PLOT
TYPE	98	LETTER
XYZ	108	MACHIN
RANGE	0145	FEDRAT
MAXIPM	0096	FEDRAT
IPM	0073	FEDRAT
LOW	0063	FEDRAT
HIGH	0062	FEDRAT

5.0

SYNTAX

In an effort to provide a fairly rigorous, yet concise description of the language, a special notation is employed in this section.

The brackets <> are used to enclose a syntactical variable. These variables are defined in terms of other syntactical variables, APT vocabulary words, or semantics. The symbol ::= stands for "is defined to mean" and the symbol | stands for "or". APT vocabulary words are capitalized and semantics are underlined.

Only the singular syntactical variables are defined. If a syntactical variable is plural, then it represents a sequence of one or more of the singular variables separated by commas.

```

<address> ::= any letter
<arc direction> ::= LEFT|RIGHT
<arc mod> ::= <arc set>,<arc direction>|<arc direction>,<arc set>
<arc set> ::= RADIUS, scalar,<arc size>|START, scalar|ENDARC, scalar
<arc size> ::= LARGE|SMALL|NULL
<coordinate> ::= NOX|NOY|NOZ|XYZ|ALL
<drafting parameter> ::= <line>|PEN,<pen type>|INTENS,<intensity value>
<error modifier> ::= integer|PROCED|NOMORE
<feedrate parameter> ::= <null>|RANGE,<range value>|MAXIPM, integer
<feedrate unit> ::= <null>|IPM
<field> ::= <sign><integral part><frac. part>
<format spec.> ::= <address><field>
<fractional part> ::= digit|<null>
<increment> ::= <null>|INCR, integer
<integral part> ::= digit
<intensity value> ::= LIGHT|MEDIUM|DARK|integer
<interpolation> ::= LINEAR|CIRCUL
<lettering parameter> ::= DRAW|TYPE|HEIGHT, scalar|LENGTH, scalar|ATANGL
                                     scalar
<line> ::= SOLID|DASH|DOTTED|CTRLIN
<machine identification> ::= local option
<manufacturer's name> ::= local option
<null> ::= the empty set, nothing
<on-off> ::= ON|OFF
<option pair> ::= option number, option value
<pen type> ::= BLACK|BLUE|GREEN|RED|SCRIBE|integer
<plotting character> ::= SYMBOL, integer|HOLRTH, 6 or less characters|
                                     INTEGER, integer
<post processor modifier> ::= <null>|<coordinates>|<interpolation>|<on-off>
<post processor name> ::= <manufacturer's name><machine identification>
<range value> ::= LOW|MEDIUM|HIGH|integer
<sign> ::= +|<null>
<type> ::= PLOTTER, MILL, LATHE

```

6.0

STATEMENT TYPES

For explanation of symbols see Section 5.0.

6.1 Post Processor Selection Statement

MACHIN/<post proc. name>,<post proc. modifiers>

Examples: MACHIN/GERBER, PLOTTER, VP1000, ON,NOZ, CIRCUL

6.2 Motion Statements

Any of the APT motion statements.

Examples: GOTO/point or GOLFT/surface

6.3 Set-up or Initialization Statements

Set-up statements establish a mode to be carried out by an activation statement

6.3.1 Program identification

PARTNO any 66 characters

The 66 characters are punched in leader at both ends of the tape in a style which is readable. The word PARTNO must appear in card columns 1-6.

6.3.2 Sequence Numbering

SEQNO/<on-off>

For SEQNO/ON the sequence number is set equal to the CL tape Record number. SEQNO/OFF transfers to the mode shown below with <increment> equal to zero.

SEQNO/integer, <increment>

The specified sequence number is merged with the next output block. The sequence number is indexed by <increment> at each succeeding CL tape record containing tool centers.

Example: SEQNO/100, INCR, 2

6.3.3 Transformation Specification

TRANS/ one, two, three, or twelve coefficients or NOMORE

one: x translation only

two: x and y translation

three: x, y, z translation

twelve: complete matrix transformation

Examples: TRANS/6,4

TRANS/(VECTOR/LENGTH, 6, ATANGL, 30, XYPLAN)

TRANS/(POINT/INTOF, L1, L2)

TRANS/(MATRIX/XYROT, 45)

6.3.4 Option Specification

OPTION/<option pairs>

See Section 7.0 for list of options and their functions.

