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NUMERICAL CONTROL SERIES

INTRODUCTION TO NUMERICAL CONTROL

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INTRODUCTION

Anyone searching the literature on numerical control(NC) cannot go far without reading that NC HAS STARTED THE SECOND INDUSTRIAL REVOLUTION. Such words may at first seem toodramatic to describe the effect of automating a maching tool(m/c tool), but the excitement is indeed justified, for NC HAS CHANGED ENTIRE CONCEPTS OF COMPONENT DESIGN AND DEVELOPMENT. What's more, the greatest impact-on both design and manufacturing - apparently is yet to come. NC applications generally lower the cost of production and reduce tool inventory, the matter that causes great pleasure to the manufacturing management. On the other hand, the more sophisticated types of NC are CHANGING THE APPROACH TO PRODUCT DESIGN, and perhaps even the APPROACH TO PRODUCT PLANNING. Complex Surfaces, for example, can now be produced easily and rapidly without error. Designers can use mathematical equations to define contours of the m/c shop. Fewer design compromises are needed since complex shapes are easily specified and produced.

Due to NC, it is now often economical to sculpture intricate components from solid metal instead of using welded or riveted structures or metalforming processes. Also emerging are systems in which the design engineer will communicate directly with the m/c tool through computer-aided design.

In the field of Numerical control (NC), general purpose programming systems consist of two parts:

1. A Programming Language

2. A Number of Computer Programs

THE PROGRAMMING LANGUAGE:

In used to describe:

1. The geometry of the part to be produced
2. The tools to be used
3. The tool motion to cut the desired part

THE COMPUTER PROGRAMMES:

They are divided in two main sets

1. THE PROCESSOR:

Is the first set of programs. This is used within the computer to interpret the statements written in the programming language by the part program, evaluate them and calculate a general solution

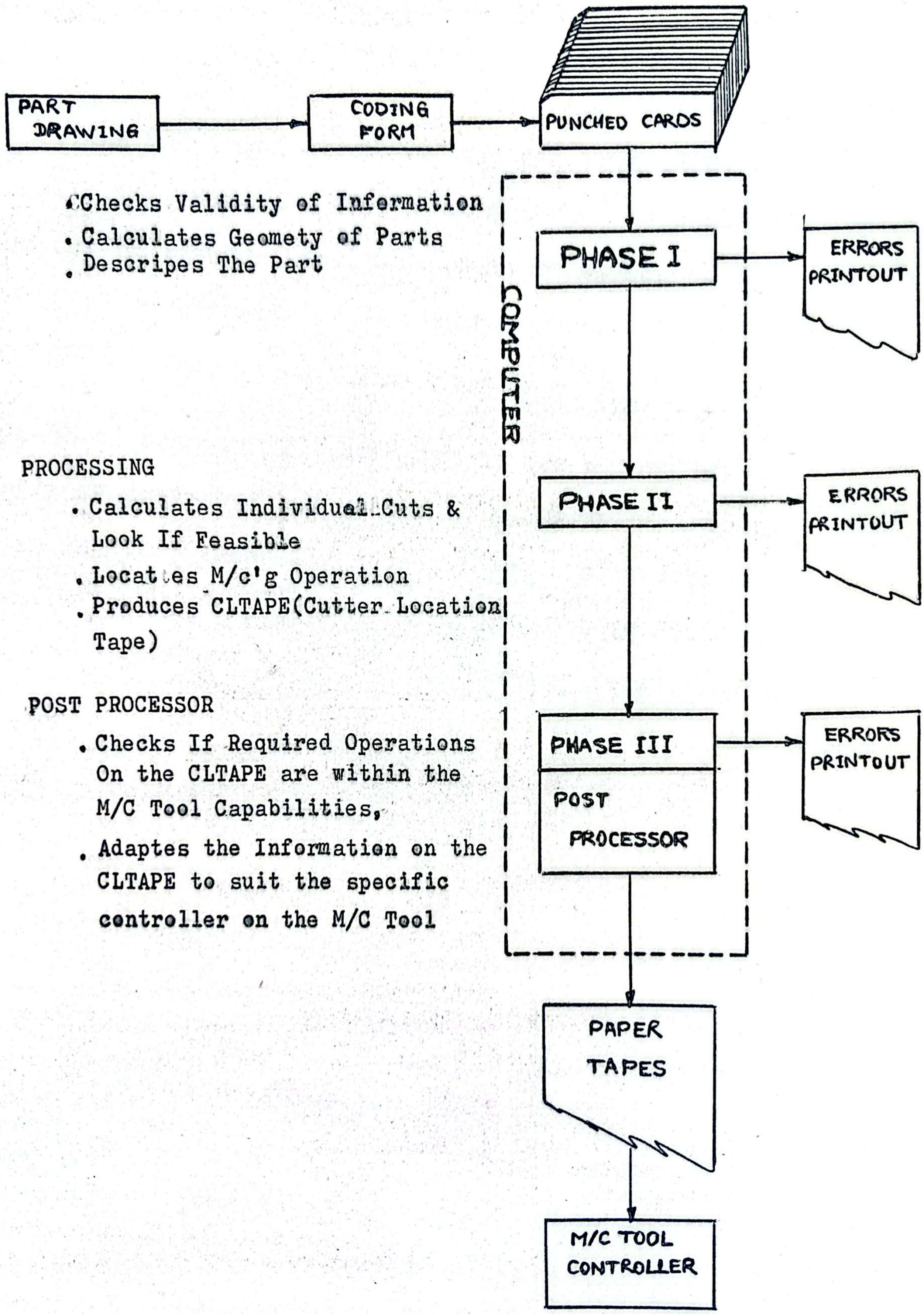
THE GENERAL SOLUTION:

