INTERNATIONAL STANDARD ISO 2539

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Numerical control of machines — Punched tape variable block format for contouring and contouring/positioning

Commande numérique des machines — Bandes perforées à bloc à format variable pour contournage et mise en position

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FOREWORD

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Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 2539 was drawn up by Technical Committee ISO/TC 97, *Computers and information processing*, and circulated to the Member Bodies in February 1972.

It has been approved by the Member Bodies of the following countries :

Australia	Italy	Spain
Belgium	Japan	Sweden
Brazil	Netherlands	Switzerland
Canada	New Zealand	Thailand
Egypt, Arab Rep. of	Poland	United Kingdom
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The Member Body of the following country expressed disapproval of the document on technical grounds :

Czechoslovakia

Printed in Switzerland

Numerical control of machines — Punched tape variable block format for contouring and contouring/positioning

1 SCOPE AND FIELD OF APPLICATION

1.1 This International Standard applies to variable block format punched tapes, with tabulation, with addresses or with tabulation and addresses, for contouring and positioning machining. It is intended to

a) recommended application of the rules providing a minimum of uniformity of input media between machines of compatible characteristics;

b) inform users of numerically controlled machines on the potentialities of control systems.

1.2 This International Standard is consistent with ISO 1058. Compliance with the conditions expressed in this International Standard does not guarantee interchangeability of tapes between machines of compatible features.

1.3 The format characteristics are specified in clause 6 and in annexes C and D.

1.4 The technical terms used in this International Standard are based on the ISO data processing vocabulary.[1)]

1.5 Tape dimensions, character codes and nomenclature of axes conform respectively to ISO 1154 and ISO 1729, ISO 840 and ISO 1113, and ISO 841.

2 REFERENCES

ISO 840, *Numerical control of machines — 7-bit coded character set.*

ISO 841, *Numerical control of machines — Axis and motion nomenclature.*

ISO 1056, *Numerical control of machines — Punched tape block formats — Coding of preparatory functions G and miscellaneous functions M.*[2)]

ISO 1058, *Numerical control of machines — Punched tape variable block format for positioning and straight-cut machining.*

ISO 1113, *Information processing — Representation of 6- and 7-bit coded character sets on punched tape.*

ISO 1154, *Information processing — Punched paper tape — Dimensions and location of feed holes and code holes.*

ISO 1729, *Information processing — Unpunched paper tape — Specification.*

3 FORMAT MAKE-UP

3.1 Addresses

The address consists of a character which shall be in accordance with annexe B.

3.2 Blocks

3.2.1 A block consists of the following :

3.2.1.1 The "sequence number" word.

3.2.1.2 The data words.

3.2.1.3 The "end of block" character showing the end of each block, and which shall, in addition, precede the first block of the program.

3.2.2 The data words are presented in the following sequence, and shall not be repeated within a block.

3.2.2.1 The "preparatory function" word.[3)]

3.2.2.2 The "dimension" words.

These words shall be arranged in the following sequence :

X, Y, Z, U, V, W, P, Q, R, I, J, K, A, B, C, D, E.

3.2.2.3 The "feed function" word or words.

The "feed function" word applying only to a specific axis shall immediately follow the "dimension" word for that axis.

1) ISO 2382 : in preparation.

2) At present at the stage of draft. (Revision of ISO/R 1056.)

3) For coding of preparatory and miscellaneous functions, see ISO 1056.

The "feed function" word applying to one or more of several axes shall follow the last "dimension" word to which it may apply.

Separate feed function programming is not applicable when operating in a contouring mode.

3.2.2.4 The "spindle speed function" word.

3.2.2.5 The "tool function" words(s).

3.2.2.6 The "miscellaneous function" word.[1)]

3.2.3 The words, the "tab" character excepted, may be omitted when not indispensable in a specific block of data. This should be understood as meaning that there is no change in the condition of the machine with respect to the function denoted by the omitted word. Instructions which are inherently executed in a single block must be repeated whenever necessary, for example, a tool change.

3.2.4 In any block, the words appearing after the last one having an actual use may be omitted, including the "tab" character, i.e. the "end of block" character may be used after any complete word.