Example: OPTION/2, 3, 24, 0.3

6.3.5 Drafting parameters

DRAFT/<drafting parameters>

Example: DRAFT/DASH, PEN, RED, INTENS, LIGHT

This statement specifies the type of line to be drawn when a DRAFT/ON is given. (See 6.4.1)

6.3.6 List of characters for plotting

PLOT/<plotting characters>

Example: PLOT/SYMBOL, 60, HOLRTH, PT, INTEGR, K

This statement specifies the symbol, hollerith field, and integer which will be plotted when a PLOT/ON is given (see 6.4.2)

6.3.7 Lettering specification

LETTER/<lettering parameters>

This statement sets up the character size, mode, and direction to be carried out by PLOT and PPRINT statements.

Example: LETTER/DRAW, HEIGHT, .125, ATANGL, 0

6.3.8 Feedrate specification

FEDRAT/scalar, <feedrate units>, <feedrate parameters>

Example: FEDRAT/50, MAXIPM, 150

6.3.9 Circular path to next point

ARCSLP/<arc mods>

The circular arc in accordance with <arc mods> will apply from current position to the next position on CL tape.

Example: ARCSLP/RADIUS, 5, LEFT

6.3.10 Error number limit and exit control

ERROR4/<error modifiers>

When the number of errors reaches the limit specified, processing of the input tape is terminated. The output is processed into a machine tape depending on the modifier PROCED or NOMORE.

Examples: ERROR4/20, PROCED

ERROR4/1, NOMORE

6.4 Activation Statements

An activation statement initiates the specified function in accordance with the current values of the defining parameters. The defining parameters are initially set in the option table but may be changed by an appropriate set-up or activation statement.

6.4.1 Draft Activation

DRAFT/<on-off>

DRAFT/<on-off>, <drafting parameters>

A line is to be initiated (or terminated) at the current position. The draft mode is also terminated by a DRAFT/OFF or PLOT/ON.

6.4.2 Plot Activation

PLOT/<on-off>

PLOT/<on-off>, <plotting characters>

The characters specified are to be plotted at the current position and at the terminating position of each succeeding motion statement. The Plot mode is terminated by a PLOT/OFF or by a DRAFT/ON statement.

6.4.3 Lettering Activation

PPRINT any 66 characters

This is a one-shot command. The specified characters are either drawn or plotted at current position in accordance with the LETTER statement (see 6.3.7). The word PPRINT must appear in card columns 1-6.

Example: PPRINT SURFACE FINISH 65 RMS

6.4.4 Auxiliary Function Activation

STOP Command to stop tape reader (EIA punched tape code: m00)

OPSTOP Optional tape reader stop (EIA code: m01)

REWIND Activates tape rewind. Tape to be rewound to previous "end of record" character (1-2-4 punch) which was punched in tape by SEQNO/START. (EIA code: m30)

SEQNO/START Punches "end of record" character (1-2-4 punch); see REWIND

END End of logical section of part program. Leader is inserted into the punched tape. (EIA code: m02)

6.4.4 Auxiliary Function Activation (Cont'd)

AUXFUN/m The auxiliary or miscellaneous function m is placed directly on the punched output tape in a block by itself.

DELAY/t The integer t specifies the duration of the delay (no motion of the machine) in seconds. (EIA code: g04---)

LEADER/d This statement produces d inches of leader on the punched output tape.

PREFUN/g The preparatory function g is placed directly on the punched output tape in a block by itself.

6.5 Direct communication to machine control unit

INSERT up to 66 characters
The word INSERT must appear in card columns 1-6.
Example: INSERT N035G01X+1265M00

6.6 Format specification

FORMAT <format specifications>*
This statement allows the part programmer to specify the exact format detail of the punched tape. The word FORMAT must appear in card columns 1-6.
References: NAS 955 A2 and EIA RS 274
Example: FORMAT N3.G2.X+23.Y+23.Z+23.D2.M2*

6.7 Messages to Machine Operator

MESSAG any 66 characters
This statement allows the part programmer to communicate with the machine operator by printing out a message on a typewriter attached to the machine. The word MESSAG must appear in card columns 1-6.
Example: MESSAG PLOT THIS TAPE ON SIZE C PAPER

DISPLY/one or more integers

This statement turns on an enunciator panel signal. The signal may consist of display lights, bells, or buzzers and is normally turned off by the operator. This command gives the part programmer the capability to signal that operator action is required. For example: tool change, check set-up, or inspect part.
Example: DISPLY/1, 2, 5

6.8 Part Program Termination

FINI The word FINI must appear on a card by itself and indicates the end of a part program.