Called "CUTTER LOCATION DATA", is the result of geometric calculations which were executed to solve the problem of calculating the path of one geometric body, the TOOL, over anather geometric body, the PART. The General Solution is M/C TOOL INDEPENDENT. It will be stored on an intermediate storage device such as disc or magnetic tape.

(2) THE POST PROCESSOR

Is the second set of programs. It is used to adapt the general solution generated by the processor to a specific M/C tool with a specific control unit. This is generally supplied by M/C tool manufacturer for each of his Machines.

The Relation between those different parts are shown by the following chart:



- Checks Validity of Information
- Calculates Geomety of Parts
- Descripes The Part

PROCESSING

- Calculates Individual Cuts & Look If Feasible
- Locates M/c'g Operation
- Produces CLTAPE(Cutter Location Tape)

POST PROCESSOR

- Checks If Required Operations On the CLTAPE are within the M/C Tool Capabilities,
- Adaptes the Information on the CLTAPE to suit the specific controller on the M/C Tool

ADVANTAGES OF TWO-PHASE PROCESSING:

The procedure of processing of the part program into two phases (PHASE II & PHASE III) may seem lengthly, but it has the following advantages:

(1) The increased flexibility and standardization:
Separation makes it possible to use one programming language for parts to be machined on M/C's having point - to - point as well as multi-axis controls.

(2) Ease of developing POST PROCESSORS to adapt the general solution generated by the processor to a specific M/C tool-controller combination.

(3) Possibility to include, in the programming language, requirements from users with a wide range of types of M/C tools. This helps to standardize programming languages.

(4) No need for rewriting a new processor for each newly manufactured M/C Tool, in this case only the post processor has to be written.