3.3 Words

3.3.1 Whenever it is necessary to reduce the tape length of blocks of data because of reading speed limitations, either leading zeros or trailing zeros may be omitted, from the "dimension" words only, where consistent with the control system, the location of the implicit decimal sign as defined in the format specification remaining constant. When a system with "tab" and without address is used, a number containing only zeros must be expressed by, at least, one zero; it is to be understood, however, that by omitting these zeros, format checking of the input tape will not be possible.

3.3.2 The "tab" and/or "address" characters are the first of the word; the "address" character follows the "tab", if any, and is followed by digital data.

The "tab" character shall be omitted in the "sequence number" word.

3.3.3 The "dimension" words shall be either co-ordinate dimension words (absolute dimension) or incremental dimension words (relative dimension) according to format specification, and shall contain digital data as follows :

3.3.3.1 The most significant digit of the "dimension" word shall be first.

3.3.3.2 UNITS

3.3.3.2.1 All linear dimensions shall be expressed in millimetres or in inches and decimal fractions thereof.

3.3.3.2.2 All angular dimensions shall be expressed in decimal parts of a revolution or in degrees and decimal parts of a degree.

3.3.3.3 DECIMAL SIGN

Decimal sign shall not be used, its implicit position being defined by the format specification.

3.3.3.4 SIGN OF LINEAR AND ANGULAR DIMENSIONS

3.3.3.4.1 When the control system allows using absolute dimensions, either positive or negative with respect to the origin of the co-ordinate system, the algebraic sign (+ or −) is part of the "dimension" word and shall precede the first digit. If the algebraic sign is omitted a plus (+) sign shall be assumed.

3.3.3.4.2 When the control system only permits use of positive absolute dimensions, the algebraic sign shall be omitted from the "dimension" words.

3.3.3.4.3 When the control system uses incremental dimensions, the algebraic sign (+ or −) shall precede the first digit of each dimension in order to show the direction of motion. If the algebraic sign is omitted a plus (+) sign shall be assumed.

3.3.4 Non-dimension words, when employed, shall contain digital data as follows :

3.3.4.1 The "sequence number" shall consist of a minimum of three (3) digits.

3.3.4.2 The "preparatory function" shall be expressed by a two (2)-digit coded number. For designation see ISO 1056.

3.3.4.3 The "feed function or functions" shall be expressed by a coded number, or a direct designation as described in annex A.

3.3.4.4 The "spindle speed function" shall be expressed by a coded number, or a direct designation as described in annex A.

3.3.4.5 The "tool function" shall be expressed by a coded number, the number of digits being specified in the format specification.

It is preferred that the tool identification and tool compensation are selected by the "T" word. The last group of digits will select the tool compensation.

When tool compensation is selected by a different word the "D" address should be used. The position of the "D" word in a block shall be detailed in the format specification.

1) For coding of preparatory and miscellaneous functions, see ISO 1056.

3.3.4.6 The "miscellaneous function" shall be expressed by a two (2)-digit coded number. For designation, see ISO 1056.

4 PROGRAMMING METHODS FOR INTERPOLATION

4.1 Principles

Interpolation is performed over a pre-determined portion of a given curve. The portion interpolated is called a "span" and may be covered by one or more blocks of information.

Data necessary to define a span obey one or more of the following principles.

4.1.1 An appropraite G-code will be used to define the functional nature of the curve, i.e. linear, circular, parabolic or higher order curve.

4.1.2 The starting point of each span is identical to the end point of the previous span and, therefore, it is not necessary to repeat this point in the new block. Each subsequent point on the span for which coordinates are specified requires a separate block of information and shall use a valid motion address such as X, Y or Z.

4.1.3 Interpolation parameters shall be addressed I, J or K and will be used for defining the geometric properties of the curve such as the centre point, radius, focus, angles, etc., or any other parameters, except the coordinates defined in 4.1.2.

4.1.4 The interpolation parameters are not defined in this document and details shall be given in the itemized data.

4.2 Formats for various methods of interpolation

4.2.1 *Linear interpolation*

A straight line span is defined in one block which contains :

a) The G-function word (if not already previously programmed).

G01 Linear interpolation

b) The coordinates of the end point shall be expressed either in absolute or incremental dimensions and addressed by any valid motion address such as X, Y or Z.

If the control system provides both absolute and incremental dimensioning, the mode of control shall be selected by one of the following G-codes :

G90 Absolute dimension

G91 Incremental dimension.