7.0

OPTION TABLE

<u>Number</u>	<u>Value</u>	<u>Explanation</u>
1		<u>Coordinates from CL tape to be punched in output tape.</u>
	1	NOX, (14), y and z coordinates only
	2	NOY, (15), x and z coordinates only
	3	NOZ, (16), x and y coordinates only
	4	ALL, (51), x, y, z, i, j, and k coordinates
	5	XYZ, (108), x, y, and z coordinates
2		<u>Format of punched tape</u>
	1	Variable Block, word address without tabs
	2	Variable Block, word address with tabs
	3	Variable Block, tab sequential
	4	Fixed block, tab sequential
	5	Fixed block, sequential
3		<u>Leading and trailing zeroes</u>
	-1	Omit trailing zeroes
	0	Include leading and trailing zeroes
	+1	Omit leading zeroes
4		<u>G code requirements in punched tape</u>
	0	Modal, omitted if no change in value
	1	G code required in every block
5		<u>Dimension words are</u>
	0	incremental
	1	absolute
6		<u>Interpolation Mode - XY Plane</u>
	0	Linear Interpolation only
	r	Circular when DS is cylinder perpendicular to XY Plane and radius is less than 0.
7	$f \geq 0$	<u>Normal feedrate in inches per minute, does not apply if zero</u>
8	$f \geq 0$	<u>Maximum feedrate in inches per minute, does not apply if zero</u>
9	$k \geq 0$	<u>Maximum value for f word in punched tape, does not apply if zero</u>

Number	Value	Explanation
10		<u>f word calculation from feedrate value</u>
	0	Does not apply
	1	Method 1
	2	Method 2
	3	Method 3
11		<u>Acceleration - Deceleration Mode</u>
	0	No acceleration
	1	Provide acceleration
12		<u>Type of line for drafting</u>
	0	Does not apply
	1	SOLID (123)
	4	DASH (124)
	6	DOTTED (125)
	7	CTRLIN (126)
13		<u>Pen Selector Turret Position</u>
	0	Does not apply
	1	SCRIBE (129)
	2	BLACK (130)
	3	RED (131)
	4	GREEN (132)
	5	BLUE (133)
14		<u>Intensity Value for Drafting</u>
	0	Does not apply
	1	MEDIUM (61)
	2	LIGHT (100)
	3	DARK (137)
15	d	<u>D Code of symbol for plotting, if zero, does not apply</u>
16		<u>Lettering Mode</u>
	0	Does not apply
	1	DRAW (197)
	2	TYPE (98)
17	h	<u>Letter height, does not apply if zero</u>
18	w	<u>Letter width, does not apply if zero</u>
19	a	<u>Lettering angle</u>

Number	Value	Explanation
20	k	<u>Sequence number initial value</u>
21	n	<u>Sequence number increment</u>
22		<u>Output Listing</u>
	0	Error Diagnostics
	1	Above plus operator message
	2	Above plus x,y, z coordinates (3 axes)
	3	Above plus rotary coordinates (5 axes)
	4	Others
23	x	<u>Offset between Print wheel and pen, x direction</u>
24	y	<u>Offset between Print wheel and pen, y direction</u>
25	z	<u>Offset between Print wheel and pen, z direction</u>
26		<u>Octal dump</u>
	0	No dump
	1	Dump if error occurs
27	v	<u>DRAFT does not apply if zero</u>
28	n	<u>Maximum allowable error count</u>
29		<u>Error exit mode</u>
	0	NOMORE
	1	PROCD
30	v	<u>LETTER does not apply if zero</u>
31	v	<u>PLOT does not apply if zero</u>
32	v	<u>MESSAG does not apply if zero</u>
33		<u>N/C Machine Input Tape is:</u>
	1	Punched Tape (EIA Code)
	2	Magnetic Tape (EIA Code)
	3	Punched Tape (ASCII Code)
	4	Magnetic Tape (ASCII Code)
	5	Special Punched Tape Format
	6	Special Magnetic Tape Format
34	p	<u>Pulse Value</u>