STRUCTURE OF PART PROGRAM

(I) CONSTANTS:

1) Type of M/C, either a or b

   a) Standard M/C (Path control M/C)

   b) One Dimensional M/C (Track control M/C)

2) Actual Power of the M/C
3) Maximum Torsion The M/C can stand
4) cutting Reaction
5) Proportional Factor
6) Preceding Spindle Table
7) Post Processor Indicator

(II) TOOL DETAILS:

1) Type of Used Tool Set
2) Description, Specifications & Dimensions, of Each Used Tool as required by post processor

(III) AVAILABLE SPEEDS OF MOVING PARTS:

1). Spindle Speeds (In Case of Lathes, For Example)

(IV) GEOMETRY DESCRIPTION:

1) Before Machining (Blank)
2) After Machining (Final Shape)

PHASE II: The processor performs further checks to see whether the machining of the part altogether is feasible or not. Such as: Machining of adjoining Surfaces, Sequence of Machining Directions, Existance of Stochastic Machining Operations (which have to divided into shorter and easier operations,) Invalid Finishing, Invalid Grooving or Beveling, checking whether roughing comes before finishing (for different faces) or not. If there are any errors, they appear on the printout and post processing is interrupted. In case of Warning errors, post processing continues.

PROCESSOR SOFTWARE:

The processor is composed of a deck of FORTRAN IV statements including all the Instructions & Validity Tests Necessary to perform the processor functions previously analyzed. The necessary SUBROUTINES for different cutting actions, tools placing and moving, adjusting feeds and depth of cuts; special Purpose subroutines are also included such as, for example,

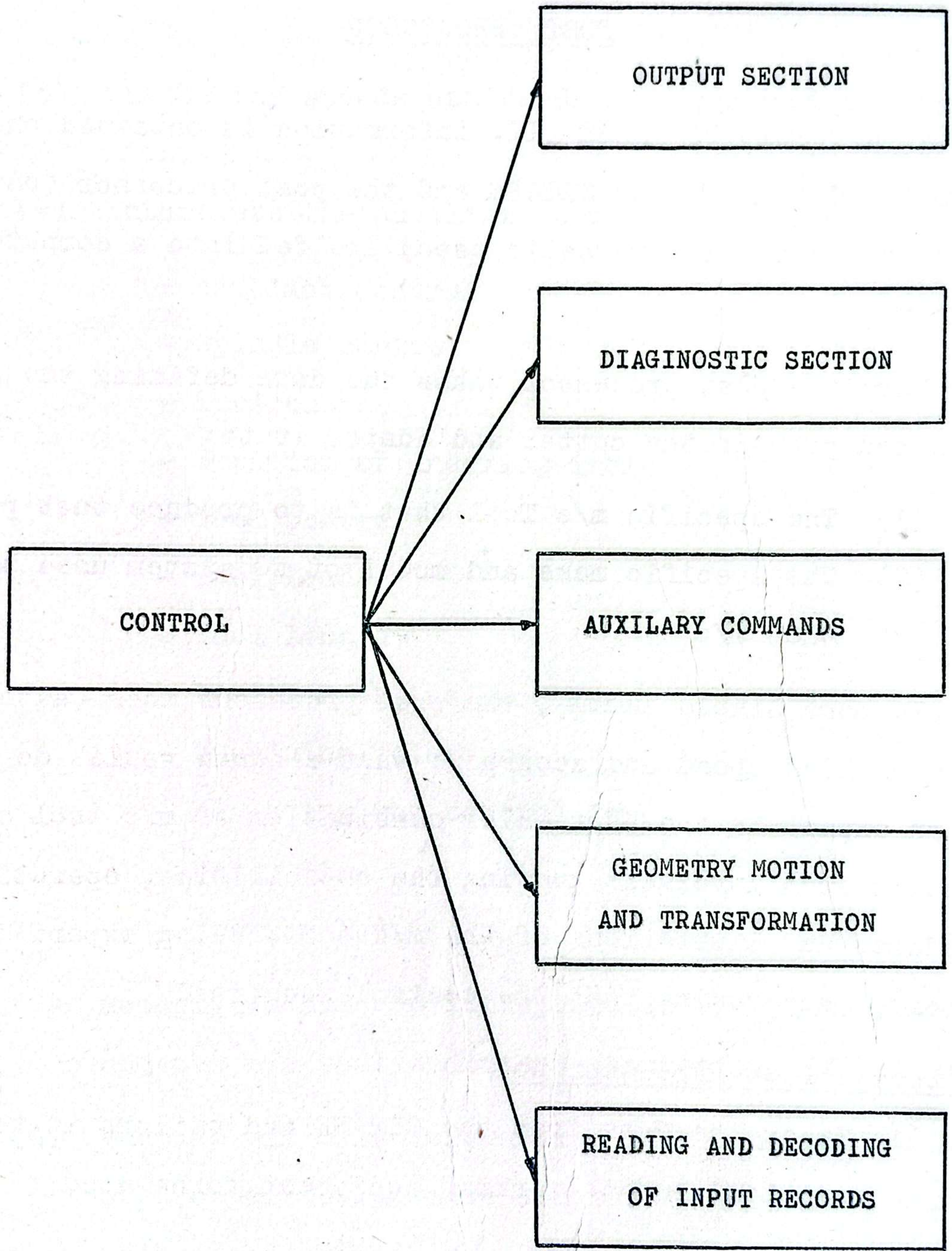
- Subroutine For Reaming
- Subroutine For Thread Cutting
- Subroutines For Grooving:
  - (1) Ordinary Grooves
  - (2) Grooves With Bevels
  - (3) Grooves With Inclined Roots