The example in figure 1 shows the geometric properties of the span and gives an example of meaning of the coordinate values to be programmed.

4.2.2 *Circular interpolation*

A circular span lying in one of the three principal planes of reference is defined in one or two blocks.

4.2.2.1 PROGRAMMING IN ONE BLOCK USING INTERPOLATION PARAMETERS

The block must contain

a) the G-function word (if not already previously programmed).

G02 circular interpolation Arc CW

G03 circular interpolation Arc CCW

b) the coordinates of the end point, which shall be expressed in either absolute or incremental dimensions and addressed by any valid motion address such as X, Y or Z.

If the control system provides both absolute and incremental dimensioning, the mode of control shall be selected by one of the following G-codes :

G90 Absolute dimension

G91 Incremental dimension.

c) the interpolation parameters addressed by I, J, K.

I, J, K may be the coordinates of the centre point according to the plane of reference.

In place of this centre point other properties such as slope, radius and angle may be used as the interpolation parameters.

4.2.2.2 PROGRAMMING IN TWO BLOCKS

If the circle is defined by three coordinate points on the span, the intermediate point and the end point must be programmed in two successive blocks.

The first block must contain

a) the G-function word (if not already previously programmed).

See 4.2.2.1 a).

b) the coordinates of the intermediate point.

The second block must contain the coordinates of the end point.

The coordinates of both points shall be expressed in either absolute or incremental dimensions and addressed by any valid motion address such as X, Y or Z.

If the control system provides both absolute and incremental dimensioning, the mode of control shall be selected by one of the following G-codes :

G90 Absolute dimension

G91 Incremental dimension.

The example in figure 2 shows the geometric properties of the span and gives examples of meanings of the coordinate values to be programmed.

4.2.3 *Parabolic interpolation*

A parabolic span lying in any plane in space is defined in one or several blocks.

4.2.3.1 PROGRAMMING IN ONE BLOCK USING INTERPOLATION PARAMETERS

The block must contain

a) the G-function word (if not already previously programmed).

G06 Parabolic interpolation.

b) the coordinates of the end point, which shall be expressed in either absolute or incremental dimensions and addressed by any valid motion address such as X, Y or Z.

If the control system provides both absolute and incremental dimensioning, the mode of control shall be selected by one of the following G-codes :

G90 Absolute dimension

G91 Incremental dimension.

c) the interpolation parameters addressed by I, J, K.

I, J, K may be the coordinates of the tangent intersection point; in place of the tangent intersection point other properties such as slope, focus, directrix may be used as these interpolation parameters.

4.2.3.2 PROGRAMMING IN TWO OR MORE BLOCKS

If the parabola is defined by three or more points on the span, the intermediate points and the end point must be programmed in two or more successive blocks.

The first block must contain

a) the G-function word (if not already previously programmed).

G06 Parabolic interpolation.

b) the coordinates of the first intermediate point.

The following blocks must contain the coordinates of the additional intermediate point(s) and the coordinates of the end point. The coordinates of each point must be programmed in one separate block.

The coordinates of all points shall be expressed in either absolute or incremental dimensions and addressed by any valid motion address such as X, Y or Z.

If the control system provides both absolute and incremental dimensioning, the mode of control shall be selected by one of the following G-codes :

G90 Absolute dimension

G91 Incremental dimension.

The example in figure 3 shows the geometric properties of the span and gives examples of meanings of the coordinate values to be programmed.

4.2.4 *Higher order interpolation*

Higher order interpolation will be programmed by a number of successive blocks consistent with the previously discussed methods. Appropriate G-functions are to be selected from unused G-functions.

NOTE — The examples of various methods of interpolation are in no way restrictive to other uses or techniques of interpolation, but are given to clarify the meaning of the basic principles stated earlier. Any method of interpolation must be defined in detail in the itemized data.

5 CUTTER COMPENSATION

Cutter compensation deals with the alteration of the cutter path geometry in order to compensate for the variation between the actual cutter and that for which the part was programmed.

In order to accomplish this task, it is often necessary to provide additional information on the input tape. The type of information usually needed is the derivative functions to the original programmed curve.

This information takes on the appearance of unit vectors at the beginning of each span and is programmed as correction parameters using the addresses P, Q, R (if not used elsewhere) respectively, for X, Y and Z directions.