GENERAL SYSTEM FLOW CHART

8.1

MAJOR SUBROUTINE FUNCTIONS

Subroutine Name and the function that is performed by the routine

ARC	This routine produces circular interpolation blocks to move from the previous point to the present point in accordance with the ARCSLP command.
ARCSLP ₂₀₀₀ *	This routine is called when the ARCSLP/ command is read. The appropriate circle parameters are stored for utilization by subroutine ARC.
AUXFUN ₂₀₀₀	An M code of n specified by the AUXFUN/n command is placed in the M register and the appropriate routines to generate an output block are called.
CIRCUL	This routine fits a circle to the CLTAPE cutter centers of the circle drive surface and produces the required output blocks for the circular interpolation mode.
DELAY ₂₀₀₀	A delay of t seconds, where t is defined by the APT statement DELAY/t, is produced.
DISPLY ₂₀₀₀	This routine generates the necessary output blocks to energize a panel indicator on the specific machine.
DRAFT ₂₀₀₀	The routine examines the DRAFT/ command and takes appropriate action on all the modifiers; that is, ON, OFF, PEN specification, kind of line and INTENS of the line.
END ₂₀₀₀	An M02 code is placed in the M register and the appropriate routines to generate an output block are called.
ERROR4 ₂₀₀₀	The ERROR4/ statement modifiers establish common flags specifying the number of errors which may occur before processing of the input tape is terminated, and whether the resulting output blocks are to be deleted or preserved when the error limit is reached.
FEDRAT ₂₀₀₀	An F code that corresponds to the feedrate value given in the FEDRAT/ command is calculated in the manner specified by current conditions and placed in the F register.
FINI	This routine completes the output requirements and all necessary bookkeeping to terminate the program and then returns to Chain 400 DISPAT.

* Indicates subroutine processes a 2000 record type.

FORMAT ₂₀₀₀	The output format contained in the FORMAT statement replaces the standard for all the "ON" machines. All subsequent output for that (those) machine(s) will be in the newly specified format.
INSERT ₂₀₀₀	Up to 66 characters following the INSERT command are picked up and appropriate routines are called to generate an output block.
LEADER ₂₀₀₀	The necessary number of output blocks are generated to produce t inches of blank tape where t is defined by the command LEADER/t.
LETTER ₂₀₀₀	This routine examines the LETTER/ modifiers to determine character size, orientation and mode to be used by the PLOT and PPRINT commands.
LINEAR	This routine processes the CLTAPE cutter data and produces the required output blocks for linear interpolation.
MACHIN ₂₀₀₀	The routine examines the MACHIN/ command to determine whether it applies to the current machine and, if it does, to establish the proper conditions, i.e., (ON, OFF), coordinates to be plotted, and interpolation mode.
MESSAG ₂₀₀₀	The characters following the word MESSAG are treated as a comment to the machine operator and appear in the output list. For machines having a message center (typewriter) the output tape will contain necessary characters to activate the message center.
OPTION ₂₀₀₀	Option number n is altered from its initialized value to the value t, where n and t are defined by the statement OPTION/n,t. Each couplet is processed independently and any number of couplets may be included in the statement.
OPSTOP ₂₀₀₀	An M01 code is placed in the M register and the appropriate routines are called to generate an output block.
PARTNO ₂₀₀₀	This routine stores the characters following the PARTNO statement and calls appropriate subroutines to produce tape leader.
PLOT	This routine examines the PLOT/ command and takes appropriate action on all modifiers; i.e., ON, OFF, hollerith character sets, etc.

PREFUN₂₀₀₀ A G code of n specified by the PREFUN/n command is placed in the G register and the appropriate routines to generate an output block are called.

PPRINT₂₀₀₀ Characters (up to 66) following the PPRINT statement appear in the output listing. For drafting machines the characters are placed on the drawing at the current position in a mode established by the LETTER/ command.

READER A record is read from the CLTAPE and stored in common locations which are available to any subroutine.

REWIND₂₀₀₀ An M code of 30 is placed in the M register and appropriate routines to generate an output block are called.

SEQNO₂₀₀₀ The SEQNO/ statement is interrogated to determine the type of sequencing desired. The appropriate flags and parameters are set to insure that the proper sequence number is available to the output routines when needed.

STOP₂₀₀₀ An M code of 00 is placed in the M register and appropriate routines to generate an output block are called.

TRANS₂₀₀₀ The TRANS/ statement is examined and the appropriate transformation is determined and applied to applicable CLTAPE data.