As an example, the IBM AUTOPOL PROCESSOR is composed of 8000 FORTRAN IV cards stored on a disc, a FORTRAN IV COMPILER is needed.

HARDWARE NEEDS:

Needs differ according to type of processor, the IBM AUTOPOL PROCESSOR needs, on the minimum:

	IBM - 360/25	DOS	32K	2 DISKS
or	IBM - 1130	Monitor	16K	1 DISK


OUTPUT SECTION
DIAGINOSTIC SECTION
CONTROL
AUXILARY COMMANDS
GEOMETRY MOTION AND TRANSFORMATION
READING AND DECODING OF INPUT RECORDS

POST PROCESSOR

As a result of PHASE II, information is obtained on a CLTAPE (or CLFILE). The CLTAPE and the post processor (usually stored on a disc or a magnetic tape) are fed into a computer together.

Here the post processor takes the data defining the previously calculated path of the cutter and adapts it to:

(1) The specific m/c Tool that is to produce that part

(2) The specific make and model of NC system used to run that m/c

In more simple terms, the post processor does (automatically at a very high speed and accuracy) what a human would do if he were an expert in the particular combination of m/c tool and control system involved; knowing the capabilities, operating procedures and limitations of the m/c tool; being experienced in the format and coding that the control requires.

What Does A Post Processor Do?

(1) Takes the data from the CLTAPE and tailors it to the particular metalworking equipment to be used

(2) Checks limits of travel (to make sure the programmer hasn't programmed the work table off the slides of the M/c!)

(3) Checks the speeds and feeds and dynamics of acceleration.

(4) Interprets the auxiliary commands such as:

- cooldant control
- Spindle control
- Tool change
- Position of Indexing Table
- Feed control
- Tool Load
- Tool Length
- Position of the Turret
- Machining Tolerance
- Rewinding the control Tape
- Delay Time
- Program End

(5) Recognizes and conflicts between the part program and the m/c tool and makes compromises if possible

(6) Encodes all this information into the special Language of the particular make and model of control that is to be used.

As a result, a printout is produced containing:

(1) A complete guide to the entire program

(2) Information needed to help the programmer in trouble-shooting or to guide in operating the machine

(3) Error & warning messages.

In case of no errors, a paper tape is produced containing all necessary information to operate the controller which, in turn, operates the m/c tool. A special Plotting subroutine can be called, it causes a graph plotter to produce an image of the machine tool in its final shape.