The use of these parameters is left to the discretion of the individual control builder. It is important to note that these parameters are not the same as interpolation parameters, even though their structures are similar.

6 FORMAT SPECIFICATION

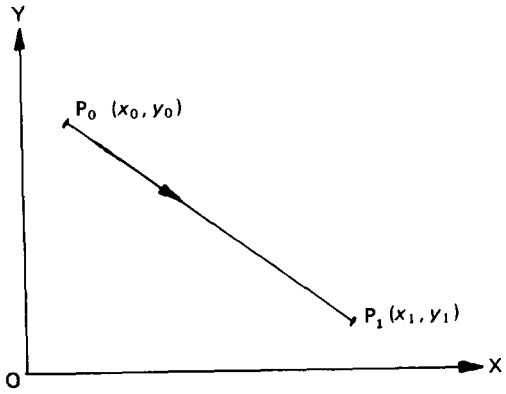
This consists of three sections, as follows :

— format classification shorthand, in accordance with annex C;

— format classification detailed shorthand, in accordance with annex D;

— itemized data of the format contents, which are not subject to standardization. An explanatory note is attached for guidance of users (annex F).

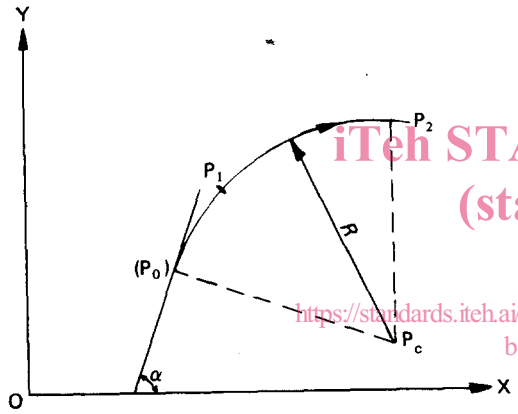
NOTE — Annex E shows an example of tab and address variable block format.



– using end point (G01 XYF)

absolute dimension $\begin{cases} X = x_1 \\ Y = y_1 \end{cases}$ incremental dimension $\begin{cases} X = x_1 - x_0 \\ Y = y_1 - y_0 \end{cases}$

FIGURE 1 – **Linear Interpolation**



– using end point and centre point (G02 XYIJF)

absolute dimension $\begin{cases} X = x_2 \\ Y = y_2 \\ I = x_c \\ J = y_c \end{cases}$ incremental dimension $\begin{cases} X = x_2 - x_0 \\ Y = y_2 - y_0 \\ I = x_c - x_0 \\ J = y_c - y_0 \end{cases}$

– using end point, angle and radius (G02 XYIJF)

absolute dimension $\begin{cases} X = x_2 \\ Y = y_2 \\ I = \alpha \\ J = R \end{cases}$ incremental dimension $\begin{cases} X = x_2 - x_0 \\ Y = y_2 - y_0 \\ I = \alpha \\ J = R \end{cases}$

– using end point (G02 XYF)
and intermediate point (XY)

absolute dimension :

first block $\begin{cases} X = x_1 \\ Y = y_1 \end{cases}$

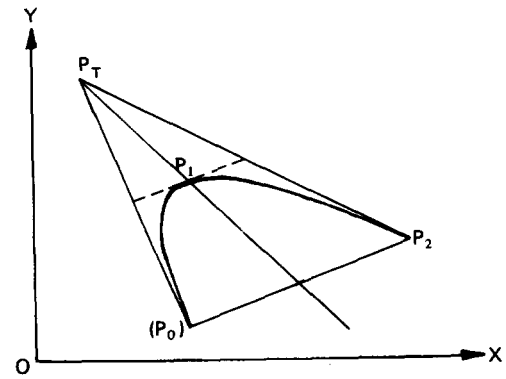
second block $\begin{cases} X = x_2 \\ Y = y_2 \end{cases}$

incremental dimension :

first block $\begin{cases} X = x_1 - x_0 \\ Y = y_1 - y_0 \end{cases}$

second block $\begin{cases} X = x_2 - x_1 \\ Y = y_2 - y_1 \end{cases}$

FIGURE 2 – **Circular Interpolation**



P_0 = start point

P_T = tangent intersection point

P_1 = intermediate point (tangent parallel to $P_0 P_2$)