9.0

INPUT/OUTPUTA. INPUT

Input to the Generalized Postprocessor is standard APT III CLTAPE (cutter location tape) produced by Section III of the APT System. It consists of a series of logical records each of which contains an ordered set of words which provide the input data to the postprocessor. For detailed information as to the record format, refer to Section 10.01 of the APT III Section 3 CLTAPE PROCESSOR documentation.

B. OUTPUT

There are two general types of output from a postprocessor.

1. A media, presently either a punched or magnetic tape, is used for controlling the machine. This control tape may have various forms:
 - a. Punched tape
 1. EIA Standard
 2. ASCII Standard
 3. Special Punched tape
 - b. Magnetic tape
 1. EIA punched tape standard images
 2. ASCII Standard
 3. Special magnetic tape format*

* The necessary work has been completed to produce magnetic tape input for a Benson-Lehner Model J plotter at the Oak Ridge installation. Available information implies that most magnetic tape plotters have a unique format, thus modification would be necessary for each particular input format.
2. Printed information for part-programmer and/or operator use. Printed output may vary depending on the type of machine being controlled. The following information is largely machine independent and hence should be available.
 - a. Diagnostic comments
 - b. Operator information
 - c. Listing of information contained in the N/C tape with appropriate conversions for easy interpretation.

In order to provide maximum flexibility for the part-programmer, printed output is under option control. The available options include:

- 0. Error diagnostics
- 1. Operator messages (with 0)
- 2. Three axis (or less) machine listing (with 0 and 1)
- 3. Five axis machine listing (with 0 and 1)
- 4. Other (with 0 and 1)

An example with OPTION 22 = 2 specified would resemble the following:

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UNION CARBIDE APT POST PROCESSOR OUTPUT LISTING

PARTNO EXAMPLE OF UCAPP LISTING
MACHIN/GERBER, PLOTTER, VP1000

N	G	X	Y	Z	PUNCHED TAPE
02	01	3.7	2.5	0.0	N02G01X+0370Y+0250D02
04		3.9	2.5	0.0	N04X+0390Y+020D01

10.0

ERROR DIAGNOSTICSStatement Processing and Error Diagnostics

The ERROR4/ statement is used to specify the number of errors allowed in the postprocessor before part program processing is terminated. It is also used to decide whether or not the available output is processed into a machine tape. In this manner the part programmer has complete control over the extent of Section 4 processing. If processing is terminated by the FINI statement, error diagnostics, if any, are printed on a separate page of the output listing.

I. Discussion

1. A statement is not processed if it does not apply to the given machine. Therefore no error diagnostics are set regardless of errors in the statement.
2. If a modifier or couplet is syntactically correct but does not apply to the given machine it is ignored and no error diagnostics set.
3. If a modifier or couplet applies but is not syntactically valid it is ignored (no change in the state of the machine), the error index is incremented, a diagnostic error comment is set, and the remainder of the statement is examined.
4. The error exit is taken and all diagnostic comments printed when the total number of errors exceeds the specified error index. Exit is with or without machine tape as specified.

II. The following list of error diagnostics may occur during processing:

- 1.. NO INCREMENT VALUE SPECIFIED AFTER INCR IN THE SEQNO STATEMENT, 1.0 ASSUMED
2. NO MODIFIER OR AN INVALID MODIFIER SPECIFIED IN THE AUXFUN STATEMENT
3. NO TIME SPECIFIED IN THE DELAY STATEMENT
4. ERROR IN DETERMINING DIRECTION OF CIRCULAR INTERPOLATION MOVEMENT CAUSED BY INVALID CLTAPE DATA
5. INVALID MODIFIER IN THE DRAFT STATEMENT.
6. INVALID PEN OPTION IN THE DRAFT STATEMENT
7. INVALID PEN INTENSITY SPECIFIED IN THE DRAFT STATEMENT
8. INVALID ERROR4 MODIFIER
9. INVALID MODIFIER SPECIFIED IN THE LETTER STATEMENT
10. INVALID MODIFIER IN THE PLOT STATEMENT
11. THE MACHIN STATEMENT HAS INCORRECT OPTION SPECIFICATIONS