Writing Post Processors:

Post Processors are supplied by the m/c tool manufacturer for a particular type (or class) of machines. To write the post processor, it takes about 2-3 man months with experience in programming and m/c tool operation. To show the enormous amount of work involved in writing it, if we consider computer commands, a typical post processor includes from 8000 to 10000 commands on the average.

CONTROL EQUIPMENT

In any workshop, with NC m/c tools, several types of control systems are available, such as:

A) NC SYSTEMS, as for example:

1. PLESSEY INTEGRATED CIRCUIT SYSTEMS:

   The PLESSEY 2200 SYSTEM provides two-axis control for a Burgmaster 2 BXTHL turret drilling machine.

2. FERRANTI MULTIAX NC SYSTEM

   It provides simultaneous continuous path control for six axes. At the meantine, 1000 ancillary command functions can be accomodated.

3. PLESSEY FLUIDIC 220 NC SYSTEM

   It is a co-ordinate table and point-to-point control system employing fluid logic and hydraulic for high speed - positining in two axes.

4. EKCO M/C TOOL AND NC SIMULATOR

   a. E 214 NC SYSTEM

   b. E 117 NC AND M/C TOOL SIMULATOR

      The E117 system is used to investigate the behaviour of leadscrew type positioning system.

5. EMICON S1000 CONTROL SYSTEM

It is of the point-to-point type of control system with the addition of line milling facility. Some auxiliary facilities can also be provided.

This system is capable of providing singals suitable for all m/c tool drive systems.

6. AIRMEC-AEI PTL 100 POINT-TO-POINT SYSTEM

This system combines the advantages of an absolute system of measurement with the flexibility of an incremental system.

B) PROGRAMMING SYSTEMS, as for example:

1. OLIVETTI PROGRAMMA 101 DESK-TOP COMPUTER
2. TELEMECANIQUE CONTROL ELEMENTS

C) SEQUENCE CONTROL, as for example:

1. IAN NICKOLS MUSCLEMATIC SEQUENCE CONTROL
2. NICKOLS EMI CONTROL OF HERBERT MONOSLIDES
3. HEPWORTH DIAL-SET SEQUENCE CONTROL

D) DIGITAL READOUT, as for example:

1. PLESSEY 400 SERIES DRO
2. ROTAX DRO
3. BAC AUTOGRT 400 DRO

A more detailed discussion of different control systems will be set in an individual article.

PROGRAMMING LANGUAGES

There are perhaps dozens of computer languages for programming NC equipment. Some languages are designed only for simple point-to-point work; others for continuous path operation. While most programs are designed for general-purpose use (processor and post-processor are separately used to allow the output to be used for any control system), some others are designed for specific equipment (in such cases there is no need to separate processor and post processor). Some programs can be used only on particular computers; others can be used on a variety of computers. In very particular cases, programs are developed within a single company to meet special needs. Among this wide array, the languages given in the following table are considered to be major languages.

NAME	MEANING	CLASSIFICATION	AXES	APPLIED TO	REMARKS	DEVELOPED & USED
APT	Automatic Programming for Tools	Continuous Path	5	IBM 7090 UNIVAC CDC		MII, IIT & IBM 1955
AD-APT	Mini APT	" "	2	IBM 1620	Not Widely used	IBM
AUTOSPOT	AUTOmatic SPotting of Tools	Point-To-Point	3	IBM 1620, 1138	Used for Milling	IIT & IBM 1963
PROFILEDATA		Continuous Path	2½	ICL 1900		FERRANTI (ICL)
AUTOPOL	AUTOmatic Programming Of Lathes	" "	2	IBM 1130 IBM 360		IBM (very Recent)
2C,L	2 axis Continuous one axis straight Line	" "	2	UNIVAC ELLIOT ICL	Subset & Extension of APT	FERRANTI (ICL)
EXAPT I EXAPT II EXAPT III	Exceptional APT	Point-To-Point Continuous Path " "	3 2 2½	IBM 360	Used for Drilling " " Turning " " 2½D Contouring	3 German Institutions