P_2 = end point

– using end point and tangent intersection point (G06 XYIJF)

absolute dimension $\begin{cases} X = x_2 \\ Y = y_2 \\ I = x_t \\ J = y_t \end{cases}$ incremental dimension $\begin{cases} X = x_2 - x_0 \\ Y = y_2 - y_0 \\ I = x_t - x_0 \\ J = y_t - y_0 \end{cases}$

– using end point (G06 XYF)
and intermediate point (XY)

absolute dimension :

first block $\begin{cases} X = x_1 \\ Y = y_1 \end{cases}$

second block $\begin{cases} X = x_2 \\ Y = y_2 \end{cases}$

incremental dimension :

first block $\begin{cases} X = x_1 - x_0 \\ Y = y_1 - y_0 \end{cases}$

second block $\begin{cases} X = x_2 - x_1 \\ Y = y_2 - y_1 \end{cases}$

FIGURE 3 – **Parabolic Interpolation**

ANNEX A

FEED AND SPINDLE SPEED CODE

Feed and/or spindle speed should be selected by any one of the following five methods. For rapid traverse use G00 or the highest feed or code possible.

A.1 TIME RECIPROCAL METHOD (Applied to Feed only)

It is recommended that the "feed function" for rates of vectorial motion (linear or rotary) independent of spindle speed be expressed by a "feed command".

A.1.1 Linear Interpolation

The "feed command" is the reciprocal of time in minutes to execute the block. It is equal to the velocity of any axis or combination of axes (in millimetres per minute or inches per minute) divided by the corresponding incremental move (in millimetres or inches). It is expressed by a four (4) or more digit number, depending upon the possible velocity and movement in one block. The number of digits is to be detailed in the format specification.

A.1.2 Circular Interpolation

The "feed command" is equal to the rate of circle generation (in radians per minute) i.e. the path feedrate (in millimetres per minute or inches per minute) divided by the radius of the generated arc (in millimetres or inches). It is expressed by a four (4) or more digit number, depending upon the possible rate and radius in one block. The number of digits is to be detailed in the format specification.

A.1.3 Parabolic Interpolation

Not generally applicable.

A.2 ARITHMETIC PROGRESSION METHOD (Three- (four- or five-) digit coded number method)

A.2.1 Basic units

It is recommended that the rates of vectorial motion independant of spindle speed be expressed in millimetres per minute or inches per minute.

It is recommended that rates of rotary table motion and spindle speed be expressed in revolutions per minute or degrees per minute.

A.2.2 Number

The coded number is composed of digits, the signification of which is as follows :

– the first digit is a decimal multiplier, and has a value three (3) greater than the number of digits to the left of the decimal sign of the speed value;

– the second and subsequent digits are the feed or spindle speed rounded to the corresponding accuracy.

When there are no digits to the left of the decimal sign, then the number of zeros immediately to the right of the decimal sign is subtracted from three (3) to provide the value of the first digit.

Example

Spindle Speed	Coding
1 728	717
150,3	615
15,25	515
7,826	478
0,153 7	315
0,012 68	213
0,008 759	188
0,000 462 4	046

NOTE – The second digit can never be zero unless all digits are zero.

If the three-digit coded number does not satisfy the degree of control necessary for the process, this number may be expanded to a four (4)- or five (5)-digit number, as necessary, to meet the requirement. This coded number for the "spindle speed function" is rounded to three (3)-digit accuracy for a four (4)-digit code and rounded to four (4)-digit accuracy for a five (5)-digit code. This must be defined in accordance with format classification detailed shorthand. (See annex D.)

Example

Spindle Speed	4-digit Coding	5-digit Coding
1 728	7173	71728
150,3	6150	61503
15,25	5153	51525
7,826	4783	47826
0,153 7	3154	31537
0,012 68	2127	21268
0,008 759	1876	18759
0,000 462 4	0462	04624

NOTE – The second digit can never be zero unless all digits are zero.

A.3 GEOMETRIC PROGRESSION METHOD (Two-digit coded number method)

A.3.1 Basic Units

It is recommended that the rates of linear vectorial motion independent of spindle speed be expressed in millimetres per minute or inches per minute.

It is recommended that the rates of vectorial motion dependent on spindle speed be expressed in millimetres per revolution or inches per revolution.