12. THE OPTION STATEMENT HAS INCORRECT OPTION SPECIFICATIONS
13. AN APT WORD SPECIFIED AS AN OPTION VALUE IN THE OPTION STATEMENT
14. IMPORPER PLANE SPECIFIED IN OPTION (2)
15. INVALID MODIFIER FOLLOWED SYMBOL OR INTEGR IN THE PLOT STATEMENT
16. A PLOT/ON COMMAND GIVEN BEFORE INFORMATION TO BE PLOTTED
17. ALL BLANK WORDS SPECIFIED IN PPRINT STATEMENT
18. INVALID OR NO MODIFIER SPECIFIED IN PREFUN STATEMENT
19. INVALID MODIFIER SPECIFIED IN TRANS STATEMENT
20. INVALID CHARACTER OCCURRED IN THE FORMAT STATEMENT
21. INVALID POINTS FOR ARCSLP MOVEMENT
22. NEITHER LEFT NOR RIGHT SPECIFIED IN ARCSLP COMMAND
23. INVALID MODIFIER IN ARCSLP STATEMENT
24. INVALID CHARACTER OCCURRED IN CONBCD
25. INVALID OR NO MODIFIER SPECIFIED IN LEADER STATEMENT
26. ERROR IN READING CLTAPE

PARTNO DRAFTING POSTPROCESSOR - EXAMPLE 1 W.V.SCHELLINGER
CHARGE#4065

MACHIN/GERBER,PLOTTER,VPI000,NOZ

\$\$

FRROR4/1,PROCFD
CLPRNT
OPTION/200,1,22,0
OPTION/34,.001
OPTION/4,0

\$\$

\$\$ GEOMETRIC DEFINITIONS FOR TEMPLATE LAYOUT

\$\$

OR #POINT/n,0
XAX #LINE/OR,ATANGL,0
YAX #LINE/OR,ATANGL,90
L1 #LINE/PARLFL,XAX,YLARGE,4.50
L2 #LINE/PARLFL,XAX,YLARGE,2.25
L3 #LINE/PARLFL,XAX,YSMALL,1.00
L4 #LINE/PARLFL,YAX,XSMALL,1.00
L5 #LINE/PARLFL,YAX,XLARGE,4.25
PI #POINT/3.25,3.25
CSM #CIRCLE/CENTER,PI,RADIUS,1
CLG #CIRCLE/YSMALL,L1,XSMALL,OUT,CSM,RADIUS,2

\$\$

\$\$ CALCULATED POINTS AND LINES

\$\$

P2 #POINT/CENTER,CLG
LA #LINE/P2,PERPTO,L1
LP #LINE/PI,P2
LC #LINE/PI,PERPTO,L2
PT1 #POINT/INTOF,L1,LA
PT2 #POINT/XLARGE,INTOF,LB,CLG
PT3 #POINT/INTOF,L2,LC

\$\$

\$\$

\$\$ SETUP PLOTTING, DRAFTING, AND LETTERING PARAMETERS

\$\$

PLOT/SYMBOL,58 \$\$\$SYMBOL 58 # *
DRAFT/SOLID,INTENS,DARK
LETTER/DRAW,HEIGHT,.2,ATANGL,0

\$\$

\$\$

\$\$ PART TRACE

\$\$

FROM/OR

```

GOTO/5,0,0
DRAFT/ON
GOTO/4.85,.1,0
DRAFT/OFF
GOTO/4.85,-.1,0
DRAFT/ON
GOTO/5,0,0
GOTO/OR          $$DRAW X-AXIS
GOTO/0,5,0       $$DRAW Y-AXIS
GOTO/.1,4.85,0
DRAFT/OFF
GOTO/-.1,4.85,0
DRAFT/ON
GOTO/0,5,0
INDIRV/0,-1,0
GO/ON,L1
GLEFT/L1
GOFWD/CLG,ON,LB
DRAFT/DASH          $$CHANGE TO DASH LINE
GOFWD/CLG,ON,L4
GOFWD/CLG,ON,YAX
DRAFT/SOLID
GOFWD/CLG,ON,LB
ARCSLP/RADIUS,1,RIGHT
GOTO/PT3
DRAFT/DASH
ARCSLP/RADIUS,1,LARGE,RIGHT
GOTO/PT2
DRAFT/SOLID
GOBACK/CSM,ON,LC
GOFWD/L2,ON,L5
GORG/L5,ON,L3
GORG/L3,ON,L4
GORG/L4,ON,L1
GORG/L1,ON,YAX
DRAFT/OFF