ANNEX B

CHARACTERS

B.1 ADDRESS CHARACTERS

Character	Meaning
A	Angular dimension about X axis
B	Angular dimension about Y axis
C	Angular dimension about Z axis
D	Angular dimension about special axis or : third feed function or : tool function for selection of tool compensation[1)]
E	Angular dimension about special axis or : second feed function[1)]
F	Feed function
G	Preparatory function
H	Permanently unassigned
I	Interpolation parameter or thread lead parallel to X
J	Interpolation parameter or thread lead parallel to Y
K	Interpolation parameter or thread lead parallel to Z
L	Permanently unassigned
M	Miscellaneous function
N	Sequence number
O	Do not use
P	Tertiary motion dimension parallel to X[1)] or cutter compensation parameter
Q	Tertiary motion dimension parallel to Y[1)] or cutter compensation parameter
R	Rapid traverse dimension in the Z axis, or : tertiary motion dimension parallel to Z[1)] or cutter compensation parameter
S	Spindle speed function
T	Tool function
U	Secondary motion dimension parallel to X[1)]
V	Secondary motion dimension parallel to Y[1)]
W	Secondary motion dimension parallel to Z[1)]
X	Primary X motion dimension
Y	Primary Y motion dimension
Z	Primary Z motion dimension
:	Alignment function[2)]

1) When D, E, P, Q, R, U, V and W are not used as indicated above, they become unassigned and may be used as necessary for special application.

2) After an "alignment function" word, all information necessary to commence or recommence machining must be punched on the input tape. The "alignment function" character shall be used instead of N as the address character for the "sequence number" word. The "alignment function" character may be used as a "reference rewind stop".

B.2 MISCELLANEOUS CHARACTERS

Character	Meaning
+	plus
–	minus
[tab][1)]	tabulation
/	optional block skip[2)]
%	program start[3)]
[LF][1)]	end of block
(	control out[4)]
)	control in[4)]

1) Square brackets indicate non-printing characters.

2) The "/" (slash) character shall be used to provide an "optional" block skip" function validated at the option of the operator. When used, this character shall immediately precede the "sequence number" word.

3) The "program start" character shall precede the first "end of block" character in the program. It may be used as an "absolute rewind stop" character.

If a punched tape contains several programs, these can be marked by program numbers. The program number is to be placed immediately after the "program start" character. The number of digits of the program number must be designated in the itemized data.

4) Any statement appearing between "left parenthesis" character and "right parenthesis" character shall be ignored by the control system. If such a statement appears within a control program, it shall contain neither ":" nor "%" characters.

ANNEX C

FORMAT SPECIFICATION
Format classification shorthand

The format classification shorthand shall consist of groups of characters defined as follows :

C.1 The first group of characters shall contain letters selected as follows :

C.1.1 C for the variable block format applied to a system permitting contouring and positioning.

C.1.2 A for systems with addresses and without tabulation.
T for systems with tabulation and without addresses.
S for systems with addresses and optional tabulation.

C.1.3 M for linear dimensions expressed in millimetres and decimal fractions thereof

or

I for linear dimensions expressed in inches and decimal fractions thereof.

C.1.4 If need be :

R for angular dimensions expressed in decimal fractions of a revolution

or

D for angular dimensions expressed in degrees and decimal fractions thereof.

C.2 The next group, comprising three digits, denotes the geometrical characteristics of both machine and control system, as follows :

C.2.1 The first digit shows the number of motions either digitally or symbolically controlled.

C.2.2 The second digit shows the number of motions controlled by the "dimension" words (and not by marks denoting an indexed setting, etc.).

C.2.3 The third digit shows the number of simultaneously controlled motions.

TYPICAL EXAMPLE

The format of a control system for a machine featuring

- a vertical spindle head moving on vertical slideways,
- a cross-slide,
- a table,
- an indexing rotary table,

will be written thus : CSM 432.

This denotes variable block format for contouring and positioning (C), control system with addresses and optional tabulation (S), the linear motions of which are expressed in millimetres (M), there being no angular motion.

This machine has four (4) different motions controlled by the numerical control system; three (3) of them are defined by "dimension" words, the fourth (indexing of the rotary table) being defined by a symbolic figure; contouring concerns only two (2) motions simultaneously.