```

\$\$

\$\$

\$\$

```

IDENTIFY POINTS OF TANGENCY

```

```

GOTO/PT1
PLOT/ON
GOTO/PT2
GOTO/PT3
PLOT/SYMBOL,26          $$ ORIGIN # 0
GOTO/OR
PLOT/OFF

```

```

      GOTO/0,-1.5,0          $$ TYPE THE TITLE
PPRINT TEMPLATE LAYOUT
      GOTO/5.25,-.1,0
PPRINT X
      GOTO/-..08,5.25,0
PPRINTY
$$
$$      CHANGE TO CHARACTER DRAW MODE
      LETTER/DRAW,HEIGHT,.1
$$
      GOTO/1.38,5.25,0
PPRINT NOTE - * MARKS POINTS
      GOTO/2.38,5.75,0
PPRINT OF TANGENCY
      REWIND
      END
      FINI

```

PARTNO DRAFTING POSTPROCESSOR - EXAMPLE 2

W.SCHENK

9704-2

CHARGE#4065

MACHIN/GERBER,PLOTTER,VPI000,ON,NOZ,CIRCUL

CLPRNT/1

RESERV/T,5,R,14,Q1,5,Q2,14,XP,70,YP,70

OPTION/28,10,22,0

OR # POINT/0,0,0

\$\$

\$\$

\$\$

\$\$

PROGRAM CONSTANTS

T(1) # .005

T(2) # .001

T(3) # .0005

T(4) # .0001

T(5) # .0002

R(1) # .250

R(2) # .500

R(3) # 1

R(4) # 2

R(5) # 3

R(6) # 4

R(7) # 5

R(8) # 6

R(9) # 7

R(10) # 8

R(11) # 9

R(12) # 10

R(13) # 11

R(14) # 12

\$\$

\$\$

REMARK THE CALL OF THE MACRO WAX WILL PRODUCE A SET OF

LAELED COORDINATE AXES FOR THE FIRST QUADRANT

\$\$

\$\$

REMARK COMPUTE THE ARRAY OF POINTS TO BE PLOTTED

\$\$

N #0

LOOPST

A) N#N+1

Q1(N) # 1/SQRTF(2*T(N))

IF (N-5) A,B,P

B) LOOPND

K#0

LOOPST

C) K#K+1

```

      Q2(K) # 1/SQRTF(R(K))
      IF (K-14) C,D,D
D)    LOOPND
      N#1
      K#1
      L#1
      LOOPST
E)    YP(L) # Q1(N) * Q2(K)/10
      XP(L) # R(K)/2
      L#L+1
      IF (L-70) F,F,H
F)    K#K+1
      IF (K-14) E,E,G
G)    K#1
      N#N+1
      JUMPTO/E
H)    LOOPND
$$
$$    INITIALIZE DRAFTING AND LETTERING PARAMETERS
$$
      DRAFT/SOLID,PEN,BLUE,INTENS,MEDIUM
      LETTER/DRAW,HEIGHT,.24,ATANGL,0
$$
      I#1
      J#1
      LOOPST
      FROM/OR
A1)   GOTO/XP(I),YP(I),0
      DRAFT/ON
A2)   I#I+1
      J#J+1
      GOTO/XP(I),YP(I),0
      IF (I-70) A3,A5,A5
      IF (J-14) A2,A4,A4
A3)   IF (J-14) A2,A4,A4
A4)   J#1
      I#I+1
      DRAFT/OFF
      JUMPTO/A1
A5)   DRAFT/OFF
      LOOPND
      GOTO/1.75,-.75,0
PPRINT RADIUS (INCHES)
$$
$$    CHANGE IN LETTER SIZE
$$
      LETTER/HEIGHT,.1

```

\$\$ THIS LOOP PRODUCES THE
 \$\$ GRAPH OF THE POINT ARRAY


```

      GOTO/2.75,4,0
PPRINT TOLERANCE
      GOTO/4.5,.375,0
PPRINT.005
      GOTO/4.5,.760,0
PPRINT.001
      GOTO/4.5,1.10,0
PPRINT.0005
      GOTO/4.5,1.73,0
PPRINT.0002
      GOTO/4.5,2.37,0
PPRINT.0001
$$
$$ LABEL THE ORDINATE
$$
      LETTER/HEIGHT,.24,ATANGL,90
      GOTO/-.5,2.5,0
PPRINT POINTS/INCH
      GOTO/OR
      GOTO/0,9,0
      DRAFT/ON
      GOTO/OR
      GOTO/7,0,0
      DRAFT/OFF
      REWIND
      END
      FINI

```

12.0

APPENDIX

Code assignments listed in this Appendix are in conformity with perforated tape standards NAS 955 and EIA RS 274. Certain additions to the standards were necessary to achieve full capabilities of this generalized drafting post processor. For example, see Section 12.4 of this Appendix where certain D code assignments were made to specify characters and symbols for drawing or plotting. No standard for these assignments exist at present and the list merely represents the character set as implemented.

12.1

ADDRESS ASSIGNMENTS

<u>Address</u>	<u>Assignment</u>
N	sequence number
G	preparatory function
X	x coordinate
Y	y coordinate
Z	z coordinate
U	
V	
W	
O	
P	
Q	
R	
H	
I	x distance to arc center or feedrate dir. cos.
J	y distance to arc center or feedrate dir. cos.
K	z distance to arc center or feedrate dir. cos.
L	
A	
B	
C	
D	type of line and character selection
E	
F	feedrate
S	
T	pen selection
M	auxiliary (miscellaneous) function

12.2

EIA G Code Numbers

<u>Number</u>	<u>Function</u>
00	Point to Point
01	Linear Interpolation (Normal Dimensions)
02	Circular Interpolation CW (Normal Dimensions)
03	Circular Interpolation CCW (Normal Dimensions)
04	Dwell
05	
06	
07	
08	Acceleration
09	Deceleration
10	Linear Interpolation (Long Dimensions)
11	Linear Interpolation (Short Dimensions)
12	
13	
14	
15	
16	
17	XY Plane Selection
18	ZX Plane Selection
19	YZ Plane Selection
20	Circular Interpolation CW (Long Dimensions)
21	Circular Interpolation CW (Short Dimensions)
22	
23	
24	
25	
26	
27	
28	
29	
30	Circular Interpolation CCW (Long Dimensions)
31	Circular Interpolation CCW (Short Dimensions)
32	
33	
34	
35	
36	
37	
38	
39	
40	
41	
42	
43	
44	

<u>Number</u>	<u>Function</u>
45	
46	
47	
48	
49	
50	Plot characters at 0° angle with respect to x-axis without spacing after each character
51	Plot characters at 0° angle with respect to x-axis with spacing after each character
52	Draw characters at 0° angle with respect to the x-axis
53	Draw characters at 90° angle with respect to the x-axis
54	
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NumberFunction

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98
99

12.3

EIA M Code Numbers

<u>Number</u>	<u>Function</u>
00	Program Stop (stop tape reader)
01	Optional (Planned) stop
02	End of logical program section
03	
04	
05	
06	Tool Change Signal
07	
08	
09	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	End of Tape (Rewind)
31	
32	
33	
34	
35	
36	
37	
38	
39	
40	
41	
42	
43	
44	
45	

<u>Number</u>	<u>Function</u>
46	
47	
48	
49	
50	X1 Scale Character Multiplier
51	X2 Scale Character Multiplier
53	X4 Scale Character Multiplier
54	X8 Scale Character Multiplier
55	X16 Scale Character Multiplier
55	
56	
57	
58	
59	
60	
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:	
99	

12.4

EIA D Code Numbers

<u>Numbers</u>	<u>Explanation</u>
00	Unassigned
01	Pen Down
02	Pen Up
03	Index Turret
04	Dash Line on
05	Dash Line off
06	Dotted Line on
07	CTRLIN Line on
08	Unassigned
09	Transfer hold

D numbers above 9 specify characters

<u>Numbers</u>	<u>Character</u>	<u>Number</u>	<u>Character</u>
10	blank	37	G
11	/ slash	38	H
12	S	39	I
13	T	40	O
14	U	41	1
15	V	42	2
16	W	43	3
17	X	44	4
18	Y	45	5
19	Z	46	6
20	- minus	47	7
21	J	48	8
22	K	49	9
23	L	50	.
24	M	51	,
25	N	52	(
26	O	53	)
27	P	54	=
28	Q	55	±
29	R	56	Π
30	+ plus	57	⊕
31	A	58	*
32	B	59	.
33	C	60	.
34	D	61	.
35	E	62	.
36	F	63	.
		64	Δ